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Sludge Management 2016

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FORWARD

Romania experiences an intensively developing period in water infrastructure sector, in which the extension and the modernization of the water sewage systems and the wastewater treatment technologies are of main interest. In over 2300 agglomerations with a population of 2000 – 10,000 equivalent inhabitants, new systems will be put into operation, so that an important number of new wastewater treatment plants are to be developed. Consequently, one of the main difficulties in the extension of the sewage systems and the development of the wastewater treatment plants is the increased production of the sludge. The disposal and valorization routes of wastewater treatment sludge are relatively limited and they depend on many factors, some of them independent on the possibilities of operator's intervention:

- The technological equipment of the WWTPs, mainly those in the sludge line, will influence the characteristics of the produced sludge; many of the wastewater treatment plants have been designed without a strict correlation with the parameters of the resulting sludge which will restrict the possibility of choosing the alternative routes for sludge disposal or valorization;
- The quality of the wastewater and especially the industrial wastewater will influence the quality of the sludge; even if now it is conform with standard requirements, this could be changed in the future and will restrict the alternatives of sludge disposal;
- Local availabilities of farmland and crops suitable for sludge use; the need for awareness and information campaigns for farmers on the benefits of using sludge in fertilizing land;
- The existing local facilities for Waste Disposal; the legislative restriction imposed on the humidity level and also the content of organic substances for waste storage are factors that must be taken into account in defining this option;
- The existing incineration or co-incineration facilities in the area.

The international Conference "Sludge Management 2016" organized by the Romanian Water Association stands for the approval of the fact that the Romanian technical - scientific community is in line with the European Union strategies and with the National Strategy of the wastewater treatment sludge management. The papers submitted to this conference approach almost all of the European current priorities in the topic of the sludge management field.

One must notice the large number of the papers submitted, over 40, consistently proving the real concern and attention not only to develop high performance technologies in the field of wastewater treatment, especially the sludge line, but also to find the best and adequate routes of disposal and valorization of the sludge according to the local conditions and availabilities. Topics like: advanced technologies for sludge treatment, removal of the pathogens, biogas production and power recovery, technologies for the reduction of the sludge volumes, new composting methods, different routes for sludge valorization, legal, economical and environmental aspects in sludge management are to be discussed at the conference. The papers presented by the specialists from abroad will approach international solutions in this field, with the view to experience useful knowledge in solving the difficulties establishing the local sludge management solutions in the future.

It is my belief that the debate in the sections of this conference will provide with powerful and effective solutions for better knowledge in this field in view of increasing the performance in sludge management and to the benefit of the water association members and of the customers. The conclusions of the debate could be implemented in the new investment projects for the period 2014 – 2020, ensuring high level technologies and providing the best routes in wastewater treatment sludge management.

Professor Ioan BICA, Ph. D.

President CTS - ARA


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CHAPTER I

ADVANCED TECHNOLOGIES FOR SLUDGE TREATMENT

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Optimising Municipal Sludge Treatment Using Ultrasonic Disintegration And Thermal Drying. Case Study Târgu Mureș Wastewater Treatment Plant.

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Abstract
Compania Aquaserv is the regional operator for water and sewage services in Mures and partly in Harghita counties. The company recently completed a rehabilitation project in wastewater treatment plant Târgu Mures, regarding the sludge infrastructure. Additionally to the existing process formed of sludge concentration, anaerobic digestion (including biogas utilisation in CHP unit) and mechanical sludge dewatering were added two new elements: ultrasonic sludge disintegration and thermal sludge drying. Due to the new technology the efficiency of the digestion and the biogas production increased. The quality of the sludge resulted at the end of the process line is highly improved (humidity, odour, general aspect) and the quantity is lower.

Keywords
Sludge, ultrasonic disintegration, thermal drying.

1. INTRODUCTION

Compania Aquaserv is the regional operator for water and sewage services in Mures and partly in Harghita counties. According to the operated system (1200 km water network, 870 km sewage network) and the turnover of the company (90 Mil RON), on a national level Aquaserv is a middle size operator.
Aquaserv is considered a pioneer of the infrastructure development programmes, starting with MUDP I, followed by ISPA and now POS Environment.
The increasing expectations of the waste management regulations put wastewater treatment plant operators in front of high challenges. In the same time due to different infrastructure development projects more and more wastewater treatment plants are operated on high treatment efficiency, which generate higher quantity of sludge. The increasing connection rate to the sewer systems cause also higher sludge quantities. In these circumstances, when WWTP operators are facing a continuously increasing sludge production, they have to find solutions to reduce sludge quantities as much as it is technically possible and economically feasible. This environment makes innovative technologies spreading, and the market competition makes them available in terms of the acceptable investment costs.
The main objective of the rehabilitation project development was to reduce the quantity of the sludge which will be eliminated. For this purpose there were applied two directions in the process: dry solid elimination and water content reduction. For increasing the volatile solid elimination the refurbished process includes ultrasonic disintegration. In order to eliminate the most of the water content of the sludge thermal drying is applied.
The secondary objective of the rehabilitation project is to use the energetic potential of the sludge by transforming the organic matter in biogas. This will produce thermal and electrical energy sustaining in this way the energy demand of the wastewater treatment process.

2. DESCRIPTION OF THE SLUDGE PROCESSING

The existing process has been developed in different stages during the last 30 years. It is specific for many wastewater treatment plants with this size. The main concept is following a classic scheme including sludge concentration, anaerobic digestion with biogas utilisation, dewatering and thermal drying.

Figure 1 shows the existing process scheme. Practically excepting elements 3 and 9, all the other technological elements were established in the past. Through this refurbishment project all the elements were renewed, buildings and structures were repaired, all the electrical and mechanical equipment were replaced with new ones. Two new elements were added to the process line: ultrasonic disintegration and thermal sludge drying.

The primary sludge resulted in primary clarifiers, having a dry solid content of 3%, is directly transferred to the digesters. The biological excess sludge is concentrated in two steps, first by gravity (1) from 1% DS up to 3% DS, after that mechanically (2) up to 6%. Ultrasonic disintegration (3) is applied to 60% of the concentrated excess sludge flow.

The biogas produced is stored in gas holders (5), it can be used for energy production. The most efficient way of utilisation is to produce thermal and electrical energy in a CHP unit (6). There is also a boiler house (7) which can produce thermal energy for heating the different consumers of the wastewater treatment plant.

After the digestion (4) the mixture of the two sludges is dewatered with centrifuges (8), after that the sludge cake is processed on a belt dryer (9).

The thermal energy which is required for the drying process is coming from different sources:

- the biogas kept in the gas holders is burned (5);
- thermal energy from cogeneration plant (6);
- natural gas is also available.

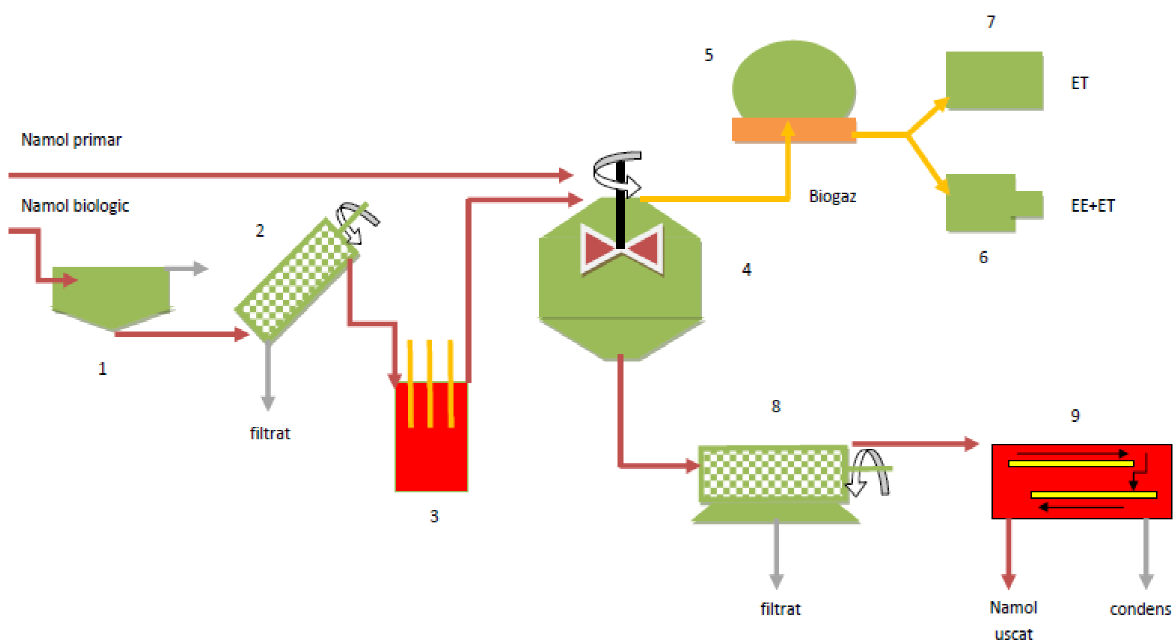

Figure 1. - Process scheme

3. ULTRASONIC SLUDGE DISINTEGRATION

Eliminating the volatile solid from the sludge is one of the most important options to decrease the sludge which will be eliminated. Anaerobic digestion is widely applied for many wastewater treatment plants. Târgu Mures plant had this technology since 1984. Besides the first advantage of decreasing the volatile solids digestion also has a secondary effect, it generates biogas which is a valuable renewable energy source.

Treating the sludge with ultrasonic waves has the scope to disintegrate sludge particles and braking-up bacteria's cell wall. In this way organic material becomes more available for anaerobic digestion, decreasing significantly the volatile part of the sludge. Figure 1 below shows the microscope image of a biological excess sludge before and after treatment.

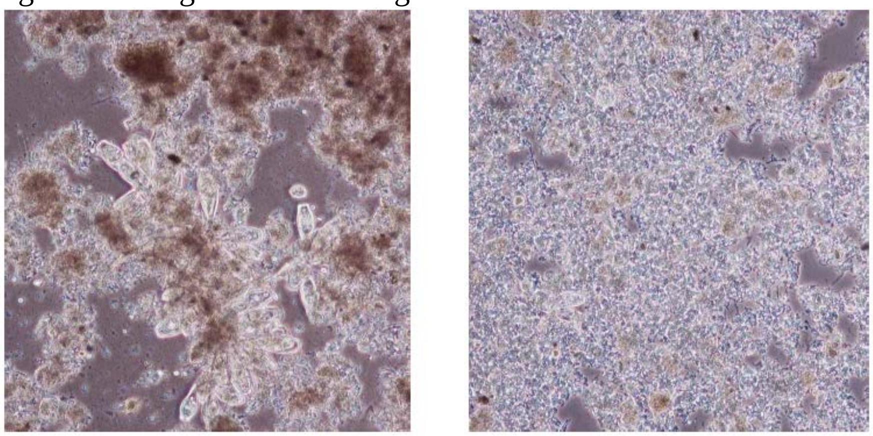

Figure 2. – Biological excess sludge before and after disintegration

As it can be seen after disintegration the flocks are broken and also bacteria cell is broken forming a homogeneous mass.

Disintegration rate is the directly measurable parameter of the process. This parameter indicates the soluble COD released in the liquid phase of the sludge due to the disintegration process, comparing with the COD content in the liquid had before treatment. According to the laboratory tests carried out the disintegration rate is 68-98%, which means that soluble COD after treatment is almost double than before.

Figure 3. – Photo of VTA ultrasonic reactor

Disintegration installation from wastewater treatment plant Târgu Mures is designed to treat at least 40% of the thickened biological sludge.
The equipment installed is a group of three reactors produced by VTA Austria, and each of them contains 6 oscillating bars which operate at 25 Hz.

4. THERMAL DRYING

Thermal drying is a well-known and widely applied process in many industrial applications. The main objective of Tirgu Mures project was to decrease significantly the quantity of the sludge due to humidity elimination.
The drying unit is a low temperature belt dryer (65/80 ^{0}C), produced by STC Spain, which operates in closed air circuit, having an evaporation capacity of 1000 kg water per hour. The sludge cake which feeds the dryer through a hopper has a consistency of 25% DS. An extruder places the sludge on the belt homogenously. This system can operate with the following energy sources:

- Residual heat from cogeneration plant, hot water with 90 ^{0}C, which is available in period of April-September, when the thermal energy demand of the digesters is lower.
- Hot water produced by burning biogas or natural gas.

The sludge cake placed by the extruder on the upper belt will lose humidity under the action of hot air and this will be saturated with moisture. A part of the saturated air flow will cross a condenser in order to remove humidity from the closed circuit air flow, after that the air will be heated again to be capable for another evaporation process. Because the dryer operates in a closed circuit tunnel the moist air condensates inside and only the water is extracted out (see figure 3).

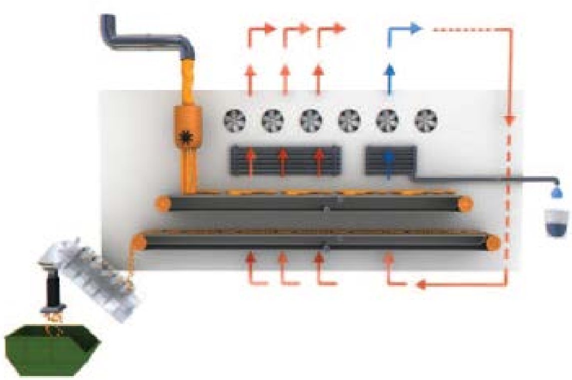

Figure 4. – STC belt dryer scheme

Figure 5. **–** Photo of installation

The belts cover the entire tunnel avoiding dust generation and possible obstruction. The final product is formed by odourless and dust free granules which has 75-92% DS.

5. OPERATIONAL RESULTS

There are available data just for a short period of operation of the rehabilitated plant. The data in the table below shows different parameters of the sludge process. Because in the two different situations, before and after the project, the plant was processing almost the same quantities of raw sludge, with the same quality it’s considered that the two situations can be compared.

Table 1. – Operational results

Parameter	Unit	Before project	After project
Volatile solids destroyed	kg/day	2502	5064
Biogas production	Nm^3/day	2227	3595
Fermentation efficiency	%	46	62
Sludge to eliminate	tone/day	50.5	6.3

6. CONCLUSIONS

The efficiency of the anaerobic fermentation process increased from 46% to 65% and this doubled the volatile solid eliminated.
The biogas production increased with 60%. Comparing the specific biogas production related to the volatile solids reduced in the two situations, we can find that before de project it was higher, around 900 l/kgVS while the value after the project is 700 l/kgVS. During the optimization of the fermentation process there were some gas losses thru the safety valve of the biogas network which decreased the specific biogas production figure.
Using the biogas for energy production in cogeneration plant, resulted a residual heat which assured about 15% of the thermal energy demand of the drying process. Because the after project data are from a cold season (December 2015 - March 2016) when also the digesters require high quantities of thermal energy, this coverage rate of the thermal energy demand for the drying process is considered satisfactory.
The most important result is that the sludge suffered significant transformation. Loosing most of its humidity the final quantity was reduced to less than 15% of its initial value. Having also a totally different look, because its dryness and odourless form. So it turned from a waste to a valuable product which opens multiple utilisation and elimination routes. Farmers could accept more easily dried sludge on their lands, because the sludge keeps its nutrients during the process, smell disappear and became very simple to transport it and to spread it.
With this low humidity and still having half of the total dry solid in organic form this sludge in also attractive for energetic use or to co process it in cement kills.
Because the drying process requires high amount of thermal energy Aquaserv is focusing to identify and to implement solutions to cover the thermal energy needs of the drying process as much as it possible from other sources than from methane gas. First of all increasing the specific biogas production to 900 l/kgVS will increase also the energy which is available for the drying process but also other solutions are investigated, in order to reduce the operational costs of the whole process.

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Innovative Technologies for Sludge Treatment

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Abstract
VWS is one of the promoters of the innovative technologies in the field of sludge treatment. Having a portfolio of more than 200 innovative solutions and 1000 patents in the field, VWS designs specific solutions for each case itself in order to: reduce sludge quantities, avoid bad smells and recover and recycle the energy from the sludge. The paper presents the important progress made by the company regarding thermal hydrolysis, sludge drying and sludge incineration.

Keywords
Sludge, hydrolysis, incineration, drying.

1. INTRODUCTION

In many countries treatment and disposal of wastewater sludge became compulsory and often this is a complex problem which generates important costs for the operator.

The norms related to sludge quality but also to sludge processing became more stringent in order to comply to a sustainable development, fact which determined an important progress of the treatment technologies.

The present paper presents some of the sludge treatment processes applied by VWS with success in different wastewater treatment plants all over the world.

2. INNOVATIVE PROCESSES

Sludge pre-treatment

By coupling the thermal hydrolysis and the anaerobic digestion, Exelys™ offers better performance than a conventional digestion and optimizes sludge treatment by producing [1]:

- 25 to 35% less dry matter;
- 30 to 50% more biogas;
- No odors;
- A pasteurized digestate, for control over the sanitation hazards and safe agricultural reuse.

Exelys™ provides continuous thermal hydrolysis that can operate 24 hours a day with real time adjustable feed rate. Exelys™ operates under controlled temperature (165°C), pressure (6-8 bars) and duration time (approximately 30 minutes) conditions [2].
Exelys™ handles all kinds of organic, industrial or municipal sludge and can also handle grease.
The sludge higher dryness (DS>22%) minimizes steam consumption.
The Exelys™ process can work in 3 different configurations [2]:

- **Lysis/Digestion (LD) Configuration –** Thermal hydrolysis is performed on the whole or a part of the sludge stream prior to digestion. This configuration reduces digester volume by a factor of 2 to 3, reduces the amount of sludge and guarantees that it is sanitized while increasing biogas production. Using the LD configuration, the throughput of an overloaded digestion plant can be doubled, thus avoiding the need to build additional digestion capacity;

- **Partial Lysis / Digestion (Partial LD) Configuration** – The Hydrolysis reactor may process only the biological (secondary) sludge with corresponding enhancement on biogas production. This configuration gives the client the greatest savings in regards to reactor capacity and steam consumption. Using the partial LD configuration, digestion capacity of an existing installation can be increased by a factor of 2;

- **Digestion/Lysis/Digestion (DLD) Configuration Veolia Patent** – Thermal hydrolysis is applied to all of the digested sludge from digester 1. Then the sludge is cooled and diluted before breakdown continues in digester 2. This is the optimum formula in energy terms as it uses less steam while producing more biogas and electricity. It also means that the quantity of sludge to be disposed of is reduced.

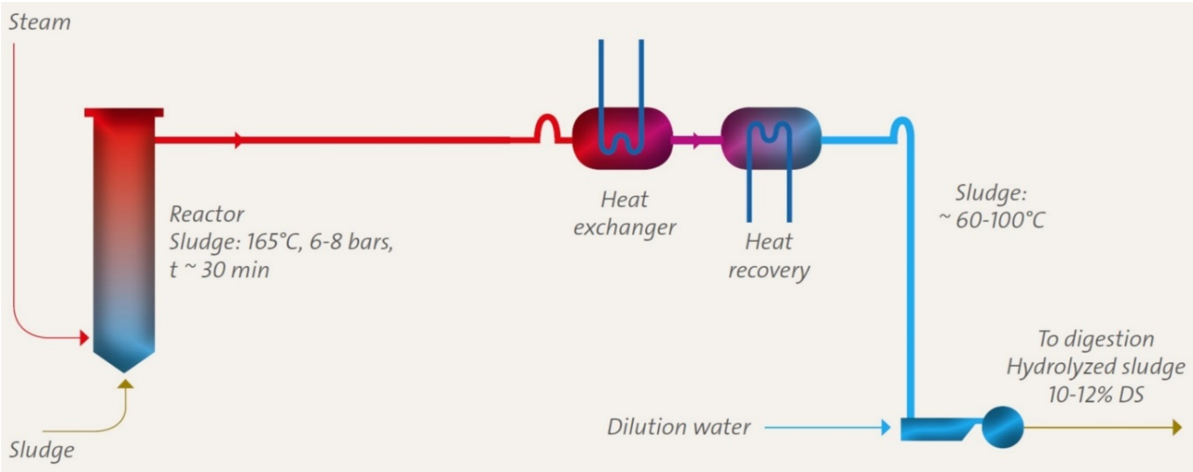

Figure 1. Schematic of Exelys™ Process [2], [3]

The main benefits of the process are [3]:

- Continuous 24 hour a day operation and simplified operation and maintenance;
- Limited footprint;
- Reduced digester-related investment for new installations;
- Reduced Operating costs:
- Improved sludge dewaterability saves on chemical costs;
- Reduced sludge volume provide savings on the transport;
- Income is generated from:
  - Ability to process imported organic materials for co-digestion;
  - Selling the energy produced from co-generation, or bio-methane.

Sludge drying

Drying sludge has several advantages, including [4]:

- Sanitization: sludge is dried at high temperatures, removing pathogenic germs;
- Stabilization: biological activity in sludge is stopped by drying;
- Weight reduction: water in sludge is almost completely removed which reduces sludge tonnage to 1/5 - 1/3;
- Better sludge utilization: it can be used without causing problems, storage is easier, and spreading is feasible with conventional fertilizer spreading resources. Sludge is a high quality fuel which is suited to various combustion methods.

The BioCon™ dryer is completely air-tight and sealed [4]. It is provided with 2 stainless steel belts placed one above the other. The sludge retention time in the dryer exceeds 60 minutes at a temperature below 180°C.

The sludge drying process is undertaken by circulating hot drying air through the sludge layer on the belts. The drying conditions provide a dry solid content in the sludge of 90% minimum at the dryer outlet.

The dried sludge delivered in granules or pellets can be stored and recycled again in agriculture, without further treatment. Sludge can also be reused in a BIOCON™ Energy Recovery System (ERS), installed downstream from the drying unit. With this system, the energy recovered is utilized for drying the sludge, without an external energy supply.

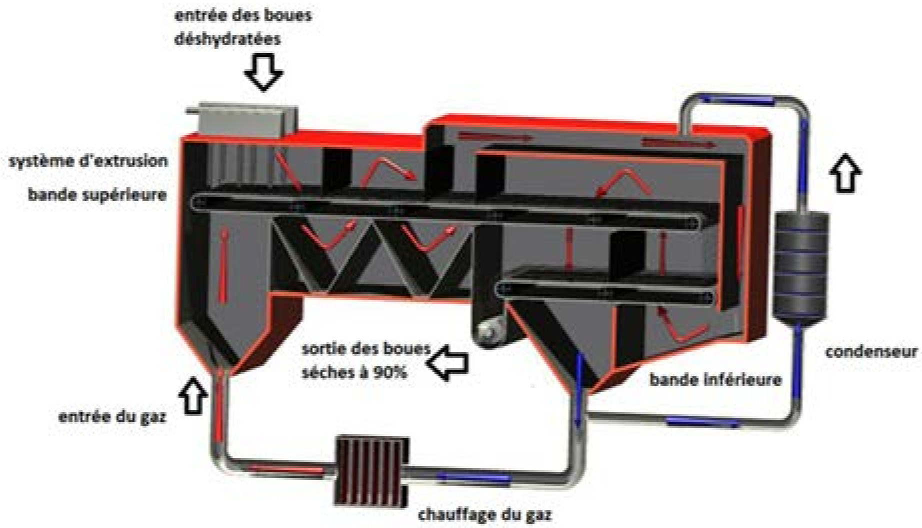

Figure 2. Schematic of BioCon^{TM} Process [4], [5]

The performance of the process is revealed by the following aspects [5]:

- Reduction of initial sludge quantity to less than 5% (with an Energy Recovery System);
- No odor nuisances;
- Sludge disinfection;
- No equipment abrasion;
- No dust;
- Quiet process;

- Energy recovery;
- Low operating costs;
- Risk control.

As a pioneer and expert in solar sludge drying, VWS has developed innovative solutions such as SOLIA™ Mix. This new and more compact process can achieve a dry solids content up to 90%, reducing sludge volume and disposal costs [6].
Based on combined solar drying and bio-drying, SOLIA™ Mix dries and stores sludge in a horticultural greenhouse under continuous ventilation with dry air from the outside.
Dewatered sludge and drying sludge are mixed into drying sludge and spread throughout the greenhouse as windrows by the SOLIA™ Mix windrow turner.

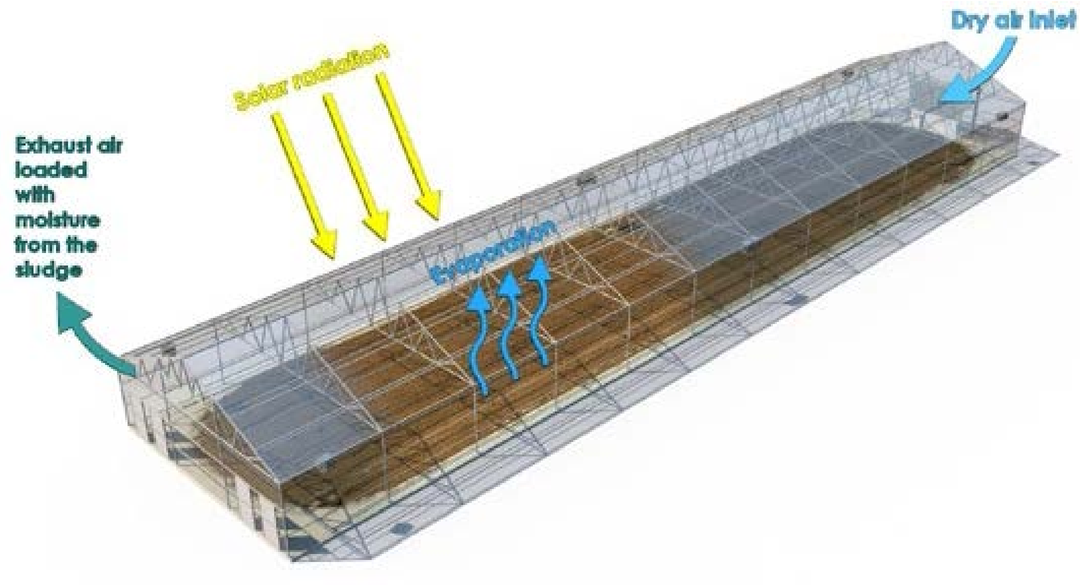

Figure 3. Schematic of Solia™ Mix Process [6]

The main advantages of the solution are [7]:

- Sludge volume reduced by 3 to 4 times;
- Sludge storage before reuse;
- Fully automated process operation;
- Uses renewable energy sources;
- A low carbon footprint process;
- Aesthetic and easily integrated architecture;
- Odor control;
- Sludge sanitation.

Incineration
Pyrofluid™ is a thermal treatment solution that oxidizes organic matter contained within sewage sludge. It is a fluidised-bed incinerator (where sand is maintained in suspension by a constant up-flow of air) that operates at approximately 900°C in order to incinerate sludge within a matter of seconds. Pyrofluid™ is able to:

- Treat urban sewage sludge within plants of variable capacities (200 kg to 5 t DS/hr*),
- Produce stable and recyclable by-products (ash, dust),
- Comply with the most strict emission standards.

The performance of the process is revealed by the following:

- Total mineralization of sludge 100% reduction of initial sludge quantities combined with mineral by-product recycling (road construction and civil engineering projects)
- Total destruction of pathogens
- Energy recovery:
  - Recycling within the combustion process (in order to reduce the need for additional fuel);
  - Heat distribution;
  - Production of electricity (to meet the plant's energy needs).

The next figure presents a schematic of the incinerator.

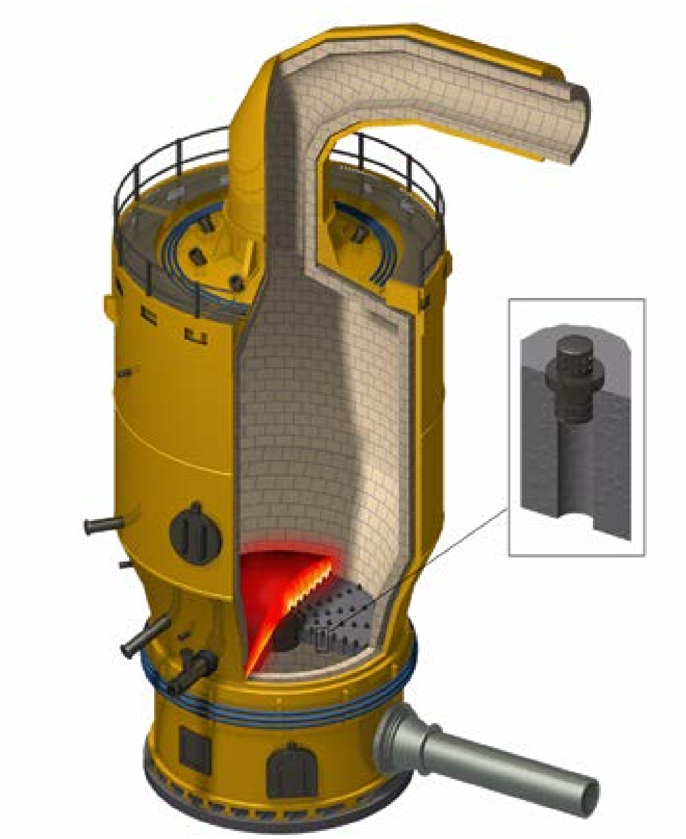

Figure 4. Process diagram of Pyrofluid^{TM} Process [8]

Option analysis

In order to demonstrate the efficiency of the innovative sludge treatment processes, an option analysis has been developed for a 850.000 p.e. wastewater treatment plant. The following scenarios have been analysed:

- Mesophilic Anaerobic Digestion (MAD) + Combined Heat Power (CHP) Unit;
- MAD + CHP + Exelys + BioCon + Energy Exchange System (BEES);
- MAD + CHP + Exelys + BioCon + Energy Exchange System (BEES) + Energy Recovery System (ERS).

The following unit prices have been used:

- N-gas: 4,5 cents €/KWh;
- Biogas selling: 5,5 cents €/KWh;
- EL price selling& buying: 12 cents €/KWh;
- Waste heat selling (CHP, steam from BERS, BEES): 45 – 15 €/MWh;
- Sludge disposal: 40 €/t;
- Fly ash disposal: 80,5 €/t;
- Bottom ash disposal: 54 €/t;
- Residuals disposal: 120,8 €/t;
- Sodium bicarbonate incl. activated carbon: 550 €/t;
- Polymer for dewatering: 3,5 €/Kg;
- CW building: 1,6-2 K€/m^2;
- WWTP electricity consumption: 0,46 Wh/l and 150 l/PE/d;
- Amortization loan: 15y with interest rate=3,5%.

The following figures presents the schemes of each option.

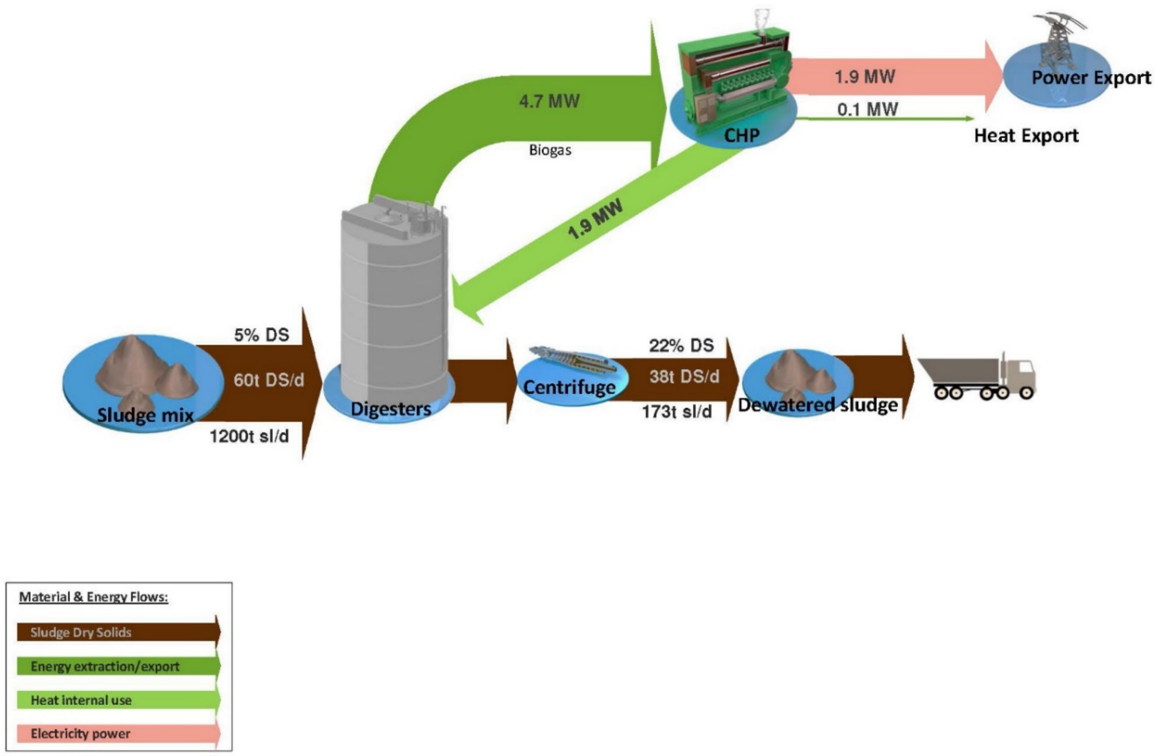

Figure 5. Base Scenario: MAD + CHP

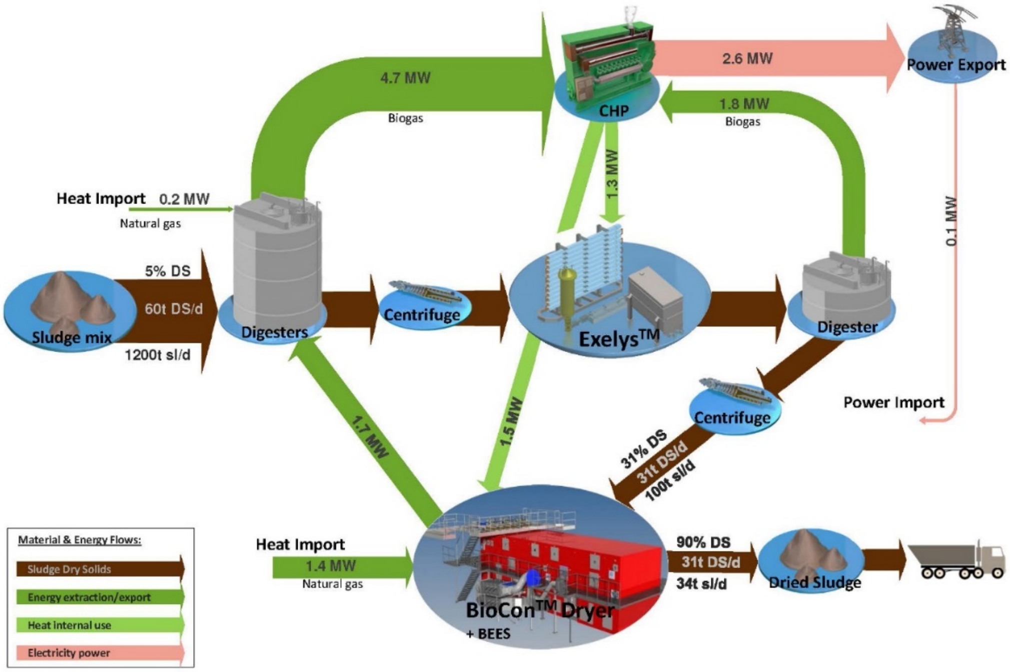

Figure 6. Exelys^{TM} DLD + BioCon^{TM} sludge drying + BEES

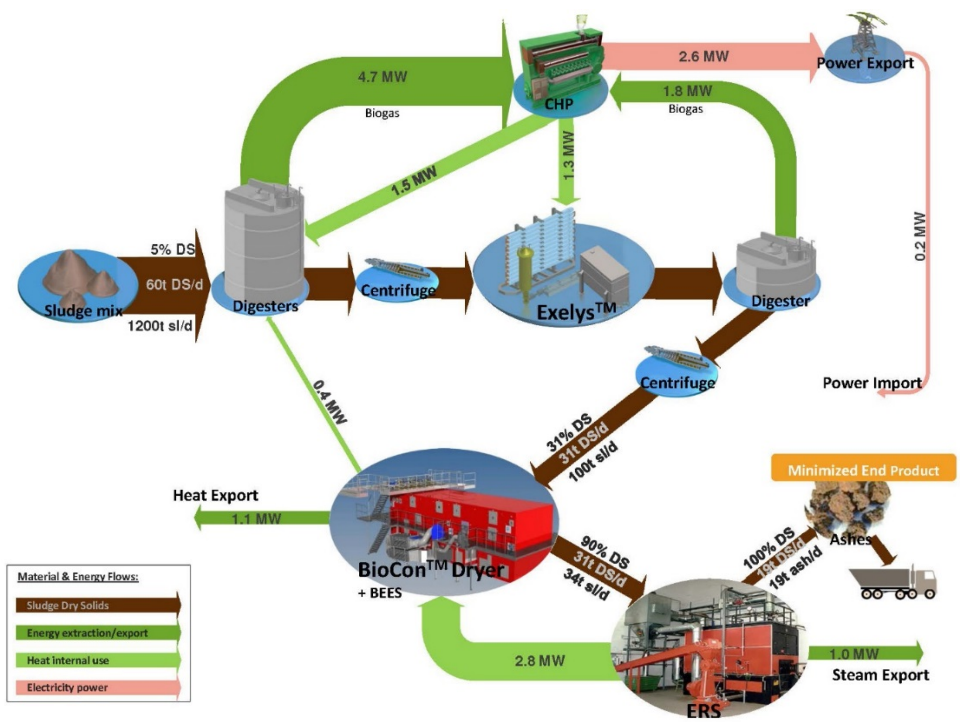

Figure 7. Exelys^{TM} DLD + BioCon^{TM} ERS + BEES

Considering a lifetime of 25 years, the base scenario will create a deficit of 15.2 MEuro, while the third option will determine a profit of 7.9 MEuro, which determine a financial difference between the analysed options of 23.1 Mill Euro.

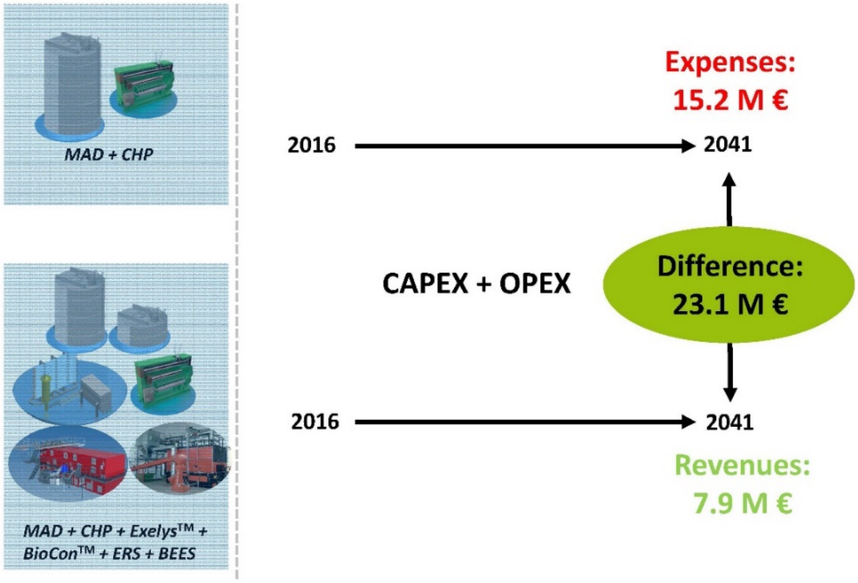

Figure 8. Financial analysis of the relevant options

The main advantages of the proposed option are:

- Lower sludge production: 19 t/day of inorganic ashes in option 3 versus 173 t/d liquid sludge in option 1;
- Increased energy cogeneration from biogas production: 6.5 MW in option 3 versus 4.7 MW in option 1;
- Increased power net export: 2.4 MW in option 3 versus 1.9 MW in option 1;
- Increased heat net export: 2.1 MW in option 3 versus 0.1 MW in option 1.

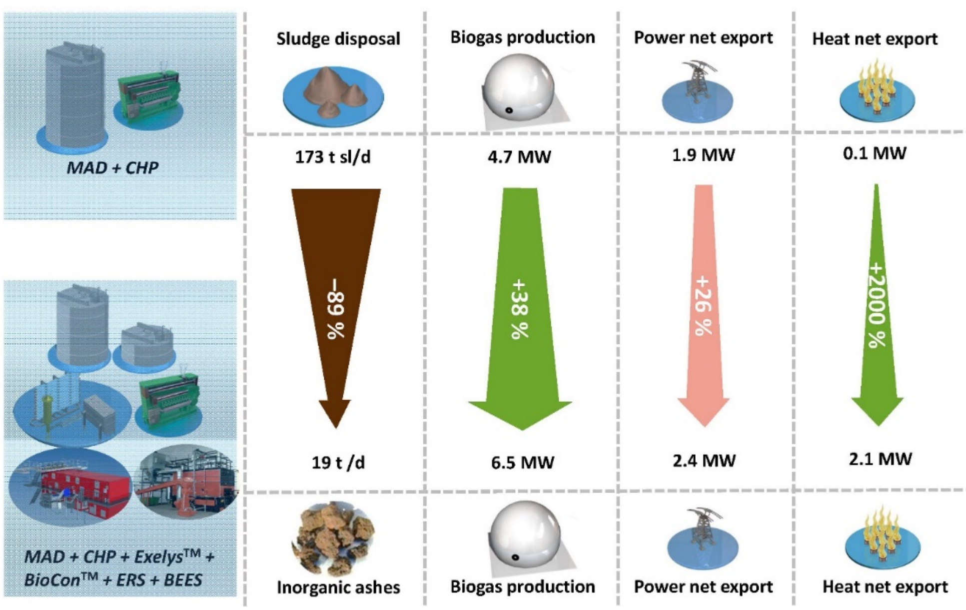

Figure 9. Benefits of the third option

3. ROMANIAN EXPERIENCE

VWS Romania is a local company created in 1998, which belongs to SADE Group.The company is acting on the local market as General Contractor for Design & Built - municipal and industrial projects.The expertise of VWS Romania refers to the performant water, wastewater and sludge treatment process integrated within ”Design & Built” Projects, along with sewage systems integrated projects. This expertise covers a large range of treatment capacities - from small to big plants as well as water and sewage networks.

VWS Romania has the benefit of having created a solid competence center on the local water projects market, covering all the necessary activities: tendering, engineering, operational (purchasing, project execution, testing on/after completion, maintenance and technical assistance after completion) as well as all necessary supporting activities (legal, contract management, finance, QA).

The Group policy requires the “Design and Built” facilities within its entities’ Projects to be based on the concept of sustainable development and environmental protection - this rigor imposes performant equipment, advanced solutions of specific treatment as well as accurate control philosophy.

Proofs are given by the successful process developed in all our local referenced wastewater treatment plants, as presented in the following.

Buzău WWTP

Take Over	• August 2014
Flow rate:	• 46,000 m^3/day;
Treatment capacity	• 235,000 PE
Beneficiary/Operator:	• Compania de Apă Buzău S.A.
Objective:	• Design & Built Project: rehabilitation and extension of the existing wastewater treatment plant for advanced treatment purpose *(nitrification-denitrification and phosphorous removal.*
Treatment description:	• Wastewater and sludge treatment lines: **Wastewater treatment line**: pre-treatment *(coarse screens, inlet pumps, fine screens, longitudinal grit and grease chambers)*, storm water tank, primary settlement, advanced biological treatment, final settlement with return and excess sludge pumping, outlet flow measurement, discharge to river. **Sludge treatment line**: gravity thickening for primary sludge and mechanical thickening of biological sludge (*by gravity belt thickeners)*, anaerobic stabilization *(digestion with biogas valorization by cogeneration) a*nd all dewatering and storage facilities for sludge: dewatering units by centrifugation / sludge conditioning plant - lime treatment. **Odor treatment**: biological odor removal

Râmnicu Sărat WWTP

Take Over	• November 2014
Flow rate:	• 15,576 m^3/day;
Treatment capacity	• 80,000 PE;
Beneficiary/Operator:	• Compania de Apă Buzău S.A.
Objective:	• Design & Built Project: *"greenfield"* construction of a wastewater treatment plant for advanced treatment *(nitrification-denitrification and phosphorous removal).*
Treatment description:	• Wastewater and sludge treatment lines:

Wastewater treatment line: pre-treatment *(coarse screens, inlet pumps, fine screens, longitudinal grit and grease chambers),* storm water tank, primary settlement, advanced biological treatment, final settlement with return and excess sludge pumping, outlet flow measurement, discharge to river.

Sludge treatment line: gravity thickening for primary sludge and mechanical thickening of biological sludge (*by gravity belt thickeners),* anaerobic stabilization *(digestion with biogas valorization by cogeneration),* all dewatering and storage facilities for sludge: dewatering units by centrifugation / sludge conditioning plant - lime treatment.

Odor treatment: biological odor removal

Fălticeni WWTP

Take Over	• August 2015
Flow rate:	• 7,733 m^3/day;
Treatment capacity	• 33,151 PE;
Beneficiary/Operator:	• ACET S.A. Suceava
Objective:	• “Design & Built” Project: reconstruction the existing wastewater treatment plant for advanced treatment *(nitrification- denitrification and phosphorous removal).*
Treatment description:	• Wastewater and sludge treatment lines:

Wastewater treatment line: pre-treatment *(coarse screens, inlet pumping station, fine screens, circular grit and grease removal tanks),* longitudinal primary settlers, biological treatment by activated sludge process, final settlement with return and excess sludge pumping, outlet flow measurement, discharge to river.

Sludge treatment line: static gravity thickening of primary sludge, mechanical sludge thickening of biological sludge by gravity belt thickeners, anaerobic stabilization *(mesophilic digestion),* thermal plant, sludge dewatering by plate pressure filters.

Luduș WWTP

Take Over	• November 2015
Flow rate:	• 2,853 m^3/day;
Treatment capacity	• 23,100 PE;
Beneficiary/Operator:	• AQUASERV S.A. – Târgu Mureș
Objective:	• “Design & Built” Project for the construction of a new wastewater treatment plant for advanced treatment (nitrification- denitrification and phosphorous removal).
Treatment description:	• Wastewater and sludge treatment lines, under SBR technology: **Wastewater treatment line:** pre-treatment *(coarse screens, pumping station, compact unit for fine screening and grit & grease removal tanks),* equalization tank & pumping station, biological tanks with nitrification-denitrification and phosphorous removal *(SBR technologie),* pumping station for treated effluent. **Sludge treatment line**: Excess sludge mechanical thickening *(by gravity belt thickener),* sludge dewatering *(by plate pressure filters).*

Țăndărei WWTP

Take Over	• November 2014
Flow rate:	• 2,202 m^3/day;
Treatment capacity	• 16,941 PE;
Beneficiary/Operator:	• RAJA S.A. Constanța
Objective:	• Design & Built Project: *"greenfield"* construction of a wastewater treatment plant for advanced treatment (nitrification- denitrification and phosphorous removal).
Treatment description:	•Wastewater and sludge treatment lines: **Wastewater treatment line:** pre-treatment *(coarse screens 20mm, raw water / inlet pumping station, compact units for mechanical pretreatment, grit & grease removal),* influent flow measurement, biological wastewater treatment *(biological tanks, coaxial with secondary settlings),* effluent flow measurement, outlet water pumping station. **Sludge treatment line**: mechanical thickening of biological sludge by gravity belt thickeners, dewatering plant by belt filter press sludge conditioning plant *(lime treatment).*

Iernut WWTP

Take Over	• November 2015;
Flow rate:	• 1,163 m^3/day;
Treatment capacity	• 6,000 PE;
Beneficiary/Operator:	• AQUASERV S.A. – Târgu Mureș
Objective:	• Design & Built Project: *"greenfield"* construction of a wastewater treatment plant for advanced treatment *(nitrification-denitrification*

	and phosphorous removal).
Treatment description:	• Wastewater and sludge treatment lines, under SBR technology: **Wastewater treatment line:** pre-treatment *(coarse screens, pumping station, compact unit for fine screening and grit & grease removal tanks),* equalization tank & pumping station, biological tanks with nitrification-denitrification and phosphorous removal *(SBR technologie),* pumping station for treated effluent. **Sludge treatment line**: Excess sludge static thickening, sludge dewatering *(by plate pressure filters).*

Ongoing projects:

- Baia Mare WWTP (163,300 PE) - to be completed October 2016;
- Caransebeș WWTP (29,700 PE) - to be completed June 2016.

For the above mentioned projects, the treatment process performance was set in accordance with the applicable Romanian and EU Norms imposed by law for the discharge of treated effluent into sensitive water bodies.

Regarding the sludge treatment steps, within the last 18 years several classical solutions were requested by Beneficiaries on the Romanian market, such as:

- Sludge thickening:
  - Gravity thickener (appropriate for primary sludge) – Buzău, Râmnicu Sărat, Fălticeni Projects;
  - Mechanical belt thickener (for biological sludge) – Buzău, Râmnicu Sărat, Fălticeni, Țăndărei, Caransebeș Projects;
- Sludge stabilization - Biogas valorization:
  - Anaerobic mesophilic digestion – Buzău, Râmnicu Sărat, Fălticeni Projects;
- Sludge dewatering:
  - Belt filter press – Țăndărei;
  - Centrifuge decanters – Buzău, Râmnicu Sărat, Caransebeș Projects;
  - Plate filter press – Luduș, Iernut, Fălticeni Projects.

Also, under the concept of sustainable development and environmental protection, VWS Romania has integrated several advanced solutions.

For example - a successful solution implemented in local Projects is the regulating system of the air injection into the biological basins of the wastewater plants, based on the continuous monitoring of the ammonium and nitrates concentrations in the aeration basin. Thus, the efficiency of the oxygen transfer is increased by maintaining the oxygen concentration at a minimum level in the aeration basins through the permanent injection of an oxygen dose adapted to the momentary demand of biomass.

The advantages given by this control system mainly referring to the optimization of OPEX by reducing energy costs for the treatment (the electricity consumption of blowers is decreased up to

15%) and also to a better control of the effluent parameters at the outlet of the plant.

The success of the proposed concept for this control system based on advanced automation is confirmed by the certified practice within the Group, in Romania as well as in France.

Also, the global process automation enables the Beneficiary to manage the station with a minimum number of staff, even at the time of the takeover of the plant.

Considering the expected future development of the Romanian water-wastewater infrastructure, implementation of advanced solution for sludge treatment will be necessary.

In order to respond to the complex issues regarding the sludge management and to give the right answer, SADE Group, by its local subsidiary VWS Romania, is ready to propose to their Clients new advanced treatment technologies for sludge process and sludge management as well.

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Municipal Sludge Treatment Technologies Achievements And Perspectives

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Abstract
In recent years, the need to achieve a sustainable sludge treatment and management strategy has become more and more important , due to the restriction (in some cases legal banning), of final disposal options. This paper presents a few effective and innovative technologies that can minimise the amount of sludge produced by the WWTP. Romanian WWTPs are used as study cases.
The paper is divided into 2 parts: accomplishments and perspectives (strategies) in sludge treatment.

Keywords
Wastewater sludge, sludge reduction, disintegration.

1. INTRODUCTION

In recent years, the need to achieve a sustainable strategy for management of sludge produced by wastewater treatment has become increasingly important due to the restriction final disposal options (in some cases legal prohibition).

This paper presents a few efficient and innovative technologies that can minimize the amount of sludge produced by sewage treatment plants. Romanian WWTPs are used as case studies.

This paper is divided into two parts: achievements and proposals for medium-term strategy in sludge treatment.

2. ACHIEVEMENTS

The new wastewater treatment plant at Targu Secuiesc (24 700 PE, 210 m3 / day - aveage size WWTP, figure 1), recently commissioned, uses a series of cutting-edge technologies aiming to minimize the final amount of sludge produced:

a. Advanced mechanical treatment

b. Deep carousel type aeration tanks

c. Mechanical and electrokinetic disintegration of excess and recycled sludge

d. Ultrasonic disintegration of excess sludge

e. Alkaline treatment of excess sludge

f. Sludge drying

Figure 1. Targu Secuiesc WWTP

a. Advanced Mechanical Treatment

After grit and grease removal, wastewater is pumped into the compact pre-treatment unit, composed of a fine sieve (e = 3 mm) with delayed mechanical cleaning & waste compactor, and grease & grease removal (figure 2).

The purpose of this unit is to remove particles larger than 0.5 mm with at least 95% efficency.

The novelty of this installation is the gap between bars of 3 mm, which provides, along with the coarse screen (s = 6 mm) a COD removal efficiency of 6.5 to 11.5% (according to laboratory tests).

This removal efficiency retention is justified both by the distance between bars (3 mm), and by the retaining effect of the filtering layer that forms on the surface of the screen.

Thus a significant reduction of the load to biological step is achieved and also of the generated excess sludge.

Figure 2. Targu Secuiesc WWTP - Advanced Mechanical Step

b. Deep carousel type aeration tanks

The carousel type aeration tanks with depths of 7 m used at Targu Secuiesc WWTP contribute to the reduced production of sludge by flexibility, ensuring the conditions for advanced aerobic sludge stabilization conditions. Advanced stabilization lowers the final amount of sludge by reducing the amount of dry matter (organic matter) and by improving the sludge dewatering properties.

In Romania experience shows (eg. WWTP Cugir, WWTP Ocna Mures, WWTP Aiud) aerobic stabilization is poor and excess sludge is generally unstabilized.

At Targu Secuiesc WWTP a sludge with 45% -55% organic content is obtained, thus an stabilized sludge, due to the carousel flexibility and the disintegration technologies presented below.

c. Disintegration of return sludge

Return activated sludge is treated entirely by mechanical & electrokinetic disintegration and partially by ultrasound disintegration.
Mechanical & electrokinetic disintegration (figure 3) has an extracellular fragmentation effect on flocs, releasing the intracellular enzymes.

Figure 3. WWTP Targu Secuiesc mechanical and electrokinetic disintegration installation

Ultrasonic disintegration of return sludge produces cell lysis, with the following effects:

- *decrease of excess sludge production*

One of the mechanisms for reducing the excess sludge produced by the biological reactor is known as a cryptic growth, which occurs by reusing intracellular compounds (compounds with carbon and nutrients) released by lysis of the cells to increase viable cells of the same population . This form of organic carbon repeated metabolism of the same organic carbon reduces biomass production because during each metabolic process a portion of the carbon is mineralized as product of respiration.

- *intensification of biological processes in aeration basins, with increased biodegradability of COD and advanced sludge stabilization*

Activated sludge disintegration triggers the release of inter-cellular enzymes, thereby increasing the enzymatic activity in the aeration basin, which has important consequences upon the biological reaction kinetics. Dehydrogenase activity was measured during tests, because this enzyme plays an important role in the biodegradation process. More intense dehydrogenase activity showed that overall enzymatic activity of activated sludge process is also enhanced and all processes of degradation are accelerated.

Disintegration of activated sludge solved the problem of low biodegradability of COD in the influent of Targu Secuiesc WWTP, where the COD measured value is high, surpassing (even 2 times) the NTPA 002 values. These values are evident in CCO tests pefomed in December 2015 according to Chart 1 below:

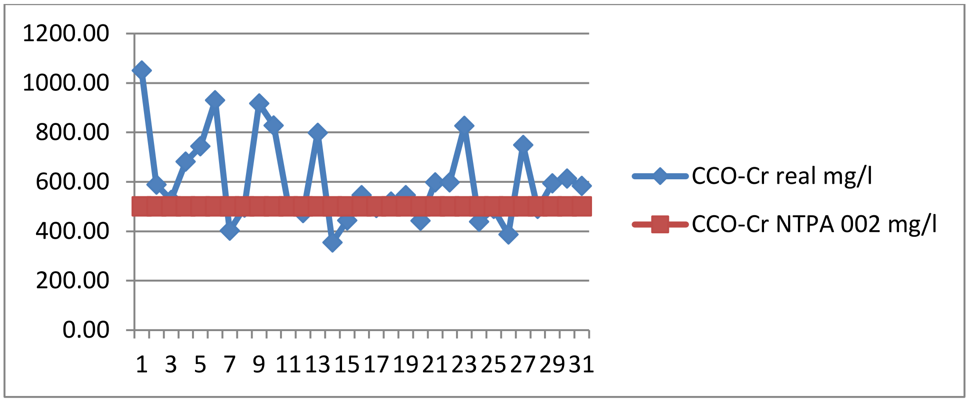


Chart 1. CCO CCO measured versus real, December 2015

Also, the measured ratio of BOD5 / COD is small (Chart 2), which signals a relatively large fraction of non-biodegradable COD in the influent.

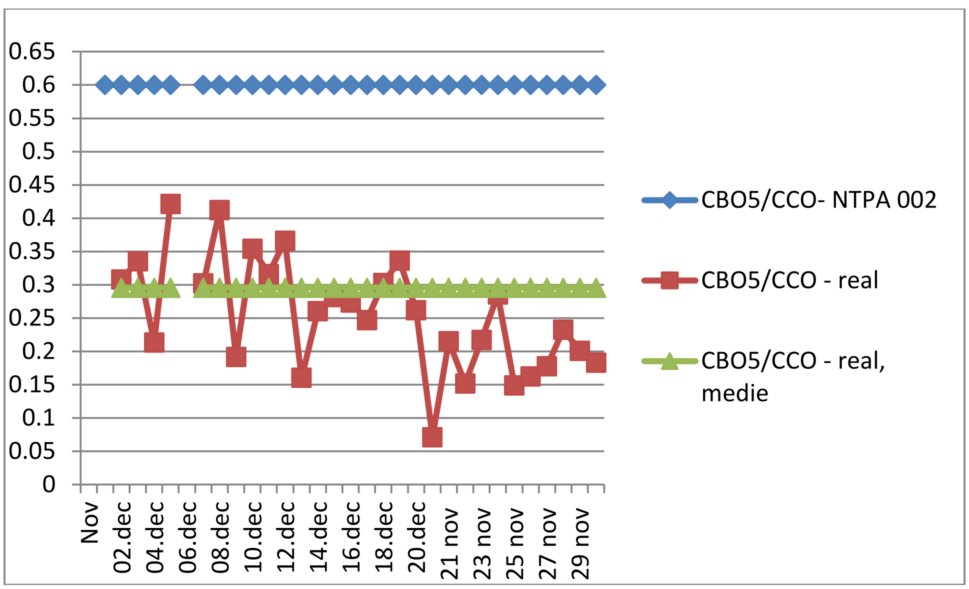
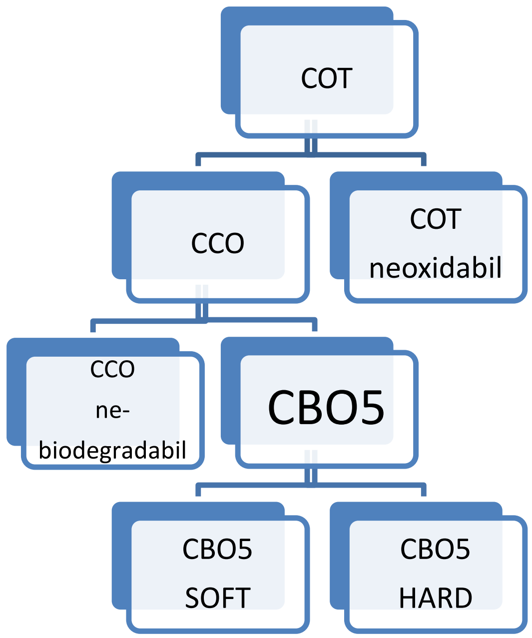


Chart 2. Measured BOD5 / COD versus contractual BOD5 / COD, December 2015

Despite unfavorable influent values , it was found that the effluent values are within the requested parameters. COD effluent value shows that the hard BOD (pat of COD, according to chart 3) was transformed during disintegration into soft BOD, thus full biodegradation of COD decreased its value in the effluent.



Source: Davis, Peter Spencer. "The Biological Basis of Wastewater Treatment." Strathkelvin Instruments, Ltd., 2005.

Chart 3. TOC fractions in wastewater

❖ *enhanced denitrification capacity, production of internal carbon source.*

At Targu Secuiesc WWTP, the measured BOD / N ratio (about 2.36) is very small. In practice, the required BOD / N ratio for denitrification. To ensure denitrification in case of low BOD/N ratio, an external source of carbon is equired, which, among other negative effects, would lead to increased production of excess sludge .
By disintegration cell lysis is achieved, destroying cell walls, releasing the intercellular/ cellular COD into the solution, thus achieving an internal source of BOD5.

❖ *improved sludge sedimentation in secondary sedimentation tanks*

The Mohlman index of excess sludge generated at Targu Secuiesc WWTP is small; this means that the sludge has very good settling properties, properties that lower the final volume of sludge because the thickening / dewatering of excess sludge is improved.

Below are tables with the influent-effluent analysis in January 2016.

An analysis of the tables above shows that the treatments applied for biodegradability improvement has led to the following results:

- Even when the temperature drops to 8.1 ° C, nitrification and denitrification still take place, ensuring the required effluent limits.

- By increasing the temperature to 16 ° C, denitrification greatly intensifies, with effluent nitrate values of 1.5 mg / l (required nitate limit is 37 mg / l).
- The effluent COD is approximately 48 mg / l (required COD limit is 125 mg / l).
- The effluent BOD5 is approximately 10 mg / l (required BOD limit is 25 mg / l).
- The laboratory samples show that sludge stabilization is advanced (up to 45-55% volatile content), which determines the degree of dewatering of about 30% SU.

Table 1. Analysis of influent and effluent in January 2016

DATA	CCO-Cr		CBO-5		MTS		Amoniu		Azot tot.
ian.16	mgO2/l		mgO2/l		mg/l		mg/l		mg/l
	influent	efluent	influent	efluent	influent	efluent	influent	efluent	efluent
CMA	500,0	300	300,0	100	350,0	200	30,0	35	35
1	613,42	44,30	151,20	10,08	303	19			
2	490,73	40,89	134,40	8,80	308	20			
3	490,73	49,41	137,60	10,60	176	40			
4	644,09	50,35	168,00	10,56	151	47			
5	398,72	41,02	117,60	8,08	368	31			
6	543,84	42,19	155,20	6,56	274	27		9,73	-
7	513,61	40,37	141,20	8,96	234	20			
8	342,61	48,45	116,40	11,30	324	21			
9	606,16	51,08	182,00	8,20	212	22			
10	513,61	42,84	153,60	7,54	239	20			
11	483,40	55,54	143,80	9,82	239	23		0,309	-
12	392,76	52,71	121,20	8,82	276	19			
13	774,27	60,49	205,50	7,92	236	16,0		-	8,029
14	588,44	47,19	184,00	9,34	328	14			
15	557,47	61,09	157,00	16,35	215	17			
16	496,53	46,76	135,60	13,20	375	17			
17	557,47	46,76	137,80	11,36	234	8			
18	526,50	47,17	159,40	8,04	194	12			
19	1083,97	41,25	364,50	8,80	880	12			
20	587,92	51,28	154,00	9,60	195	22	49,00	18,00	-
21	852,48	45,42	181,50	8,20	307	10			
22	529,12	38,08	133,00	8,52	205	11			
23	499,73	55,68	123,60	11,68	327	8			
24	529,12	41,02	144,00	9,78	276	20			
25	382,14	52,73	110,55	16,10	194	30			
26	587,92	43,95	170,25	10,58	357	37			
27	438,94	34,70			282	38		0,052	-
28	470,29	53,64			321	19			
29	689,76	63,12			326	21			
30	783,81	44,17			464	20			
31	470,29	50,48			147	15			
Media	562,58	47,88	157,03	9,95	289,26	21,16	49,00	7,023	8,029

Table 2. Analysis of effluent in January 2016

		SCADA		Laborator			
DATA	**ORA**	**MLSS g/l**	**Nitrati mg/l**	**pH**	**Oxigen diz. mg/l**		**Temp.**
					Anoxic	**Oxic**	
1	10	4359	19,12			2,08	13,20
2	10	4320	24,14			2,24	12,40
3	10	3880	28,47			2,08	8,10
4	10	4140	22,12			2,24	11,30
5	10	4497	14,54			2,32	11,50
6	10	4598	11,81			0,96	11,50
7	10	4575	9,21		0,96	1,36	12,70
8	10	4600	6,48		1,52	1,20	14,11
9	10	4582	7,31		0,96	2,40	15,40
10	10	4516	4,12		1,84	2,72	14,70
11	10	4406	8,0		1,20	1,92	14,40
12	10	4419	7,78		0,80	1,60	14,30
13	10	4389	9,15		0,96	1,12	14,20
14	10	4481	8,75		1,30	2,04	14,20
15	10	4463	9,94		1,55	2,69	14,50
16	10	4426	10,67		1,79	1,95	15,70
17	10	4351	12,87		1,06	2,04	14,80
18	10	4341	18,62		1,38	2,12	12,50
19	10	4420	6,25		1,41	1,64	14,60
20	10	4393	13,24		2,04	2,69	10,40
21	10	4363	17,38	7,25	1,14	2,28	12,10
22	10	4505	17,56	7,25	1,64	2,19	11,30
23	10	4575	16,82	7,29	1,56	2,27	11,30
24	10	4494	20,38	7,31	2,66	3,05	10,90
25	10	4478	24,31	7,44	1,41	2,50	10,90
26	10	4565	23,56	7,34	2,97	3,29	11,70
27	10	4633	22,31	7,36	1,60	2,32	13,20
28	10	4580	21,40	7,23	1,20	1,68	12,00
29	10	4746	19,80	7,28	2,40	2,64	15,60
30	10	4781	18,56	7,35	2,40	2,80	14,90
31	10	4795	19,81	7,31	3,04	2,48	13,80
Media		**4473,26**	**15,31**	**7,31**	**1,63**	**2,16**	**12,97**

Table 3. Analysis of influent and effluent in March 2016

DATA	CCO-Cr		CBO-5		MTS		Amoniu		Azot tot.
mar.16	mgO2/l		mgO2/l		mg/l		mg/l		mg/l
	influent	efluent	influent	efluent	influent	efluent	influent	efluent	efleuent
CMA	500,0	125	300,0	25	350,0	35	30,0	2,0	15,0
1	493,23	53,82	147,00	11,82	219	12			
2	433,52	50,03	119,00	9,34	139	27	46,15	0,781	-
3	406,42	45,18	122,70	8,40	223	15			
4	487,70	67,76	166,60	17,25	376	17			
5	433,51	58,11	152,00	19,65	299	25			
6	704,46	51,64	303,50	10,66	166	22			
7	552,40	51,05	138,20	11,06	534	19	55,57	0,056	-
8	617,39	61,24	212,00	15,06	210	17			
9	552,40	45,21	155,00	12,58	207	17			
10	519,91	46,67	151,80	9,18	142	9			
11	552,40	48,13	168,20	10,98	168	16			
12	584,90	43,75	179,75	8,06	240	9			
13	519,91	52,51	145,40	9,38	184	14			
14	487,41	39,38	139,00	9,22	180	7			
15	519,01	43,34	122,80	6,14	183	11			
16	499,18	51.08	104,25	5.63	185	8.5	54,35	-	**9.877
17	411,01	43,75	127,84	9,52	309	20			
18	436,70	38,79	140,40	11,16	153	15			
19	308,26	40,14	115,20	9,04	154	20			
20	385,32	45,08	117,60	10,66	200	22			
21	265,06	46,40	71,10	10,34	211	28			
22	385,32	44,15	113,85	10,34	268	12			
23	423,12	57,66	131,80	13,80	231	15	53,45	0,383	-
24	522,66	53,44	118,20	15,00	271	11			
25	398,22	47,81	108,90	10,02	136	16			
26	348,44	36,22	98,25	9,38	131	8			
27	398,22	39,01	111,30	7,58	252	14			
28	348,44	52,94	112,80	12,50	218	14			
29	348,44	44,59	104,25	10,60	126	7			
30	543,00	48,59	153,40	9,04	103	8	68,65	0,998	-
31	383,29	41,42	109,20	9,22	168	12			
Media	**460,30**	**48,03**	**137,46**	**10,73**	**212,45**	**15,08**	**55,63**	**0,555**	**9,877**

Table 4. Analysis of effluent in March 2016

SCADA				LABORATOR		
DATA mar.16	ORA	Turbiditate	Nitrati mg/l	Oxigen diz. mg/l Anoxic	Oxigen diz. mg/l Oxic	Temp.
1	10	4157	11,86	1,46	1,79	15,40
2	10	4065	10,26	1,58	2,37	16,30
3	10	4141	8,55	1,98	2,21	16,20
4	10	4243	8,72	1,02	2,69	14,50
5	10	4332	3,38	1,50	2,93	15,20
6	10	4420	9,19	1,18	2,45	15,40
7	10	4345	14,85	1,74	1,98	16,40
8	10	4395	13,58	1,22	1,95	15,20
9	10	4479	6,55	1,06	2,12	15,00
10	10	4482	12,60	1,55	2,04	15,50
11	10	4520	14,01	1,79	2,04	15,70
12	10	4518	13,78	1,30	2,52	14,70
13	10	4506	12,19	1,22	2,85	13,60
14	10	4369	8,24	1,45	1,69	13,90
15	10	4456	13,98	1,37	1,53	15,90
16	10	4366	12,25	1,05	0,72	15,20
17	10	4424	7,73	1,29	2,02	13,70
18	10	4427	4,78	1,13	1,61	15,20
19	10	4441	1,86	1,29	1,53	15,00
20	10	4433	1,50	1,05	1,61	13,30
21	10	4406	2,41	0,88	2,26	14,10
22	10	4371	2,74	0,64	1,61	15,60
23	10	4342	1,80	1,53	1,05	16,10
24	10	4289	1,63	1,61	1,37	16,10
25	10	4274	2,00	2,02	1,61	15,10
26	10	4241	2,11	1,37	1,53	15,20
27	10	4185	2,04	1,69	1,45	15,00
28	10	4017	2,91	2,42	2,42	16,10
29	10	3869	4,14	2,18	3,15	14,30
30	10	3901	4,56	1,53	1,37	15,30
31	10	3934	4,67	1,61	2,42	16,50
Media		**4301,55**	**7,125**	**1,44**	**1,96**	**15,18**

d. Disintegration of excess sludge

Targu Secuiesc WWTP is provided with 100% ultrasonic disintegration of thickened excess sludge (image 4). A percentage of 30% of the disintegrated sludge is redirected back to the biological reactors on sludge return line, with the effects mentioned above. The remaining disintegrated sludge is sent to dewatering.

Effects of excess sludge disintegration before dewatering are:

- sludge cell destruction, stripping away water to improve filtrability before thickening / mechanical dehydration
- reduced consumption of polyelectrolyte by 18%

The extent of sonication of thickened activated sludge can be adjusted by varying the number of hours of operation of the sonication installation.

Figure 4. Ultrasonic disintegration installation at Targu Secuiesc WWTP

With the technologies listed above (stabilization and advanced disintegration) the dewatering degree achieved at Targu Secuiesc WWTP is 28-31% DM (table5), using Teknofanghi Italy belt filters. The manufacturer guarantees 20-22% DM for aerobically stabilized sludge excess sludge.

Table 5. Humidity of thickened and dewatered sludge at Targu Secuesc WWTP in January-February 2016

DATA	UMIDITATE % NAMOL CONC.		UMIDITATE % NAMOL DESHIDRATAT	
	W%	S.U	W%	S.U
06.01.16	99,00%	1,0%	69,80%	32,00%
12.01.16	98,80%	1,20%	73,75%	26,25%
20.01.16	98,30%	1,70%	72,75%	27,25%
27.01.16	98,50%	1,50%	68,25%	31,75%
03.02.16	98,65%	1,35	72,35%	27,65%
10.02.16	98,39%	1,61%	68,53%	31,47%
17.02.16	97,57%	2,43%	71,58%	28,42%

Thus at Targu Secuiesc WWTP is the only case in the country where the dewatering degree of 30% DM was obtained, consuming 3 g / kg DM polyelectrolyte when dewatering excess sludge with belt filters.

e. *Alkaline treatment of sludge*

In order to further increase the degree of dehydration, alkaline treatment was provided at Targu Secuiesc WWTP in addition to disintegration ; this facility is still unused, given the great success of dehydration achieved so far.
Alkaline treatment with lime prior sludge dewatering would ensure an increase by 2% of dewatering degree.

f. *Drying of dewatered sludge*

For a sludge dry content of up to 35% DM sludge solar thermal drying was provided at Targu Secuiesc WWTP, on the floor of a drying zone within the sludge deposit. Dewatered sludge is discharged and distributed all over the drying zone. Scattering, coultering, leveling of sludge is done with the front loader with attached devices.
From April through October solar energy and greenhouse effect are sufficient for sludge drying.
Additional thermal energy needed in the cold is produced by waste water heat recovery with heat exchangers installed in the secondary sedimentation tanks (image 5). Heat exchangers transmit heat to the heat pump installed in the boiler (image 6). The heat pump raises the temperature of the heating fluid up to 55 ° C and is transmitted to the sludge by heating the sludge drying floor.

Figure 5. Targu Secuiesc WWTP -Treated water heat recovery installation

Figure 6. Targu Secuiesc WWTP heat - pump

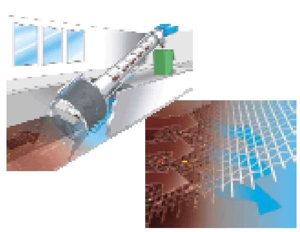
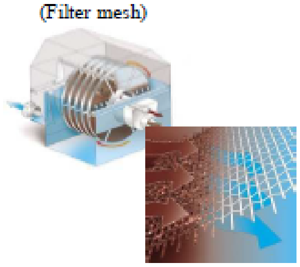
3. LONG-TERM STRATEGY

In order to reduce the production of sewage sludge, we propose the following strategies:

- ***For small and medium-sized WWTPs:***

-Screening followed by secondary screening with e = 0.25 mm and microscreening with e = 10 µm (Hans Huber and Salsnes technology), with / without chemistry, according to the following table:

Table 6. Reduction efficiencies of mechanical or mechanical-chemical treatment

Treatment technology	Screen aperture [mm]	COD reduction* [%]	
		Without chemicals	With chemicals
Wedge wire 	1.5-1.0	5-10	-
Fine screening (Mesh or perforated plate) 	1.0-0.2	10-30	30-55
Micro screening (Filter mesh) 	0.1-0.02	20-40	40-60

The aperture sieve type CCO% Discount
- Mechanical and electrokinetic disintegration of excess and return sludge
- Ultrasonic disintegration of excess sludge, out of which 30% is recycled
- Treatment of thickened excess sludge at 60 ° C, 1-3 hours, in order to release through thermal disintegration the inter- and intra-cellular water. Dehydration final grade greater than 35% DM, without requiring thermal drying or the addition of lime. Heat required is taken by heat pumps and heat exchangers from treated wastewater.
-For more than 35% DM: Solar thermal drying in greenhouse and on the floor with additional energy

- ***For large WWTPs with anaerobic degestion - Case Study: Alba Iulia WWTP (image 7)***

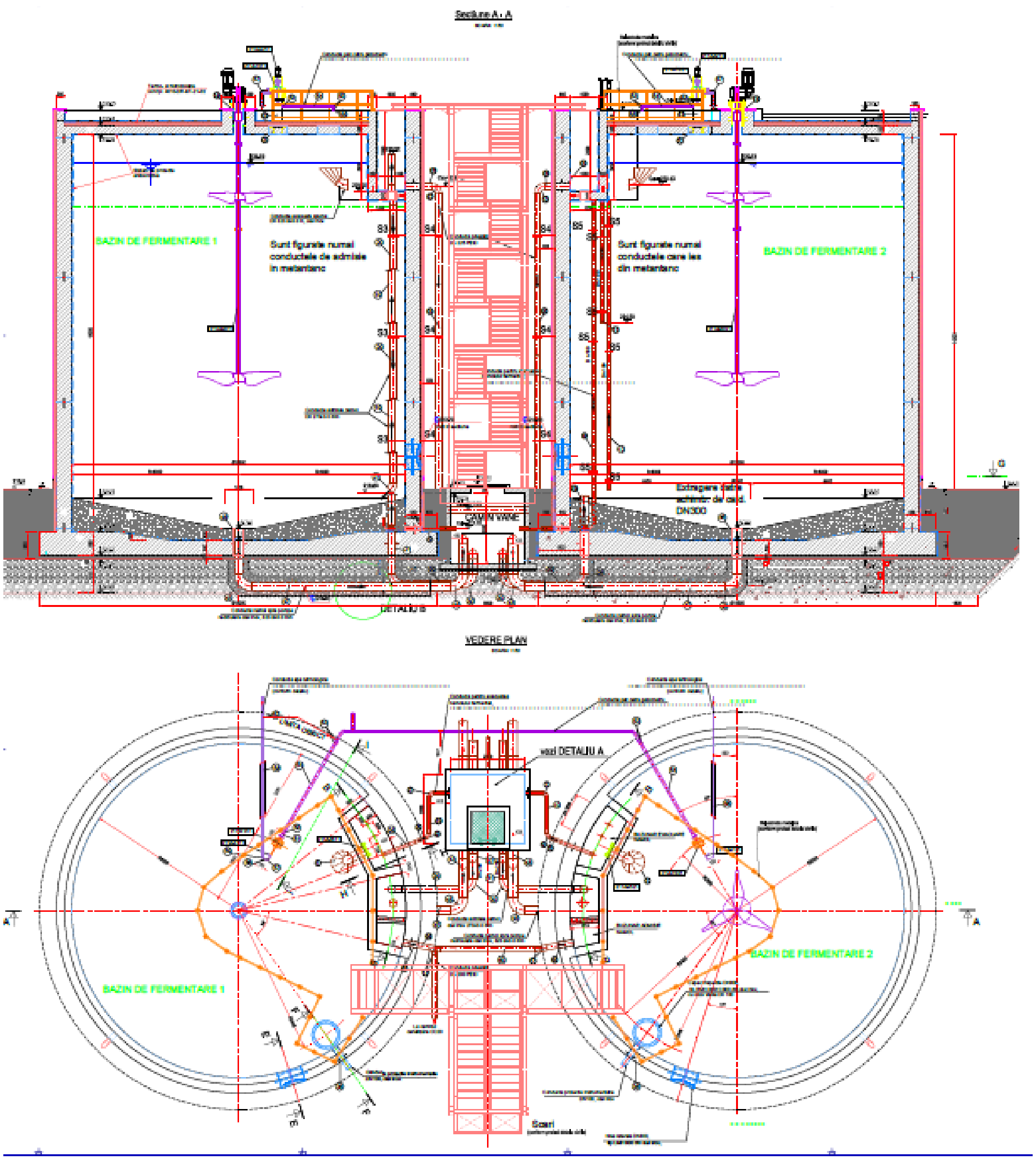


Figure 7. Sludge digesters at Alba Iulia WWTP

Alba Iulia Waste Water Treatment Plant, commissioned in 2015, includes the mechanical biological treatment step and sludge treatment step. Proposed measures to reduce the final amount of sludge at Alba Iulia WWTP are:

Table 7. Proposed methods

	Proposed methods:	**Effects:**
1	Full introduction of excess sludge in digesters	Additional production of biogas Excess sludge stabilization Decrease of final sludge quantity Increase of dewatering degree
2	Pre-disintegration of thickened excess sludge by sonication prior dewatering	Increase of digestion efficiency, thus increase of biogas production and decrease of final sludge quantity Increase of dewatering degree
3	Pre-disintegration of thickened excess sludge by sonication and partial return to biological tanks	Decrease of final sludge quantity Prevention of sludge foaming Improvement of biological processes
4	Post-disintegration of digested sludge (primary and excess sludge) by electrokinetical and sonication prior re-digestion	Increase of overall digestion efficiency Increase of dewatering degree Decrease of lime quantity required to achieve 35% DM content Decrease of final sludge quantity
5	Post-disintegration of digested sludge (primary and excess sludge) at 60°C	

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CHAPTER II

ADVANCED TECHNOLOGIES FOR SLUDGE TREATMENT

Actual Technologies In Engineering Practice For Sludge Treatment In Wastewater Treatment Plants

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Abstract

Development infrastructure funding programs in Romania resulted in a comprehensive process of refurbishment and/or new investment for Waste Water Treatment Plants and respectively for potable Water Treatment Plants.

Both types of treatment plants have two basic treatment lines: the line of water treatment technology and sludge treatment technology. In both types of investment, sludge is being produced in large quantities, so the sludge that has to be treated.

This paper presents a number of current designs for treatment of sludge in wastewater treatment plants for small investments (< 10.000 P.E.), for projects with less then 50.000 P.E. and also for investments with less then 100.000 P.E.

The examples presented into this paper are collective achievements through the design of some major investments in Romania. They present different treatment technologies with predehydrating treatment (anaerobic or aerobic mesophilic stabilization) and dehydration. There are also presented hydraulically transportation problems for the related installations (path for biogas and heating) and storage of treated sludge.

The projects were done in the Bacau, Botosani, Iasi, Neamt, Teleorman, Vrancea and Vaslui counties, through applications in villages, towns and municipalities.

Keywords

Sludge treatment technology, development infrastructure programs

1. INTRODUCTION

Treating wastewater, for disposal into natural receivers or recycle them, leads to detention and removal of technological line for wastewater treatment quantities of extractions defined generic sludge, takes a part of polluting materials from raw water and also from wastewater treatment processes. Therefore efficiency of such treatment plants can be analyzed if these sludges were treated well enough in the sight of capitalize them, conditioned by costs of treatmeant.

Sludge resulted from wastewater treatment, whatever is their nature, are colloidal systems with heterogeneous composition. They contain colloidal particles (diameter less than 1 μm) dispersion particles with diameters between 1 and 100 μm and suspended solids with jelly aspect, as organic polymers of biological origin.

From technological point of view sludges are different, depending on their weight as primary sludge, secondary sludge or tertiary sludge, are conditioned on the wastewater line from the wastewater treatment technology segment.

The physico-chemical parameters of sludge depends on the origin and treatment technology. To characterize sludges we are using general indicators and specific indicators, but also other parameters that characterize the behavior of sludge in certain manufacturing processes.

Sludge treatment processes are many and varied and so it can't be established recipes and

technologies for general use, therefore every objective must be analyzed in its specific conditions, based on a thorough knowledge of the characteristics of the sludge being processed.
Underlying sludge treatment processes are the following technological processes from sludge treatment line, namely: collecting and transporting sludge, predehydratation stage, treatment sludge stage, dehydratation stage and their capitalization.
Classification of these processes is made after reduced humidity criterion, the criterion of reduced organic component criteria, cost price criteria etc.
Technological line treatment sludge deals with organic sludge from the three stages of wastewater treatment (primary, secondary and tertiary). The waste materials from racks (site) are collected, washed and composted and sent to waste materials warehouse.
Mineral sludge (SM>70%) extracted from sand trap is concentrated and dehydrated with different types of equipment (binders, etc.) and after that it can be used in road infrastructure. Oils and fats held in the separation chamber are processed in mechanical separator then there will be recovered in the chemical industry. [1, 3]

*

Taking into account the complexity of situations depending from the current situation and the outlook, we present a series of case studies of our team on many treatment plants, where we divided presentation on the two types of sludge treatment technologies:
- Anaerobic treatment technology - which is based on anaerobic processes of mineralization of organic substances contained in sludge composition;
- Aerobic treatment technology - which is based on mineralization by aerobic biological processes.

2. SLUDGE TREATMENT PROCEDURES BY ANAEROBIC TREAMENT TECHNOLOGY

Case study no 1 – Waste Water Treatment Plant of the city Alexandria, Teleorman

Overview
From wastewater treatment line are disposed a series of retainers which are generically called sludge. Discharged retainers are several types:

- Organic sludge is retained from primary clarifier with exceeding percent of 70% of S.O. and which requires treatment in sludge treatment technology line. Its humidity can not be less than 95% to avoid problems during transport by pumping oil order not to obstruct discharge pipes. Sludge from primary clarifier is called primary sludge (PS) and is collected by bridge scrapers of clarifiers into one location and from there reach in the primary sludge pumping station, where is pumped and sent to the mixing sludge tank below the technological sludge treatment warehouse;
- In the biological reactors RB1, RB2 and RB3 is eliminate the excess activated sludge (N.A.Ex.) with the help of N.A.Ex pumps. After that is sent to the mixing sludge tank below the technological sludge treatment warehouse and after that goes in the treatment technological line. Moisture content of this kind of sludge is higher than ≥ 99%. This sludge is called secondary sludge (NS);
- From the compensation tank, the tertiary sludge is eliminated (NT) with a humidity of 98-99%. This sludge is pumped into the mixing chamber below the technological building.

These sources of sludge (NP, NS and NT) transmit, by pumps, sludge in the mixing chamber from the technological waterline in the sludge line.

Effective sludge treatment line

This stage is made of the following treatment steps:

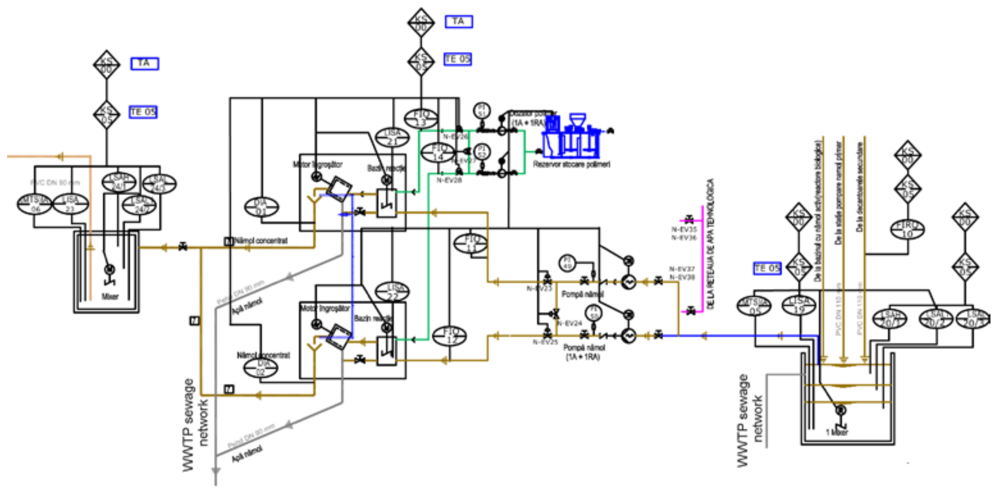
I - **Predehydratation sludge treatment** (figure 1):

a) the collection system and transport to the mixing chamber (SPNP, SPNs, SPNT);

b) mixing chamber (mixing) is performed by mixers;

c) processing sludge - made up from transporting pumps, reagent dosing pumps household, mixing sludge tank with reagent (polyelectrolyte) - (flocculator), processing sludge. Polyelectrolyte household is automated and prepared in the compositon the solid state form polyelectrolyte, mixing it with technological water and after this is processed. Sluge water is discharged into internal sewage system and sent into the water cycle. The sludge is discharged into a storage tank;

d) sludge storage tank is equipped with mixers for helping the homogenization;



Legend: KS00 - central control unit and which is given to the central SCADA; KS05 - PLC / RTU found in TE05 switchboard; FIQ - Circuit flow measurement and indication; LISA - Measuring circuit level indication, signaling and interlocking; DIA - Measuring circuit density, indication and alarm; PI - local circuit-gauge pressure measurement indicator

Figure 1. Predehydratation stage

II. – **Sludge treatment stage** is made of the following main steps :

a) pumping station from storage tank sludge to the methane tanks through underground pipes;

b) it is home fermentation tank the loading chamber located in its upper part (outside of fermentation tank);

c) methane-tankers - realizes anaerobic treatment (mesophilic treatment);

There are four stages of anaerobic treatment:

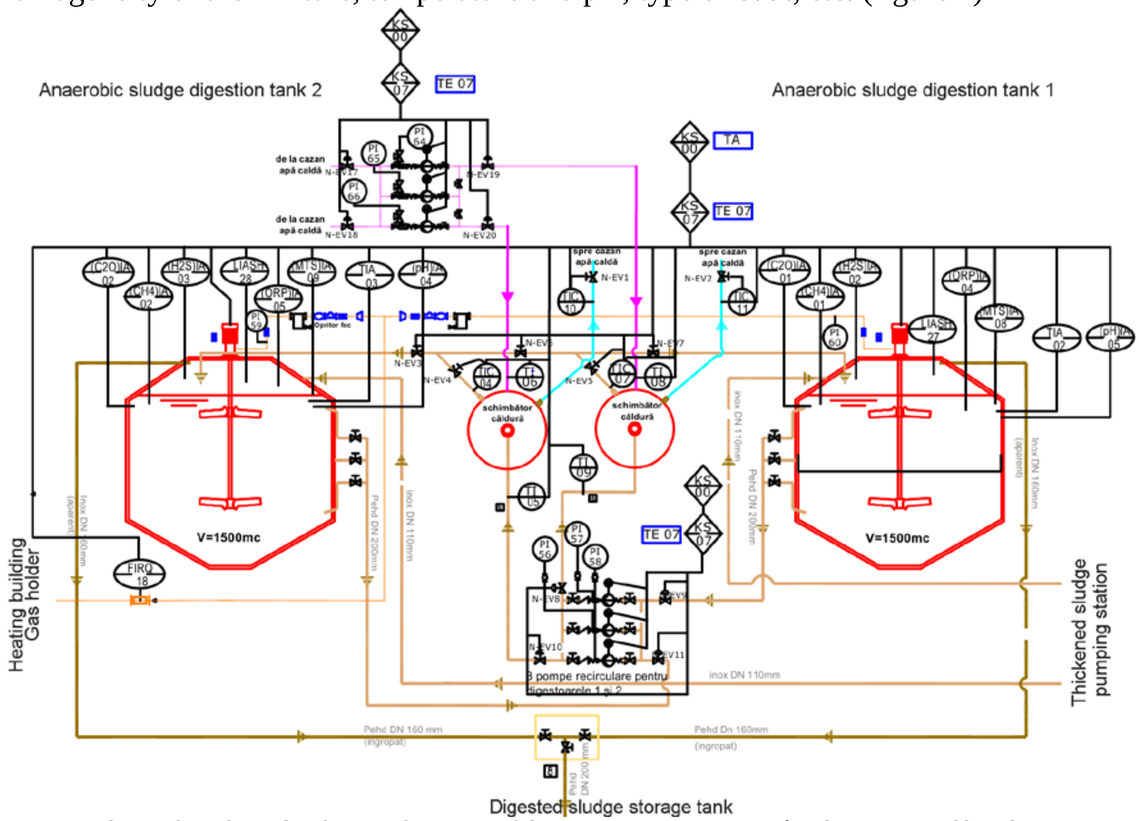
- *Hydrolysis*: is the process of dissolving the organic compounds with a high molecular weight complex in simple organic compounds (sugars, amino acids, fatty acids).

- *Acidogenesis*: some organic matter resulting from the hydrolysis process can be taken directly by methanogenic bacteria, but other substances must be transformed into compounds that can be directly assimilated by them. Acidogenesis is the acetogenic bacteria decomposing under the action of organic substances in volatile fatty acids and ammonia, carbon dioxide and hydrogen sulfide.

- *Acetogenesis*: the process of acidogenesis resulting from simple molecules are converted, under the influence of acetogenic bacteria, mainly acetic acid, carbon dioxide and hydrogen.

- *Methanogenesis*: the last part of digestion is methane bacteria action on substances from previous stages, leading to the formation of methane, carbon dioxide and water, the main components of biogas. [4, 5, 9]

The chemical reaction that synthesizes the above processes is as follows: $C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$
The processes described above occur simultaneously in the methane tank, so sludge requires a fairly long period of retention and this period is strongly influenced by a number of factors such as the homogeneity of the mixture, temperature and pH, type of S.O., etc. (figure 2)



Legend: KS00- central control unit located to the central SCADA and data; KS07- PLC PLC / RTU found in TE07 switchboard; LISAH - Measuring circuit level indication, signaling and interlocking at its optimum level. (C2O) Take Measuring circuit C2O - pointing signal; (CH4) IA - Measuring circuit CH4 - pointing signal; (H2S) IA - Circuit measuring H2S - pointing signal; (ORP) IA - Redox Potential Measuring circuit - pointing signal; (MTS) IA - Measuring circuit MTS - pointing signal; TIA - Circuit measuring temperature-indicating, signaling; (Ph) IA - Circuit measuring pH - pointing signal; TI - local circuit measuring temperature thermometer indicator. ICT - Measuring circuit temperature indicator, signaling; PI - local circuit-pressure measuring gauge indicator.

Figure 2. Sludge treatment stage

The two sludge digesters (1500 cm/unit) were rehabilitated. All the pipes have been replaced, (Figures 3a, 3b). Sludge inlet and outlet are located in the outside chamber of the anerobic sludge digestion tank.
Sludge agitators were installed in each fermentation tank. The two methane tanks have a valve chamber, where there are pipes, valves maneuver, sludge recirculation pumps, heat exchangers, all sensors of automatic control engineering..
Heat exchangers are supplied with heat produced by C. T. Into and out of the water and sludge that were predicted temperature sensors for better process control. Sludge from the tanks is recirculated through the recirculation sludge pumps.

d) the methane tank valve chamber in which the sludge recirculation pumps, heat exchangers for heating water produced by the boiler, various valves and fittings for maneuvering;

e) home outlet pipes for transporting digested sludge at sludge treatment technology;

f) buffer tank for storing digested sludge (mineralized).

Figure 3a. Rehabilitation Anaerobic Sludge Digestion Tank- foto

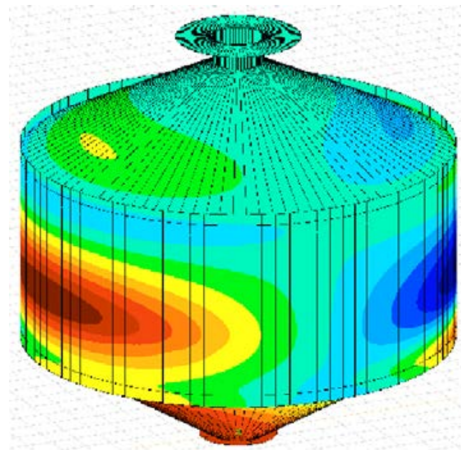
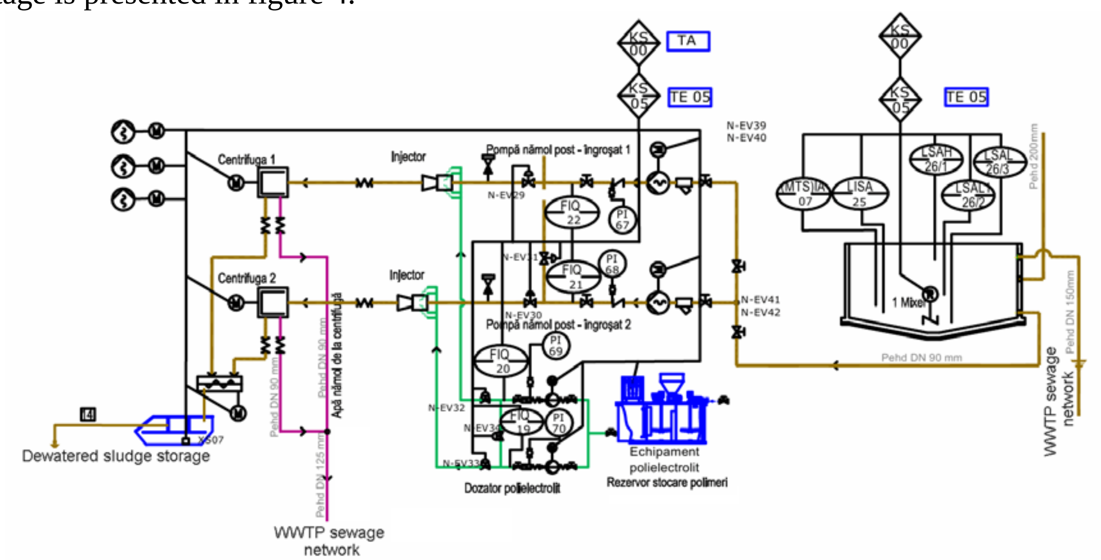


Figure 3b. Anaerobic Sludge Digestion Tank – 3D model

III. - **Sludge dehydratation and storage stage**
This stage is presented in figure 4.



Legend: KS00 - central control unit and which is given to the central SCADA; KS05 - PLC / RTU found in TE05 switchboard; FIQ - Circuit flow measurement, indication and metering; PI - local circuit measuring pressure - pressure gauge indicator; Xs - Proximity sensor for the presence of container. LSAL, LSAL1, LSAH - Circuit detection level - signaling and interlocking Touch minimum / intermediate / peak; LISA - Circuit measurement and signal level indicator.

Figure 4. Dehydratation sludge stage

1. digested sludge pumping station for the installation of buffer tank mixing with the reagent (polyelectrolyte) and then to the centrifuge;

2. household reagents (polyelectrolyte) with dosing pumps;
3. flocculator - pool of sludge mixed with reagents;
4. centrifuge.

The installation of mechanical dehydratation

The technological dehydration by centrifugation differ technological pre-dehydratation flow processing the sludge by centrifuges, which mainly have a much better yield. Thus, if the influent sludge moisture content in the third step of the sludge treatment is defined as a 95-97% dehydrated sludge to outlet may have a moisture content between 70-80%, depending on the needs (season, time for storage etc.) (Figures 5a and 5b).

It should also keep in mind that methane-tankers haven't mineralized by anaerobic treatment the entire quantity of organic matter in sewage influent sludge line, which is why the continuation occurs for bacterial anaerobic sludge treatment. Considering this is only fair that after dehydration containers of dewatered sludge to be transported to the county landfill, where composting of the sludge will continue through mineralization and possible with production of biogas and finally capitalizing compost, used in agriculture as a mineral fertilizer.

When dehydrated digested sludge will be used in agriculture, it must be a very close collaboration between the technologist of plant, the agronomist and land farmer. In this case, the dehydration will be determined after the needs imposed by transportation and distribution of sludge on agricultural land. If there are no possibilities to transport the dewatered sludge was built, according to the opinions given by the Environmental Protection Agencies, a storage platform, for a maximum period of six months. The warehouse is achieved by draining slab and concrete vertical walls of 1,50 m. The remaining deposit is as such: the walls are free, are only metal poles and the roof is metal.

Households reagents which prepare the polyelectrolyte solution are identical with those of prehydratation with the difference that the metering pumps have another dose of the polyelectrolyte and the injection pressure in the centrifuge is different from the thickeners. During centrifugation, sludge water from the plant is discharged and reintroduced into the circuit by discharging waste water into domestic sewage system. Dehydratated sludge is discharged directly into shipping containers or conveyors which transports it directly on the platforms. [2, 6, 8]

Figure 5a. Dehydratation Installation- photo

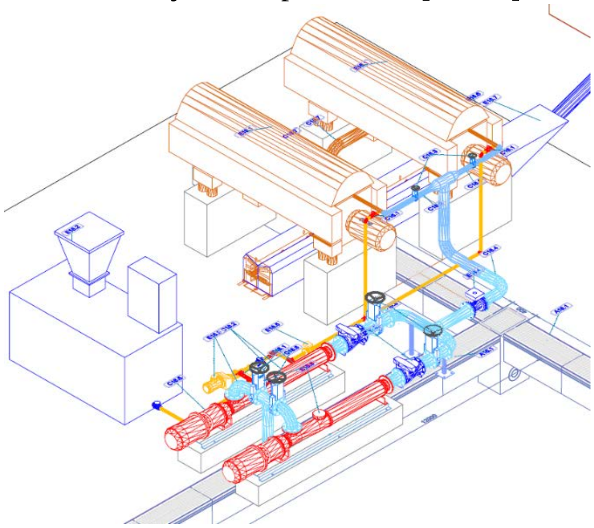


Figure 5b. Dehydratation Installation

1. transportation rails for dehydratated sludge transport in storage;
2. storage halls are open space, roofed halls and slab drainage. Water sludge is reintroduced into the water cycle and dehydratated sludge is loaded into vehicles and being used in agriculture.

Technological auxiliary installation in sludge treatment technology line

Biogas recovery technology line
Biogas, is secondary product of fermentation into the anaerobic sludge digestion tank, is kept and used as fuel in the boiler. For this biogas is controlled with specific parameters (fitted with safety overpressure), piped to the meter, used as volume compensation and then sent by pipeline to the boiler where it is used with burners specific or heating boilers. On the way there is relief valves, flame burning the extra biogas, which can not be used for boiler installation of biogas remediation.

The production of thermal agent
Thermal agent necessary for heat transfer in heat exchangers valves chamber is produced by a boiler natural gas / biogas. The boiler is automated, which is dictated by temperature 35 ± 1°C of methane tank. The water needed in the boiler is softened by own facilities. It comes from internal process water circuit and other equipments that are requiring process water (centrifuges, thickeners, screens, etc.).

Electricity networks needed
a) supply circuit for sludge technological line; b) general transformer station includes the necessary components for sludge treatment and electric generator; c) force main network that supply equipments including electrical switch panel; d) lighting circuits, with specific switch panel and sockets for line items sludge; e) specific lightning discharger for technological line treatment (especially in the area of biogas and methane tanks).

Automation and SCADA networks - all sludge line is automatic
a) sensor circuits to control computers and then to process computers and transmission level I decision (for the equipment); b) circuits to process computers at the level I to level II (groups of equipment or steps) and vice versa; c) circuits to process computers at the level II to level III (production lines) and vice versa; d) circuits to process computers at the Level III Level IV (wastewater treatment plant) and vice versa;

Sewers system
These networks are of several kinds;
Networks for water discharge sludge; Networks for discharge wastewater from cleaning technology; Sewers from the sanitary line sludge; Sewers for drainage of rainwater inside the sludge treatment line.

Low voltage electrical networks for:
a) video camera technology; b) security cameras; c) motion sensors security; d) technological warning; e) security warning.

Auxiliary constructions deservent
Administrative building/dispatcher; Laboratory; Road; Systematization and land protection (environment).

Other examples of wastewater treatment plants

Bacau Town – Expertise report result allowed reusing the old anaerobic sludge digestion tanks but with some changes in structural and technological part: rehabilitation the upper catchment area and rehabilitation of gas chambers and valves.
General technology remains the same as in the case study 1, but with the differences in the amount of sludge specification.

Targu Mures Town - has a general technological line similar to the following differences:
- Use gravitationally processing sludge;
- It was among the first biogas cogeneration plant in the country and further transformation into electricity.

Iasi Town has a line of sludge treatment technology similar, but with the difference of producing higher quantities of sludge, of course related to the higher flow of Iasi.
One of the current problems is the "sanitary sludge" collected by emptying septic sludge in nonsewerage area or from the collecting services from various industries with biodegradable liquid organic waste or semi-liquid waste.

In the country there are several cities that do not have a precise management of drainage, which is a big problem for water treatment line, that does not give the desired yields after all of these „shocks” in the treatment line.

This kind of sludges must be managed territorial y, collected and transported in the line of treatment technological sludge after laboratory tests (which do not indicate the presence of toxic substances, jeopardizing treatment process), unloaded in special tanks and transported with special pumps in the pre-dehydratation stage, the processed sludge catchment area and raw material mixture creates a sludge treatment stage.
Wastewater treatment plants from **Adjud, Marasesti, Panciu, Odobesti in Vrancea** county have anaerobic sludge treatment line, similar to case study 1 but having the following differences:

1. In pre-dehydratation stage there is gravitationally sludge processing;
2. Stirring sludge in methane tank, if the other examples were made with mechanical agitators, in these plants stirring is done with ejectors;
3. To protect from low temperatures the intake chambers /ou ttake chambers sludge methane tanks are located inside the tanks;
4. To reduce moisture dehydrated sludge, Solar Buildings (like greenhouses) with low drainage, which have special air conditioning interior equipment and other equipment that "cut" away sludge with his wheels, allowing to evacuate easily the water retained in the sludge mass.

Also all wastewater treatment plants have the sludge treatment technology line, pre-dehydratation line of sanitary sludge to solve septage sludge (Figure 6a).
Vaslui Town - has almost the same production line for sludge treatment, but it does extra gravitationally processes and anaerobic sludge digestion tanks are made of synthesized glass OL protected. The differences are from different quantities of sludge (Figure 6b).

Barlad Town- same as Vaslui Town

Figure 6a. Anaerobic Sludge Digestion Tank - Odobesti

Figure 6b. Anaerobic Sludge Digestion Tank - Vaslui, Barlad

3. AEROBIC PROCEDURES FOR TREATMENT SLUDGE

Case Study 2– Waste Water Treatment Plant in Rosiorii de Vede, Teleorman County

Overview of technological sludge line

Sludge treatment technology line is similar to case study 1 with anaerobic treatment.
The production line consists of the following steps:

1. Pre-dehydratation sludge stage;
2. Aerobic treatment (stabilizer/mineralization) sludge stage;
3. Dehydration stage.

Differences between **predehydratation stage** previously presented (case study 1) and this one is that in this case: sludge process is done in gravitationally process tank, directly from vertical clarifier.
Aerobic treatment stage consists of:

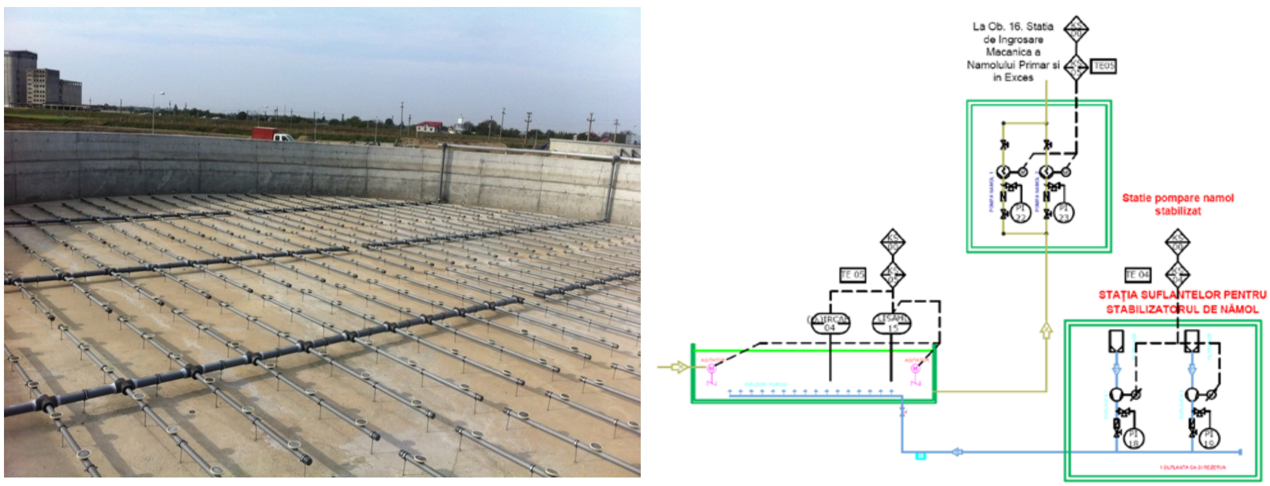
1. sludge pump station process goes to stabilization tank;
2. Stabilization aerobic tank with air blowers station, air distribution network with specific Fine Bubble Diffusers and mixers.

The stabilization aerobic/mineralization process is biological aerobic process that is accomplished out at 0,1÷1,0 mg O_2 /l, depending on the load that can be carried out in 30÷60 h.

Stabilization / aerobic mineralization tank (Figure 7) was a new object with a diameter of 30 m and depth of 3.0 m, built from a previous biofilter construction of treatment plant which was used as lost formwork. The tank is equipped with overflow water and sludge outtake.

- Stabilized sludge pumping station - is designed to transport sludge from the stabilization tank and buffer tank (for dehydration). [9, 10, 11]

Dehydratation stage - after aerobic stabilization process, first is made the sludge procces thickening, centrifuging and then dewatered sludge storage respectively. Mechanical thickening is the same as in step pre-dehydratation from case study 1 and dewatering with centrifuges is the same as the first step of dehydration case study differences in equipment due to the differing amounts of sludge to be treated.



Legend: KS00 - central control unit located dispatcher date and SCADA; KS04 - PLC PLC / RTU version TE04 Located electrical panel; KS05 - PLC PLC / RTU version TE05 Located electrical panel; LISAHL - Circuit Measuring the level pointing to interlocking and signaling reached the minimum / maximum; (O2) IRCAH - Circuit measuring dissolved oxygen, indication, registration, metering and maximum warning level; PI - local Circuit Pressure Measurement - indicator gauges;

Figure 7. Aerobic treatment stage

Other examples for aerobic sludge treatment

Wastewater Treatment Plant in Targu Neamt Town

Prehydratation stage is similar to case study 2. Step aerobic treatment is carried out in a longitudinal primary clarifier that was modified as a stabilizer. Dehydration stage is similar study case 2 with the modification that sludge thickening is gravitationally.

Wastewater Treatment Plant in Turnu Magurele Town - the technological sludge line is similar to that of Roşiorii de Vede, only aerobic sludge stabilization tank is a Imhoff clarifier and it was modified as a stabilizer tank. Differences in equipment is due to the quantities of sludge quantities from case 2.

Wastewater Treatment Plant in Campulung Moldovenesc Town - similar to case study 2.

Wasterwater Treatment Plant in Homocea, Vrancea County

The technological sludge treatment line is identical to that of Case Study 1, except that the treatment stage is accomplished in a stabilization tank (new object).

The production line also features the "sanitary sludge" line in predehydratation stage.

4. CONCLUSIONS

Sludge treatment lines are varied, they are conditioned to the existing situation, to the perspective and the economic analysis of the costs for sludge treatment. The greatest influence is given by secondary sludge (excess activated sludge) and the sanitary sludge (in some cases the biodegradable industrial waste have a high intake). So influences are given by wastewater treatment technology and industries from adjacent area.
Clearly, MBBR technologies (moving bed biofilm reactor) in waste water treatment (given by the climate of our country) will be applied widely increasingly higher scale. This will significantly reduce the quantities of secondary volumes sludge and available volumes will be allocated to industrial waste biodegradable, in quantitative growth, by storing agro-industries.

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The Possibility Of Reuse In Concrete Production Of The Ash Resulting From The Incineration Of The Jiu Valley Sewage Sludge

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Abstract

Starting from the necessity of finding viable solutions for the reuse/recovery of the Jiu Valley sewage sludge from the Danutoni and Uricani Wastewater Treatment Plants (WWTPs) located in Hunedoara County, this paper aims to present the results of the laboratory tests in regards to the potential use of the ash obtained from incineration of wastewater treatment sludge in the process of production of concrete.

The use of the additive material in cement production started in 1960, taking into account various issues related to: the protection of the environment, the reduction in energy consumption and the concrete quality obtained with these types of cements (improvement of the following features: workability, impermeability level, resistance to aggressive chemical agents, etc.).

A series of studies regarding the results of the use of ash and slag for cement production on the properties of the cement have been conducted both locally and internationally. This research study investigated the possibility of replacement fly ash from power plant with the ash obtained from incineration of sludge. No available information regarding such studies ever performed in Romania has been found to date.

Considering the fact that the properties of "sludge incineration ash" depend on the chemical composition of burned sludge, chemical analysis were carried out on a representative sample of sludge taken from the Danutoni WWTP, managed by the Regional Operator in Jiu Valley, APA SERV SA Petrosani. The sample of sludge was combusted at 900°C in an incineration facility.

The "sludge incineration ash" collected after combustion was analysed to determine the main properties and composition, and it was then added in the three separate concrete recipes, replacing 10%, 20% and 30% of the typical 0/1 grain size sand input, respectively. The results of tests performed on the output concrete samples, were compared with the tests performed on a typical concrete sample, considered the reference sample.

Keywords
Sewage sludge, incineration, ash, concrete.

1. INTRODUCTION

Considering the conditions imposed by the European Union and by the national legislation, which mostly transpose EU Directives, sewage sludge management/reuse - is still a major issue that Romania must solve. Although the responsibility for the sludge management generated from WWTP belongs to sludge producer, which is the Regional Operator of Water and Wastewater, in practice it is a national scale issue due to the following:

- Very limited feasible options for reuse or disposal of sewage sludge;
- Technical, legislative constraints and, in some cases, the lack of national regulations regarding the reuse of the sludge (in forestry land improvement, for restoration of damaged contaminated land or in the composting process);

- Lack of public awareness, including potentially interested farmers, on the methods and benefits of using sludge from WWTP in agriculture;
- Lack of interest of other economic operators on the introduction of sludge into their processes.

Until now the elimination at the municipal waste landfill was the common practice for sewage sludge management, which was accessible at the national level. The reuse in agriculture was done on a small scale in a few counties in Romania.

In the proximity of the Jiu Valley area, that is the interest zone for this study, five options for sewage sludge management were identified, which were ranked according to the average percentage for each management option considered - versus the total quantity of sludge. The quantities presented are estimated for the 2016 - 2044 period, which overlaps - period of implementation of the Large Infrastructure Operational Program (LIOP 2014 - 2020):

1. Disposal at municipal waste landfills – 50%;
2. Coincineration/incineration – 35.6%;
3. Land improvement – 10%;
4. Agriculture use – 3.5%;
5. Forestry use – 0.85%.

This paper aims to analyse the possibility to reuse the ash resulting from the sewage sludge incineration in the concrete production process. The sludge samples of this study are generated from the Danutoni and Uricani WWTPs.

The activities of the study included analysis of the chemical composition of the sludge, the incineration of sludge, the characterization of the resulting “sludge incineration ash” and tests performed on fresh and hardened concrete produced.

The necessity and planning of this study is justified by the fact that after 2020 the amount of sewage sludge accepted to be landfilled is expected to decrease significantly due to new legal requirements regarding the reduction of the amounts of biodegradable waste disposed at landfills in favour of recycling or reuse methods. Also it was taken into account that in the Jiu Valley area sewage sludge incineration is a necessity, although it is a very expensive alternative.

If possible to reuse the ash resulting from the thermal treatment of the sewage sludge, in the concrete production process, this would lead to a series of interrelated impacts that benefit both the environment and human health. In such case, some of the regional operators could choose recovery of “sludge incineration ash” and consequently they would directly contribute to the gradual alignment of Romania to the European Union requirements on sewage sludge management and to the reduction of the amount of biodegradable waste disposed.

2. RESEARCH ON THE USE OF “SLUDGE INCINERATION ASH” IN CONCRETE PRODUCTION

In Europe, an often used good practice for management of the sludge generated in WWTPs is incineration, especially in the big cities or urban agglomerations.

Until now insufficient options on the possibilities of using various ash types resulting from the combustion of sewage sludge in the production of concrete have been identified, neither in terms of environmental protection nor in terms of technical feasibility [6].Therefore, many scientists got involved in testing of “sludge incineration ash” to be potentially used in concrete production; the results of these studies have been published in scientific papers on the matter. However, in most cases, the research activities have been limited to performing laboratory tests.

Some scientists have indicated that the “sludge incineration ash” has a high pozzolan activity and improves the workability and compression strength of concrete [4]. On the other hand, there are other scientists who have concluded that “sludge incineration ash” has a low pozzolan activity [8] and reduces the workability and compression strength of concrete [9]. The conclusions reached by the researchers were that the pozzolan activity of the “sludge incineration ash” depends on the incineration temperature [13]. Thus, sewage sludge incineration at temperatures of 700^{o} C [22], 800^{o} C [23] or 850^{o} C [15] may lead to the formation of “sludge incineration ash” that may be highly reactive [3], moderate [20] or low [5] reactive and to the improvement or reduction of workability of cement based materials.

A major program, based on the results obtained, was conducted in Denmark between June 2005 and December 2007. After obtaining encouraging results on small scale laboratory tests, a large-scale demonstration project on the use of “sludge incineration ash” in the production of concrete was planned. This resulted in the promotion and development of the project - "Use of ash from the incineration of sewage sludge (bio-ash) in concrete production" with the acronym „BioCrete” funded by the European Union through LIFE Environment Program [6].

The following parties participated in the project: two wastewater treatment plants, which are serving the western and central part of Copenhagen, a Scandinavian concrete producer and the Danish Technological Institute [6].

During project development, two incineration units were installed at the two locations of the WWTPs. The ash from the two incinerators was transported to the concrete producer for input into the manufacturing process. Next, the Danish Technological Institute conducted laboratory tests on the resulting concrete samples.

As a result of the tests conducted during "BioCrete", the use of “sludge incineration ash” as substitute material of fly ash in concrete recipes proved to be an acceptable option, however only up to the replacement of maximum 50% of the fly ash with "sludge incineration ash". The advantage of using “sludge incineration ash” may be attributed to its good performance as additive in concrete recipes [6].

The tasks on the project included the preparation of a *Guideline for the Use of “Sludge Incineration Ash” in Concrete Production (Guideline)*, whose main aim was to provide specific information useful for operators of WWTPs and concrete production facilities [24].

According to the Guideline, the environmental impact of concrete produced with “sludge incineration ash” is assessed on the basis of three categories of waste/soil to be used according the provisions of *Danish Order no. 1635 from 13 December 2006, regarding the use of waste and soil for construction works and civil engineering and the use of sorted, uncontaminated waste from constructions* [24].

3. CHARACTERIZATION OF MATERIALS USED IN THE RESEARCH STUDY

Sewage sludge generated from Jiu Valley

Sewage sludge generated from Jiu Valley comes from Danutoni and Uricani WWTPs and has a predominantly organic composition. Sludge treatment (stabilization, thickening and dewatering) is performed in the mechanical/biological wastewater treatment plant (Danutoni). Before final disposal or reuse, the sludge is mechanically dehydrated with a filter press and further stored on drying beds.

For the physical and chemical characterization of the sludge, physical and chemical analysis were performed on a representative sludge sample collected from the Danutoni wastewater treatment plant. The sample was collected prior to the sludge is fed into the anaerobic fermentation tank (methane collection tank) and analysed in the laboratory of the National Institute of Research and Development for Industrial Ecology (INCD ECOIND) in Bucharest. The humidity of the sewage sludge at the time of sampling was approximately 84%. The parameters analysed were as follows: pH, humidity, heavy metals (cadmium, copper, nickel, lead, zinc, mercury, chromium, cobalt, arsenic), sum of organohalogene compounds, polycyclic aromatic hydrocarbons (anthracene, benzoanthracene, benzofluoranthene, benzoperylene, benzopyrene, chrysene, fluoranthene, indeno (1,2,3) pyrene, naphthalene, phenanthrene, pyrene), sum of polychlorinated biphenyls (28, 52, 101, 118, 138, 153 and 180), chlorides, sulphates and fluorides.

Considering the fact that in Romania, no experimental trials on the use of “sludge incineration ash” in concrete production have been conducted to date, no legal regulations are stipulated neither on the tests to be performed nor on the maximum admissible values for contaminant content in sludge to be achieved in concrete material produced. Given these considerations, the values obtained for the parameters analysed were compared with the maximum values stipulated in Annex 6 of Danish Order no. 1635, First Category [19].

The values obtained for the parameters analysed can be used as reference values for sludge composition for future experimental studies or tests.

The physical and chemical characteristics of the sewage sludge are presented in the Table no. 1.

Table 1. Analysis results of the sludge sample collected from Danutoni WWTP

No.	Parameter	Unit	Result	Admissible Values*
1	pH	unit. pH	6.8	-
2	Humidity	%	76.9	-
3	Cadmium	mg/kg d.s.**	1.33	0 - 0.5
4	Copper	mg/kg d.s.	64.5	0 - 500
5	Nickel	mg/kg d.s.	17.8	0 - 30
6	Lead	mg/kg d.s.	25.4	0 - 40
7	Zinc	mg/kg d.s.	231	0 - 500
8	Mercury	mg/kg d.s.	0.57	0 - 1
9	Chromium	mg/kg d.s.	16.0	0 - 500
10	Cobalt	mg/kg d.s.	2.45	-
11	Arsenic	mg/kg d.s.	3.17	0 - 20
12	Absorbed organic halite	mg/kg d.s.	351	-
13	Anthracene	mg/kg d.s.	<0.01	-
14	Benzoanthracene	mg/kg d.s.	0.18	-
15	Benzofluoroanthene	mg/kg d.s.	<0.01	-

16	Benzoperylene	mg/kg d.s.	<0.01	-
17	Benzopyrene	mg/kg d.s.	<0.01	-
18	Chrysene	mg/kg d.s.	<0.01	-
19	Fluoranthene	mg/kg d.s.	<0.01	-
20	Indeno(1,2,3)pyrene	mg/kg d.s.	<0.01	-
21	Naphthalene	mg/kg d.s.	<0.01	-
22	Phenanthrene	mg/kg d.s.	0.07	-
23	Pyrene	mg/kg d.s.	<0.01	-
24	The sum of polychlorinated biphenyls compounds (28, 52, 101, 118, 138, 153 and 180)	mg/kg d.s.	0.25	-
25	Chlorides	mg/kg d.s.	0.197	-
26	Sulphates	mg/kg d.s.	301	-
27	Phluorides	mg/kg d.s.	932	-

* First Category Danish Order no. 1635/2006

** d.s. - dry substance

The test results, presented in Table 1 indicate the presence of contaminants in low concentrations, except sulphates and chlorides which were found in higher concentrations, 301mg/kg d.s. and 932mg/kg d.s. respectively.

These higher values may be a direct result of the contribution of the industrial wastewater discharged from the activities of certain industrial operators in the Jiu Valley area; these industrial wastewaters also reach the WWTP.

When comparing the values obtained on the samples with the admissible values imposed by the Danish Order no. 1635/2006, the cadmium level is the only one to exceed the admissible limit.

The levels of the other parameters, including copper, nickel, lead, zinc, mercury, chromium and arsenic, were significantly below the corresponding admissible levels stipulated by Danish Order no. 1635/2006.

For the other parameters analysed, no admissible levels are stipulated by Danish Order no. 1635/2006.

“Sludge incineration ash”

To obtain the resulting “sludge incineration ash”, the sludge sample collected from Danutoni WWTP was burned in an ATI Muller incinerator (from a producer of waste treatment incinerators and air filtration systems with on-going activity from 1930 to date).

The temperature in the combustion chamber was of 900^{o}C, and the incineration was performed using natural gas fuel and air intake.

The incinerator is provided with flue gas filtration system, according to European emission standards.

The WWTP sludge had an average humidity of about 84%.

Prior to incineration, the sludge was spread on a drainage area and allowed to dehydrate for three hours in order to remove excess water. No heating of the sludge for drying was performed on sludge before incineration.

Figure 1. "Sludge incineration ash" resulted from incineration of sewage sludge

Figure no. 1 presents the "sludge incineration ash" sent for analysis to the laboratory of the Technical University of Civil Engineering in Bucharest. The "sludge incineration ash" it is a granular material of low density. It was found that after the incineration process, the existing mineral components in sludge, were concentrated in particle agglomerations with colours ranged from white, brown, deep brownish red, dark brown and black.

As presented in Figure no. 1, the resulted "sludge incineration ash" is a material composed of angular particles of various grain size from fine to coarse. The ash grain size was determined according SR EN 933-1: 2012 - Tests for geometrical properties of aggregates. Part 1: Determination of particle size distribution [35]. Based on data presented in Figure no. 2, the ash has a predominantly coarse size distribution, with particle sizes between 0.063mm and 16mm.

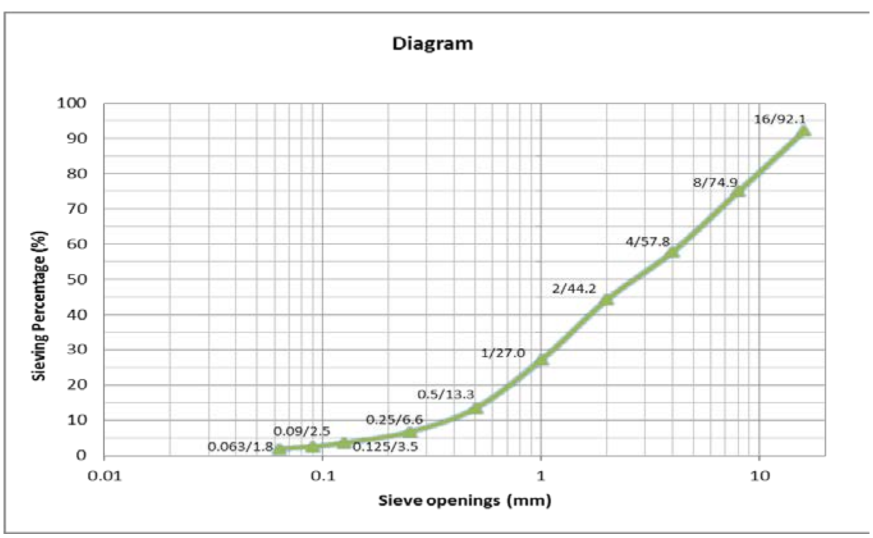

Figure 2. Particle size distributions of the ungrinded "sludge incineration ash", [2]

Considering the predominantly coarse particle distribution in the resulting ash, and the fact that the use of this raw ash would lead to a reduction in the strength of the concrete, grinding the ash was necessary to allow it to pass through a 1mm sieve prior to being added into the concrete recipe as a replacement for sand [2].

The resulting particle size distributions, after grinding the "sludge incineration ash", is presented in Figure 3.

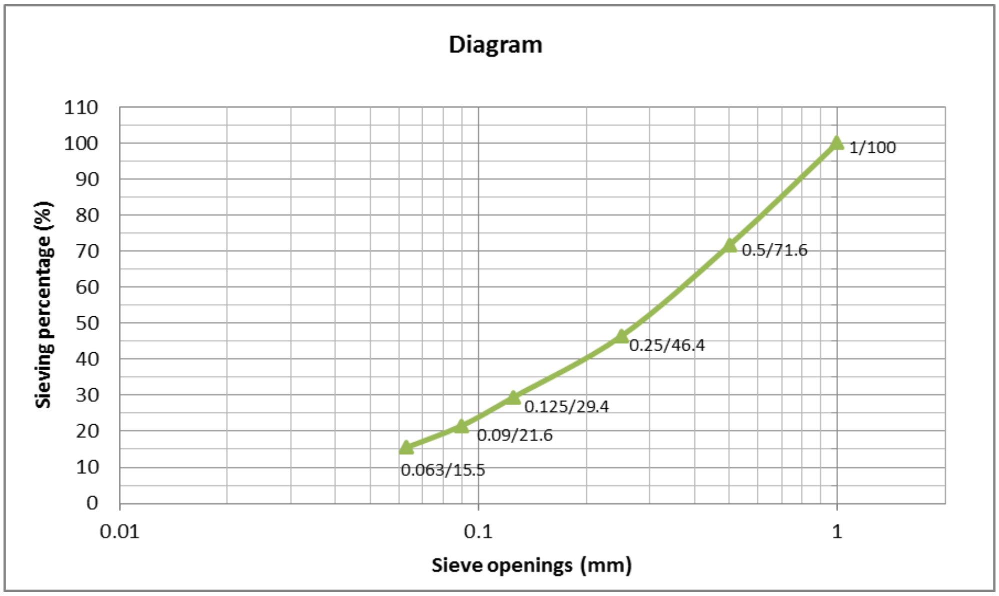

Figure 3. The particle size distributions after grinding the "sludge incineration ash", [2]

Fineness of grinding on a 0.063mm sieve was determined by wet sieving according SR EN 450-1:2012, Fly ash for concrete. Part 1: Definitions, requirements and conformity criteria [34]. The penetration achieved - through the 0.063mm sieve is of 15.5%, corresponding to S ashes category [2].

The identification of the main features of the "sludge incineration ash" consisted in performing of chemical determinations regarding the content of chloride, sulphates, calcium oxide, silicon dioxide, sum of silicon oxides, aluminum oxides, iron oxides, and magnesium oxides, fineness of grinding through a 0.063 mm sieve, activity index, density, stability and the impact on the initial concrete setting time. The laboratory determinations were conducted in accordance with SR EN 196-2:2006, Methods of testing cement. Part 2: Chemical analysis of cement [29].

Due to the absence of specific regulations, in order to assess the suitability of using "sludge incineration ash" in concrete production, the values of the parameters analysed on the sample were compared with specific requirements for fly ash for concrete production included in SR EN 450-1:2012 and with the limit values set by „BioCrete" LIFE Environment Program.

The fine ash density was determined according to SR EN 196-6:2010, Methods of testing cement. Part 6: Determination of fineness [31].

The stability was determined on a CEM I 42.5R cement paste, in which 25% of cement was replaced with ash, according to SR EN 196-3:2006, Methods of testing cement. Part 3: Determination of setting time and stability [30]. The value for the stability determined was 8mm, in conformity with the technical requirement specified in SR EN 450-1:2012. This value shows a significant hydraulic potential, similar to fly ash [34].

Table 2. The main characteristics of "sludge incineration ash" determined

No.	Parameter	Unit	"Sludge incineration ash" Results	Fly ash for concrete - technical condition SR EN 450-1: 2012	„BioCrete" limit values
1	Content of chlorides	%	< 0.005	< 0.10	< 0.05
2	Content of sulphates	%	0.25	< 3	-
3	Content of magnesium oxides (MgO)	%	2.65	< 4.0	< 4.0
4	Content of calcium oxide (CaO) – total CaO	%	8.68	< 10	> 18
5	Content of silicon dioxide (SiO_2)	%	44.95	-	≥ 18
6	Content of aluminum oxides (Al_2O_3)	%	12.85	-	4 - 8
7	Content of iron oxides (Fe_2O_3)	%	10.84	-	13 - 20
8	Sum of silicon oxides, aluminum oxides and iron oxides	%	68.64	< 70	-
9	Fineness of grinding	%	10.2	S category < 12	-
10	Powder density	g/cm^3	2.35	-	-
11	Stability	mm	8	< 10	-
12	Activity index (at 28 days)	%	76.4	75	-

As presented in Table 2, the main constituents of "sludge incineration ash" are the oxides of silicon, aluminum and iron. The sum of these oxides (68.64%) is compliant with the technical conditions from SR EN 450-1:2012 for concrete specific fly ash. Also, the ash is characterized by a low content of calcium oxide (8.86%) under the limit imposed by SR EN 450-1:2012. The values obtained on the content of chlorides, sulphates and magnesium oxides are significantly below the required maximum content limits.

According to a recent study published, *Evaluation of the Pozzolanic Activity of Sewage Sludge Ash* [13], the content level of silicon, aluminum and iron oxides in the ash are directly related to the use of alum (aluminum sulphate salt with various basic elements), ferric salts and calcium oxide in the wastewater treatment process.

When the values obtained are compared with the limit values recommended by „BioCrete" LIFE Environment Program, it may be observed that the content levels of chloride, sulphates MgO, CaO, SiO_2 and Fe_2O_3 obtained are below the limit values. For the Al_2O_3 content, an exceedance of the limit by approximately 5% is noted.

Considering the low concentrations of heavy metals found in the sludge sample collected from the WWTP and the generally low leaching level of heavy metals from concrete, in this particular study, leachate tests were not performed for the heavy metals.

The determination of the initial concrete setting time was performed both for a mixture of cement CEM I42.5R with distilled water and for a mixture of cement CEM I42.5R with aqueous extract of ash for comparison purposes [2].

The activity index was determined after 28 days according to SR EN 450-1.

The value obtained exceeded by 1.4% the standard value [34].

Table 3. Values obtained for concrete setting time

No.	Determination	Unit	Result	
			Cement CEM I42.5R with distillate water	**Cement CEM I42.5R with aqueous extract of ash**
1	The initial concrete setting time	min	145	135
2	The final concrete setting time	min	175	175

According to the values presented in Table 3, no influence on setting time of the cement tested is identified.

Cement CEM I 42.5 R

In the concrete recipe used for the laboratory tests, Portland cement with high initial strength, type I, included in strength class of 42.5 N/mm^2 was added, according to the requirements of SR EN 197-1:2011, Cement Part 1: Composition, specifications and conformity criteria for common cements.

The main constituents of cement CEM I 42.5 R are Portland (K) clinker in proportion of 95 – 100% and minor constituents in proportion of 0 – 5%. According to producer specifications [7], CEM I 42.5 R can be used for precast concrete elements from plain and reinforced concrete.

Sika Viscocrete 1052 Additive

The Sika Viscocrete 1052 Additive, a super-plasticizing additive with high dehydration potential in concrete, was added to the concrete recipe [2].

Aggregates

Also, river aggregates, according to SR EN 206-1:2002/C92:2012, Concrete. Part 1: Specification, performance, production and conformity [33], was added to the concrete recipe.

4. DOSAGE OF THE COMPONENT MATERIALS IN THE CONCRETE RECIPES

To evaluate the effects of using “sludge incineration ash” on concrete properties, a typical concrete recipe was first prepared to be used as reference sample.

Three additional concrete recipes were prepared, replacing the sand 0/1 part with ash, in at three different proportion levels of 10%, 20% and 30%, respectively [2].

The content of input materials for the four concrete recipes, was determined in the laboratory of the Technical University of Civil Engineering, Bucharest, and the results are presented in Table 4.

Table 4. Dosage of component materials of the concrete recipes

No.	Material	Dosage (kg/m^3)			
		Reference sample	Sample with 10% ash	Sample with 20% ash	Sample with 30% ash
1	Cement CEM I 42,5 R	300	300	300	300
2	Water	179	179	179	179
3	Water/Cement Ratio	0.6	0	0	0
4	Sika Viscocrete 1052 Additive	0	1.0	1.2	1.4
5	Aggregate 0/1 (21%)	393	353	314	274
6	Aggregate 1/2 (10%)	187	187	187	187
7	Aggregate 2/4 (15%)	280	280	280	280
8	Aggregate 4/8 (22%)	411	411	411	411
9	Aggregate 8/16 (32%)	598	598	598	598
10	Ash	0	35	70	105

Comparing the 4 concrete recipes, it was observed that the concrete with ash addition is more homogeneous due to a higher content of fine particles [2].

5. EXPERIMENTAL LABORATORY TESTS ON FRESH AND HARDENED CONCRETE

Laboratory tests were completed on fresh and hardened concrete at laboratory of the Technical University of Civil Engineering, in Bucharest, according with the following standards:

- SR EN 12390-3:2009/AC:2011, Testing hardened concrete. Part 3: Compressive strength of test specimens [27];
- SR EN 12350-6:2009, Tests on fresh concrete. Part 6: Density [25];
- SR EN 12350-7:2009, Tests on fresh concrete. Part 7: Contents of air. Pressure methods [26].

Laboratory test results are shown in Table 5.

Table 5. Laboratory test results on fresh and hardened concrete

No.	Laboratory tests	Unit	Result			
			Reference sample	**Sample with 10% ash**	**Sample with 20% ash**	**Sample with 30% ash**
1	Density of fresh concrete	kg/m^3	2,350	2,340	2,340	2,330
2	Air content	%	1.5	1.6	1.4	1.5
3	Compression strength at 7 days	N/mm^2	22.8	25.3	25.8	29.0
4	Compression strength at 28 days	N/mm^2	29.2	31.2	32.0	34.7

Comparing the evaluation results of the three samples of concrete with "sludge incineration ash" with the reference concrete sample, the following conclusions may be drawn:

- The density of fresh concrete decreases from 2,350kg/m^3 in the reference sample to 2,330kg/m^3 in the sample with 30% ash. Also, the downward trend was registered in the case of samples with 10% and 20% ash, but the difference in values of 10kg/m^3 is relatively low;
- Regarding the air content, neither an increasing nor a decreasing trend was observed; the content levels were: 1.4% in the sample with 20% ash, 1.5% in the reference sample and in the sample with 30% ash and 1.6% in the sample with 10% ash;
- The compressive strength at 7 days increases with the percentage of ash added, thus the highest compressive strength was recorded in the sample with 30% ash (29.0N/mm^2);
- The compressive strength at 28 days increases with the percentage of ash added, thus the highest compressive strength was recorded in the sample with 30% ash (34.7N/mm^2).

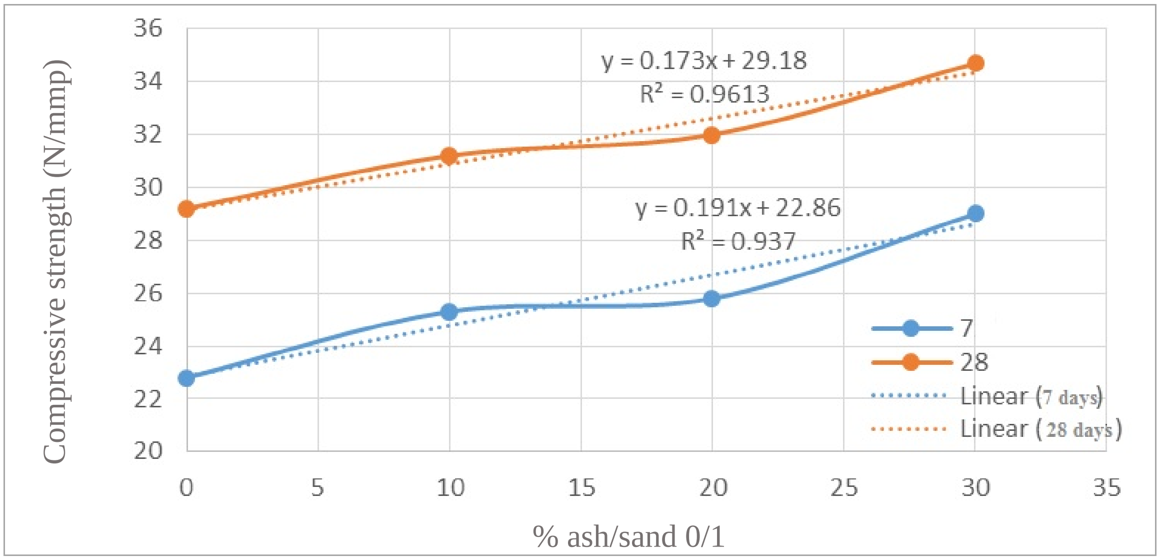

Figure 5. Variation of compressive strength at 7 and 28 days, [2]

Therefore, an increase of the compressive strength with the addition of the “sludge incineration ash” is observed, suggesting the possibility of using an even higher percentage and/or even to replace the cement content partially. The compressive strength (R) increases with the percentage of ash added and can be approximated as linear (R(y) = 0.191*%ash (x) + 22.86), resulting an acceptable regression coefficient value. An increase of the compressive strength from 0.17 to 0.19N/mm^2 for each additional percent of ash is noted [2].

An increase in the compressive strength is also observed when “sludge incineration ash” is increasingly added as a substitute for sand in concrete [2].

6. CONCLUSIONS

Upon incineration of sewage sludge, the amount of the resulting ash was about 1.6% of the total quantity of the sludge, so the amount of waste to be potentially disposed at landfills is reduced by 98.4%.

By reusing “sludge incineration ash” in the concrete production process, the lifetime of existing landfills will be extended by reducing significantly the total amount of waste disposed.

Based on these preliminary tests, the physical and chemical characteristics of the “sludge incineration ash” make it suitable for use in concrete production as an additive material [2].

Most of its physical and chemical characteristics show suitability of the ash to be used as an additive in concrete. However, this ash is resulted from the incineration of the sewage sludge using natural gas and combustion air intake and thus, other types of ashes were not evaluated [2].

The addition of ash slightly increased the required amount of mixing water, which can be adjusted by additional amounts of additive, and the ash use improved the aspect and uniformity of concrete and compressive strength, acting as a material with pozzolan properties [2].

In conclusion, the opportunity for further research activities regarding the substitution of sand in higher percent (more than 30%) and of a part of cement in concrete recipes is justified and recommended for follow-up studies [2].

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The "Straubing Model" Of Sludge Management - State Of The Art And Prospect

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Abstract
The concept of accepting sewage sludge of surrounding communal waste water treatment plants and their dehydration and drying combined with thermal combustion is a flagship project for sludge treatment in Germany.
This presentation will give you a short overview of the Straubing waste water treatment plant and a detailed overview of the sludge treatment facilities, bottlenecks and strategies to overcome those. Until recently the Straubing waste water treatment plant used to operate a thermal combustion plant by themselves, utilizing excess combustion heat to dry mechanical dehydrated sludge. Right now, dehydrated and dried sludge are transported to thermal combustion facilities nationwide. These facilities are combining other energy sources with sewage sludge.
In the second part of the presentation, a short overview of the current situation of the German law concerning sludge treatment will be given and the driving force for the development of processes and facilities for the mono treatment of sludge will be presented.
Several scenarios for the utilization of sewage sludge will be presented and pros and cons of these technologies will be given. In the mid term, one of these technologies will / must be utilized for the disposal of sewage sludge of the Straubing plant.

Keywords
Sludge, co-fermentation, combustion, gasification, hydrothermal carbonization.

1. WASTE WATER TREATMENT IN STRAUBING

The Straubing waste water treatment plant is designed for 200.000 population equivalents. The average load is 75.000. 6.2 Million m³ of waste water are processed per year. Approx. 8.000 tons of dewatered sludge are produced per year. Two 3.000 m³ Digesters are used for anaerobic stabilization of sludge. Two CHPs (installed power of 1 MW combined) are installed for energy and heat production for the facility. The sludge is utilized solely for thermal combustion, due to co-fermentation.

Being an innovative facility, Straubing realized some unique projects to not only improve the water treatment efficiency. Some examples for these projects are:

Co-fermentation

Spare capacities in the digester are used for the utilization of food wastes like uneatable milk, fat floats and slaughterhouse offal.
These products offer significantly higher production of biogas than sewage sludge itself and enable the waste water treatment plant to produce enough power to be net energy self-sufficient and to feed surplus energy back to the grid.
Infrastructure for 24/7 delivery of food waste and controlled release to the digester was built and implemented in the control system. Figure 1 shows the station for 24/7 delivery and the tanks for intermediate storage of those wastes.

Figure 1. Left: delivery of food waste, station for 24/7 Delivery
Right: Tanks for intermediate storage of these wastes

Hydrolysis

To raise the capacity for food waste, the hydrolytic steps of biogas production for these products are separated in a fermenter. These products are degraded to smaller molecules and then processed in the digester. Figure 2 shows the steps necessary in biogas production. The red rectangle shows the hydrolytic steps that are separated in the hydrolysis fermenter.

Hydrolysis lowers the retention period of the energy rich products in the digester and raises the yield of biogas.

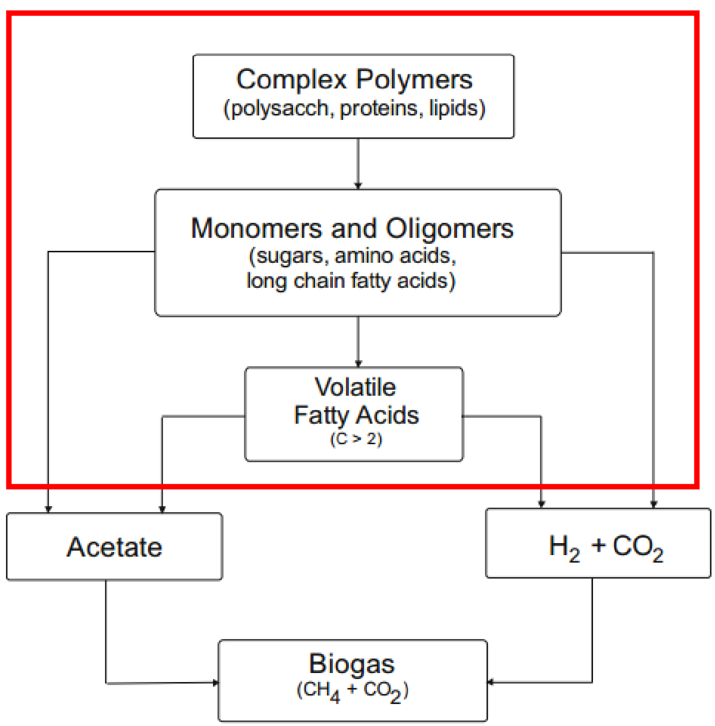

Figure 2. Stages of methane production in biogas process, separated processes in hydrolysis fermenter (own, based on[1])

The completion of the hydrolysis fermenter is expected end of June 2016.

Non-potable water

A portion of the processed waste water is used for the generation of non-potable water for industrial purposes. This water is filtrated via ultrafiltration to obtain the necessary quality. The water is regularly tested on microbial harmlessness. The water is used for cleaning und cooling purposes at the facility and is used as water for the street cleaning vehicles.

Heat from Wastewater

Several houses are heated by a system that generates heat via heat pumps. The necessary heat is drawn from waste water. Two Heat exchangers are rinsed with waste water and two heat pumps use this feed to heat water. The heated water supplies both, heating circle and domestic hot water. The process proved to be feasible and an expansion of the technology by adding further households to the facility is already planned.

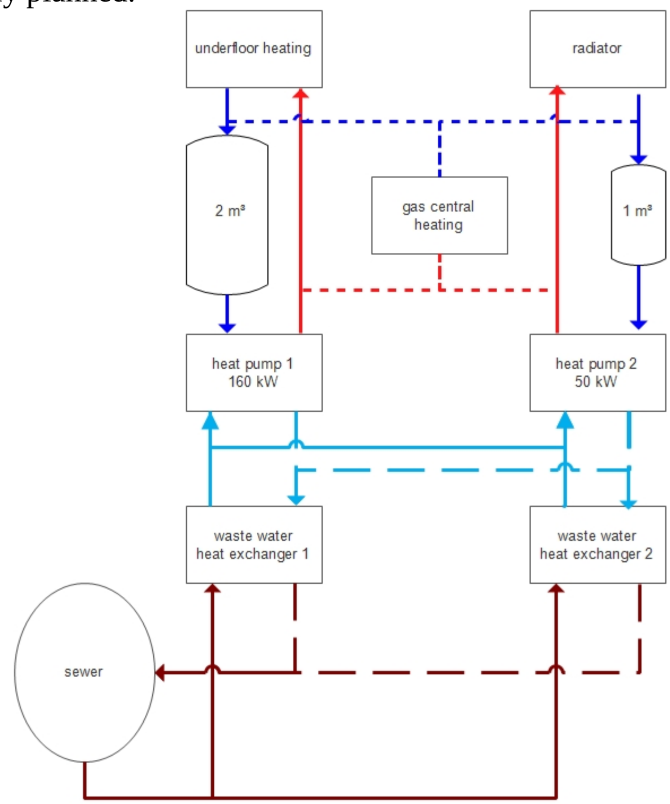

Figure 3. Scheme of waste water heat utilization

2. THE STRAUBING MODEL

The Straubing Model is a novel way for sludge management. Basically it is a centralized approach. Smaller waste water treatment plants deliver their sludge, mostly excess activated sludge to the Straubing facility. The municipalities pay for the service and the disposal of their sludge. Roughly 30 municipal waste water treatment plants deliver their sludge, leading to a twofold increase of the produced sludge in Straubing. Figure 4 shows a map of the surrounding towns and villages around Straubing and highlights those, who deliver their sludge to Straubing.

Figure 4. Surrounding towns and villages (red: delivering sludge to Straubing)

The sludge is delivered and pumped in a stirred tank. It is combined with anaerobic digested sludge from the digester and dewatered, dried and transported to thermal combustion.

The delivered sludge is then dewatered and dried at the Straubing facility. Due to the higher load of sludge at the Straubing facility a higher load in TOC and Ammonium results. Therefor the centrifugal effluent is treated both biologically and chemically to significantly lower the load of ammonium. The biological treatment (deammonification) is the elimination of ammonia via partial oxidation to nitrite and biological degradation to nitrogen. The chemical treatment (chemical stripping of ammonia) is done by removing ammonium by lowering the pH and stripping ammonia. The gas is rinsed with sulphuric acid. The resulting ammonium sulphate can be sold as fertilizer. Both techniques are applied to lower the ammonia in centrifugal effluent by 90 %. The TOC is taken care of by an aeration tank designed for high loads of TOC.

Sludge Management in Straubing

Primary sludge in combination with excess activated sludge is pumped to the digester for anaerobic degradation and stabilization. The anaerobic digested sludge and the sludge of the Straubing Model are then dewatered (by centrifuge). Medium dry matter content is 27 %. As described above, the effluent is treated to lower loads of ammonium.

The dewatered sludge is then pumped to a dryer. Excess heat of the CHPs enables the removal of water to a dry matter content of up to 95%. The resulting pellets are transported to a silo. Figure 5 shows the schematic of the sludge treatment in Straubing.

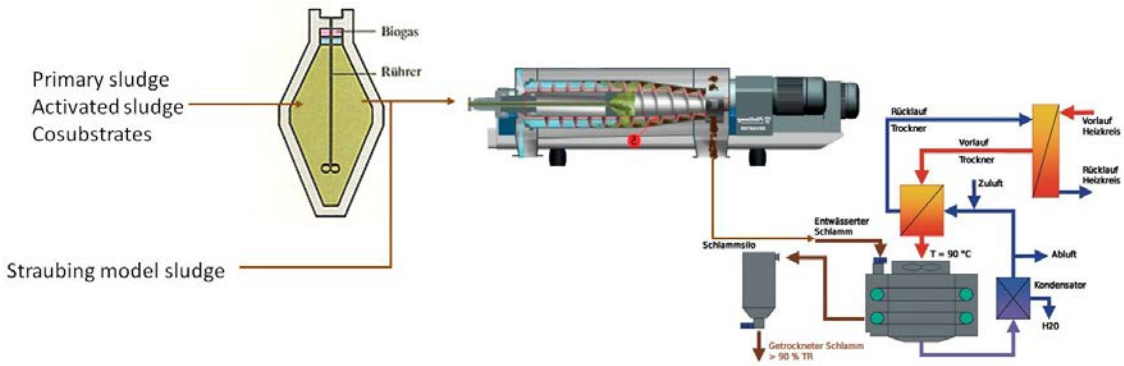

Figure 5. Pathway of sludge at the Straubing facility[2]

Until August 2014, these pellets were utilized at a mono combustion unit at the facility. This was part of a project called sludge to energy. An oven burned the sludge pellets, the produced heat was used to dry dewatered sludge. The project has proven technical, but seems to lack economic feasibility. At the moment, the combustion is on hold and the basic conditions for an economic operation are evaluated.

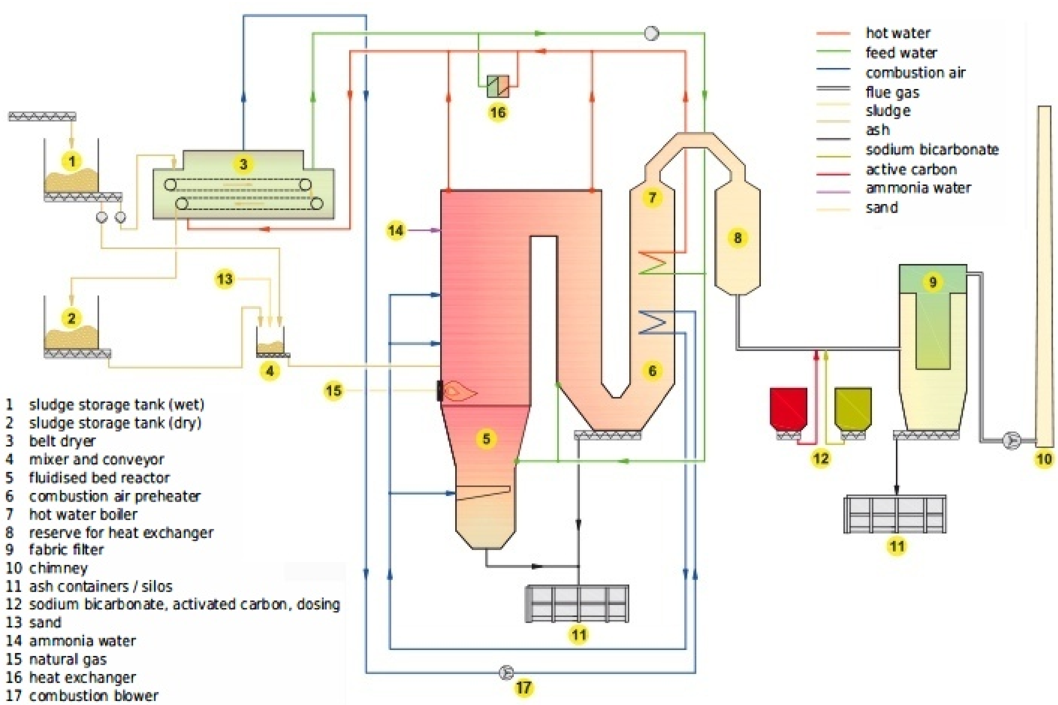

Figure 6. Advanced scheme of sludge to energy concept[3]

3. PROSPECTS OF SLUDGE MANAGEMENT IN GERMANY

Sludge Management to date

Currently approximately 60% of sludge is utilized as surrogate fuel in thermal combustion. This means, the sludge is burned instead of coal in coal plants or cement oven. The rest of the sludge is used as fertilizer in agriculture.

Developments in sludge management

The German government has decided to end the use of sludge as a fertilizer[4].This and stricter laws concerning the quality of fertilizers and the utilization of sewage sludge will lead to higher rates of thermal utilization in the future. This is sped up by a regulation, that starting January, 1st 2017 only bio-based polymers are suitable for dewatering, when utilized as fertilizer[5].

An Amendment to the sewage sludge regulation will soon stop the co-combustion of sludge in coal and cement plants. It will be mandatory to utilize sludge in a mono combustion and establish technologies for the recovery of phosphorous out of the ash.

The higher rate of thermal utilization of sewage sludge and the decrease and/or prohibition of co combustion will lead to high demands of mono combustion plants all over Germany.

Technologies for mono-utilization of sewage sludge

At the moment, there are only ca. 20 mono combustion facilities installed. Most of them utilize fluidised bed reactors[6].

Some technologies are trying to get a share of the mono utilization of sludge. The most advanced technology is the gasification, basically fluidised bed combustion without oxygen, often with steam as oxidizing agent. The produced gas (a mixture of carbon monoxide and dioxide, methane, and hydrogen) can be utilized to generate power and heat. It needs dry sludge, so energy is needed for the drying[7]. Figure 7 is an example for sludge gasification. Similar to combustion, fluidized beds are common furnace technologies utilized in gasification.

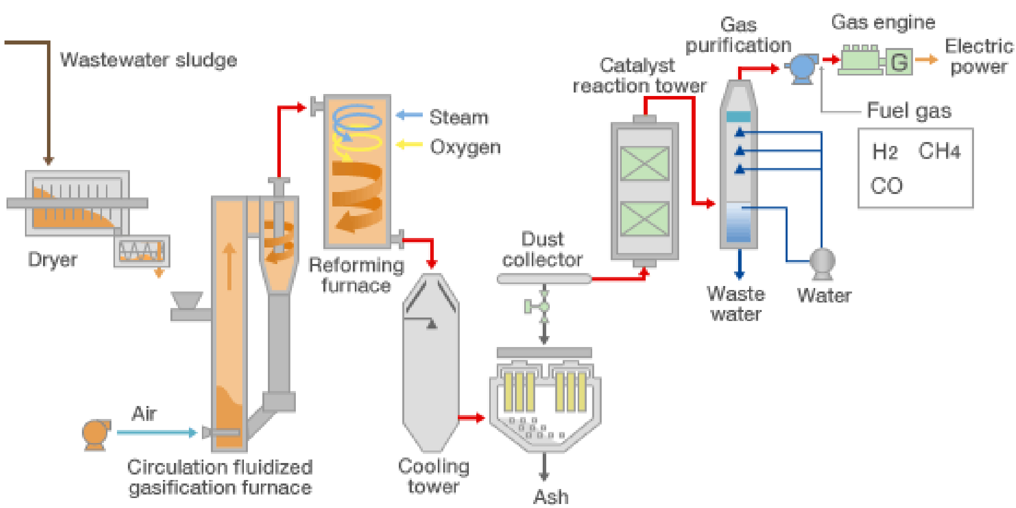

Figure 7. Schematic for sludge gasification[8]

A promising new technology is the hydrothermal carbonization (HTC). Wet[9] or dewatered[10] sludge is heated at approx. 200°C and 20 bar pressure are applied (in form of steam). An autothermic reaction is taking place and the sludge is transformed into a coal. Most hazardous components (organic material and microbes) are destroyed. The coal can easily be dewatered and be used as surrogate fuel in coal and cement plants[11], or utilized as carbon for filter materials. Process water can be tuned to low TOC loadings or be fed to the digester for extended biogas production[12].

Gasification and HTC offer high potential for the removal and recycling of phosphorous compounds, although there are technologies for the recovery of phosphorous from ash from

combustion, the compounds often lack bioavailability. Phosphorous compounds obtained from residues of gasification and HTC processes are easier accessible and offer higher bioavailability compared to combustion ashes.
Since phosphorous recovery will be mandatory, the new technologies could experience an boost and become leading technologies for the mono utilization of sludge and phosphorous recovery.

4. OUTLOOK: SLUDGE MANAGEMENT IN STRAUBING

New regulations in Germany are forcing municipal waste water treatment facilities to switch from agricultural utilization of sludge to combustion. This generates a high demand of combustion capacity that will be hard to fulfil. Plus new sludge regulations force thermal utilization to be mono combustion. This creates a high demand on mono combustion plants. Alternative mono utilization technologies are evolving strongly and on the way to reach the market. Those technologies are riskier, but offer good potential, especially for the recovery of phosphorous.
The Straubing waste water treatment plant is currently evaluating the three described technologies above for the mono utilization of sludge.
Both sizes ranging from self sufficient utilization of sludge to regional utilization of sludge are evaluated and calculated at the moment. In June 2016, these results will be discussed and the leading technology will be established at the Straubing site. A strong focus is on phosphorous removal. Concepts for phosphorous removal are crucial for the technologies to be considered useful.
This is a necessary step to a reliable disposal route and to fulfil future regulations concerning sludge management and disposal in Germany.

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VOMM Technology For The Transformation Of Sludge From Wastewater Treatment Plants And Household Waste In Secondary Raw Materials

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Abstract
In Romania, as in other European countries and beyond, the people are looking for solutions for sludge management from sewage plants and household waste. They are looking to implement a multi-branch policy that could generate economic (circular economy) and environmental benefits: the material recovery branch (spreading, compost, fertilizer transformation). Today was reached a second phase, storing the sludge in landfills as a security solution. Another attempt of the water - sewerage companies is to send the sludge to cement plant for co-incineration.
Following extensive research, VOMM proposes to transform sludge from sewage plants into secondary raw materials in order to reduce costs and environmental impact.

Keywords
Urban sludge valorisation, VOMM technologies for urban sludge.

1. CURRENT SOLUTIONS, PROPOSED IN THE ROMANIAN SLUDGE MANAGEMENT STRATEGY

The Current solutions proposed in the Romanian sludge management strategy are:

1. The use of sludge in agriculture - For the use of sludge in agriculture, the water- sewerage company has overall responsibility:

- Restrictions for some crops
- Soil Analysis
- Transport and spreading on agricultural land
- Disking land after spreading, to incorporate the sludge into the soil
- Responsibility for the quantity and quality of the crops on that land for 10 years
- It follows to impose new restrictions on pathogens (85-90% dry matter (DM) according to US-EPA directive Class A, 40 CFR Part 503 - Regulations to reduce pathogens), restrictions that can not be met by classical sludge treatment.[1]

These responsibilities involve high costs and high risks in terms of crop contamination or reduced yields and can entail costly litigations between the farmer and sludge supplier, conditions which are totally unattractive solution for water-sewerage companies.

2. Storage of sludge in landfills - raises a lot of problems for water-sewerage companies:

- Sludge can represent only 10% of the total amount of waste stored annually on the landfill. There is a risk that the landfill can not take the entire amount of sludge;
- Sludge must have a minimum of 35% dry matter. This requires a lime () treatment, raising costs of both treatment (after lime treatment, the amount of sludge increases by 50%) and storage through increasing the quantity of deposited sludge;

- Only the Environmental Tax in 2017 will be 120 RON/Ton, expected to grow continuously;
- According to EC directives, after 2020, this sludge will not be taken to landfills anymore
- Costs of landfill disposal are very high, and they are growing;
- The use of sludge in agriculture or its disposal in landfills involves increasing wastewater prices, sludge management costs being over 50% of wastewater treatment operating costs.

3. The incineration of sludge in cement factories, has the following disadvantages:
- Most cement factories require a dry matter content of 90% for sludge. Under these conditions, the sludge must be dried;
- Under the condition that they take just dehydrated sludge, transportation costs are very high and cement fees charged are very high, reaching more than 100 €/Ton of dehydrated sludge
In these circumstances, there is the need to find new solutions for the disposal of sludge, long-term and financially bearable solutions for the population.

2. VOMM's MANAGEMENT'S SOLUTION FOR SLUDGE FROM SEWAGE PLANTS

For reducing sludge volumes, drying (and granulation) of sludge is commonly used in many medium and large sewage plants.
Depending on the destination of sludge for recovery, dry matter (DM) of sludge varies according to Fig1.[2]

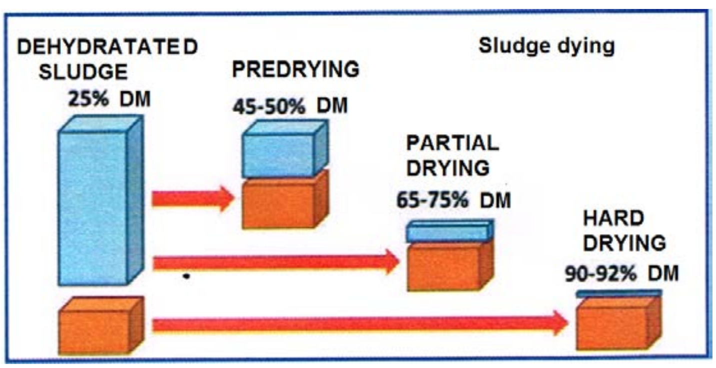

Figure 1. Dry Matter Concentration

It is obvious that only the use of a tested and flexible drying technology enables the implementation of a genuine policy of multi-channel valorisation.
VOMM produces Turbo-dryers since more than 50 years, first in the private sector for industrial sludge drying, then it was straightened to the public sector, creating sludge drying plants for wastewater treatment plants. In 50 years, VOMM has made over 120 sludge drying plants worldwide, the manufacturer accumulating great experience in this field. His know-how has enabled to create all types of plants, from very small (Capri - Italy- 6 t / day evaporated water) to very large (Beijing – China - 400 t / day water evaporated).
The Turbo-Dryer enables to dry sludge from all wastewater treatment types (primary, secondary, digested) and provides a product that meets the different branches of dry matter recovery including energy recovery as provided in Art. 14 of the European Directive no. 91/271 of 21.05.91 on urban wastewater treatment "Sludge from sewage plants are reused in case that this is possible. The

evacuation route must minimize negative effects on the environment"[3].
Mass reduction of sludge varies only at the drying level, depending especially on the branch of use that allows to obtain a favourable ratio of carbon related to the wet sludge (transport), reducing odors, cleaning which may extend to compliance with EPA for class A of sludge in case of high drying (over 90% DM) and a significant improvement in energy performance for single combustion, or incineration.
VOMM technologies developed for sludge are in closed circuit, fully automated and in full compliance with Romanian and European environmental and safety legislation.

Transformation of Sludge from Sewage Treatment Plants into secondary raw materials

WOMM's Turbo-Technology is the patent that allowed the company to transform sludge into secondary raw materials and become world leader in continuous thermal processes.

Figure 2. Turbo-Dryer

VOMM is very proud of its highly qualified staff, which develops, extends and customizes continuously the Turbo Technology for the different needs of its customers.
The Turbo Technology simplifies industrial processes and reduces operating costs. It can further be applied to thermal processes (drying, concentration, roasting, pasteurization, desorption, thermal decomposition), continuous mechanical processes (granulation, kneading, mixing, crystallizing, coating) and continuous chemical processes (synthesis of salts, soaps,etc.) for solid, liquid or pasty materials.
The VOMM Turbo-Technology is based on the creation of a thin film of liquid, pasty or solid product in high turbulence, using a turbine that rotates in a horizontal static chamber. The chamber is equipped with a double jacket in which circulates a heat carrier (eg. thermal oil, steam, hot water or ice), which creates and maintains the required temperature inside the equipment.
The product's movement inside the equipment is controlled by the turbine and, if necessary, it is also controlled by a process gas current injected in current with the product. The system operates in open gas circuit. It can also operate in a closed gas circuit, in order to avoid uncontrolled releases into the atmosphere.
Thanks to its facilities, VOMM Turbo Technology is applied in:

- Food industry;
- Environment and energy;
- Chemical and pharmaceutical industry;

- Petrochemical.

One of the most important environmental and energetically applications is turning waste with bio-energetic potential to secondary raw materials in accordance with EU directives and in compliance with European rules of waste management.
By using the VOMM Turbo Technology, sludge from sewage plants, digested or undigested, can be discharged with minimal costs by transforming it into secondary raw materials: 1) stabilized and decontaminated fertilizer with destination agriculture, or 2) slag as a secondary raw material purpose for the asphalt industry.
The transformation into a secondary raw material for the asphalt industry is done in two phases:

- Phase 1 - fuel, by drying and pelletizing;
- Phase 2 - slag, by using fuel obtained from sludge to produce thermal energy needed for drying sludge.

Transforming sludge into fertilizer or bio-fuel
Applying VOMM Turbo Technology for transforming sludge into fertilizer or fuel provides a heat treatment process with a combination of heating by conduction and convection. This process ensures excellent results in terms of energy efficiency (thin film in high turbulence - energy recovery), process time, quality and stability of the dried product and a dry product with higher apparent density at 700kg / m^3.
The VOMM Turbo - Technology is applied like in the diagram below:

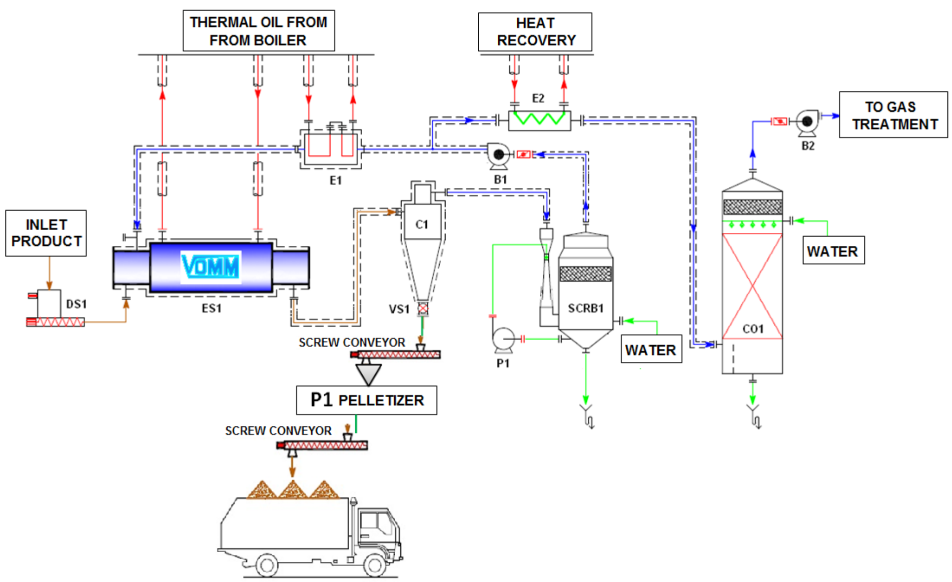

Figure 3. Scheme of drying and pelletizing

The sludge is taken from dehydration and directed to the tank dispenser **DS1** which supplies the turbo-dryer **ES1**, in which the evaporation of water from the sludge takes place, the vapors together with the dried sludge granules are introduced into the cyclone **C1**, in which the separation of vapor from the sludge granules takes place.
The sludge granules are concentrated in the conical part of the silo, being discharged using the rotary valve **VS1** into the hopper of the screw conveyor **T1**, and routed in the dosing unit **DS2** that supplies the pelletizer **P1**. The pellets are being taken over by conveyor **T2** and directed by cyclone

C2. True the valve **VS2**, they are discharged into trucks or are picked up by a conveyor.
The vapors from the cyclone **C1**, are passed through a scrubber venturi filter **SCRB1**, where any dust is remove from the dried sludge, and the fan **B1**, transfers the vapor through the heat exchanger **E2** in the capacitor **CO1**, in which the vapors are condensed and the non-condensables are separated. The fluid is removed to a wastewater treatment plant, and non-condensables are removed with the fan **B2**, and passed through a small gas treatment station **TG1**, from where they are released into the atmosphere after the treatment.
If necessary, a part of the vapors are directed by the fan **B1**, to the dryer **ES1** to maintain the amount of oxygen at less than 4%, according to ATEX safety standards.
The heat exchanger **E2** is designed to recover up to 60% of the heat used by the dryer **ES1**.
The necessary heat for the water's evaporation process is generated in a boiler on biogas, natural gas (CH_4) or pellets, and transfer to the dryer **ES1** through thermal oil heated in the heat exchanger **E1**.

Short description of the drying-pelletizing line's key components

The dosing unit **DS1** is composed by a funnel for receiving sludge, from which the sludge is removed by a screw conveyor.
The Turbo-Dryer's sludge supply flow can be adjusted using the converter gear motor for training of the screw conveyor. The flow is adjusted according to the percentage of dry matter at the entrance and at the exit of the turbo-dryer and according to the thermal oil's temperature.
The Turbo-dryer **ES1** is the heart of the sludge drying facility.

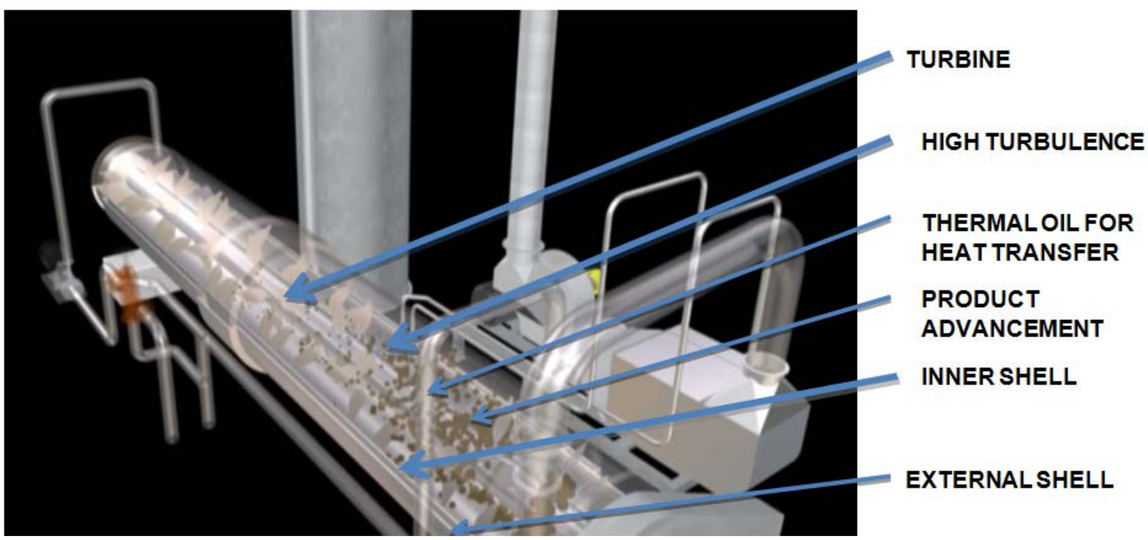

Figure 4. Turbo-Dryer

The Turbo-dryer is a cylindrical horizontal dryer, having a chamber with a double jacket through which a thermal oil is flowing, having a temperature of 240 - 290 ^{o}C.

Inside the dryers static chamber is a turbine that converts the sludge entered in the turbo-drier in a thin film of high turbulence, and drives him towards the exit of the dryer.

The necessary heat for the water evaporation of the sludge is transferred by thermal oil which is recycled between the two jackets. The energy required for evaporation is controlled in automatic mode.

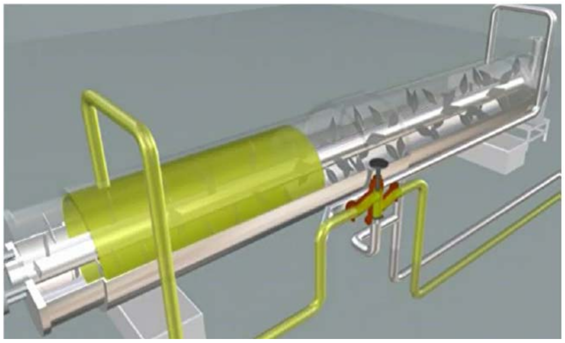

Figure 5. Thermal oil between the two jackets

The heat transfer to the sludge granules is made by convection due the high temperature of the dryer's chamber and conduction due the intimate contact performed with the inner jacket of the turbo-dryer by the granules entering in high turbulence.
The dehydration of the sludge granules takes basically place in two ways, mechanically (by the sludge granules centrifugation) and by evaporation.

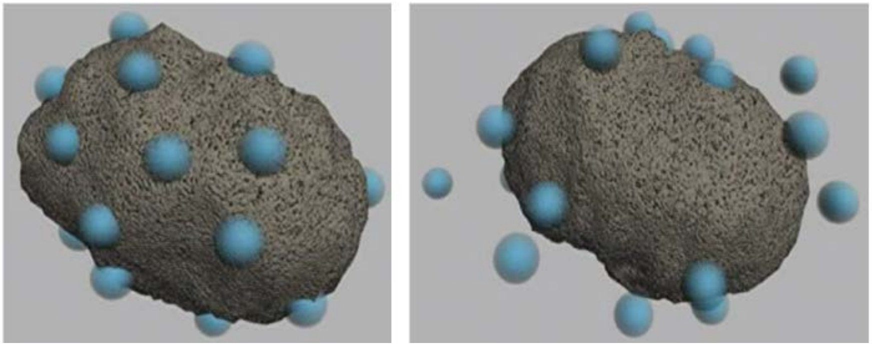

Figure 6. Mechanical dehydration

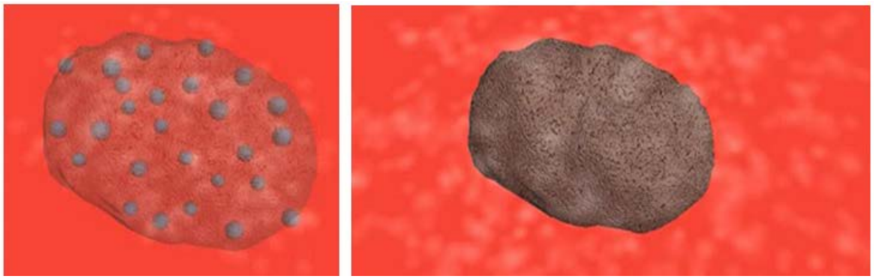

Figure 7. Dehydration by evaporation

By evaporation, the sludge granules are heated by convection and conduction at the contact between the sludge granules and the dryer's walls. The heat transfer is done according to the mass

of the product and the contact pressure. The granules having a reduced mass, at the collision with the turbo-dryers walls there is created a high pressure between the two materials. These physical phenomena are giving the turbo-dryer a very high energy efficiency, low process time, quality and stability of the dried product.
The sludges dwell time for drying is between 2 and 3 minutes, depending on the percentage of dry matter desired at the output.
The drying process is carried out in a single step without recirculation and without injection of inert gas in accordance to ATEX standards.
The Cyclone **C1**, is dedicated to the separation of vapor form dried sludge. The separation of sludge granules takes place in cyclone **C1**, gravitationally. The dried sludge is concentrated in the conically part of the cyclone, having a higher density than water vapor and non-condensable gases.

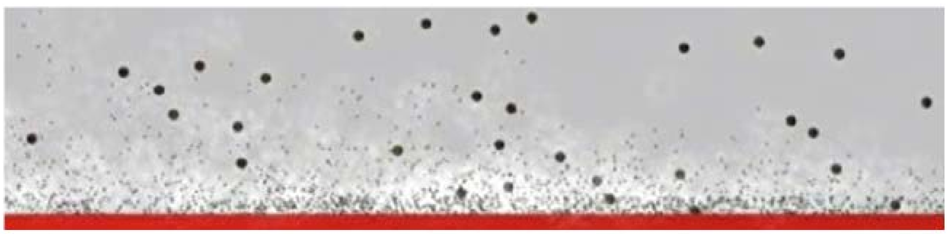

Figure 8. Gravitational separation of dry sludge granules

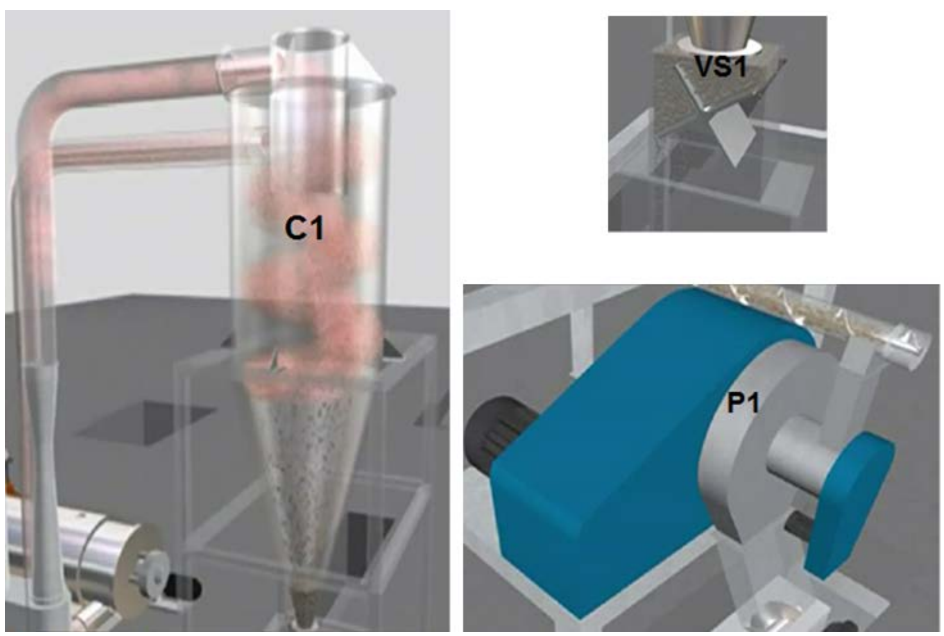

Figure 9. C1 – Cyclone; VS1 – Rotary Valve; P1 - Pelletizer

The sludge granules are discharged from the cyclone, using a rotary valve **VS1**, from where they are taken by a screw conveyor to:

1) the **P1** pelletizer, where granules are obtained in a size, suitable for their final destination.
2) Or as fine granules, directly to a silo from where they are transported by special trucks to co-incineration.

From the pelletizer, the sludge pellets will be directed, depending on their destination, to:

- Storage silos and then delivered in agriculture
- Pellet thermal plant to produce the energy needed for drying sludge.

The Venturi Scraber Filter **SCRB1**, is designed to separate the vapor together with non-condensables from sludge under powder form trained together with water vapor.

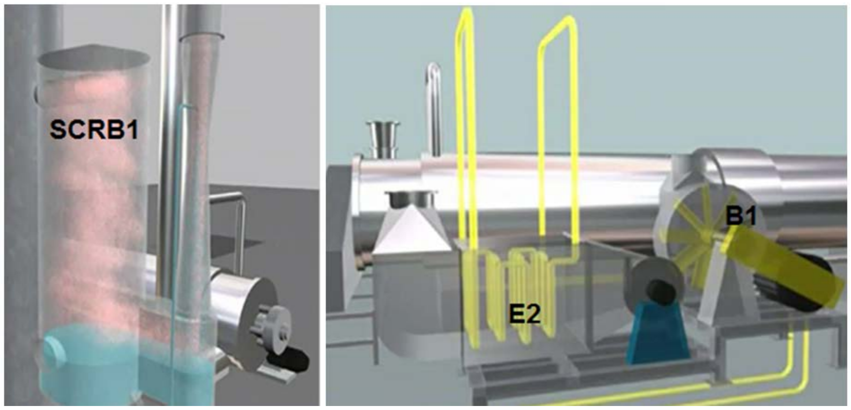

Figure 10. SCRB1 – Scrubber filter; B1 – Fan; E1 – Heat Exchanger

Where by means of the fan **B1**, the vapor is directed to the heat exchanger **E2**, with the purpose of residual heat recovery ~ 60% of the heat required for the drier. If necessary, some of this vapor will be introduced into the turbo-dryer for maintaining the oxygen inside the turbo-dryer at less than 5% in accordance with ATEX standards, without consumption of inert gas, which would involve additional operating costs.

From the heat exchanger **E2**, the vapor is directed to the condenser **CO1**.

Figure 11. C1 – Condenser; B2 - Fan

The Condenser **C1** serves to steam condensation and separation of non-condensables. This operations are needed because both steam from drying sludge and non-condensables have a load

of pollutants, exceeding discharge standards in nature, so they should be treated. To treat condensate, it is discharged to the treatment plant and the non-condensables are routed with the B2 fan to the gas treatment.
The whole technological process of drying and pelletization sludge is conducted in a closed circuit, fully automated and controlled to comply with all European and Romanian safety and environmental standards.

The benefits of applying technology VOMM

By applying the presented technology, three important advantages are obtained:
1) Reducing the mass of sludge, up to 4.5 times
2) Reducing operating costs with sludge management
3) Turning on this way sludge from a waste into secondary raw materials:
   - Fertilizer for agriculture, stabilized and decontaminated
   - Bio-fuel.

In both cases it is obtained a dry product, perfectly homogeneous, with high-density, compact, durable, ideal for use as a secondary raw material and transportation.
Optimizing energy performance by obtaining hot water.
The vapor from sludge drying are directed using the fan **B1** to the heat exchanger **E2**, with heat recovery scope in the form of hot water at 80-85 °C. It can be used to heat the digesters (where applicable, and allowing the use the biogas at the cogeneration), administrative space heating, hot water for washing, etc. reducing the costs of fuels used for this purpose.
The VOMM Turbo-dryer allows to dry the sludge from 12% to 95% dry matter. It is clear that the heat consumption depends on the amount of evaporated water, therefore, to achieve a good ratio between the investment and the operating costs, each solution is customized according to the sludge quality input and its intended use after drying.

Thermal valorisation of sludge pellets in VOMM biomass heating plant

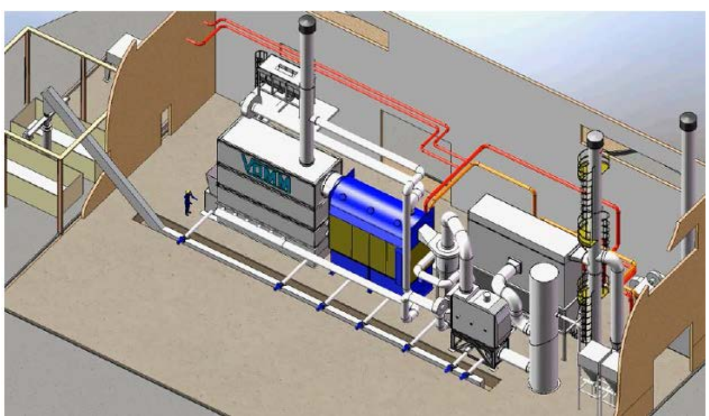

Figure 12. Heating plant running on pellets

WOMM’s expertise includes also thermal utilization of municipal sludge, industrial and biomass (Process Turbo Energy).
The combined solution drying + combustion provides the required autonomy needed for sludge drying, by using the energy produced by combustion.

The VOMM technology for fossil fuel boiler, consists of a tunnel furnace with movable flat grate.

Figure 13. Inside heating plant

This technology is flexible and checked, designed to optimize the combustion of a wide range of materials. The materials that can be used as fuel in thermal power plants VOMM are:

- Municipal and industrial sludge
- Fuel (RDF) of waste derived
- Biomass
- Manure
- Biogas digester, after drying

Equipment description and operation of the VOMM thermal power plants on biofuel

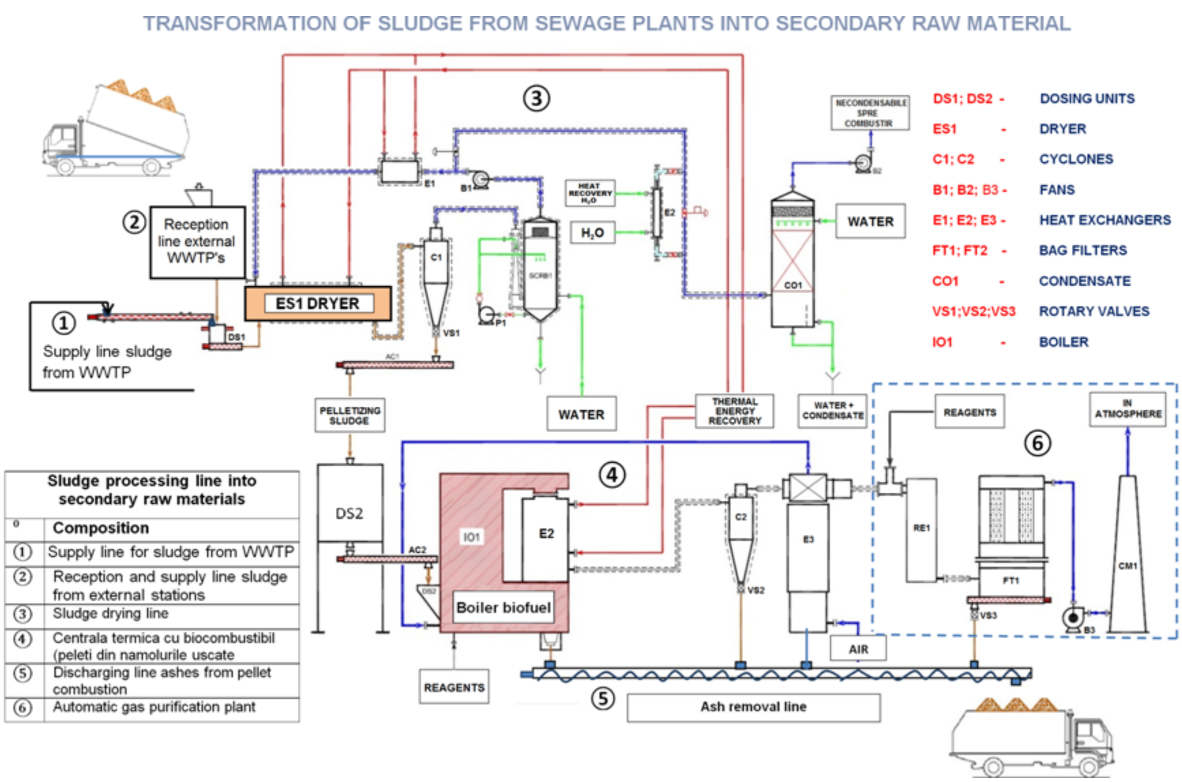

Figure 14. Schematic layout

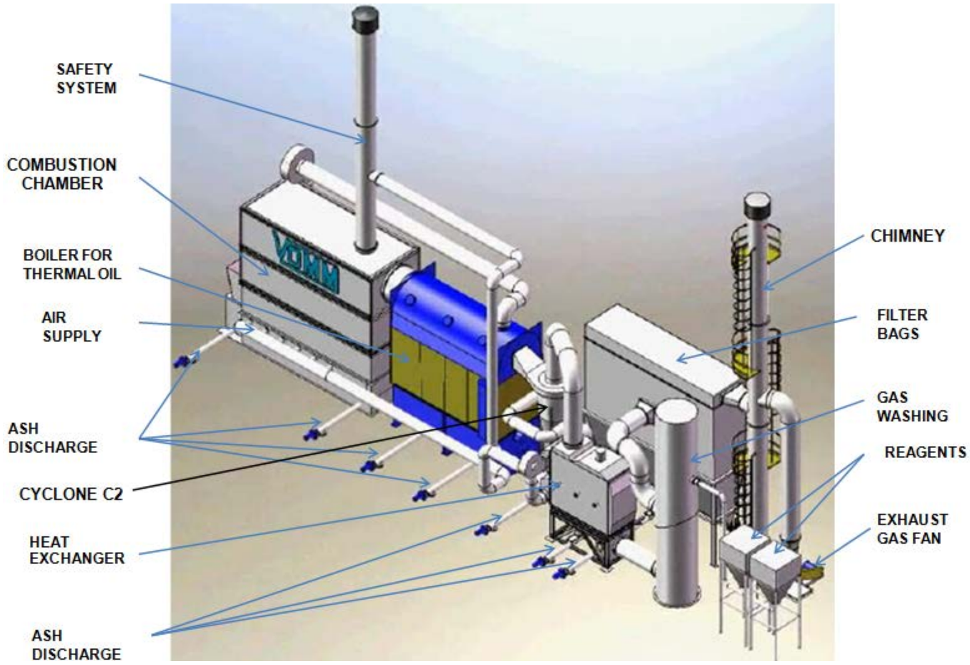

Figure 15. Components identification

Boiler

The combustion chamber is the heart of the boiler «tunnel with tape grate, supplied continuously."

The combustion chamber is lined with a refractory material to limit heat dissipation.

For waste treatment, the facility is equipped with an adiabatic chamber where the burning gases are treated for 2 seconds at a temperature equal or higher than 850 °C.

A gas burner is placed at the entrance of the adiabatic chamber for tempering the furnace coated with refractory materials (at his starting and stopping), launching the process of pellets combustion and to ensure the minimum temperature required in unexpected cases.

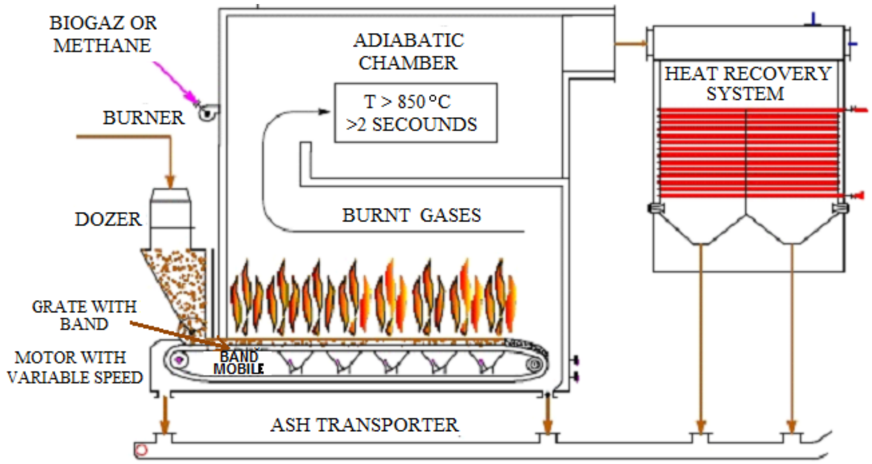

Figure 16. Furnace Scheme

Between different furnace technologies, VOMM has chosen the furnace grate with mobile band for the following reasons:

- It is a verified burning technology since over fifteen years and it has shown, that it is suitable for solid products, it is safe and complies with environmental conditions;
- It is flexible. The movable flat grate enables different materials such as coal, wood, domestic waste, dried sewage sludge pelletizing and other solid fuels to be used as a fuel;
- It is efficient. A combustion system that allows burning products with high water content, reducing the amount of generated combustion gases and simplifying the treatment of pollutant gases.

The fuel arrives from the doser to the grate with mobile band. The produced thermal energy and the combustion quality, are controlled by fuel quantity, mobile grate speed and air injection for combustion. The air injection for combustion is done along the length of the mobile grate in order to optimize the combustion in the adiabatic chamber, as it results from Fig. 17

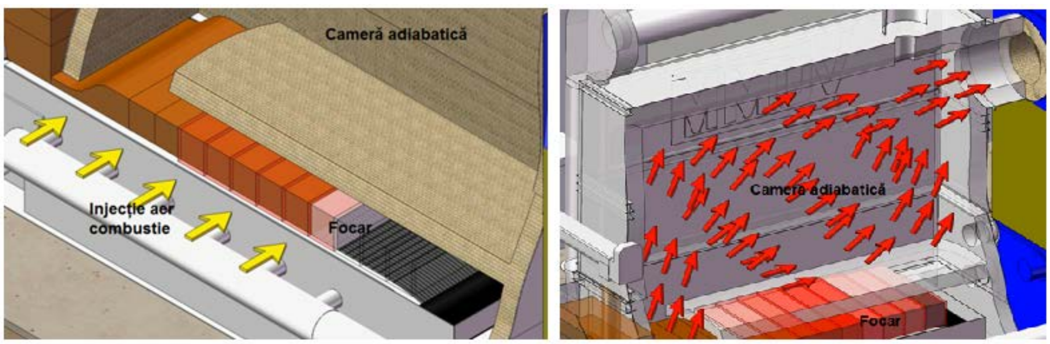

Figure 17. Furnace

The combustion gases pass through the heat exchanger **E2**, via thermal oil circulates, used for the heat transfer, needed for the water's evaporation in the turbo-drier. The thermal oil is heated at 250–290 ^{o}C.
To provide the necessary heat in the dryer, the thermal oil is circulated through the double jacket of the turbo-dryer and trough the heat exchanger **E2**.

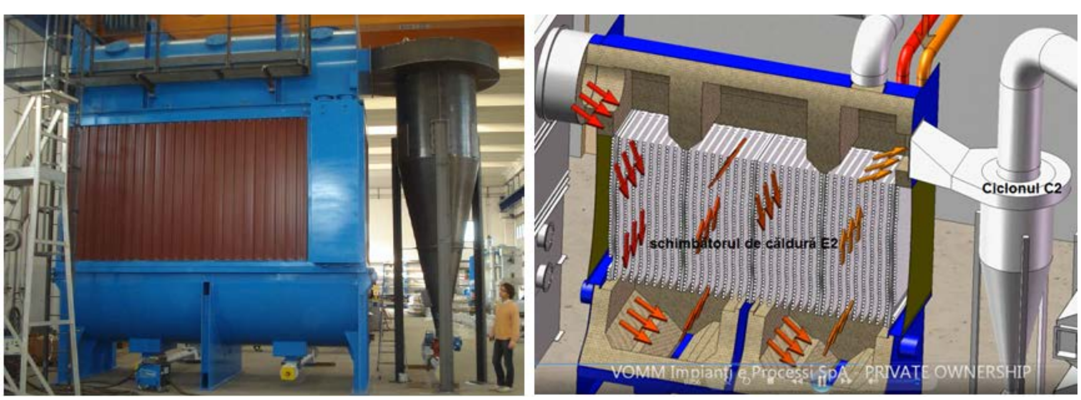

Figure 18. E2 - Heat exchanger

The combusted gases pass from the heat exchanger into the cyclone **C2**, with the scope of further separation of the combusted gases ash.

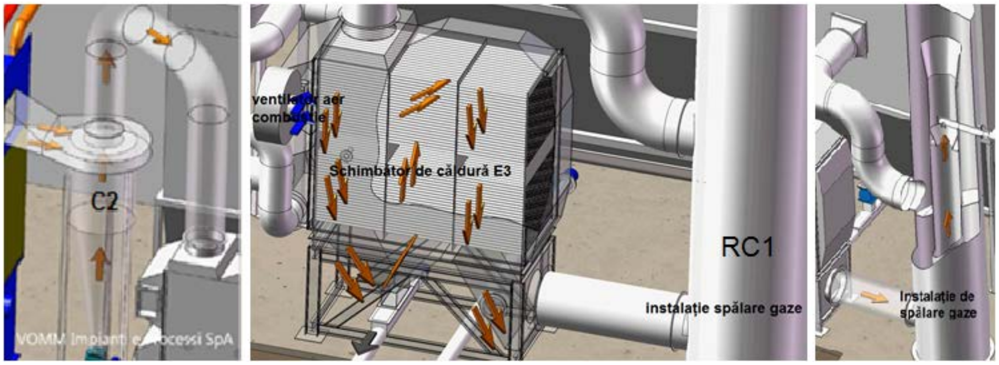

Figure 19. C2 - Cyclone; E3 - Heat Exchanger; RC1 - Reactor

The combusted gases are taken to the Heat Exchanger **E3**, where cold air is blown, having a double role:
1) to preheat air for the combustion in order to increase furnace efficiency and,
2) to cool the combusted gases, protecting the filter bags.

The combusted gases exit the heat exchanger **E3**, are passed through the reactor **RC1** for gas scrubbing in order to neutralize the pollutants contained in the exhaust gases.

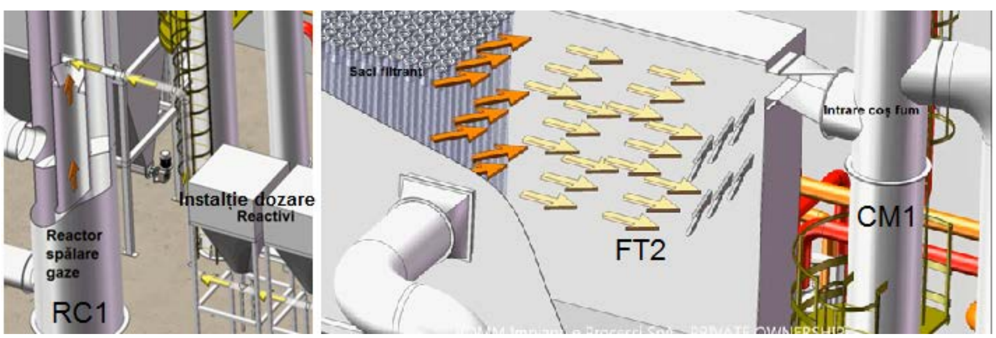

Figure 20. RC1 - Reactor; Reagent dosing facility; FT2 - filter bags; CM1 - Chimney

The dosing of reagents in the reaction tower for gas scrubbing is controlled in real-time by an automatic analyzer.

Real-time control of noxious exhaust gases guarantees the framing of pollutants in environmental parameters imposed for emissions into air and minimal consumption of reagents for neutralization.

Before the gases are released into the atmosphere, they pass through filter bags, to be retained fine particles of ash.

The Filters battery is equipped with automatic shaking and automatic discharge of ash.

The ash is taken up by the screw conveyor of the furnace, heat exchanger **E2**, the cyclone **C2**, heat exchanger **E3**, and the bag filters and is discharged into a screw conveyor collector, from which it is taken up by a bucket conveyor for being loaded in trucks.

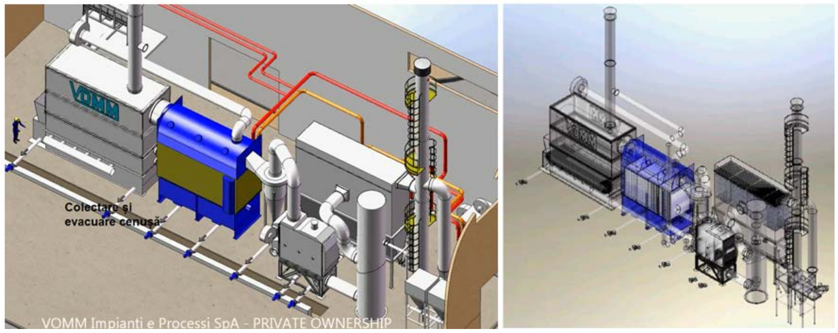

Figure 21. Ash dischargement

After the sludge pellets combustion, the ash is inert without biological load, being hold at the temperature of 850 ^{o}C for 2 seconds, according with European standards. The ash is in the form of slag due to the mineral content, melted at over 780 ^{o} C. This slag is tough and a good thermal insulation. Thanks to these properties, it is used in the production of asphalt, or in the production of building materials.

Benefits of using VOMM thermal power plans

In terms of sludge contaminated with heavy metals, the amount of ash contaminated with heavy metals is reduced up to 30% of total resulted ash, in consideration of the separate collection of ashes on every device (Cyclone **C2**, the Heat Exchanger **E3**, Filter Bags **FT2**).
Reducing the amount of ash contaminated with heavy metals within 30% of the total resulting ash is based on the fact that heavy metals are volatile at over 550 ° C, and the temperature in the furnace is reaching more than 850 °C. Heavy metals in vapor form are entrained with the flue gas and condensed beginning with the cyclone **C2**.
In these circumstances ash discharged from the furnace and the heat exchanger **E2**, (which represents over 70% from total ashes will not exceed the permissible limits of heavy metals, will be collected separately, and can be used as secondary raw materials. The ash discharged from the cyclone **C2**, if the legislation does not allow its use as secondary raw materials will be stored in places designed for hazardous waste. The amount of ash contaminated with heavy metals resulting from 1000 kg dewatered sludge with 25% DM will weight maximum 22 kg, the remaining 56 kg will not exceed the permissible heavy metals content.
VOMM drying → pelletizing → combustion technology for sludge from sewage plants, after starting the process, ensures thermal self-maintenance (no need for other fuel intake or intake of heat).
For self-maintaining the heat necessary to heat the sludge pellets multiplied by the thermal efficiency of the boiler is larger than the enthalpy required vaporizing the amount of water. This condition is generally satisfied if the digested sludge contains more than 20% dry matter after dehydration, and the digested one are containing over 23% dry matter after dehydration. For an accurate calculation and correct solution it is needed to determine the sludge calorific value of each treatment plant.

Below is a graphical presentation of the ratio: of capacity of the plant; % of dry matter; investment costs; operating costs for sludge drying - pelletizing - combustion in the boiler which supplies power for drying sludge.

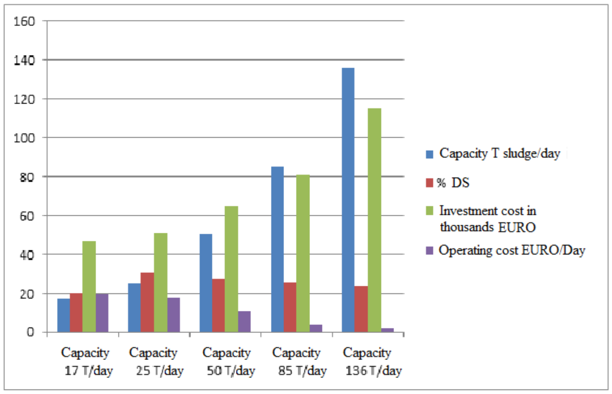

Figure 22. Graph Plant Capacity; % Dry matter; Investment Cost; Operating Cost

In the graph above are represented the operating costs per tonne of sludge, starting from the condition that only 60% of the energy recovered is used, the percentage of heat required for its use is between 60% and 70%, depending on the outside temperature. For additional lowering of costs, there must be find out solutions to use a percentage as high as possible.

Example of applying VOMM technology at the Novoceboksarsk Wastewater Treatment Plant, in Russia

VOMM has designed, manufactured, installed and put into operation a line for the transformation of sludge into fuel, for the WWTP Novocheboksarsk in Chuvash, Russia. The resulting fuel is used to produce the energy needed for drying of sludge. The produced energy exceeds by far the requirements of the treatment plant and the customer is looking for solutions for using the surplus of energy.
A special characteristic of this treatment plant is that it treats domestic wastewater mixed with industrial wastewater and it also treats the resulted sludge.

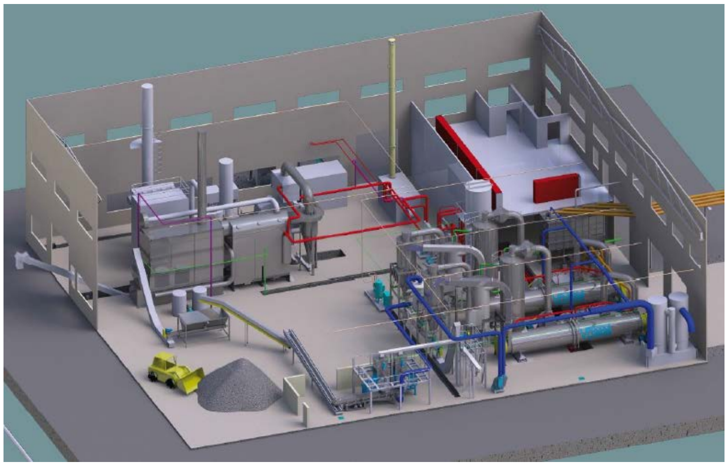

Figure 23. 3D presentation of the WWTP from Novocheboksarsk, Chuvash, Russia

In the following table we present the characteristics of the sludge treatment, limits, gas emissions and analyzes during operation at this WWTP.

CHARACTERISTICS		LIMITATIONS AND GAS EMISSIONS		
Place	Novoceboksarsk, Ciuvașia, Russia	Substances	Emission limits mg/Nm3	Test results mg/Nm3
Treated product	Urban sludge	NO	200	89,2 *
Dried sludge	58 000 t/year	CO	50	1,51
Sludge burned	14 500 t/year	SO	50	41
P.C.I. sludge	2,9 KW	HCl	10	5,75
Thermal Heat recovered	5 MW	POWDERS	10	6 - 8
Working	2700 h/year	* SNCR system off: reading without urea injection		
Startup	February 2013			

VOMM technology for the transformation of sludge into secondary raw material has also other applications for waste with much higher energy potential than sludge from sewage.

3. OTHER APPLICATIONS OF VOMM DRYING - PELLETIZING – COMBUSTION TECHNOLOGY

Energy valorisation from manure from chicken rearing farms

"Manure" resulted from chicken farms is one of the big problems of the Romanian agriculture. Manure is a fast-growing waste, which raises environmental problems, by stockpiling and use in agriculture.

Under this circumstances, there must be found viable long term solutions for introducing this waste in the circular economy.

Its high energy potential makes this waste suitable for transforming it into energy and for the valorisation of this energy to reduce production costs for rearing chicken.

VOMM solution for energy valorisation from hall manure has the great advantage that it allows storage and transport of energy in the form of pellets and they can be used as required.

The transformation of hall manure into fuel can be done centralized, to reduce investment and operating costs. Then the manure can be used in form of pellets in other locations, as needed.

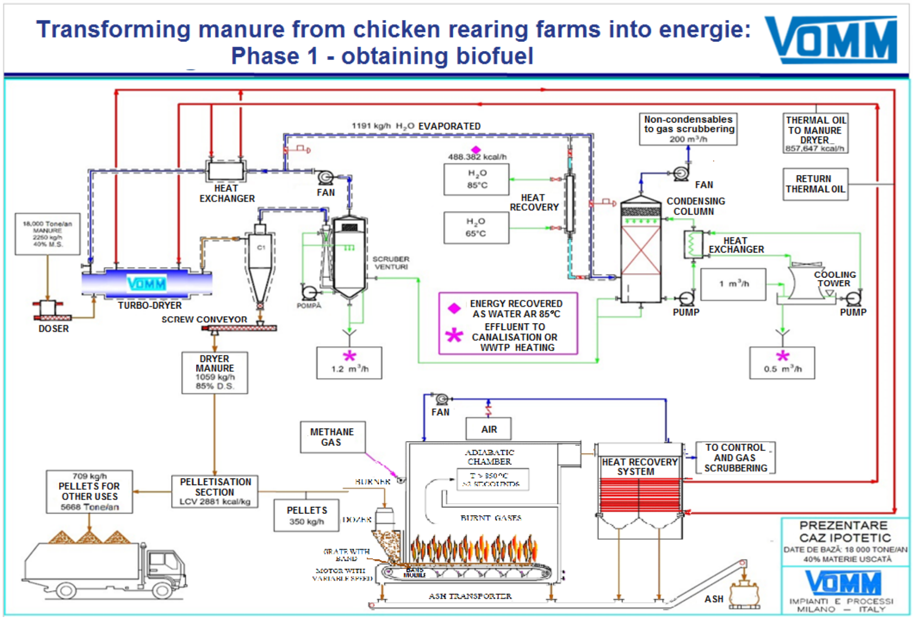

Figure 24. Scheme – Transformation of hall manure into pellets

In Fig. 25 is an example of the amount of energy that can be obtained from the resulting pellets after drying installation for the consumption and transformation of various forms of energy to get were most needed:

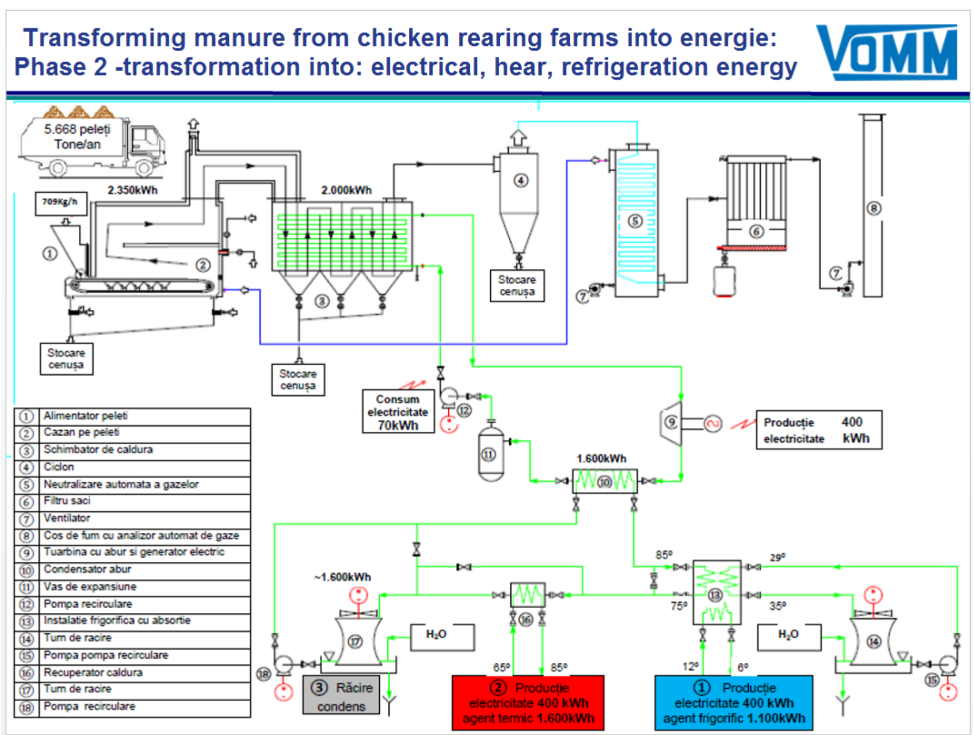

Figure 25. Scheme – Energy usage possibilities

Waste Valorisation from Municipalities

Based on the Large Infrastructure Operational Programme 2014-2020 (Version 1), Priority Axis – 1, Point: „Improving sludge management from wastewater treatment plants"; and Priority Axis 2, Points: „Reducing the amount of waste deposited" and „Increase the quantity of recycled and recovered waste", the establishment of efficient structures for waste management and waste management is foreseen. According to the Treaty of Accession and to the Waste Framework Directive[4], Romania must comply with the following requirements derived from European legislation: Phasing and rehabilitation of non-compliant landfills for municipal waste (2017); reducing the amount of biodegradable waste disposed in landfills (2016); preparation for reuse and recycling of waste from household waste (2020). Detailed information on compliance obligations and their fulfilment stage are presented in the description of the related actions OS 3.1.[5]
Waste incineration is still catalogued by many people, as a controversial solution. An article entitled "Incineration of waste solution or environmental hazard?"[6] by Cosmin Zaharia, published on www.green-report.ro presents the pros and cons of Waste energy valorisation. In the article, Daniela Burnete ISPE Bucharest says *"In conclusion, the thermal treatment of waste can be a solution for large agglomerations in Romania, for cities that do not have alternative waste management"* and Elena Rastei, representative of Zero Waste Romania believes that "*Municipal and similar waste are not a renewable energy source because they consist of finished materials. Destruction by burning or burial of these materials creates a demand for other 'waste' encouraging mining and exploitation of primary resources. Unfortunately, in Romania, municipal and similar wastes erroneously included in the category considered biomass and renewable energy source.*"
Romania, one of the EU countries with the highest rate landfill storage, approximately 96% and a very low recycling rate is required to find solutions to reduce drastically landfill storage. In this regard, VOMM with the presented technologies has the willingness and ability to develop an application for environmental friendlier waste energy valorisation, avoiding mistakes done in the past by western European states:

- Preserving the principle that the polluter must pay, to be interested in reducing waste, from product design, production and deal with their collection to disposal;
- Pursuing the collection, sorting, processing and waste recovery. After sorting recyclable materials should be directed to be introduced in the circular economy as future raw materials, not to support burning them *"(...) an economic system linearly based on exploitation, production, consumption, destruction and therefore on consumption unlimited finite resources of the planet"*[7];
- The unrecycled materials with energy potential should be used for the production of energy in cogeneration, or just heat through, mixing → drying → pelletizing, will be converted into biofuel solid, stable and uniform with excellent qualities, reducing the maximum amount of waste deposited at the landfill. The pellets produced can be stored, transported and used depending on energy needs;
- If the production of energy from waste must ensure continuously a minimal amount of energy, without to be dependent on the amount of waste collected, VOMM plants are designed to be powered also with other solid fuels, avoiding the mistakes of existing large waste incinerators *"otherwise, these technologies once installed must be feed continuously*

> *for a period of minimum 25 years, which means that depending on the capacity of the plant, it will arrive shortly at the point where either we import waste from other countries or we will have to generate more waste."*[8]

For the implementation of the application we started identifying waste with energy potential, identifying polluters and the possible way of: collecting, processing and valorising their potential energy.

Based on this information, we designed a program of *Regional Waste Management* in order to reduce discharges in landfills and their exploitation for the production of electricity and heat in cogeneration.

Our concept of waste complies with the principle that the polluter should pay, but at the same time it is reducing the costs with waste to the minimum possible, creating the opportunity to meet all long-term environmental norms.

This concept of VOMM represents for Romania is a novelty, consisting primarily that there is no difference between polluters, private individuals and companies or community, the entire society must be responsible towards the environment and its pollution. Thus we have an obligation to develop an integrated waste collection and valorisation.

The community's interest is to support businesses, to reduce their costs in order to withstand competition, to development and to create new jobs.

Polluters with waste with energy potential are:

- Sewage treatment plants – sludge;
- Rearing farms - manure (manure mixed with bedding material);
- Farms for pig, cattle, etc. – manure;
- Population – Waste;
- Restaurants, grocery stores - food scraps and expired food;
- Industrially processed meat - food co;
- Municipalities, wood - wood residues;
- Municipalities, businesses, population – vegetation.

For waste disposal and valorisation, investments in small capacity facilities and their exploitation per ton of waste, are very high, their costs decrease with increasing capacity.

For this reason, waste processing and valorisation is indicated to be done regionally to reduce investment and operating costs per ton of waste.

In Fig. 26 is scheme of this concept, describing the waste collection from polluters, processing and transforming into energy.

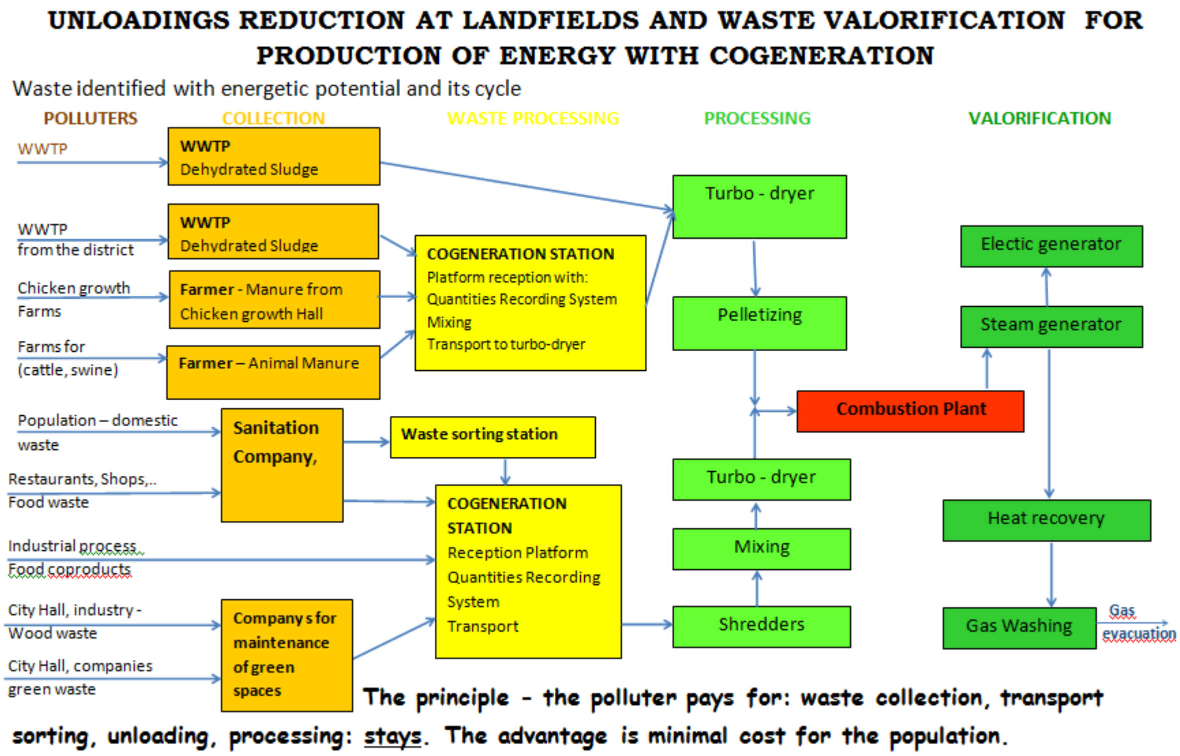

Figure 26. Waste Valorisation Scheme

As shown in the diagram, operation of a sorting station is foreseen, where for energy valorisation must be sent only materials that can not be recycled.

We eliminate the idea of energy valorisation from recyclable materials, recyclable materials entering into the circuit of circular economy.

Of course, here was introduced only a principle of waste valorisation. To valorise the waste in terms of economic and environmental impact, it has to be made a case study for each community or group of communities depending on their geographic location, specific wastes.

There is no optimal universal solution applicable, it is necessary to find customized solutions for each situation.

VOMM activities to popularize new technologies for sludge management

During these activities, VOMM has brought his pilot plant at the wastewater treatment plants in the cities Arad (09.09.2015), Cluj Napoca (15. 09.2015) and Bacău (21.09.2015).

There were theoretical presentations of its technologies drying → pelletizing → energy valorisation and demonstrations for drying → pelletizing → sludge combustion capacity.

For this practical demonstrations, sludge from the mentioned treatment plants and manure with straw content from chicken rearing halls were used.

Figure 27. Pilot plant for sludge drying→pelletizing

Figure 28. Aspects of the VOMM technologies presentation in Arad

Figure 29. Aspects of the VOMM technologies presentation in Cluj-Napoca

Figure 30. Aspects of the VOMM technologies presentation in Bacau

4. VOMM PERSONALIZATION COMPANY'S POTENTIAL TECHNICAL SOLUTIONS FOR EACH CLIENT

The company VOMM together with its collaborators, and potential beneficiaries have the capacity to find the optimum solutions for each case and their implementation through the design, manufacture, installation, commissioning of plants, operation (or training of operating personnel) and performing maintenance.

VOMM developed these technologies with a team of process experts, which bases its research & development strategy. They have at the company's headquarters eight plants for semi-industrial tests. Here they can create, together with customers, innovative process solutions and customize them for each client.

VOMM is also able to make available its pilot installations to customer and jointly developed innovative process solutions at the client.

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7. idem;
8. idem.

CHAPTER III

METHODS OF REVALUATION OF SLUDGE


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The Sludge And Organic Substrates Energy Recovery Possibility, For A Regional Waste Water Treatment Plant

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Abstract
The developing of the infrastructure for wastewater collection and treatment in Romania, with respect to Accession Treaty, is leading more and more to the production of huge quantities of sewage sludge, as direct result of the waste water treatment. This fact generates a fivefold increase in estimated production of sludge by 2020 when all the human agglomerations that have more than 2,000 inhabitants must be provided with sewerage network and treatment plant equipped with sludge processing line. The rapid and rational development of a national policy for management of sewage sludge to establish a broad and short, medium and long term must be emerged and implemented, as a necessity.
It is the obligation of the wastewater treatment plant operators to identify best environmental options and practices for treatment, recovery/disposal of sludge, at sustainable and efficient cost.

Keywords
Sludge, energy, recovery.

1. THE SLUDGE MANAGEMENT STRATEGY

The management strategy for the selection of the process suitable for treatment and stabilization of the sewage sludge is given by the quantity and quality of the sludge produced, taking into account the following possibilities:

1. Using separate facilities for the disposal of sludge on landfills, waste storage, the storage locations being special arranged, comprising drying beds, lagoons, storage, storage spaces, etc.;
2. Using of the waste in agriculture by application over the agricultural terrain, followed by its immediate incorporation or by creating a bed compost with other materials and use it as subsequent fertilization of agricultural land with the compost;
3. Energy recovery of sludge by co-fermentation or anaerobic digestion within biogas production and eventually fermented sludge incineration technologies, or incineration without fermentation, the facilities being functional in co-generation system, transforming the energy content of the sludge into usable heat and electric power, finally used for own purposes by the producer, in order to reduce its energy costs for the treatment processes of waste water and sludge;
4. Co-combustion of sludge in solid waste incinerators under clean technologies and in the frame of high efficiency thermodynamic cycles;
5. Co-processing of sludge in the cement industry, if the humidity and calorific value of sludge meet the requirements of the production process.

2. SLUDGE ENERGY RECOVERY SOLUTIONS

In the waste water treatment plants with low organic charge, the operators must identify the best environmental solutions and practices for the treatment, recovery/disposal of sludge, both sustainable and efficient in terms of costs. For selection of sludge treatment process for energy recovery, we have the following options (DG MA SOP Environment, 2012):

- Dewatered sludge and biogas combustion in co-generation system, transforming their energy content into usable heat and electric power, finally used for own purposes by the producer, in order to reduce its energy costs for the treatment processes of waste water and sludge;
- Co-combustion of sludge in solid waste incinerators under clean technologies and within high efficiency thermodynamic cycles;
- Co-processing of sludge in the cement industry, if the humidity and calorific value of sludge meet the requirements of the production process.

Where it’s not possible the recovery by combustion in municipal waste incinerators or thermal power plants as well in the situations when co-processing in cement plants isn’t possible, energy recovery “in house” is the only remaining alternative. In this case the sludge combustion plant is integrated into the technological flow of heat treatment.

The paper presents a possible novel scheme of an energy recovery plant, by combining the sludge and biogas combustion with drying technologies.

The novelty of the proposed scheme, for Romania at least, is that, to increase the efficiency of fermentation, substrates with high organic load are introduced additionally in the fermentation tanks. The substrates come from the food industry of the operating area.

Schematic diagram concerning the sludge and organic substrates energy recovery, with heat and power cogeneration, is presented in Figure 1.

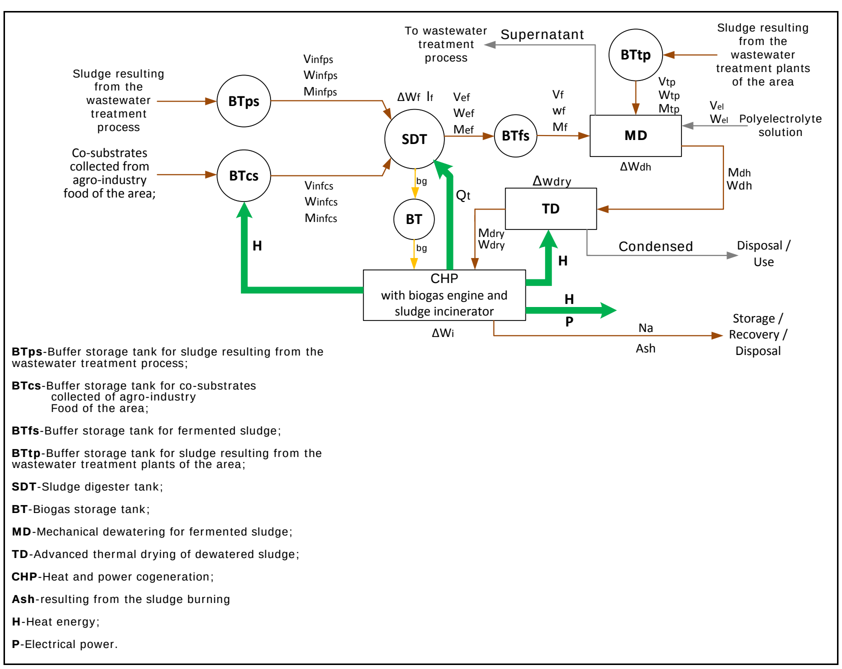


Figure 1. Schematic diagram for sludge treatment processes

The processes on the sludge line are as follows:

1. The stabilization of the sludge resulting from wastewater treatment line in order to reduce organic load. This is made by anaerobic fermentation in digester tanks, in which in addition to sludge from regional waste water treatment plant, co-substrates with high organic load from the food industry in the area are introduced as well. The digestion process ensures by fermentation, the energy conversion of sludge degradable biomass into biogas, which is used for heat and power cogeneration by burning in a combustion engine;
2. The mechanical dewatering of digested sludge along with the sewage sludge collected from waste water treatment plants in the area;
3. The drying dewatered sludge by belt dryers, using the heat supplied from the cogeneration plants;
4. The heat and power production by burning the biogas and sludge dried, takes place in CHP unit in which is also integrated the drying sludge in order to be burned. In order to estimate the energy production of cogeneration plant, it is necessary to know the mass flow and/or the mass volume of biogas and dried sludge as well as the lower heat value or enthalpy of exhaust gases from the two fuels.

To increase the fermentation efficiency and biogas production it is recommended co-fermentation of sewage sludge with co-substrates containing biodegradable solids with high organic loading, rich in proteins, lipids and carbohydrates derived from the agri-food and chemical industry of operating area.

The excess sludge coming from smaller wastewater treatment plants, situated in the operating area, is processed in the regional wastewater treatment plant.

An example of good practice in terms of obtaining biogas by co-fermenting sludge with biodegradable organic waste, is the treatment plant of Straubing– Germany.

The co-substrates ratio in the total mass of organic substrates introduced into digestion process is 70.75% (average). The biogas specific average production (Q_{bg}), according to data provided by the operator of the wastewater treatment plant from Straubing, may reach up to 2000 m^3/t of the reduced dry organic substance. It is approx. 3 times higher than the specific production from the literature on fermenting sewage sludge.

Selection of technical solutions for an efficient combustion of the sludge, involves an estimated thermal balance of the final thermal treatment plants, based on efficient thermodynamic cycles.

Therefore the input and output parameters regarding volume, mass and moisture content of the sludge are mentioned for each treatment process, in order to make the mass and energy balance.

CHP unit with biogas combustion engine

Schematic diagram concerning the recovery of heat in a CHP unit with biogas combustion engine is presented in Figure 2.

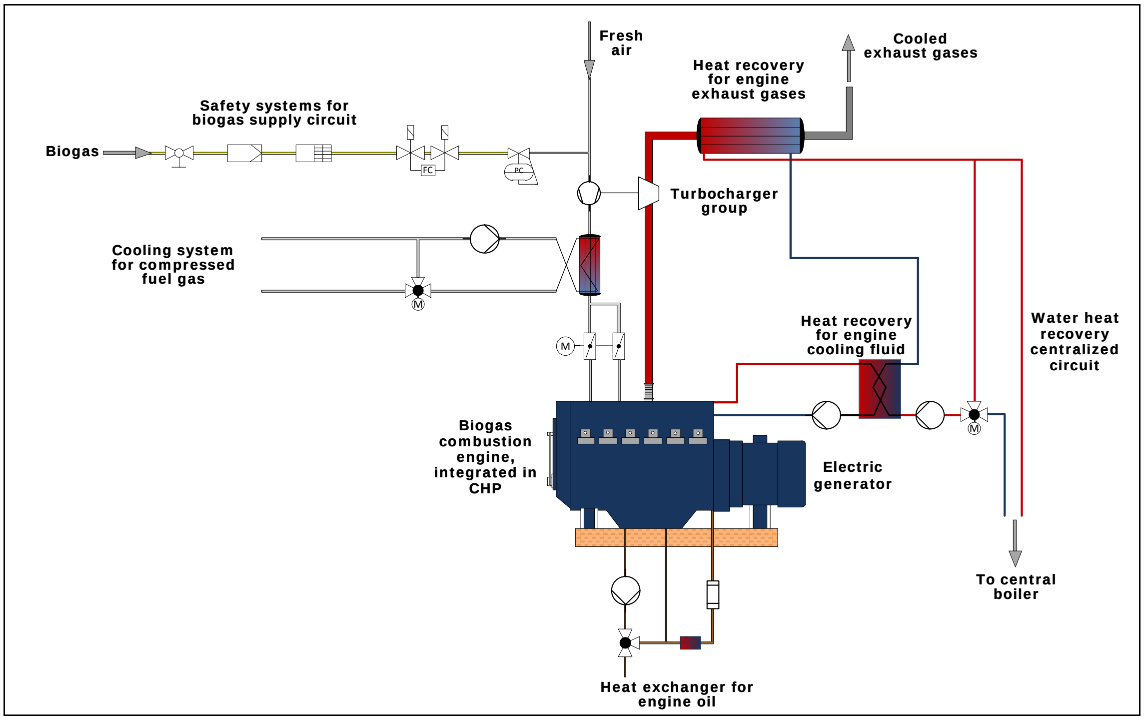


Figure 2. Schematic diagram for CHP unit with biogas combustion engine

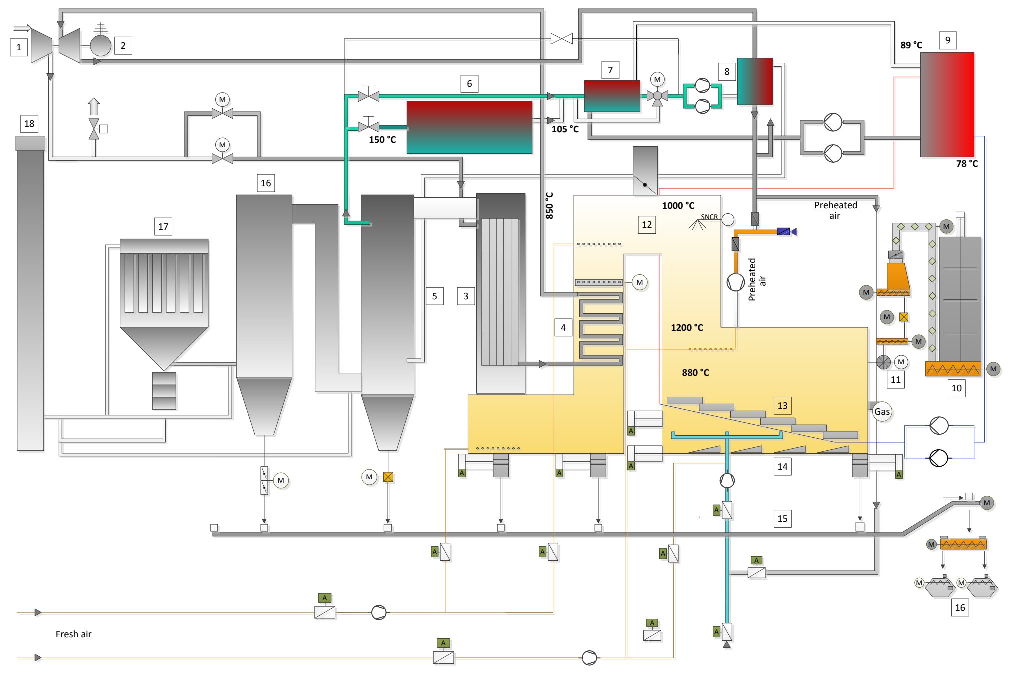
To obtain a high energy efficiency of CHP, a very important influencing factor is the chemical composition of biogas, in the main components, namely the content of methane - CH4 and carbon dioxide - CO2, expressed in % vol. An appropriate chemical composition of biogas, according to the literature, is a participation volume of at least 65% CH4. At this moment there is an increased interest regarding biogas methanisation by advanced technologies in order to increase the concentration of methane in the biogas composition up to a value between 90 and 99%.

Electric power is produced by the electric generator driven by the combustion engine, through a mechanical coupling, making sure that the transferred power from the combustion engine to the electric generator to be at a maximum efficiency (more than 95%).

Available heat from the CHP unit is recovered from engine cooling water, as well as from resulting flue gases by biogas combustion in the engine. Heat recovery is made by means of heat exchangers, whose thermal efficiency is an important factor of the CHP unit, which could influence its energy efficiency. From the flue gases of the combustion engine is recovered most of the heat produced, approx. 60%, considering the flue gases cooling, when passing through exchanger, from 500 ° C to 120 ° C. The remaining 40% of the heat produced, is recovered from the engine cooling circuit. The heat of the two cooling circuits is recovered by the water from the primary heating circuit of the WWTP and stored in a central boiler, then it is used for various technology purposes, including sludge drying.To increase engine power a turbocharger group is used, which supplies the engine with fuel gas. In order to increase the filling degree of the engine, the fuel gas is cooled by a water cooler. The system design and choice of the combustion engine, is based on the estimated annual production and the chemical composition of biogas. The total efficiency of the CHP unit is approx. 80%, out of which 40% is thermal.

CHP unit with sludge burning

Schematic diagram concerning the heat recovery in a CHP unit with sludge burning is presented in Figure 3.



1 - Micro turbine with hot air; 2 - High speed generator; 3, 4, 5, 7, 8 - Heat exchangers; 6 – Sludge dryer; 9 – Central boiler; 10 - Dewatered sludge silo; 11 - Pellets supply system; 12 - Burning furnace; 13 - Inclined grate with separate control and air supply; 14 - Mobile grate for ash discharge; 15 - Ash transport system; 16 – Cyclone; 17 - Flue gas desulphurization system; 18 – Stack

Figure 3. Schematic diagram for CHP unit with sludge burning

The dried sludge is the fuel that provides heat production by burning in the furnace, when the burning necessary requirements are satisfied. At the beginning of the combustion process before achieving the operating temperature, the furnace is heated with natural gas or biogas, after which the combustion is self-maintained by mono combustion.

The burning of the dried sludge is made in a burning furnace with grate and stepped inclined hearth, which provides a high flexibility with simple and reliable operation for the fuel used. To optimize the combustion, the areas where the grate and adjacent combustion chambers are located, are provided with control systems for additional air and nitrogen reduction. After the heat transfer in the heat exchangers and air preheaters, unburned particles from combustion gases are filtered by the cyclone filter and desulphurized. Ash, unburned particles and those resulting from the cleaning of flue gases are collected together in central collection ramp and transported to storage containers, after being cooled in advance. Electric power is produced by an electric generator, which is driven by a hot air micro turbine. The hot air enthalpy difference between the turbine entry and exit is transformed into mechanical work. From bunker storage, by means of a hydraulic transport system, the dried sludge is fed in the burning furnace through a circular dispenser. The drying process of the dewatered sludge is integrated in the CHP unit.

According to data provided by the operator of the wastewater treatment plant from Straubing, the total efficiency of the CHP unit is approx. 70%, out of which 62% is thermal.

3. CONCLUSIONS

- A production of heat and electricity which can cover completely the energy consumptions of the wastewater treatment plant can be obtained through the appropriate technologies for thermal treatment of the sludge and biogas;
- Digested sludge can be placed on thermal treatment line and burned along with the excess sludge. In this way the amount of waste that will result from wastewater and sludge treatment processes is minimized and will no longer be an environmental problem;
- The amount of waste which must be eliminated from the treatment plant is reduced by drying and burning by approx. 7 times and proportionally the transport costs are reduced.
- The final product resulting from the treatment process is ash. Phosphorus and heavy metals can be extracted more easily from the ash by specific technologies;
- Sludge combustion plants ensure the flue gas treatment as well, in order to reduce air pollutants according to the environmental legislation.

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Consideration Regarding Possible Sludge Treatment And Disposal Methods Suitable In The Area Of Cluj, România

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Abstract

The present sludge treatment, disposal methods and estimates future sludge quantities and quality are presented in this study. It is also necessary to consider and evaluate the regional infrastructure for the different methods in order to obtain unitary proposals. The quality of the sludge is of major importance for the usage so therefore the sources for pollutants and sludge quality demands are investigated. Possibilities of having strategies for pollution control are explored, since these are needed in order to improve the quality of the sludge.

Different alternatives for sludge treatment such as composting and different disposal methods such as incineration are evaluated. The objectives presented above are very broad and the study focuses on the possibilities of using the sludge as a fertiliser in agriculture. This disposal method is chosen because the usage of sludge in agriculture creates a recycling of nutrients. The usage of sludge as a fertiliser would be a complement to artificial fertilisers, which cost both money and resources to develop. Also the problem with how to dispose the sludge would be solved.

Keywords
Sludge, treatment, strategy, quantities, agriculture.

1. INTRODUCTION

The treatment of the large amounts of wastewater produced in the society of today generates large quantities of sludge. The wastewater is treated in such a way that undesirable substances are separated from the water. The first treatment is often mechanical and it removes the bigger particles from the wastewater. Substances can also be removed biologically which is often the case in for example nitrogen and carbon, which is measured in biological oxygen demand (BOD). Chemical treatment is sometimes used and it encourages small particles and dissolved substances to form larger particles which facilitate separation. This is called chemical precipitation.
Sludge is formed when these larger particles clump together during suitable separation methods [2]. All the sludge that is separated during these treatment methods (mechanical, biological and chemical) are referred to as raw sludge, which has to undergo varies kinds of further treatment. The contents of the sludge reflect all the substances that are used in the community, which means that there is a vast variation of substances. Apart from the substances that enters the treatment plant, of which some will sediment directly in the mechanical treatment, the sludge will also contain microorganisms produced in the biological treatment step and added chemicals used in the chemical treatment step. Remainders from pharmaceuticals such as antibiotics and hormones in the influent wastewater are other substances that also eventually will end up in the sludge [7].
The sludge has two main components; liquid and solids. The liquid phase contains water but also dissolved substances. These may be organic substances in the form of carbohydrates and fatty acids and inorganic salts such as ammonium. The solid phase contains organic and inorganic matter. Living organisms, their decomposition products and other organic compounds that have been broken down to varying degrees constitute the organic matter while metals and nutrients are regarded as inorganic matter [6]. The content of sludge varies depending on local circumstances

but also on the choice of treatment method and where in the process the measurements are made. In accordance with Directive 86/278/EEC [4] [10], national legislation which has been established in the Member States prohibits the use of sludge in agriculture if the heavy metals concentrations exceed specific limit values. Moreover, the Directive specifies that sludge may not be used on land when the soil concentration exceeds the limit values set out in the same Directive and that Member States have to ensure that the limit values are not exceeded as a result of the use of sludge.
The most important metal pollutants in sludge are zinc (Zn), copper (Cu), lead (Pb), chromium (Cr), nickel (Ni), mercury (Hg), cadmium (Cd).

Table 1. Limit values for heavy metals in soil ($kg/ha^{-1}/y^{-1}$)

Compound	**Limit values**
Cadmium	0.15
Copper	12
Nickel	3
Lead	15
Zinc	30
Mercury	0.1
Chromium	12

Sludge is treated by various processes that can be used in various combinations. Following are the different types of sludge treatment processes.

Table 2. Different process of sludge treatment

Sludge from Treatment Processes	
▼	
Preliminary Operations	
Sludge Grinding	Sludge Storage
Sludge Bending	Sludge Degritting
▼	
Stabilization	
Chlorine Oxidation	Anaerobic Digestion
Lime stabilization	Aerobic Digestion
Heat Treatment	Composting
▼	
Conditioning	
Elutriation	Chemical Conditioning
Heat Treatment	
▼	
Disinfection	
Pasteurization	Long Term Storage
▼	
Dewatering	
Vacuum Filter	Centrifuge
Pressure Filter	Drying Bed
Horizontal belt filter	Lagoon

▼

Drying	
Multiple Effect Evaporator	Rotary Drying
Flash Drying Multiple	Hearth Drying
Spray Drying	

▼

Thermal Reduction	
Multiple Hearth Incineration	Flash Combustion
Fluidized Bed Incineration	Co-incineration with Vertical Deep Well Reactor

▼

Ultimate Disposal	
Landfill	Reclamation
Land Application	Reuse

2. TREATMENT AND DISPOSAL METHODS

Treatment methods

The large amounts of generated sludge from the wastewater treatment plants have to be taken care of, it may be treated and disposed of in different ways. It is often hard to make a total distinction between treatment and disposal methods, some methods are a combination of both.

1. **Conditioning**

Conditioning of the sludge involves modification of the sludge structure so that more water can be separated. This will improve further treatments such as thickening or dewatering and it may also restrict the fine particle content of the reject water. There is chemical conditioning using mineral agents such as lime or salts or an organic compound which is different kinds of polymers. Another way is thermal conditioning where sludge is heated to 150-200ºC in 30 to 60 minutes. Heating to 40ºC or 50ºC is also possible and will give a partial thermal conditioning [1], [3].

2. **Sludge thickening**

The sludge produced at the wastewater treatment plant contains a lot of water and it has to be thickened in order to reduce the volume and cost for the following treatments. The thickening methods vary with the nature of the sludge and the purpose is to remove some of its free water. Flotation may be a suitable method for chemical and biological sludge while primary sludge is best thickened by various sedimentation processes. Centrifugation can be used either for thickening or dewatering purposes [3].

3. **Stabilisation**

Raw sludge is biologically active since it contains biodegradable compounds. The decomposition rate has to be increased in order to avoid problems such as odour due to anaerobic degradation etc. Stabilisation is of importance in regard to hygienisation since the odours are reduced and therefore do not attract vectors via smell. This can prohibit re-infection and re-growth of pathogens. After stabilisation, the volume has decreased, hygienisation has occurred and the sludge is no longer regarded as active [8].
Anaerobic digestion is a stabilisation method that will reduce the volume and stabilise the sludge.

It will also give a partial hygienisation. The total quantity of the sludge is reduced by about 35% [3]. Aerobic digestion is a process where the sludge is placed in an aerated vessel. The decomposition is performed by aerobic microorganisms and this generates heat. If the process is working adequately, more than 70°C can be reached.

4. Dewatering

Dewatering means that the volume of the sludge is greatly reduced by separating water. Raw sludge contains high amounts of water, usually more than 95% by weight [2], [4]. It is only possible to remove a certain proportion of free, adhered and capillary water with the technology available today [6]. Different dewatering processes are drying beds, centrifuging, filter belt and filter press. All processes except drying beds requires the addition of a chemical conditioning agent. The water content of the sludge after dewatering depends on the treatment and can reach about 30% [3].

5. Storage - air dryin

Storage is a method used in order to keep the sludge in one place until it is possible to spread it or use it elsewhere. During storage an increase in dry matter and a reduction of organic matter occur [3]. Also, there is a decrease of pathogens due to storage. During storage or spreading of sludge the microorganisms are affected by natural conditions regulated by the climate. Sunlight or UV-radiation, increases in temperature and drying are all factors that speed up the killing of pathogens [8].

6. Sludge hydrolysis

Sludge contains hydrocarbons that could be useful as a carbon source to microorganisms. Sometimes when wastewater is being processed at the treatment plant, a carbon source is needed in the biological nitrogen reduction step. The carbon source must exist in an easily accessible form so it can be utilised by the denitrifying bacteria, which are converting nitrate into nitrogen gas. This carbon course can be obtained by hydrolysing the sludge. This can be done biologically using enzymes, thermally or chemically. Both raw sludge and digested sludge will yield high concentrations of dissolved organic substances [6].

Disposal Methods

1. Composting

The aims of sludge composting at biologically stabilising sludge while controlling pollution risks in order to develop agriculture or other end use outlets exploiting the nutrient or organic value of sludge. Since organic substances and nutrients, such as phosphorus and nitrogen, are in demand by farmers, compost, rich in organic nutrients, is considered a valuable soil improver.
Sludge composted for agricultural end use are therefore of value to secondary markets. In the case of sludge treated by incineration, waste sludge can be composted as a pre-treatment to decrease the water content, thus increasing the efficiency of the incineration process.

2. Deposition

Deposition means that the treated sludge is transported to a landfill where it is deposited. The waste is then covered with land masses. In some countries there are no restrictions of the design of the landfill. Other countries have restrictions in the design, for example stating that the leakage from the landfill should be minimised. The leakage from landfills is hazardous and can often contain heavy metals and other pollution. There are landfill gases emitted to the air mainly consisting of methane and carbon dioxide. This gas is collected at some landfills and the energy content is utilised. There is also a risk for spreading of pathogens when depositing the sludge if the sludge is not sanitised in previous treatment. When depositing sludge, the sludge is disposed without making use of nutrients, energy or material [3], [4], [9].

3. Incineration

The sludge must be treated and dewatered before incineration of the sludge is possible. To incinerate the sludge without auxiliary fuel the DS content must be around 40%. Dewatered sludge normally has a DS of 25%. The calorific value of sludge is around 10-20 MJ/kg DS [6]. When sludge is incinerated, it is possible to make use of the energy in the sludge. This energy is in the form of heated water or air and this can be made use of when for example heating houses or swimming pools.

4. CASE STUDY PROCESS DESCRIPTION OF WASTEWATER SLUDGE TREATMENT FROM GHERLA WASTEWATER TREATMENT PLANT

The whole study was conducted in a wastewater treatment plant designed for an average daily flow of 9.400 m^3/d and 20.000 population equivalents. It was conceived as an activated sludge treatment plant with a simultaneous aerobic sludge stabilization. The produced sludge is treated differently at different wastewater treatment plants but the treatment is in general just a mechanical treatment in order to dewater and thicken the sludge. This wastewater sludge treatment has a combination of a thickening tank and a filter press. In order to facilitate the dewatering process at the wastewater treatment plant polymer is added to the sludge.

1. Sludge thickening

Sludge received in the screened sludge sump is maintained in a homogeneous state by operation of the submersible mixer. Sludge is transferred to the filter press by the thickener feed pumps. The filter press is used in fixed-volume and batch operations, which means that the operation must be stopped to discharge the filter cake before the next batch can be started (see. fig.1).

Figure 1. Thickener

2. Filter press and polymer plant

The Emo CC 120 is a automatic machine for batch preparation of polymer solutions. A powder feeder starts and polymer powder is fed into the dissolver cone. An ejector sucks down, mixes and transports the solution into the preparation tank. The solution is kept in motion and once matured, is transferred to the stock tank. The stock solution is pumped from the stock tank to the dosing points.

Controls of the polyelectrolyte dosing pumps are via the main PLC and are called to run in conjunction with operation of the respective thickener stream. The poly make up is controlled by a separate hardwired control panel supplied by the poly plant manufacturer. The dewatered sludge is achieved through a filter press connected to a SCADA system and is discharged through a conveyor in a container (see. fig.2).

Figure 2. Dewatering station

3. Humification beds

A form of temporary deposition or long term storage of the sludge is a humification bed (see fig. 3). The sludge lies in a basin for 8-12 years and is dewatered, mineralised and decomposed. During this time the DS content increases from a few percent up to 40-60% without the adding of polymers. The odour insignificant and does rarely cause any problems. The biological degradation is speeded up by the increased oxygen transportation due to the root system of the reed and the long retention time leads to sanitation to a certain extent.

Figure 3. Humification beds

Monitoring the quality of sludge is performed to sludge recovery or disposal according to Ministerial Order 344/2004 for disposal in agriculture.

Table 3 shows concentrations of phosphorus, nitrogen, metals and organic indicator substances in sludge from municipal wastewater treatment plant in Gherla year 2014 and 2015. The concentrations are measured in mg per kg dry solids (DS). Concentrations are often measured related to the dry solid content of the sludge since the water content varies. Dry solids are the matter that remains as residue after evaporation and drying.

Table 3. Concentrations of phosphorus, nitrogen, metals and organic indicator substances in sludge from municipal wastewater treatment plant in Gherla year 2014 and 2015

Compound	Weighted Mean	2014- Sem.I	2014- Sem.II	2015- Sem.I	Limit values according OM 344/2004
Cadmium	mg/kg DS	4.2	2.1	3.53	10
Chromium	mg/kg DS	86.4	40	74.7	500
Copper	mg/kg DS	186	192	309	500
Nickel	mg/kg DS	22	20.1	32.6	100
Lead	mg/kg DS	36.4	32.5	96.3	300
Zinc	mg/kg DS	650	563	1100	2000
Mercury	mg/kg DS	0.72	1.43	1.14	5
PAH	mg/kg DS	0.016	0.0054	0.0063	5
AOX	mg/kg DS	12.6	6.4	4.5	500
PCB 28	mg/kg DS	0.001906	0.00134	0.00201	0.8
PCB 52	mg/kg DS	<0.0001	0.00059	0.00141	
PCB 101	mg/kg DS	<0.0001	0.00015	0.00032	
PCB 138	mg/kg DS	<0.0001	0.00034	0.00031	
PCB 153	mg/kg DS	0.0052919	0.00052	0.00056	
PCB 180	mg/kg DS	<0.0001	0.00178	0.00087	
PCB 194	mg/kg DS	<0.0001	0.00042	<0.0001	

5. STRATEGY FOR THE FUTURE

Water is a scarce resource in the area of Cluj and hence the treatment of wastewater is important in order to prevent watersheds from being polluted. The goal is that 100% people are connected to the sewage network in Cluj excluding the suburbs by 2015.

The Water Company from Cluj is working with a sludge handling strategy for the future for the years 2014-2020. The work includes the estimation of future sludge quantities and analyses of different treatment and disposal methods.

Table 4. Evolution of the quantities of sludge in the period 2016-2045 from wastewater treatment plant in Gherla

Year	Sludge quantities (tons 100% DS)	Year	Sludge quantities (tons 100% DS)
2016	134	2031	145
2017	134	2032	145
2018	134	2033	145
2019	133	2034	145
2020	147	2035	145
2021	147	2036	144
2022	146	2037	144
2023	146	2038	144
2024	146	2039	144
2025	146	2040	144
2026	146	2041	144
2027	146	2042	144
2028	146	2043	143
2029	145	2044	143
2030	145	2045	143

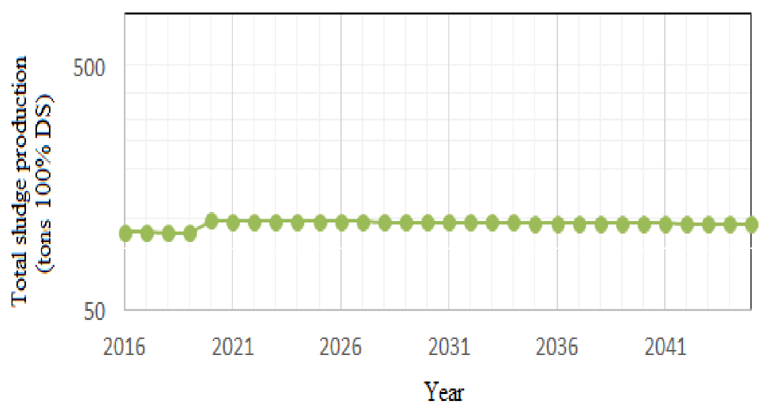

Figure 4. Evolution of the quantities of sludge in the period 2016-2045

To increase the dry solids in sludge treatment from Gherla plant its proposed a completion and a gradual expansion of existing sludge stage through a sludge dewatering facility further.
Process description
Excess sludge will be discharged to the existing excess sludge tank, equipped with a submersible mixer to homogenize the sludge volume. Biological excess sludge will be thickened with the facility of existing sludge dewatering (1 filter belt press), to a minimum of 6% dry matter. Thickened sludge will be evacuated in a new thickener, which serves as a mixing tank sludge suction for the pumps that supply a new treatment facility. In the new thickener is mounted a mixer to homogenize the sludge and prevent deposits. From the new thickener the sludge is transferred by pumps to the mechanical dewatering pumping station. The sludge will be dewatered to a

minimum of 25% dry substance through a centrifuge. Its provided for each thickening and dewatering a unit for preparation and dosing the polymers. The supernatant from the sludge installations plant will be collected and discharged gravitational to the wastewater pumping station. After increasing the degree of sludge dewatering to a minimum of 25% dry substance it can be used in agriculture.

6. FINANCIAL ESTIMATE

Sludge must almost invariably be transported from the point of production to the disposal, possibly via a centralised processing platform.
Generally, the transport step is a large share of costs for works serving large municipalities, as they must transport great amounts of sludge over a great distance to reach a suitable disposal site. However, higher costs as a consequence of great distances could be counterbalanced by savings due to large transported volumes. The cost problem is generally less important for small communities, and they can reduce investments in dewatering equipment and plan centralised solutions. Sludge can be transported by pipeline, barge, rail or truck.
When making a financial estimate of sludge spread on farmland, the following costs must be taken into consideration presented in the following tables. The table present the estimated unit costs of transport and spreading sludge for use in agriculture.

Table 5. Estimated unit costs of transport and spreading sludge for use in agriculture

Transported volume	23.00	tons/tour
Distance from WWTP to agriculture	39.00	km/return
Transport cost from WWTP to agriculture	1.00	euro/tons
Spreading costs	8.00	euro/tons DS
Application rate	5-10.00	tons/ha
Annual growth price	1-3	%

The table present the soil analysis costs.

Table 6. Soil analysis costs

Analysis costs	190	euro/ha
Annual growth price	1	%

The table present the sludge analysis costs.

Table 7. Sludge analysis costs

Inorganic parameters	21.00	euro/test
Heavy metals	148.00	euro/test
HAP, PCB, AOX	115	euro/test
Dioxin PCDD, PCDF	123	euro/test
Annual growth price	1-3	%

For the above reasons, transport by truck is the most widespread method used. The most significant advantages are relatively low investment costs and a high degree of flexibility. Rerouting and alteration of collection points are also easily arranged. Drawbacks are possible leakage and odour or dust emission.

7. CONCLUSION

There are many different treatment methods for sludge being used around the world today. Treatment methods that facilitate reuse of the sludge are desirable hence this enables recycling of nutrients. Composting is a good treatment method in this perspective but it demands a large area and therefore use in agriculture is a good alternative. The sludge use in agriculture is planned to expand in Gherla-Cluj area and also in the future. These are good treatment methods hence it also increases the public acceptance for sludge as a fertiliser.

Also the handling and transportation of the treated sludge is easier when the sludge is dry. It can then be transported and spread with the same technique as for example artificial fertilisers. The future strategy for sludge handling includes use in agriculture, composting and incineration for 90% of the sludge.

There are worries that sludge as a fertiliser might be harmful for the agricultural land but most people agree that sludge should be considered to be a valuable resource for the future as a fertiliser and soil improver. The quality of the sludge can be improved with control strategies for pollutants. It is however of major importance that the authorities regularly supervise and control that the legislation is complied with. Also more frequent measurements of the quality of the sludge are desirable but this is the case for most countries in the world.

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Possibilities Of Biosolids Utilization In Agriculture

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Abstract
Processed sewage sludge for use in agriculture by biotechnological processes of anaerobic and / or aerobic (composting), are known as "biosolids".
Biosolids contain a series of compounds with agricultural value (organic matter, nitrogen, phosphorus, potassium and lesser amounts of calcium, sulfur and magnesium), which recommended for use in agriculture, but this involves placing the contained pollutants on soil (heavy metals, toxic organic substances and pathogens).
In order to be recycled into agricultural waste, sewage sludge must be pre-processed in order to reduce the water content, fermentation properties and the presence of pathogens.
European and international current trend is to decrease the maximum quantities of biodegradable waste by its reintroduction into natural cycle, storage is considered as the last option, and it is recommended only when there is no other way to recovery.
Many researching works, in country or abroad, conclude the possibility of using of biosolids in agriculture, such as: Dumitru, M. şi col., 2003 – Codul de Bune Practici Agricole, vol. I şi II. Ed. Expert, Bucureşti; Eliade Gh., Ghinea L., Ştefanic Gh., 1983 – Bazele biologice ale fertilităţii solului. Ed. CERES, Bucureşti; Lixandru B., Masu S., Bogatu C. N., Rus V., Pricop A. (2008) - Remediation of soils polluted with heavy metals by using of biosolid and supported zeolite, EUROSOIL 2008 Congress, Vienna, Austria; Mihalache M. şi colab., 2006 – Valorificarea în agricultură a nămolurilor orăşeneşti. Ed. SOLNESS Timişoara; Trasca Florian, Mujea Gelu, collab.(2008) - Agricultural use of sewage sludge for the heavy acid soils impact on environment; Trasca Florian , Mujea Gelu, (2011) - The impact of applying sewage sludge in agriculture on the food chain system represented by the soil-plant-animal- human being -International Conference ALL FOR CLEAN WATER, Second Edition-2011; U.S. EPA, 1999 – Environmental Regulations and Technology: Control of Pathogens and Vector Attraction in Sewage Sludge. Revised October 1999. Washington, D.C. Report; US EPA 1992. US Sewage Sludge Regulations, Standards for the Disposal of Sewage Sludge; US. Environmental Protection Agency, 1993 – Standards for the use or disposal of sewage sludge: final rules. Federal Register, 59, 9248-9404; Wei Z., Z. Liu, 2005 – Effects of sewage sludge compost application on crops and cropland in a 3 – years field study. ELSEVIER. Chemosphere 59, 125.
This paper presents some results of complex research concerning the use of biosolids in agriculture (results published).
Nowadays, „For a Clean Water Association – APAC PITESTI" is running a project for the benefit of Mioveni City wastewater treatment plant with the specific purpose of designing a pilot composting station using the biosolid through a specific process, involving mesophile fermentation of sludge and its post-treatment through aerobe composting mixed with vegetal matter.
The main purpose of MIOVENI project is establishing the technological parameters for the sludge composting, and the verification of the final product as a plant fertilizer.

Keywords
Biosolid, heavy metals, pollution.

1. LEGAL FRAMEWORK

In Romania the legal framework for the agricultural valorification of the sludge was established through the Directive 86/278 regarding the environment protection in general and the soil protection in particular, when sewage sludge is used in agriculture, respectively Joint M.O. 344/707/2004 of MEWM[1] and of MAFRD[2] (table 1).

Table 1. The maximum admitted levels of the heavy metals from the sewage sludge used in agriculture (mg/kg of dry material)

Parameters	Maximum Admitted Values		
	Romania (Ord. 344/2004)	EU (86/278/EEC)	USA (EPA503/1999)
Cadmium	10	20-40	85
Copper	500	1000-1750	4300
Nickel	100	300-400	420
Lead	300	750-1200	840
Zinc	2000	2500-4000	7500
Mercury	5	16-25	57
Chromium	500	-	-
Cobalt	50	-	-
Arsenic	10	-	75
Molybdenum	-	-	75
Selenium	-	-	100

In the Joint Order of the two ministries there are mentioned other specifications needed to be taken into account referring to the sludge quality (limit values for some organic compounds) but also to the suitability of the soil.

For other polluant aspects not mentioned in the Order, the sewage sludge using restrictions are established by the environmental territorial authority based on each wastewater treatment plant outcome results after experimental research**.**

2. DEHYDRATED AND ANAEROBIC STABILIZED SEWAGE SLUDGE RECYCLING

Results and Discussions

Comparing the dehydrated and anaerobic stabilized sludge used in experiments, correlating the heavy metals content (table 2) with the maximum admitted levels (table 1) can easily be seen that the sludge is suitable for being used in agriculture.

Table 2. The agricultural used sludge characteristics, referring to the content of heavy metals

Sample no.	Pb mg/kg	Zn mg/kg	Cr mg/kg	Cu mg/kg	Ni mg/kg	Cd mg/kg	Mn mg/kg
74	126,2	1384,2	0,0	119,8	93,8	0,0	340,6
79	0,0	1323,0	15,0	148,6	0,0	8,2	343,8
84	0,0	1131,2	0,0	119,8	0,0	0,0	261,2
90	0,0	826,4	8,0	93,8	0,0	0,0	206,2
93	0,0	1142,0	13,6	125,6	0,0	0,0	286,2
98	0,0	1020,0	0,0	101,6	0,0	0,0	277,4

Dependencies between the crops and the sewage sludge dosage. The cereals and technical plants production resulted on the improved soil with sewage sludge is dependent on the applied biosolid dosage but also on the soil fertility, as seen in the figure 1.

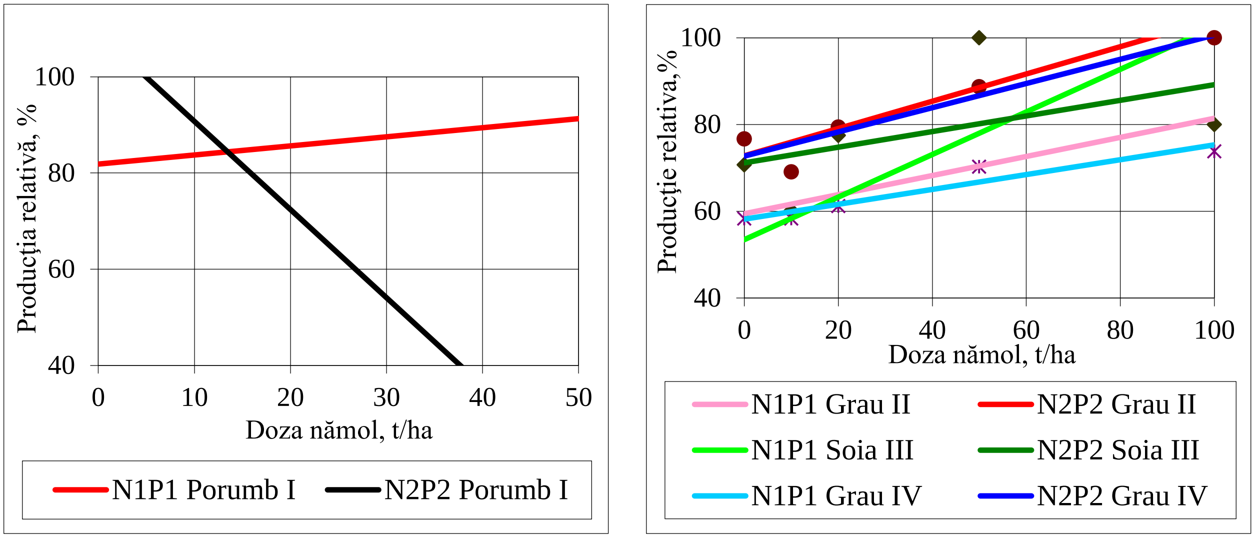


Figure 1. Dependencies between the crops and the sewage sludge dosage (Trasca and collaborators, 2008)

In the monovariant representation, the dependency between the production and the sludge dosage is a direct one;

- In medium mineral fertility conditions, the resulted crops level on the improved soil with maximum sludge dosages is equal or higher than that resulted in optimum mineral fertility conditions;

- The wheat productions differences between the 2nd year using-sludge versus not using (after using it in the 1st year) are slightly ones, demonstrating that the positive using-sludge effect is still maintained in the next year.

The soil level contamination with heavy metals through the years when the sludge was applied in various fertility conditions. Due to the fact that the soil maintains the heavy metals with direct implications over the soil-plant-animal-human system, the limitation of the contamination indices for the Pb – Cd – Ni system, having a major impact on soil, should be a value of maximum 1.

The value of this index is based on the formula:

$$Ic: [Pb]/75 + [Cd]/2 + [Ni]/75 \leq 1.$$

The tested heavy metals contamination indices are under the pollution levels. No matter of the application years there's no risk of exceeding the maximum admitted levels mentioned in MO no 344/2004, when the application is scientifically coordinated. (Table 3)

Table 3. The soil level contamination with heavy metals during the application of the sludge under various conditions, (Trasca and collaborators, 2008)

No	Fertilizer kg/ha	Sludge t/ha	First year						Second year					
			v.e.c.*	e.c.	m.c.	h.c.	v.h.c.	Soil contam index	v.e.c.	e.c.	m.c.	h.c.	v.h.c.	Soil contam index
1	N_0P_0	0	Cd	Cu, Zn	Pb, Ni	-	-	0,585	Cd	Cu	Pb, Zn, Ni	-	-	0,562
6	N1 P_1	0	Cd	Pb, Cu, Zn	Ni	-	-	0,570	Cd	Cu, Zn	Pb, Ni	-	-	0,529
8		10	Cd	Cu	Pb , Zn, Ni	-	-	0,608	Cd	Cu, Zn	Pb, Ni	-	-	0,681
10		50		Cd, Cu	Pb, Ni, Zn	-	-	0,759	Cd	Cu	Pb, Zn	Ni	-	0,773
11	N2 P2	0	Cd	Cu, Zn	Pb, Ni	-	-	0,582	Cd	Cu	Pb, Zn, Ni	-	-	0,574
13		10	Cd	Cu	Pb, Zn, Ni	-	-	0,643	Cd	Cu	Pb, Zn, Ni	-	-	0,709
15		50		Cd, Cu	Pb, Zn	Ni	-	0,811	Cd	Cu	Pb, Zn	Ni	-	0,816

***v.e.c.** – very easy contamination
e.c. – easy contamination
m.c. – medium contamination
h.c. – high contamination
v.h.c. – very high contamination

The effect of sludge-using on the modification of phytotoxic contamination/pollution with heavy metals on the resulted crops. According to the initial database regarding the chemical composition of the crops it was established the macronutrients, micronutrients and heavy metals exceeding risk based on the Joint M.O. no 249/358/2003 of MAFP[3] and MHF[4] which makes references on utilizing of cereals and technical plants as forage (plant material eaten by grazing livestock).

For the resulted crops on the fertilized soil with biosolid a phytotoxic polluting relative index is proposed based on the formula:

$$I_p = (Cu/30)^2 + (Ni/50) + (Zn/140)$$

Table 4. The effect of sludge use on the modification of phytotoxic contamination/ pollution with heavy metals on the resulted crops, (Trasca and collaborators, 2008)

No	Dosages		Application for 2 years consecutively		Application only on first year	
	Fertilizer kg/ha	Sludge t/ha	1st year	2nd year	1st year	2nd year
21	N_0P_0	0	0,17	0,52	1,26	0,39
6	N_1P_1	0	0,17	0,52	1,49	0,37
8		10	0,20	0,70	1,19	0,49
10		50	0,29*	0,84	1,28	0,33
11	N_2P_2	0	0,17	0,63	1,64*	0,24
13		10	0,20	0,77*	1,44	0,33
15		50	0,25*	0,89*	1,17	0,34
DL 5 %			0,07	0,25	0,33	0,13

Conclusions regarding the utilization in agriculture of dehydrated and anaerobic stabilized sewage sludge

1. The sludge resulted from the urban sewage treatment, based on the level of the harvested crops, could be an enricher of the soil.
2. The soil enrichment with the sludge do not pollute the soil or the plants with heavy metals, nitrites or nitrates if a series of conditions or followed such as:
   - the quality of the sludge;
   - the optimal dosage;
   - the recovery period;
   - the cultures structure;
   - the succession of cultures (assolement);
   - the terrain suitability;
   - the application period.

   are taken into consideration.
3. For the establishing of the sludge dosage all the limiting factors will be taken into account, but most important: its content of heavy metals and nitrogen, according to the standard admissible maximum concentration.
4. For the evaluation of the heavy metals pollution/contamination level, a pollution index, based on the next formula, is suggested:
   $$[Pb]/75 + [Cd]/2 + [Ni]/75 \leq 1$$
5. Cereals and technical plants can be grown on sludge improved soil, the analytical data of their chemical composition shows no exceeding of the heavy metals maximum admitted concentrations.
6. For the evaluation of the heavy metals pollution/contamination level of the plants grown on biosolid improved soil, the utilization of an synthetic index is proposed, based on the following formula:
   $$I_p = (Cu/30)^2 + (Ni/50) + (Zn/140)$$

3. THE RECYCLING OF THE COMPOSTING OF THE SEWAGE SLUDGE

Results and discussions

The chemical composition of the composted sludge used in experiment. The data showed in Table 5 shows the presence of some content of heavy metals under the heavy metals maximum admitted concentrations from M.O. no 344/2004. Regarding the macro-elements, this organic enrichment can be used on sown soil due to its almost the same concentration as that of the manure.

Table 5 - The chemical composition of the composted sludge used in experiment

No	Quality indicator	Unit	Concentrations	No	Quality indicator	Unit	Concentrations
1	Dry substance	%	28,2	10	Cu	ppm s.u	94
2	Volatile substance	% s.u.	65	11	Ni	ppm s.u	46

3	pH	-	6,25	12	Pb	ppm s.u	86
4	Nt	ppm s.u	31569	13	Zn	ppm s.u	1029
5	P_2O_5	ppm s.u	1320	14	Co	ppm s.u	< 0,02
6	K_2O	ppm s.u	28779	15	As	ppm s.u	< 1,3
7	CaO	ppm s.u	23265	16	C organic	%	26,4
8	Cd	ppm s.u	< 0,02	17	PCB	ppm s.u	< 0,01
9	Cr	ppm s.u	33,8	18	HAP	ppm s.u	0,64

The corn harvest and the composted sludge. The improvement of soil with composted sludge determined various levels of corn crops, the dependency relation, expressed as probability densities (15) and with a statistic correlation factor as 0,6457, is shown in the figure 2.
The resulted data demonstrates that the applicability of a composted sludge dosage between 5 and 10 to/ha registers a maxim probability of getting of corn harvest of approximately 9,8 to/ha.

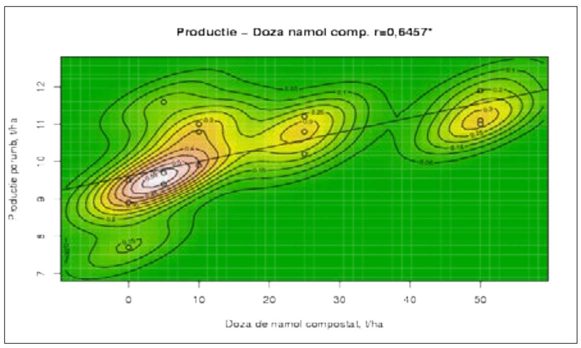
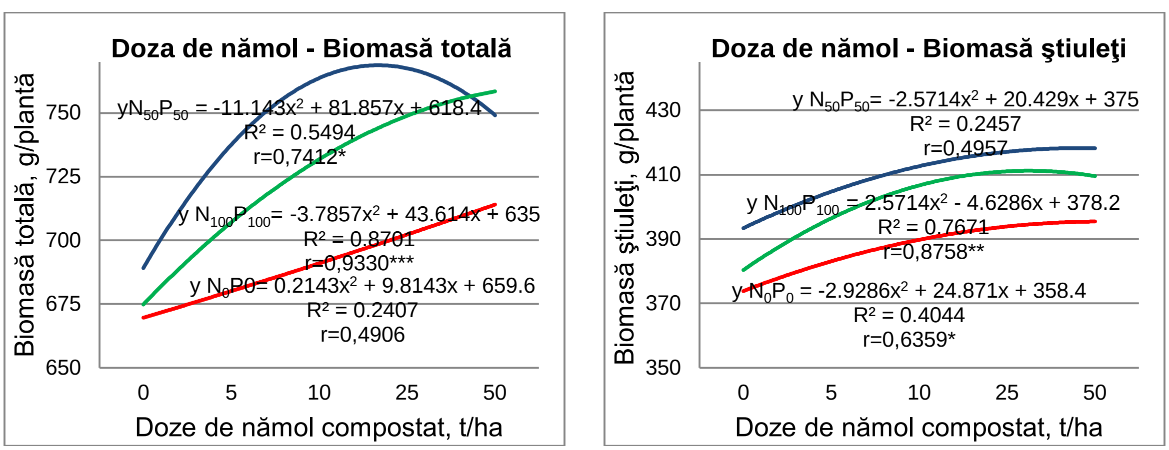


Figure 2. Probability densities between composted sludge dosages and the resulted corn crops in various fertility conditions, (Trasca and collaborators, 2011)

The applicability of the composted household sludge directly influenced the corn plant, as shown in figure 3.



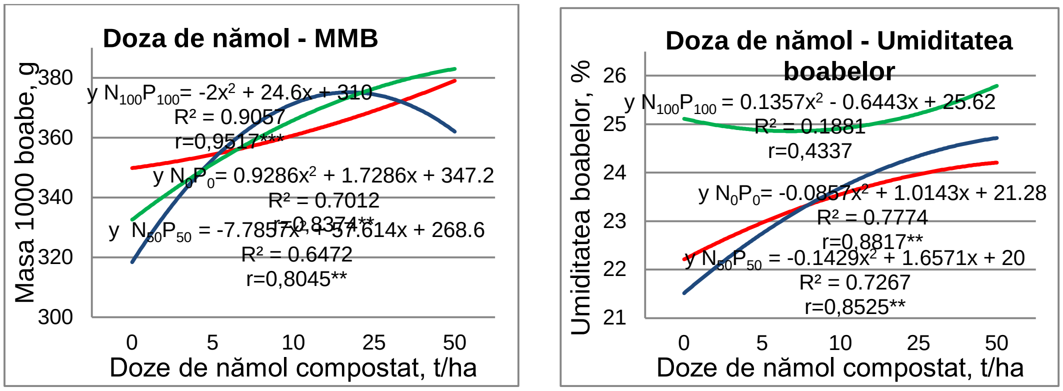


Figure 3. The dependency between the composted sludge dosages and some morphological characteristics of corn plants sown on this soil**,** (Trasca and collaborators, 2011)

From the analyzing of the presented connections comes out that the monitored dependency correlations are statistically guaranteed through correlation factors distinctively significant for the composted sludge appliance on optimal mineral fertility soil (beans humidity makes an exemption).

As an organic fertilizer, the composted household sludge determines major modifications of the macro-nutrients content of soil, as is observed in Table 6 where the variations for N_t, P_t, K_t şi Ca_t during the harvest phase are shown.

Table 6. The influence of the composted sludge dosages over the total macro-elements content from the soil sown with corn (ppm), (Trasca and collaborators, 2011).
Sampling phase: Harvest

No	Sludge dosage (to/ha)	Chemical fertilizer dosage (kg/ha)	Nt	Pt	Kt	Cat
1	0	N0P0	2342	743	1630	2304
2	5	N0P0	1466	787	1131	4543
3		N50P50	2150	816	1290	7268*
4		N100P100	1002	760	887	8106*
5	10	N0P0	1502	788	759	3297
6		N50P50	1181	880	1029	5224*
7		N100P100	1743	938	1350	9405*
8	50	N0P0	2210	976	1434	7765*
9		N50P50	3050	1026	2065	13990*
10		N100P100	3815	1232*	3187*	16462*
	DL 5 %		1897	290	1309	2836

If through the applicability of the composted sludge only the increasing tendency for the total macro-elements content is recorded (without statistic proving for the total nitrogen, and with statistic proving only for the maximum dosage of the composted sludge in optimal mineral fertilization conditions for P and K), for the calcium ions the accumulations are statistically proven for the medium and optimum dosages of chemical fertilizers.

The data showed in table 7 demonstrates the fact that Zn and Ni is accumulating into soil through mineral fertilization and enrichment with composted sludge. Mn is drastically reducing and Pb and Cr has a random variation which implies the action of multiple factors in the evolution of these micro-elements concentration.
The data demonstrates the fact that the accumulations/reductions of the heavy metals from soil are statistically proven and also a consequence of the composted sludge appliance.

Table 7. The influence of the composted sludge appliance over the heavy metals content modification from the soil sown with corn (ppm), (Trasca and collaborators, 2011)
Sampling phase: Harvest

No	Sludge dosage (to/ha)	Chemical fertilizer dosage (kg/ha)	Pb	Zn	Ni	Mn	Cr
1	0	N0P0	43,0	57,0	29,7	1880	39,3
2	5	N0P0	28,5	62,5	26,8	1481	52,9
3		N50P50	29,1	51	29	1420	34,2
4		N100P100	29,5	60,6	23,5	1137	47,2
5	10	N0P0	24,1	62,8	42,1	1369	23,1
6		N50P50	37,8	65,7	40,2	871	32,3
7		N100P100	32,2	70,1	29,9	708	36,5
8	50	N0P0	40,7	89,6	26,4	970	21,3
9		N50P50	38,3	71,1	41,4	1288	33,7
10		N100P100	45,1	112	38,3	1124	35,9

The enriching effect on the heavy metals pollution/contamination indices, also on the soil index is shown in table 8.

Table 8. The variation of heavy metals contamination indices of an enriched soil with composted sludge and sown with corn, (Trasca and collaborators, 2011)
Sampling phase: Harvest

No	Compost dosage to/ha	Chemical fertilizer dosage $kgha^{-1}$	Pb	Zn	Ni	Cd	Cr	Soil contamination index
1	0	N0P0	0,860	0,190	0,594	< 0,007	0,393	0,970
2	5	N0P0	0,570	0,208	0,536	< 0,007	0,529	0,747
3		N50P50	0,582	0,170	0,58	< 0,007	0,342	0,785
4		N100P100	0,590	0,202	0,470	< 0,007	0,472	0,717
5	10	N0P0	0,482	0,209	0,842	< 0,007	0,231	0,893
6		N50P50	0,756	0,219	0,804	< 0,007	0,323	1,050
7		N100P100	0,644	0,234	0,598	< 0,007	0,365	0,838
8	50	N0P0	0,814	0,299	0,528	< 0,007	0,213	0,905
9		N50P50	0,766	0,237	0,828	< 0,007	0,337	1,073
10		N100P100	0,902	0,373	0,766	< 0,007	0,359	1,122

Referring to the heavy metals contamination/pollution index is easily observed that it doesn't exceed the contamination level.
For a higher assurance regarding the pollution level of soil, it had been introduced a supplementary synthetic index, characteristic for clayey soil, and it was demonstrated that the application of a 50 to/ha chemical fertilizer dosage, in medium and optimal fertilizing conditions, generates the starting of pollution of soil.
The soil enrichment with composted sludge highly influences also the chemical composition of corn plants.
The experimental data shows a macro-elements decreasing of corn beans along with the fertility increasing of the improved soil, as a consequence of dilution effect.
It's remarkably interesting that there's an irregular variation of macro-elements concentrations, which demonstrates the existence of a big number of factors in the process of plants growing, many of them with synergetic or antagonist effects.
Speaking about the level of heavy metals from the harvested plants, the corn leaves have a low level content under the 0,2 ppm for Pb and Co, 0,02 ppm for Cd and Zn, 0,06 ppm for Cu and Mn, 0,08 ppm for Ni, 0,1 ppm for Cr and under 1,3 ppm for As (table 9).

Table 9. The variation of the heavy metals content in the leaves of corn planted on enriched soil with composted sludge (ppm), (Trasca and collaborators, 2011)
Sampling phase: Growing

No	Compost dosage to/ha	Chemical fertilizer dosage kg/ha	Pb	Zn	Ni	Co	Cd	As	Mn	Cu	Cr
1	0	N0P0	<0,2	<0,02	<0,08	<0,2	<0,02	< 1,3	126	<0,06	< 0,1
2	5	N0P0	<0,2	<0,02	<0,08	<0,2	<0,02	< 1,3	156	<0,06	< 0,1
3		N50P50	<0,2	<0,02	<0,08	<0,2	<0,02	< 1,3	144	<0,06	< 0,1
4		N100P100	<0,2	<0,02	<0,08	<0,2	<0,02	< 1,3	147	<0,06	< 0,1
5		N0P0	<0,2	<0,02	<0,08	<0,2	<0,02	< 1,3	135	<0,06	< 0,1
6	10	N50P50	<0,2	<0,02	<0,08	<0,2	<0,02	< 1,3	156	<0,06	< 0,1
7		N100P100	<0,2	<0,02	<0,08	<0,2	<0,02	< 1,3	177	<0,06	< 0,1
8		N0P0	<0,2	<0,02	<0,08	<0,2	<0,02	< 1,3	138	<0,06	< 0,1
9	50	N50P50	<0,2	<0,02	<0,08	<0,2	<0,02	< 1,3	147	<0,06	< 0,1
10		N100P100	<0,2	<0,02	<0,08	<0,2	<0,02	< 1,3	139	<0,06	< 0,1
	DL 5 %		-	-	-	-	-	-	33	-	-

The shown data illustrates that both the bottom critical levels (plants/animals deficiency) and the top critical levels (phytotoxic and zootoxic level) of heavy metals content are not exceeded when corn is planted on an enriched soil with household sludge and vegetal matter.

4. CONCLUSIONS RESULTED FROM THE RECYCLING OF THE SEWAGE SLUDGE AND USING IT IN AGRICULTURE

- Due to its chemical composition the sludge compost with vegetal matter was tested for its utilization as an organic enrichment of soil.

- During the past experiments the corn was chosen as a test plant because it optimally values the direct effect of using the composted sludge.
- The resulted corn harvest is directly dependent of the sludge applied dosages no matter the level of mineral fertility of soil, all factors suggesting this aspect.
- The enriched soil with this organic fertilizer supports multiple improvements due to the accumulation of the needed macro-elements for an optimal nutrition of plants even in moderate mineral fertility conditions.
- The heavy metals concentrations from the enriched soil with this organic fertilizer, during the tests, are much below the established levels through the M.O. no 344/2004 Order, this demonstrating that the composted sludge can be used as an enrichment of soil without any risk of environment polluting.
- Whatever the regarded critical nutrition phase, the corn plants don't accumulate heavy metals on the growing or harvest phase, their level being much below the phytotoxicity threshold.
- For the low fertility soil, the enrichment with composted sludge could be a feasible and economic solution for planting corn, considering that the phytotoxicity phenomenon doesn't occur.
- With the help of the resulted data and the specific legal framework it was established the nutrition basis of corn planted on enriched soil with household sludge.

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From Agriculture To Energetical Sludge - Feasible Solutions For Regional Waste Water Treatment Plant Operators From România

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Abstract
At this point, the regional waste water operators have major issues in waste water treatment plant sludge management and storage.
We are showing the actual problems involving this sludge and the possibilities of its discharge in relation with the quantities and the quality of the sludge.

Keywords
Sludge, disposal, waste water.

1. INTRODUCTION

Sludge comes from the treatment of urban and industrial wastewater, as well as from the treatment of drinking water. The main sludge sources are the urban wastewater treatment plants.

The polluting elements and products eliminated out of the liquid phase during the treatment of industrial and urban effluent are found, in most of the cases, in sludge. Some sludge is chemically inert, other, such as the one coming from biological treatment processes, is fermentable. Organic sludge requires a specific treatment process, which allows its re-inclusion in the natural environment or reuse.

Given its large volume, the processing and disposal of sludge raise complex specific engineering issues in the global field of treating the residual effluent. The complexity of issues on sludge treatment derives from the following considerations:

- sludge includes the most part of the substances responsible for the polluting nature of the residual effluent;
- the excess activated sludge resulted from the biological treatment process and which needs to be disposed includes organic compounds resulting from the treatment process which could have a higher polluting potential than the initial pollutants.

Sludge is a poly-phased mixture consisting of a basic fluid, water, various constituents of mineral or organic nature dispersed in aqueous environment. Therefore, the word “sludge” is a very broad notion designating various aqueous solutions with a heterogeneous composition, which include suspended solids, colloidal particles of mineral or organic nature, with gelatinous appearance at higher concentrations and black-brownish colour.

In terms of chemical composition, sludge can be classified as follows:

- mineral sludge with preponderant mineral solids, exceeding 50% - sludge resulted from the water treatment process;
- organic sludge with organic substances exceeding 50% of the total retained solids – sludge resulting from the wastewater treatment process.

Current technologies impose the concentration of sludge from all the WWTP stages with a view to centralized processing. This enables the use of complex treatment plants with high stabilisation efficiency, which can lead to high dewatering percentage. For this reason, the purpose of the sludge treatment methods is to eliminate as much water as possible from the poly-phase mixture. Suspended solids in sludge may vary within the range 1-10% of the weight.

After finalization of the investments and by entering in regular operation sludge will be generated every day and has to be handled. A complex strategy developed on local conditions and capacities for each agglomeration is presented, but extensive efforts to come in compliance with this strategy must be undertaken by the local service operator. The cost of the final selected alternatives (agriculture/forestry/forestry and disposal) of this strategy are included in CBA.

2. OBJECTIVES

It is very important to have a strategy for the sludge based on the resulted quantity of sludge from WWTPs and WTPs from the project area and available county capacities for the reuse or disposal of sludge, applying the relevant EU directives for environmental protection and also the national regulations.

The general objectives of the sludge strategy are to identify some options to revaluate/ remove the sludge produced within the Water and Wastewater Treatment Works in the design area, which are feasible according to the particulars of each County.

The main objective is to assist the Beneficiary in establishing the best practical option concerning the environment, both with regard to the management of the wastewater treatment sludge and also of the drinking water treatment sludge, by means of an integrated approach on the planned usage and removal with additional treatment (thickening, dewatering), in accordance with the regulations in force.

The main sludge removal options comprise: spreading sludge on agricultural and forest lands and on degraded lands; storing the sludge in non-hazardous waste landfills, land reclamation and for a long term may also be burning the sludge (incineration, pyrolysis etc. with energy recovery).

When developing the sludge management strategies all potential options must be considered depending on the local particulars, practicability, the quality of the environment, social influences and costs. However, the European Commission considers agriculture/forestry to be the most sustainable option, provided that the quality level of the product and the usage manner are harmless to human health and to the surrounding environment.

Sludge production is a continuous process which implies finding flexible and safe removal options.

The selection of the sludge management options has been made on the basis of certain criteria and also by taking into consideration the capacities at the level of each County. The specified criteria are:

- law requirements;
- existing sludge storage capacities in each County;
- impact of the chosen option on the environmental factors;
- cost of final disposal.

3. LEGISLATION FRAME

As part of the accession process to the European Union, Romania has progressively transposed the European Directives on environment into the national legislation in Romania. The Directive on Wastes will be completely implemented by 2017, and the Directive on Urban Wastewater Treatment - by 2018. The regulations directly related to the sludge management are shown in the next:

- Directive no. 86/278/EEC on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture/forestry;
- Order no. 344/2004 and Order no. 708/2004 for approving the technical norms on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture/forestry;
- Directive no. 99/31/EC on the landfill of waste;
- Order no. 757/2004 for approving the technical norms on the landfill of waste;
- Directive no. 2000/76/EC on the incineration of waste;
- Order no. 756/2004 for approving the technical normative on the incineration of wastes etc.

4. APPROACH AND METHODOLOGY

The pollutant elements and the transformation products eliminated during the liquid phase of the drinking water treatment process and of the industrial and urban residual effluents of the wastewater treatment process are mostly retrieved in more or less concentrated suspensions, called sludge. Therefore, in case of each County, sludge will be obtained - sludge resulting from the wastewater treatment process – mainly organic.

The sludge generated by the water treatment processes contains a high quantity of inorganic substance and it is mainly mineral. This sludge of inorganic nature requires a simple treatment process which consists of thickening and dewatering from max 20-35 % DS.

This sludge coming from wastewater treatment processes contains a large amount of organic substance and is fermentable. The organic nature sludge requires a specific treatment process which enables its re-inclusion in the natural environment or reuse. Given that it is extremely voluminous, the sludge processing and disposal raise complex engineering issues in the global field of treating the residual effluent.

As a consequence of the fact that high quantities of both types of sludge are produced, both its processing and its storage generate specific and complex engineering problems, in the general field of its treatment.

The complexity of issues regarding the sludge treatment derives from the following:

- sludge includes most of the substances responsible for the pollutant nature of the effluent;
- the excess activated sludge which is to be disposed, resulted from the biological treatment process, contains organic compounds resulted from the treatment process with a higher polluting potential than the original pollutants;
- the contents of solids in sludge is lower (0,25-12% mass).

Given these aspects, the processes and operations that are object of the sludge treatment technology are meant to reduce the contents of water and organic matter in sludge and to bring the sludge to a stage that enables it to be reused or disposed.

The sludge processing technologies include the totality of technical procedures for stabilisation and for resolving the issue regarding the wastes resulted from wastewater treatment activities. Sludge is a poly-phase mixture consisting of a base fluid, water and various constituents of material or organic nature, dispersed in aqueous environment.

Therefore, the word “sludge” is a very broad notion designating various aqueous solutions with a heterogeneous composition, which include suspended dissolved solids, colloidal particles of mineral or organic nature, with gelatinous appearance at higher concentrations and black-brownish colour.

Considering the aforementioned aspects, the processes and the operations subject to the sludge treatment technology are focused on the reduction of the content of water and organic substance in the sludge in order to transform the sludge into a form that allows its reuse of final landfill.

Criteria to be adopted in developing a sludge management strategy

Besides the general considerations mentioned before the sludge disposal strategy to be developed has to follow specific criteria which reflect the “economical, technical and ecological soundness”. They are specified as follows:

- Practicability: The strategy has to be based on the local conditions and resources or has to be easy adaptable to the potential applicable ones. This includes the infrastructure practice and the existent or potential resources, in particular, in pursuit of the agriculture/forestry use of the sludge, and the proper geographical, pedological and meteorological conditions.
- Flexibility: The strategy does not depend on one lonely option for the sludge disposal. The combining of two or many options is a recommendation.
- Environmental Acceptability: The potential risks and the eventual impacts upon the environment should be avoided or reduced.
- Safety and Viability: The strategy must comply with actual national and international standards, but has also the prospective potential to be valid for the complete project period (until 2035).
- Cost Efficiency: The proposed solution or solutions should combine the above aspects with economic efficiency. No solution shall be indicated as advisable if implies highest investment and/or operation cost.

Specific Methodology applied

To come up with a final recommendation for sludge treatment and management, a very elaborate and comprehensive approach has been implemented. This approach included the following steps:

- Analysis of the legislative framework in the EU, in Romania and on current developments in EU member countries;
- Summary of current sludge disposal characteristics;
- Summary of expected future sludge volumes and sludge qualities after the construction of new WWTPs;

- Assessment of the expected future sludge quality in terms of heavy metals, organic pollutants and hygienic parameters;
- Analysis of available capacities for agricultural/forestry reuse of sewerage sludge, both in terms of strategic considerations and in terms of specifically available land. Regarding the latter, written agreements were collected from the municipalities involved, which clearly define fields that are assigned for reuse of sludge after start-up of the new WWTPs;
- Analysis of available capacities for sludge disposal at landfills. To that ends all available landfills in the area were specifically analysed as to their suitability to accept the sludge;
- Analysis of the available potential for sewerage sludge composting;
- Analysis of available capacities for sewerage sludge coincineration or incineration. To that ends all available incinerators in the area were specifically analysed as to their suitability to accept sewerage sludge;
- Analysis of the available potential for land reclamation with sewerage sludge;
- Pre-selection (screening) of sludge treatment technologies that might be suited;
- Screening of options for sludge storage;
- Least-cost analysis of sludge treatment combined with adherent wastewater treatment technologies. Calculation of NPV for feasible sludge reuse / disposal pathways, taking the recommended process technology for wastewater treatment into account.
- Assessment of main sludge management options (agriculture/forestry/ forestry, landfill, land reclamation co-incineration, incineration). Definition of measures to safeguard the viability of all these options. Derivation of a priority order for the various sludge management options:
    - Sludge reuse in agriculture/forestry/ forestry;
    - Sludge disposal on ecological landfill (municipal or dedicated landfill);
    - Co-incineration or incineration of the sludge.
- Overall assessment of alternative sludge treatment technologies.
- Finally, a sludge management strategy for short, medium and long-term was developed.

5. WASTE WATER SLUDGE, WASTE OR RAW MATERIAL?

Waste water sludge is by definition hazardous waste according to GD no. 856/2002, having as a code 19 08 05).

The sludge can be considered as a raw material because of the following aspects:

- It is valuable for the nutritious substances that it contains , N, P;
- It is a valuable producer of hummus with high organic content;
- The sludge thermic treatment is possible in order to obtain energy;

- P recovery from the ash with through sludge burning;
- The sludge can be considered a waste, because of the following aspects:
- The WWTP sludge represents an accumulation of toxic substances;
- Heavy metals problem;
- Organic microelements problem (dioxins, PFT, PCB, medical waste, endocrine substances etc.);
- Little knowledge about the accumulation in the food chain;

6. THE ADVANTAGES OF WASTE WATER TREATMENT PLANTS SLUDGE:

Energy Source

- Rich in organic substances;
- It is a possible green energy source;
- Because of the large quantities of sludge from the WWTPs and because of the limitation of this waste, thermic treatment offers an ecological alternative for sludge management;
- The concept represents an essential step to create an energetic recyclable substance in a close circuit and it offers to municipalities a practical and durable waste management.

Phosphorous Source

- Ash residues form an ideal resource for phosphorus recuperation;
- they contain a high quantity of phosphorus compounds, beeing comparabile with mineral phosphate deposits;
- thus, valuable substances contained in the sludge can be used without risks in agriculture or for phosphorus recuperation (a very costly procedure at this time).

PRODUCED SLUDGE QUANTITIES are calculated as specific flows reported for inhabitant/ day, considering 150 l/ inhabitant /day).

Fresh sludge comes from:

- Primary sludge primary treatment 30 g SU/(L·day);
- Secondary sludge biological trreatment 40 g SU/(L·day);
- Tertiary sludge Precipitation / floculation 5 g SU/(L·day).

There are two ways to stabilize the sludge (aerobic and anaerobic)

- aerobic stabilization 55 g SU/(L·day);
- anaerobic stabilization 50 g SU/(L·day).

“waste water sludge” means stabilized sludge – MANDATORY!!!

For example in Timisoara waste water treatment plant (440.000 P.E.), after treating a flow of Q daymed = 4500-5500 mc/h are produced about 150 - 200 mc/day dehydrated sludge at 20% SU.

The quality of the obtain sludge in this waste water treatment plants meets the required conditions asked by law, but in every big town there are hospitals, there are humans which use a lot of medications and the sludge is not controlled with this point of view.

Final deposit options. For the big WWTPs:

Option 1 – Agriculture – minimum or excluded

Motives:

1. Large quantities of sludge. Using as a fertelizer can be done only 2 times a year (during the spring and during the autumn) that means that it isn’t a viable option for the big WWTPs, because the sludge must be stored in enormous quantities.

2. The transformation of the water companies into “agricultural ones”, because of the Order no. 344/2004, wich states that the company must do the following:

- analyzes of land (must pay for the OSPA studies);
- the sludge transport to the farmer on his own expense;
- to pay for the spreading.

3. So the sludge producer is responsible for the quality, quantity, transport, spreading on the surfaces, and last but not least for the efects on the environment and the health of the people after they consume de products (Order no. 344/2004).

4. The operators are responsible for what happens after years, and there are accountable for the prejudices. Now there are not enough studies on pilot plants to say what happens to the soil/products after a long period of time (5-10-15 years).

Option 2 – Depositing in ecologic deposits – excluded

Acording to 4.2.2.1. Depositiong requirements – the wastes that can raise problems with the stability of the deposit, must be mixed with stable waste: SLUDGE-HOUSEHOLD WASTES 1:10.

Acording to the european guideline, after 2017, the quantity of the organic substance which will be deposited, must drop constantly.

Even if nowadays this alternative is the easiest choice, we must not forget about the EU Directive for the depositing of waste. Starting 2017 till 2021, the quantity of the organic substance wich will be deposited, must be diminished, thus the salubrity operators must accept less sludge in their ecologic deposits, even below the 10-1 ratio. This is now regulated by the M.O. no. 757/2004.

Probably starting 2022, it will not be possible to deposit sludge in the ecologic deposits.

Option 3 – Burning sludge with energy recovery

At this hour there are many possibilities for sludge incineration like this ones:

- Burning together with hosehold waste;
- Sludge incineration in combustion plants;

- Burning in cement factory.

For this option to be possible the sludge must be dry. It can be dried in-situ or where is an incineration installation, in order to use the energy that is produced.

The thermic processes of sludge treatment can be: incineration, pyrolysis, gasification, etc.

The thermic process must be chosen depending on the operating costs, also on the characteristics of the sludge that must be burned.

Options for final storage regarding small waste water treatment plants:

1. The transfer of thickend and dehydrated sludge (with mobile instalations) in the central waste water treatment plant. Together with the sludge form the central WWTP, this one will be dried, and termical treated.
2. Using as fertilizer in agriculture.
3. “Sludge insolation”.

7. CONCLUSIONS

WWTP sludge can be used as a fertilizer, but also through burning resulting in energy recovery.

The method of sludge valorification depends on the quantity of the obtained sludge, but also on the type of the sludge, where it comes from.

Because of the development of the big cities, thus the raising of the quantities of produced sludge, we must think more and more of the valorification through sludge burning.

The possibility of the prohibition of sludge depositing in ecological deposits, beginning with 2022, bring to light the development of sludge incinerators.

We must not neglect the possibility of sludge valorification in agriculture, but we must keep the quantities and qualities in mind.

Energy Recovery Of Biomass Coming From Domestic Waste Water And Sludge From Wastewater Treatment Plants (WWTP)

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Abstract

In the paper are highlighted technologies on energy recovery in the form of biogas through anaerobic fermentation, biomass in waste or sludge retained in settling tanks primary and secondary of the sewage treatment plants using contact anaerobic digesters arranged on the waterline, in case of advanced technologies, namely methane tanks, located on the sludgeline, in case of conventional technologies.

Biomass from wastewater and sludge, generate energy, heat and various chemicals, is considered sustainable energy source for the future of humanity.

Treatment technologies, provided with contact digesters, are arranged on the water line, instead of primary decanters, after mechanical stage, can operate in mesophilic or thermophilic regime. These types of systems, coupled in series or in parallel are recommended for wastewater with high temperatures and high organic loads.

Conventional treatment technologies, equipped with anaerobic digesters / methane tanks arranged in line sludge, uses sludge retained in decanters primary and secondary, processes of fermentation are mostly mesophilic, determined by the physicochemical characteristics of organic masses subjected to fermentation and operating conditions of fermentation installations.

The proposed technologies were tested on pilot stations and a treatment plants from food industry. The paper is in line with current trends on energy recovery from unconventional resources by producing biogas from organic materials existing in household wastewater coming from the hearth population centers, in parallel with the separation of the nitrogen and phosphorus, below the limits admitted from Romanian legislation for environmental protection.

The resulting sludge after capturing biogas, by technologies proposed, lacking pathogens and heavy metals, can be a useful to fertilized crops, but also guarantee to ensure a clean and healthy environment.

Keywords
Biogas, biomass, contact digester, methanetank.

1. GENERAL CONSIDERATIONS

Treatment technologies with biomass energy recovery from wastewater coming from populated centers in the form of biogas and biohydrogen, are complex processes determinated mainly by: water leakage characteristics; sewage system used; size of area with sewerage and type of the community; wastewater temperature and climate of geographical area [1], [2], [4], [9], [20], [22], [24].

The unitary system of sewerage requires a supplementation of mechanical step from waste water treatment plant with retention basin during rain, amplification of the objects of retaining inorganic matters in mechanical step with sand trap and fats separator, reducing or even eliminating the volumes necessary for primary settling tanks in case in which are low concentrations of organic substances contained by waste water.

Advanced cleaning technologies required supplementation of biological step with activation basin and the sludge removed in primary and secondary settling tanks is treated anaerobically in methane tanks or digesters resulting biogas and biohydrogen and also a material with capacities to do the fertilising of crops and harmless to the environment.

Interventions imposed on the waterline is reflected not only in enhancing the efficiency of treatment at the main quality indicators (MTS, BOD, Nt and P), but also by generating more biogas [7], [32], [33] .

In case of a separative system for waste water, the advanced treatment processes can be strongly influenced by the size of the specific consumption of drinking water, compared to the norm [6], [7].

A low specific consumption of drinking water (below 40-60 l/people and day) are not able to ensure the transport of wastewater through the sewage networks, favoring deposition of mineral substances and transformation of organic matter into biogas or toxic gases, both dangerous for operating personnel and the environment [6], [7], [31], [33].

Specific consumption of drinking water greater than 200-250 l/people and day reduce concentrations of organic material, disturbing microbiological processes which increase in the water line, and also occurring in the sludge line [6], [7], [31], [33].

Running optimal, microbiological processes occurring in wastewater treatment plants from the population centers, must be made for specific flow rates which are around 150 l/people and day, flow that ensures environmental comfort and hygiene requirements for public health.

Energy recovery in the form of biogas, of the biomass from waste water or sludge retained in primary and secondary settling tanks from waste water treatment plants, can be done in anaerobic digesters, arranged in sludge line or in contact digesters arranged on water line. Biomass from wastewater and sludge can generate electricity, heat and various chemicals, considered one of the energy resources unconventional for the future of humanity [10], [11], [18], [23], [29], [30].

Conventional treatment technologies, equipped with anaerobic digesters / methane tanks arranged in sludge line, use sludge retained in primary and secondary settling tanks, after a thickening in sludge concentration.

The anaerobic fermentation proceses are predominantly mesophilic determinated by the physico-chemical characteristics of organic masses subjected to fermentation, but also by operating conditions of fermentation instalations.

The biogas obtained is a product used for own needs of the wastewater treatment plant in the form of heat energy required for heaters of fermentation installation (methane tanks / digesters) or for other categories of consumers, by converting it into electricity [14], [15], [16], [18].

Wastewater technologies using contact anaerobic digesters, disposed on the water line, usually replacing the primary settling tanks, can work with one or two-stage in mesophilic or thermophilic regime. These types of systems can be arranged in series or in parallel are recommended not only for wastewater with high temperatures and high organic load, but also for domestic wastewater from population centers, with temperatures and loads common [1], [2], [23], [25].

The proposed technologies develop, in particular, mechanical treatment, for retaining minerals suspensions and fat, in order to replace primary settling tanks with anaerobic digesters/ digesters to produce biogas, followed on the channel water to ensure elimination of nitrogen and phosphorus compounds through a sequence of objects and advance technological processes [23], [31].

Microbiological processes necessary to produce biogas, and also those for nutrient removal of nitrogen and phosphorus, are possible because the organic matter in wastewater, coming from the population centers, have a share of about 58% and their temperature is between 20 and 35ºC.

The biogas produced in the anaerobic digesters is used not only for biomass heaters in these reactors at temperatures of 28-55ºC, offices and laboratories of the adjoining spaces, but also for electricity generation through cogeneration and the sludge from the anaerobic digestion (mesophilic and thermophilic) being able to be use as fertilizer for crops and also for the forest [8], [17], [21], [29].

2. CHARACTERISTICS OF WASTEWATER AND SLUDGE COMING FROM WASTE WATER TREATMENT PLANTS (WWTPS)

Characteristics of wastewater and sludge from waste water treatment plants (WWTP) are determined mainly by the size of the discharge, the locality and climate, the living standards of residents and level of equipment and installations for centralized hot and cold water.

In Table 1 are shown the physical, chemical and biological characteristics of wastewater from population centers and quality limits allowed by the Romanian norms at the discharging points into natural receivers [4], [5], [6], [24], [25], [27].

Table 1

Nr. Crt.	Quality indicators	Concentrations entry into WWTP [mg / dm^3]	NTPA 001/05
1.	MTS	110-350	35
2.	BOD	120-300	20-25
3.	COD-Cr	150-500	70-125
4.	NH_4-N	5-10	2
5.	NO_2-N	0,05-2	1
6.	NO_3-N	11-40	1
7.	N	25-35	10
8.	PO_4-P	6-12	4
9.	P	2-3	1
10.	pH	6,2-10	6,5-8,5
11.	T ºC	25-35	35

The concentration of quality indicators is determined by the origin of wastewater discharges and also the size of the discharges. Biochemical processes of anaerobic fermentation necessary to produce biogas and nutrient removal from waste waters are determined mainly by the organic mass effluents, expressed through content of biochemical oxygen demand (BOD), the concentration of volatile substances, but also temperature from unfolds the aerobic and anaerobic biochemical processes in the objects of WWTP [4], [6], [10], [11], [24], [30].

In Table 2 are shown the characteristics of wastewater from population centers, depending on the size of the leak discharges [25], [27].

Table 2

Nr. Crt.	Q [l/s]	MTS [mg/dm^3]	CBO_5 [mg/dm^3]	SV [mg/dm^3]
1.	1800-2000	50-550	20-200	10-210
2.	250-300	35-235	20-65	12-50
3.	80-100	60-200	30-415	20-195
4.	30-50	10-500	25-627	5-185
5.	10-15	8-780	60-2740	15-375

The composition of domestic wastewater at a specific drinking water consumption of 150 l / people.day, is shown in Table 3 [6], [7], [33].

Specific water consumption for household needs really small (40-60 l/people and day), evidenced by excessive water savings at individual household or apartment, affects largely hygiene, health of people, around the house, transport and disposal of waste water through the sewage networks, favoring processes of sedimentary with formation of toxic gases and combustible, dangerous for both maintenance staff and operation of sewerage networks, but also for the environment [13], [19], [31], [32].

Table 3

Nr. crt.	**Tipe of Substance**	**Minerale substance [%]**	**O [%]**	**Total [%]**
1.	Sediment suspensions	10,30	21,50	31,80
2.	Coloidal substance	5,60	10,30	15,90
3.	Dissolved substance	21,10	26,20	52,30
	Total	42,00	58,00	100,00

Chemical content of the sludge from domestic wastewaters raported at the total of dry weight solid mass is shown percentage in Table 4 [4], [5], [6], [24].

Table 4

Substances contained in sludge from domestic wastewater	**Sludge**	
	fresh %	**fermented %**
Organic substances (volatile)	60-80	45-60
Total mineral substances	20-40	40-55
Insoluble ash	17-35	35-40
(N_2)	(2,4-3,5)	(3-3,5)
Sodium nitrate	1-3,5	1,4
(P_2O_5)	1-3,5	0,5-3,7
(K_2O)	0,2-0,5	0,4
(SiO_2)	…	15-16
(Fe_2O_3)	(3-2)	5,4
Cellulose and other substances	10-13	10-13
Fats and other oils	7-35	3-17
Protein	22-28	16-21
Lignin	(5,8-8,5)	(5,2-5,6)

Wastewater characteristics, determines the technology that can be used to ensure greater production of biogas and also an operating efficiency at all quality indicators required by NTPA 001/2005 [31], [32] [33].

3. ADVANCED WASTEWATER TREATMENT WITH DIGESTERS PRODUCING BIOGAS

3.1. Advanced treatment technologies with digesters in sludge line

Advanced wastewater treatment with digesters on the sludge line and primary settling tanks on water line can be used successfully in separative sewage, at which the loaded of organic wastewater is over 58% requirement imposed for unfolds proper the microbiological processes from activation tank [6], [7], [24].

Technological scheme, outlined in Figure 1, with primary settling tanks (DPO) on the waterline and digesters sludge (BFN) / digesters (D) on the waterline, ensuring not only quality indicators for effluent discharged (Qe) in natural emmisar (EM), and also a significant amount of biogas obtained by anaerobic fermentation of primary excess sludge. Proper functioning of the entire system is conditioned mainly by the retention of mineral substances in sand trap and in fats separator but also the water temperature reaches to WWTP [4], [6], [24], [25], [28].

This scheme can be adapted as those situations, where domestic wastewater can get into wastewater treatment plants with concentrations lower than normal, due to the specific consumption of excessive drinking water, evidenced by the (so called) „used water”, seepage of groundwater by joints damaged of sewer system, intake of storm water through the holes in the covers manholes, respectively collecting simultaneously rainwater with domestic waste, in case of unitary sewage system [4], [5], [6], [24].

In the case of the unitary system of sewage, technological scheme, outlined in Figure 1, will be completed with weirs, pumping stations and retention basins for storm water, with capacities dictated by the volume of water accumulated throughout the rain, following that a part of the primary settling tanks to be used partly or fully for storing rainwater in order to maintain the required concentration of organic substances necessary for the proper microbiological processes that occur on the lines of water treatment and sludge.

Basins for sludge fermentation (BFN) will be supplied with sludge from primary and secondary settling tanks (DP) (DS), after previous thickening in concentrator sludge (CN), so the ratio of waste water and organic substrate to be of from 0.40 to 0.50 [8], [27].

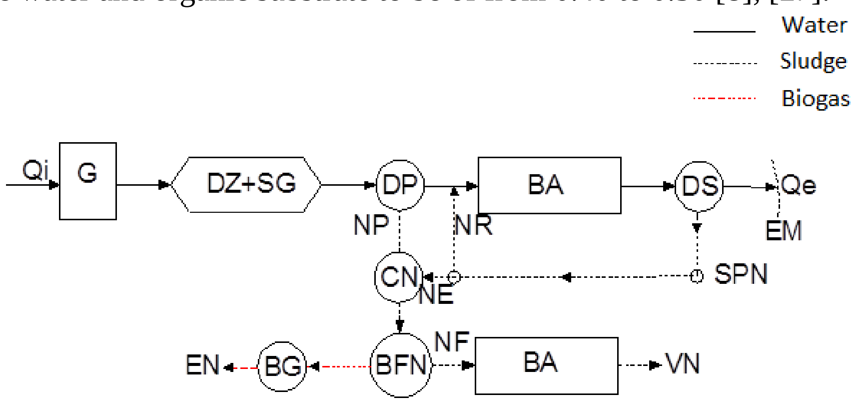

Figure 1. Technological scheme for advanced treatment of sludge with digesters in sludge line
Qi - the wastewater influent flow; G - rare and frequent grate; DZ + SG - sand trap coupled with fats separator; DP - primary settling tanks; BA - Activation basins; DS - secondary settling tank; QE - flow of wastewater effluent; EM - emmisar; SPN - sludge recirculation pumping station in excess; NR - sludge recirculation; NE - excess sludge; NP - primary sludge; CN - concentration of sludge; BFN (D) - sludge fermentation tank / digester; BG - biogas collector / meter; EN - energy, thermal or electrical; NF - fermented sludge; DM - mechanical sludge dewatering; VN - valorification of fermented sludge

3.2. Advanced treatment technologies, with contact digesters to the water line

Advanced treatment technologies, with contact digesters to the water line, also known as bioenergetics technologies, are construction and equipment with which ensure capture of biogas from biomass of waste water, in parallel with the elimination of compounds based on nitrogen and phosphorus. These types of digesters, arranged in series with two-stage, or in parallel, replace primary settling tanks, ensuring the capture of biogas produced from anaerobic mesophilic or thermophilic fermentation of a part of the biomass contained in wastewater.

Technologies like this are recommended both for wastewater from food industries (beer etc.), characterized by high organic loads and high temperatures (up to 50-55 ºC), but also for waste water treatment, collected from population centers, characterized by lower organic loads and moderate temperatures (up to 35ºC).

The microbiological anaerobic processes are temophil in primary settling tank and mesophilic in secondary digesters heating reactors being provided by some of the biogas produced. [8], [24], [25], [27], [28].

In Figure 2 is shown technological scheme for advanced treatment of domestic wastewater with primary and second contact digesters (D1) (D2) and are arranged in series, each equipped with biogas collection tanks (BG1 and BG2). The sludge fermented (NF) will be mechanically dewatered (DM) together with the excess sludge (NE), provided from secondary settling tanks (DS) being valorisationed in agriculture or forestry. [23]

The Figure 3 presents the technological scheme for advanced treatment of wastewater with contact digesters arranged in parallel, equipped with tanks for biogas collection. Fermented sludge from digesters will be mechanically dewatered with the sludge from excess (NE) being used for agricultural or forestry [23],[28].

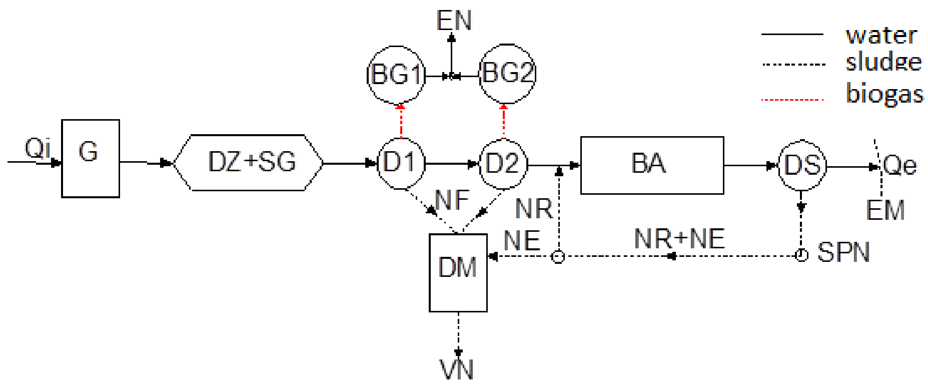

Figure 2. Technological advanced scheme with contact digesters from the water line arranged in series

Qi - the wastewater influent flow; G - rare and frequent grate; DZ + SG - sand trap coupled with separators for fat; D1, D2 – contact primare and secondary digesters arranged in series; BA - Activation basins; DS - secondary settling tanks; QE - flow of wastewater effluent; EM - emmisar; SPN - sludge recirculation pumping station in excess; NR - sludge recirculation; NE - excess sludge; NF - fermented sludge; BG1, BG2 - collecting biogas / gasometers; EN - energy, thermal or electrical; DM - mechanical sludge dewatering; VN - valorification of fermented sludge

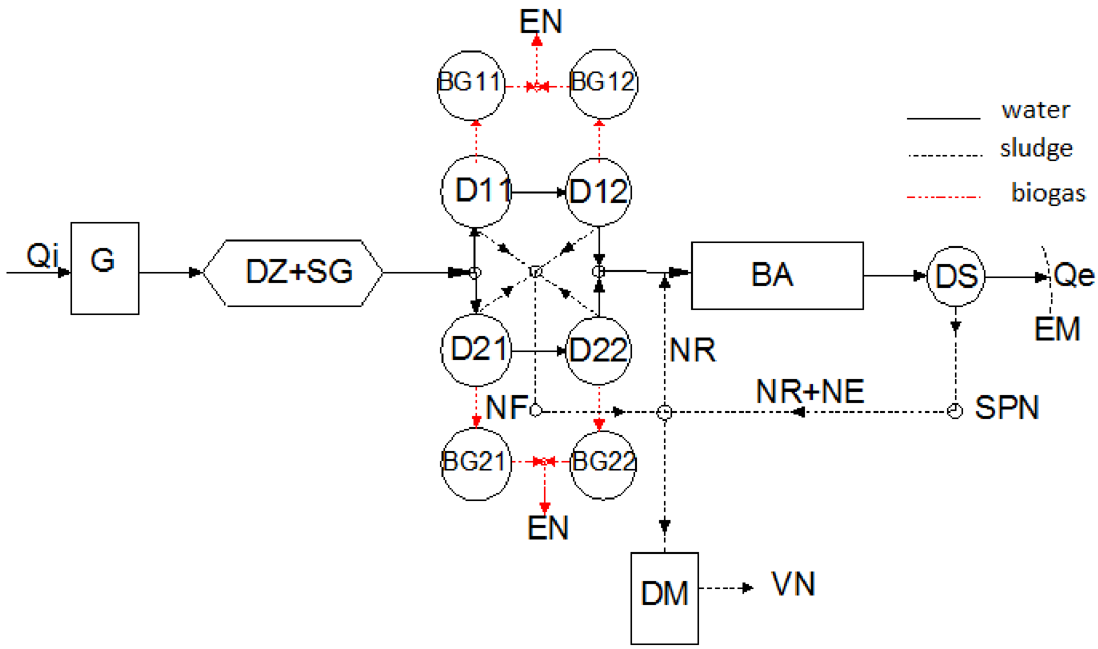

Figure 3. Advanced technological scheme with contact digesters in water line arranged in parallel

Qi - the wastewater influent flow; G - rare and frequent grate; DZ + SG - sand trap coupled with separators for fat; D11, D12, D21, D22 - digesters arranged in parallel in water line; BA - Activation basins; DS - secondary settling tanks; QE - flow of wastewater effluent; EM - emmisar; SPN - sludge recirculation pumping station in excess; NR - sludge recirculation; NE - excess sludge; NF - fermented sludge; BG11, BG12, BG21, BG22 - collecting biogas / gasometers; ENE - energy, thermal or electrical; DM - mechanical sludge dewatering; VN - valorification of fermented sludge

Advanced wastewater treatment, with contact digesters arranged in water line, require development especially of mechanical treatment, consisting of: - rare and frequent grate, sand trap coupled with separators for fat but without primary settling tanks in order to retain fully bodies coarse sands and fats contained in the wastewater.

The effluent so clear, will be pumped into anaerobic digesters producing biogas, then it has to pass through all constructions and instalations provided for the removal of nitrogen and phosphorus compounds from waste water.

Part of the sludge retained in the secondary settling tanks will be recycled in activation basins, and the excess together with the fermentation will be dewatered mechanically and then used as fertilizer in agriculture or forestry [12], [23], [24], [25].

In Figure 4 is shown contact digesters connection arranged in series, or in two stages to produce biogas through development of thermophilic anaerobic process in primary contact digester (D1) and the mesophilic in the secondary contact digester (D2).

Contact digesters efficiency can be increased by equipping them with various support materials, consisting by: sand, sludge granules, glass balls, PVC bodies with different geometrical shapes, etc. to attach the microorganisms and keeping them in action, the water circulation in each reactor being done in upflow [21], [23], [25].

Anaerobic digesters without a support material, are equipped with devices which continuously mixed, in order to maintain the development of methanogenic microorganisms producing biogas [4], [9], [23], [17], [24], [25].

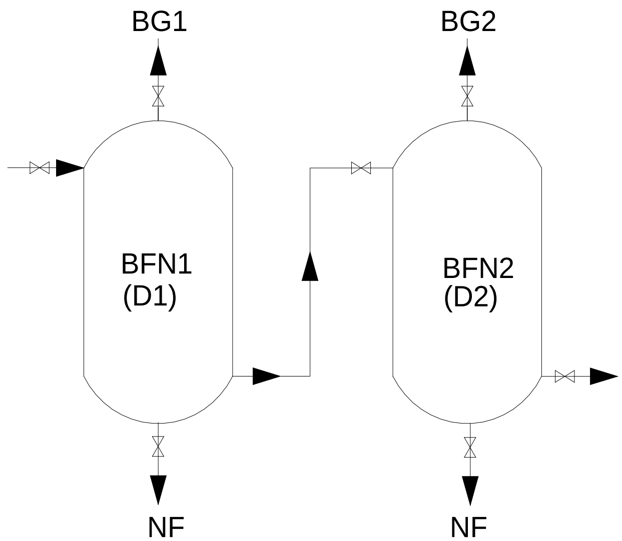

Figure 4. Contact disposal digesters, two-stage, located on the waterline

The resulting effluent from the anaerobic fermentation from the contact digesters, is passed through the different types of constructions and instalations necessary for the removal of nitrogen compounds and phosphorus [23].

Biological step to remove nitrogen and phosphorus compounds can be consisting of activated sludge basins for nitrification; aerobic activated sludge reactors, air-lift; denitrification basins and secondary settling tanks; Activation basins with simultaneous or separate development nitrification-denitrification processes; biofilters; Equipped with rapid sand filters, activated carbon or other absorbent material properties; apparatus and equipment for disinfection of treated effluent [4], [9], [23].

4. PRODUCTION AND USE OF BIOGAS

Biogas is a product of anaerobic fermentation, in which communities of microorganisms developed in areas oxygen free, break down organic substances, into methane, carbon dioxide and other gases.

Growth of microorganisms producing biogas from waste organic is the result of three communities of microorganisms: non methane, but liquefying and acidogenic; non methane, but the acetogenic and methanogenic ones.

Anaerobic fermentation processes, shown in Figure 5, include three stages: liquefaction acidogenic (I) acetogenesis to form acids (II) and methanogenesis with methane formation (III).

In the first part of the liquefaction acidogenic stage under the action of extracellular enzymes and microorganisms from the first community, take place the organic waste liquefaction through a hydrolytic degradation (hydrolysis) in organic compounds with a small molecular weight.

In the second part of the first stage, microorganisms transform micro molecular organic compounds resulting from the liquefaction process in organic acids.

Acidogenesis can take place in two ways. In the first path is formed acetate, bicarbonate, reduce equivalents and hydrogen and can be achieved only when molecular hydrogen is removed immediately after its formation. If molecular hydrogen is not removed, but rather accumulates, it becomes mainly the second path, in which, in place of acetate it forms volatile fatty acids and includes propionic acid and butyric acid, ethanol and other alcohols in small quantities. Both sides of the stage of the acidogenic liquefaction are made of a single community of microorganisms.

In the second stage - acetogenesis that develops under the action of acetogenic community of microorganisms, propionic and butyric acids and lower alcohols produced in the first stage of the acidogenic liquefaction are transformed into acetate, bicarbonte, reducing equivalents and molecular hydrogen. Acetogenesis is conditioned in this case the removal of molecular hydrogen. In the third stage - methanogenesis, which develops under the influence of methanogens bacteria form biogas, which is a mixture of gases composed mainly of methane, carbon dioxide and small proportion of hydrogen sulfide, hydrogen, ammonia, carbon monoxide, nitrogen and water vapors.

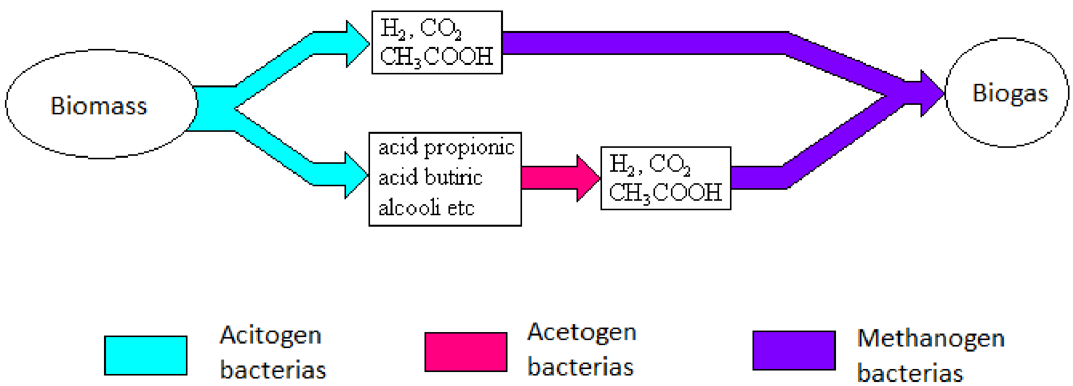

Figure 5. Stages of anaerobic fermentation processes in contact reactors

The quantity and quality of biogas are dependent on the composition of fermented organic material, the temperature for conducting microbiological process, the contents of acids, pH and alkalinity of environment in which it develops, especially, microbiological processes.

The temperature is the determining factor for proper development of anaerobic fermentation processes directly influencing metabolism and methanogenic bacteria breeding rate, duration of fermentation, gas quantity and quality product.

Depending on the temperature achieved in the fermentation space three fermentation characteristic areas apper: the high temperatures area (44-60 ° C), in which acts thermophilic bacteria, the optimum temperature is 55 ºC; the moderate temperatures area (15-43 ° C) in which acts mesophilic bacteria, the optimum temperature is 37 ºC; the low temperatures area (5-15 ° C), where cryophilic bacteria act.

For energetical valorification of biomass from waste water and sludge from WWTP are used mainly microbiological processes that occur the areas with moderate temperatures (mesophilic) and the high temperatures (thermophilic), the cold area (criofila) being specific to the natural environment processes.

Because methanogenic bacteria have the metabolism ability and lower reproduction speed, than methanogenic bacteria by overdosing or overloads of digesters with organic substances, it can be created a surplus of volatile acids that can brake activity of methanogens bacteria, phenomenon which can occur when pH dropped below 6.5.

For methane fermentation process not to be disrupted is necessary that in contact digester the content of volatile acids to be within the values of 600-1500 mg/dm^3, the pH limit values of 6,5- 8.5 and alkalinity to be within the values of 1500- 5000 mg $Ca(HCO_3)_2$/dm^3.

Methanogenesis bacterial process can be disturb by increasing content of volatile acids and the carbon dioxide from gas produced or by increasing the alkalinity and pH. The content of carbon dioxide from the fermentation gas is recommended to be within 30-35% [25], [26], [27].

The composition of biogas for sludge from WWTPs of population centers is as follows: 50-80% methane; 20-50% of carbon dioxide; 0.50% hydrogen; 0.10% hydrogen sulfide; 0.30% nitrogen; 0.10% oxygen; 0-1% oxygen and negligible amounts of ammonia [8], [14], [26].

Hydrogen sulfide gas contained by the sludge is highly toxic, and quite small amounts (0.001%) can be sensed by smell. At concentrations of 0.1% is poisonous. In such cases should be made a dry or wet treatment of gas treatment, gas scrubbers in treatment instalations plants, which takes the form of filters on many levels, filter material is iron hydroxide.

The hydrogen sulphide in addition to being toxic, attacks iron pipes and plants. In order to remove carbon dioxide and hydrogen sulphide gas washing operations using water is applied [8], [14], [25].

In the composition of the biogas predominates methane (70%) and carbon dioxide (30%). A cubic meter of biogas is equivalent to 1 kg of coke; 1.27 m^3 gas for lighting; 5,1 Kwh; 0.56 kg of diesel and 0.47 m^3 of natural gas [17], [19]. Calorific power of biogas produced is 5500-5900 Kcal / m^3 and usable to the burning of 4750 Kcal/N m^3.

In recent years, has been promoted a new anaerobic process research for convertion of organic pollutants into biohydrogen, instead of methane.

The bioydrogen is a higher energy vector than methane for two reasons:

- First, hydrogen has a wide application more extensive compared to methane, which can be used for synthesizing of ammonia, alcohol and aldehydes and for the hydrogenation of oils, petroleum, synthetic oil, coal while methane is used just like fuel.

- Secondary, hydrogen is an ideal fuel, producing only water as a secondary product, after combustion. Hydrogen can be used directly in internal combustion engines, or to produce electricity [1], [2], [20], [22].

5. VALORIFICATION OF FERMENTED SLUDGE

The sludge fermented in contact digesters and the excess resulting from secondary settling tanks, after being mechanically dehydrated, can be used both in agriculture and in forestry, although its value as a fertilizer is quite low.

The proportion of N: P: K for fermented sludge derived from advanced wastewater treatment from the population centers are only 1: 0.67: 0.22, generally unsatisfactory for the agricultural and forestry sectors. It is note that these do not contain many toxic substances which can be harmful to plants. It is recommended that the use of sludges to be done to crops which have genetic changes (sugar beet, soy) that produce large amounts of biomass for the production of biogas or even biohydrogen [3], [4], [8], [10], [12], [24].

6. CONCLUSIONS

In the paper, are highlighte the advanced treatment technologies, equipped with contact bioreactors on the water line (in series or in parallel) equipped with mobile support layer. The mobile support layer is composed by granular material in order to stimulate the growth of microorganisms, which produce biogas, along with retention and disposal of nitrogen and phosphorus compounds from domestic wastewater collected from population centers.

The sludge resulted from mesophilic and thermophilic anaerobic fermentation in contact digesters will be mechanically dewatered, together with excess sludge coming from secondary settling tanks, being recommended for agriculture and forest fertilizing.

The proposed technologies were tested on pilot stations and wastewater treatment plants from the food industry.

The paper is in line with current trends in energy recovery from unconventional resources by producing biogas from organic residues from wastewater, in the same time with separation of nitrogen and phosphorus compounds, below the limits of legislation for environmental protection.

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Technical Aspects, Economic, Legal And Administrative Encountered When Using Sludge In Agriculture - Experience Water Company Târgoviște Dâmbovița

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Abstract

An analysis of the technical, economic, administrative and legal organization faced in spreading sludge in agriculture, sewage plant in Targoviste South.

The presentation is based on the provisions of Order no. 344/2004 approving the technical norms on environmental protection and in particular of the soil, which has incomplete regulations conditions spreading of sludge from treatment plants, which leads to the impossibility of its use in agriculture.

Describe the difficulties in spreading sludge in 3 farms. Although it has obtained a permit from spreading to 49 ha due to the costs incurred and the lack of regulations has not been possible to implement the spreading of sludge.

The paper analyzes and evaluation expenditure groups per ton of sludge, coupled with tariff structure sewage treatment plants.

Are analyzed risk factors that legislation is not sufficiently regulate but can lead to high costs, sometimes with possible sanctions.

Finally presents concerns of the team of specialists from Water Company Targoviste, Valahia University, OSI Service company in Italy, OSPA 2000 Pitesti and Water Company Pitesti in order to reduce current risks identified in the spreading of sludge in agriculture

Keywords
Management, sludge, agriculture

1. REGULATIONS

The national policy for managing sludge from wastewater treatment was developed by Mott MacDonald Limited.


Elaborarea politicii naţionale de gestionare a nămolurilor de epurare

Strategia naţională de gestionare a nămolurilor de epurare

Strategia naţională de gestionare a nămolurilor, Partea a III-a
(versiune finala nr. 2)
Cod proiect: POSM/6/AT/I.1.2010

Februarie 2012

Direcţia generala AM POS Mediu

Proiect cofinanţat prin Fondul European de Dezvoltare Regională

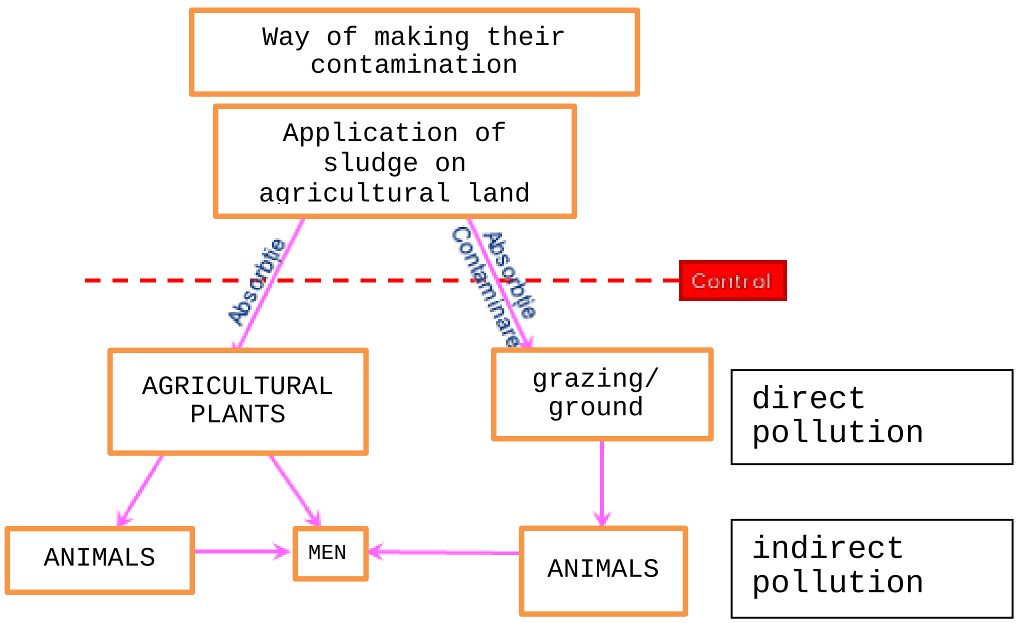
In the Water Company of Targoviste - Dambovita was tried to apply the provisions of this policy and there was found a number of outstanding issues in the areas of technical, economic, administrative and legal. The paper will briefly analyze these elements and their regulation.

The difficulties began from the content of *Order no. 344/2004 approving the technical norms on environmental protection and in particular of the soil*, which contain incomplete regulations regarding: conditions for spreading of sludge from treatment plants, which leads to inabilitiy to use in agriculture in terms of legality:

A) At Chapter 1 - Stipulations

"These technical rules aimed at unlocking the potential agrochemical sewage sludge, prevention and reduction of harmful effects on soil, water, vegetation , animals and man, so as to ensure proper use of this sludge."

In order are listed all the problems of the sludge: the beneficial and precautions that they need to be taken by producers (in our case water companies) so that the risk of pollution / contamination is direct (soil, water) and infestation indirect (plants and animals) to be removed.



B) The content of the order used three concepts:

1 - manufacturer of sludge;
2 - user of sludge;
3 - beneficiary of sludge.

In the description of three concepts of the Order there are not defined sufficiently rigorous, that generates confusion and that can lead to risks in the assignment of responsibilities in case of pollution/ accidental infestation.

C) The order says:

"b) Treated sludge - sludge which has undergone biological, chemical or heat treatment, long-term storage or any other appropriate process to significantly reduce their power fermentation and health risks resulting from its use"

It is not mentioned and assessed rigorously defined notion "significant".
In Order is not explain the assessment of data related to quantitative and qualitative structure of pathogens,there are not rules limits of pass / fail.
In conclusion: the order must be completed with the definition of treated sludge. It must be defined limits values of the biological, bacteriological, chemical components of sludge that must be met.

D) Is expected in the Order:

"In areas of use of sludge organize the monitoring of environmental factors (soil, water, plants) in addition to the national system."

Referring to:

Soil monitoring

In order there are references to the monitoring. Soil Survey and Agrochemical Office (OSPA) has methodology, technology and ensure specialized personel dedicated to this work.

The normative act establishes such monitoring but it takes many years, this activity generates costs that must be included in the sewer service charge.

From the analysis of Pitesti resulted that OSPA need to monitor for three consecutive years, pH and heavy metals.

In order it is necessary to specify the period of monitoring of land and on which the sludge where spreaded.

E) The Order establishes a number of responsibilities for ICPA:

Research Institute for Soil (ICPA):

a) organizes the activity monitoring (soil, water and plants) after the use of sludge on agricultural land, based on funding received for this activity from the Ministry of Agriculture and Rural Development ;

b) perform investigations to determine behavior of the pollutants presented in the soil - plant - water in sewage sludge and there are setted limits values with these pollutants."

2. THE COSTS

Accumulated sludge wastewater treatment plants be evacuated authorized warehouses used in agriculture / soil improvement, cremated or a combination of these methods. Which ever generates costs that operators of wastewater services have to cover the tariff.. We present below (Table 1) a cost structure identified at Dambovita Targoviste Water Company for the use of sludge in agriculture.

Table 1. Costs for using

COSTS FOR USING SLUDGE IN AGRICULTURE **Table 1**

Nr. crt.	**Name**	**Specific price**	**Nr**	**Total lei (not TVA)**	**Total Euro**	**Euro/ton sludge**	**Observ ation**	**weight EURO**	**percent %**
I	Water company							**29,0963**	**48,15 %**
1	SLUDGE ANALYSIS COMPANY	1309 lei/set	2	2.618	595	0,1859	3200 tone	**48,15 %**	0,308
		1502 lei/set	2	1.502	341,36	0,1067			0,177
2	SLUDGE ANALYSIS CONSULTANCY	1750 lei/set	2	3.500	795,45	0,2486			0,411
3	ANALYSIS SLUDGE dioxin	490 euro/proba WESSLING TARGU MURES (Analysis made in Germany)	1	2.156	490,00	0,1530	3200 t.		0,253
4	TRANSPORT COSTS WITH SLUDGE	139,2 lei/truck/24 tons; neccessary 42 trucks	42-50	5.846,4	1.329	**1,7720**	1000 t.		2,932
5	Costs Loaders sludge	206 lei/ora		8.240	1.329	1,3290	1000 t.		2,199
6	Dispensing machine sludg	300 lei/ha or hour tariff		15.000	3.409	3,4091	1000 t.		5,641
7	Leasing	450 lei/ha;		450	102	5,1136	3200 t.		8,462
8	Weighing Scale sludg			1.000	227,27		1000 t.		0,376
9	Salary costs to workers involved	12 months X 4.200 lei/month	12	50.000	11.363,64	3,5511	3200 t.		5,876
10	Protective equipment for workers involved	200 lei/person	1	200	45,45	0,0455	1000 t.		0,075
11	Permit application		1	150	34,09	0,0341	1000 t.		0,056
12	Fuel for transport workers in the company	2 l/ha, 2x50=100l x5,3 lei	100	530	120,	0,1205	1000 t.		0,199
13	Depreciation spreader		2			12,800	3200 t.		**21,181**

II	Soil monitoring by OSPA							**4,4545**	**7,37**
14	OSPA study (study 1 , 2 profiles)	12600 lei/study	1	12.600	2.863,64	2,8636	1000 t.	**7,37%**	4,739
15	OSPA study 2016	2000 lei/study	1	2.0000	454,55	0,4545	1000 t.		0,752
16	OSPA study 2017	5000 lei/study	1	5.0000	1.136,36	1,1364	1000 t.		1,880
III	Calcium carbonate amendments							**13,1818**	**21,81**
17	Calcium carbonate (EXPENSES only transport)	8 tons/ha; Neccessary 8 tonsx50 ha= 400 tons; 2688 lei/25 tons; 107,5 lei/tons		43.000i	9.772,73	9,7727	1000 t.	**21,81 %**	**16,171**
18	Calcium carbonate (EXPENSES distributed only with transport machine rental for calcium carbonate)	300 lei/ha or hour tariff		15.000	3.409,09	3,4091	1000 t.		5,641
IV	Monitoring water							**4,1765**	**6,91**
19	well drilling	150 lei/ml; 2 drill x 20 ml	2	6.000	1.363,64	1,3636	1000 t.	**6,91%**	2,256
20	OPINIONS ACT		1	1.036	235,55	0,2355	1000 t.		0,390
21	Hydro-geologic study		1	900	204,55	0,2045	1000 t.		0,338
22	monitoring water 2015	870 lei/sample; 2 samples/ year	4	3.480	790,91	0,7909	1000 t.		1,309
23	monitoring water 2016	870 lei/ sample; 2 samples/ year	4	3.480	790,91	0,7909	1000 t.		1,309
24	monitoring water 2017	870 lei/ sample; 2 samples/ year	4	3.480	790,91	0,7909	1000 t.		1,309
25	monitoring water								

	2018								
V	Monitoring plants							**3,0000**	**4,96**
26	monitoring plants 2016					**1,0000**		**4,96%**	1,655
27	monitoring plants 2017					**1,0000**			1,655
28	monitoring plants 2018					**1,0000**			1,655
VI	Pathogens							**4,0000**	**6,62**
29	Monitoring 2015					**1,0000**		**6,62%**	1,655
30	Monitoring 2016					**1,0000**			1,655
31	Monitoring 2017					**1,0000**			1,655
32	Monitoring 2018					**1,0000**			1,655
VII	Consultinf							**1,0227**	**1,69**
34	Consulting		1	4.500	1.022,73	1,0227	3200 t.	**1,69%**	1,692
VIII	Insurance							**1,5000**	**2,48**
		2,5% from 60 EURO/tons				1,5000		**2,48%**	2,482
	TOTAL GENERAL			**91.192,4**	**20.182,09**	**60,431**	**1000 t.**	**60,4319**	**100**

A synthetic situation is presented in Table 2 below:

Table 2. A synthetic situation

Category of costs	percent	Euro/1000 tons
Water Company	48,15%	29,09
Soil monitoring OSPA	7,37%	4,45
Calcium carbonate amendments	21,81%	13,18
monitoring water	6,91%	4,18
monitoring plants	4,96%	3,00
pathogens	6,62%	4,00
consulting	1,69%	1,02
Insurance	2,48%	1,50
Total	100,00%	60,43

The data in Table 2 are shown in Table 3, as table 3b percentage and in absolute terms, the main elements of costs:

Table 3a.

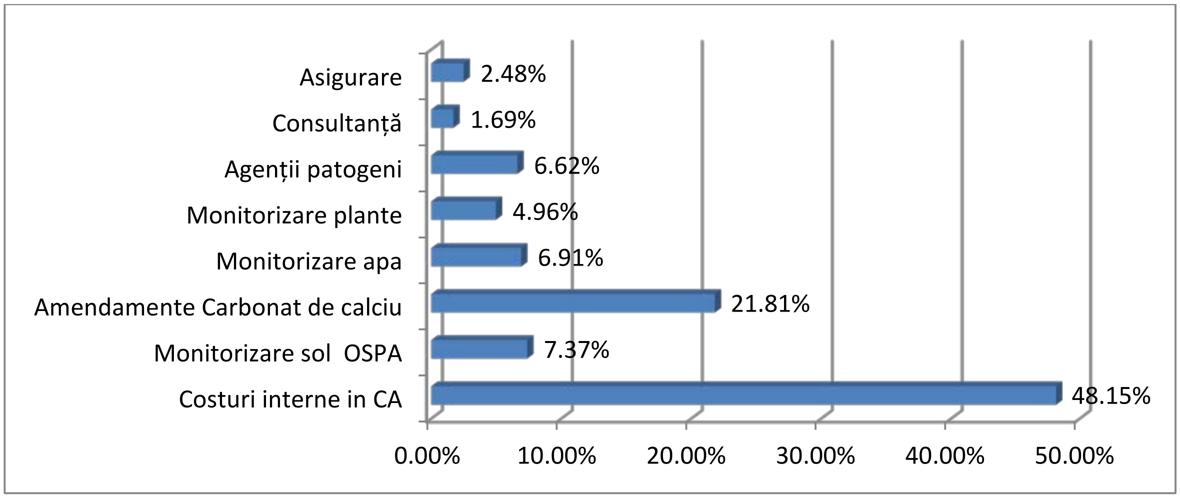
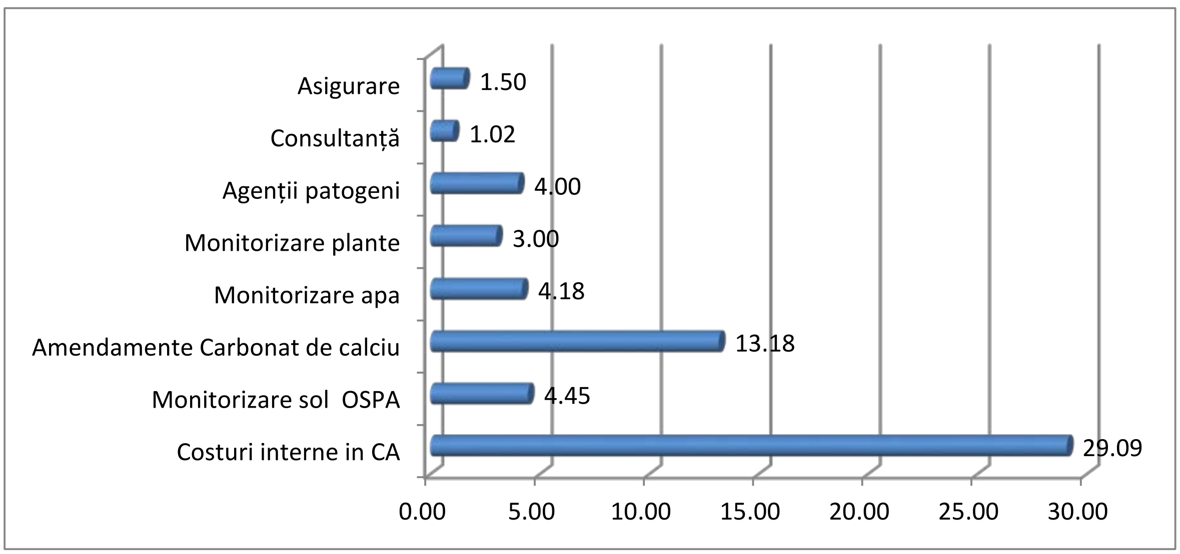


Table 3b.



In Table 1 have been analyzed and evaluation expenditure groups per tonne of sludge if the water company manages activity for spreading sludge in agriculture.

3. EXPERIENCE WATER COMPANY TARGOVISTE

After getting Permit Application No. 01/10.23.2015, the problems started

Permit Application No. 01 / 23.10.2015

Application conditions -Stage I

- PH from 6.5

- Calcium carbonate 8 tons / ha

Application conditions - Stage II

Special study should be conducted including also agrochemical control and monitoring soil, plant, surface water and groundwater after application of sludge - are not enough regulations

Producer is responsible for everything that sludge quality, quantity , transport, spreading sludge on farmland , as well as its effects on the environment and human health after use - requires costs that must be provided in waste water costs.

4. CONCLUSIONS

The regulatory framework needs to be improved.
Afferent costs from wastewater treatment sludge disposal should be included in the price separately.

CHAPTER IV

PRODUCTION AND USE OF BIOGAS; ECONOMICAL ASPECTS IN SLUDGE MANAGEMENT

Danube Eastern Europe Regional Water Forum
International Conference
Sludge Management 2016

Organiser

Bucharest, Palace of Parliament

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Production And Use Of Biogas In Cluj-Napoca Waste Water Treatment Plant

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Abstract

SOMES Water Company's Waste Water Treatment Plant in Cluj Napoca is the largest among the eight urban such facilities serviced in Cluj and Salaj Counties. It was modernized in several stages, the latest completed in 2013. Currently it has a capacity of 367,000 population equivalent and an daily average volume of 111,000 m3 processed waste water.

Through the waste water treatment are generated daily some 500 m3 primary sludge (3% dry substance) and 330 m3 active sludge in excess respectively (6% dry substance). The biogas resulted through the fermentation of the sludge is co-generated into electrical and thermal energy used to reduce operation costs within the station.

The equipments used for the production and conversion of the biogas consist of:

- Mesophilic anaerobic fermentation digesters (4 x 3500 m3);
- Biogas recirculation blowers (6 x 460 m3/h);
- Membrane biogas storage gas tank (2000 m3);
- Equipment for biogas cleaning/purification;
- Generators (2 x 330 kWh);
- Safety torch for biogas (600 m3/h).

The operation of the fermentation digesters is continuously monitored for various parameters such as temperature variations, volumes and quantities of the sludge and of the biogas, pumping cycles quantity and quality of reaction components and so on. Technological adjustments are made according to the evolution of the process.

All equipments as well as all process data are monitored, acquired and stored within SCADA.

The two GE-Jenbacher four stroke, water cooled eight cylinders in line generators are using as fuel the biogas resulted following the anaerobic fermentation. These are using a mixture of biogas and air in excess to reduce emissions even from the phase of engine burn. The electric power produced by the generators is of 330 kW/engine, which can cover more than 45% of the power needed for the operation of Cluj-Napoca WWTP, the daily average consumption of energy being of some 25,000 kWh.

SOMES Water Company is permanently interested in improving the parameters of the WWTP, including the increase of the co-generated power potential. Also studies/researches are made in the following areas: co-fermentation of some sublayers, sludge thermal hydrolysis, sludge sonification, dehydrated sludge cremation, phosphorus recovery from dehydrated sludge, use of dehydrated sludge.

Keywords

Biogas, sludge, technology.

1. INTRODUCTION

Somes Water Company is a regional operator of water supply and waste water collection-treatment, one of the largest in Romania. The company services almost three quarters of a million people in 8 cities and towns over Cluj and Salaj counties.

Beginning with 1997 we have accessed four large investment programs with European co-financing: MUDP II, ISPA, SAMTID, and at present we are close to finishing the Sectoral Operational Program (SOP) Environment, stage 2008-2015.

Based on the Company's Master Plan – Long Term Investment Coordination Program (2008 –

2026), 196 Million EURO have been accessed under SOP Environment stage I, while under SOP Environment stage II our proposal amounts to approximately 280 Million Euro.

One of the major investments performed by Somes Water Company was Cluj-Napoca Waste Water Treatment Plant. The investment, amounting around 33 million Euro, included the extension, modernisation and implementation of tertiary stage within the station.

The WWTP was designed to treat waste water for about 350,000 population equivalent, with a capacity of treating 1287 l/day during dry time, reaching up to 3600 l/day during rain time.

Figure 1. Overview of the Waste Water Treatment Plant

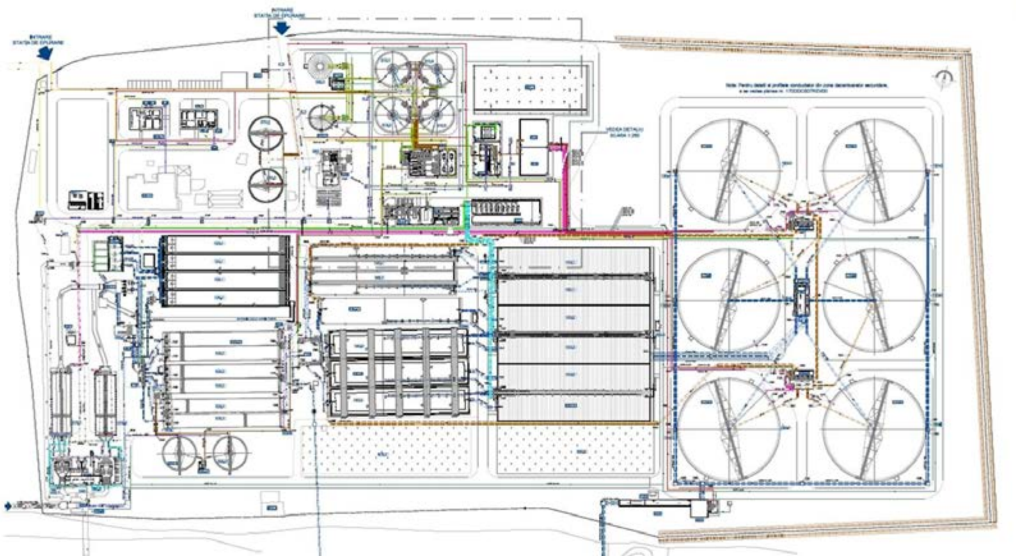


Figure 2. Process diagram of the WWTP

2. PRESENTATION OF CLUJ-NAPOCA WASTE WATER TREATMENT PLANT (EQUIPMENT)

The plant is provided with two lines of waste water intake fitted with coarse and fine screens, grit and grease removal units, sewage utility vehicles intake station, waste water pumping station, primary settlement tanks, denitrification tanks, aeration tanks, blowers station, ferric chloride dosing station, secondary settlement tanks, sludge recycling and excess active sludge pumping stations.

The plant processes 110,000 m^3/day of waste water which is discharged conventionally clean, as per quality indicators defined in the Water Management Authorisation according to NTPA001.

Month	pH	CCO-Mn mg/l	CCO-Cr mg/l	BOD_5 mg/l	Total susp. mg/l	Fixed residue mg/l	Ammonium mg/l	Nitrates mg/l	Nitrites mg/l	Total N mg/l	Total P mg/l	Sulphates mg/l	Extractable subst. mg/l	Detergents mg/l	Flow rate l/s
Admissible			125mg/l	25mg/l	35mg/l	1000mg/l	2mg/l	25mg/l	1mg/l	10mg/l	1mg/l	300mg/l	20mg/l	0,5mg/l	
Jan	7.54	8.89	20.07	2.67	8	278	0.42	13.55	0.094	4.80	0.41	16.59	2.66	0.100	1324
Feb	7.61	7.80	20.63	1.98	6	262	0.41	13.20	0.064	4.20	0.45	24.16	3.00	0.082	1249
Mar	7.58	8.33	20.85	2.13	7	264	0.59	13.56	0.125	4.56	0.48	31.55	2.33	0.120	1345
Average	**7.58**	**8.34**	**20.52**	**2.26**	**6.70**	**268**	**0.48**	**13.44**	**0.094**	**4.52**	**0.45**	**24.10**	**2.66**	**0.101**	**1306**

Figure 3. Analysis report for discharged treated waste water

Waste water treatment produces, every day, about 500 m^3 primary sludge (3% dry matter), as well as 330 m^3 excess active sludge (6% dry matter);

Resulting sludge is stabilised by anaerobic mesophilic fermentation (~35°C) in the four sludge digesters.

Figure 4. Sludge digesters before and after rehabilitation

Digested sludge is subject to dewatering (~30 % dry matter) and applied on agricultural land as per application permits issued by Environment Agency.

Figure 5. Heat exchangers before and after rehabilitation

With the modernisation of WWTP, the SCADA system was also upgraded, as a technology allowing the operator to receive information from remote equipment and to send them a limited set of instructions.

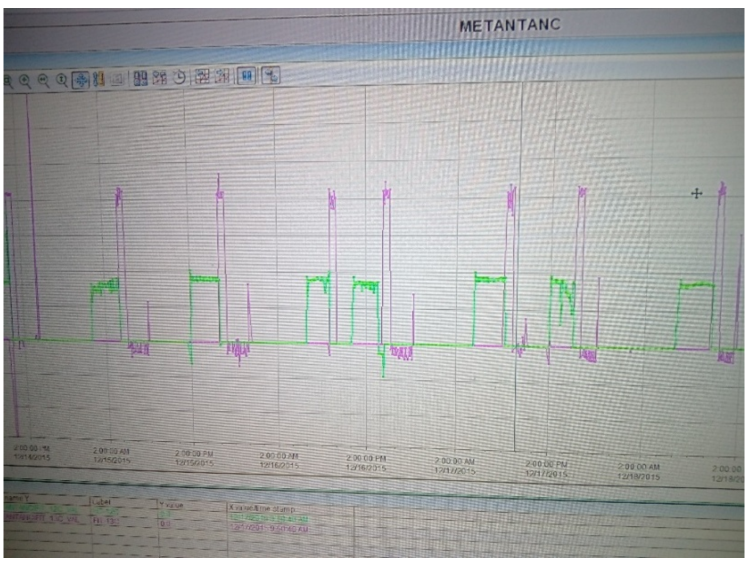
Figure 6. Operation of sludge digesters (SCADA)

With SCADA system, the sludge line is being monitored as regards the process running and the quality indicators.

purple, blue, yellow – trend over time of fermentation temperature in 3 digesters

black, red, green – trend over time of internal pressure in 3 digesters

Figure 7a. Operation of sludge digesters (SCADA – graphs)



green – volume of thickened primary sludge

purple – volume of thickened excess active sludge

Figure 7b. Operation of sludge digesters (SCADA – graphs)

Sludge digesters operation includes monitoring of:

- temperature variation over time;
- daily volumes and amounts of sludge pumped into each digester;
- pumping cycles for each digester;
- quality of thickened primary sludge and of thickened excess active sludge;
- laboratory analyses for monitored indicators (pH, NH_4, H%, MS%, VS%, RT, RF);
- quality of produced biogas.

Biogas produced in the plant is stored in two gas tanks – one is the existing, rehabilitated gas tank, with a capacity of 1000 m^3, and the second is the new tank, membrane type, with a capacity of 2000 m^3.

Figure 8. Gas tank

A safety torch was provided in order to protect the gas tanks, which burns the excess biogas until reaching optimal operation conditions.

Figure 9. Safety torch

Following the rehabilitation of WWTP, two GE - Jenbacher generators were purchased. Their engines use as fuel the biogas from anaerobic fermentation, they are 4-stroke, water cooled, inline 8-cylinder engines.

Figure 10. Power generator

Supply consists of a mixture of biogas and excess air in order to minimise emissions since the burning stage. Electric power provided by generators is of 330 kW/engine, and it covers about 45% of the Waste Water Treatment Plant’s energy needs, which has a daily average consumption of 25,000 kWh.

Somes Water Company is constantly aiming to improve technical and economical quality indicators of the Waste Water Treatment Plant. As regards the sewage sludge, the 2016-2020 investment program provides, besides its agricultural use, the performance of certain thermal treatment processes.

Collection And Recovery Of Sludge Treatment Plants Obtained From Satu Mare County

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Abstract
In this essay it is described the technological process of sediments extraction, from Satu Mare, Carei, Negresti Oas, Tusnad, Ardud and Livada waste water treatment plants. It has also been analyzed the effect of industrial water on the quality of waste water from the urban sewage networks. In the second part of this essay there are analyzed the potential costs and the actual possibilities of exploiting the sediments. There are also presented new alternative ways of recycling the sediments.A series of solutions have been proposed, in this essay, regarding the exploitation of sediments, dependent on the amount of sediments found in the waste water from the above mentioned waste water treatment plants. Regarding the SEAU Satu Mare, it has been presented the posibility of obtaining electricity, natural gases and thermal energy from the industrial exploitation of sediments.

Keywords
Sludge, energy recovery, biogas.

1. INTRODUCTION

The sludge is a heterogeneous system consisting of an aqueous phase and a solid one, which can contain colloidal particles, dispersed and aggregates in suspension particles, resulting from the treatment of water because of the wastewater treatment process. The sludge consists of organic matter and minerals that include both the impurities in the raw water and those formed in the treatment processes. Soluble organic substances are converted into bacterial mass, which is separated from the treated water in the form of sludge [1.2.3].

The sludge results from the treatment of wastewater that came from sewerage network from the populated areas or of the industrial enterprises. The sludge is also produced during the treatment of the rainwater, although it usually has much lower organic compounds than the sludge that came from wastewater. Because of this, in the sludge it can find most of the substances responsible for the pollutant character of the residual effluent and the content of pollutant organic compounds whose potential pollutant can be higher than the initial pollutant, namely due to low solids content of the sludge [4.5.6].

The Sludge is classified according to the processes of treatment as follows:

- Primary sludge - if it’s resulted from mechanical treatment;
- Secondary sludge - if it’s resulted from biological treatment or if the mixture is resulted from the mixture of primary and secondary sludge;
- Precipitation sludge - that is resulted from the physic-chemical treatment of wastewater, because of the addition of neutralization, precipitation or coagulation;

- After processing module, the sludge can be raw, aerobic or anaerobic stabilized, dehydrated natural or synthetic, sanitized through physical and chemical treatments or as ash if sludge is incinerated [7.8.9].

The primary sludge in the sewage treatment plants, is processed in advance by the anaerobic fermentation, the mineralization of organic substances takes place, obtaining biogas consisting of methane (CH_4), carbon dioxide (CO_2) and hydrogen sulphide (H_2S), then it is dried naturally or artificially. If the sludge corresponds as bacteriological and physico-chemical content (not containing heavy metals), it can be harnessed in agriculture as fertilizer, or if not, to cover landfills or incineration [10.11.12].

In terms of compositions, the sludge may also contain organic and inorganic compounds of the type of nitrates, nitrites, ammonium, phosphates, silicates, aluminates, aromatic hydrocarbons, biphenyls, dioxins, pesticides, heavy metals (Co, Ni, Zn, Pb, Cu, As).

This study presents in parallel treatment technology in order to obtain sludge in the Wastewater Treatment Station of Satu Mare, Carei, Negresti-Oas, Ardud, Tasnad, and Livada. Also in the first part, it is presented the efficiency of wastewater treatment plants, from the perspective of comparison of the effluent loads to the influent loads. The sludge production of each treatment plant and the possibility to harness their energy are being presented. It is also presented an economic aspect concerning the operating, maintenance and staff expenses of these treatment plants [13.14.15].

2. TECHNOLOGICAL ASPECTS REGARDING THE EXTRACTION PROCESS OF SEDIMENTS IN WASTEWATER TREATMENT PLANTS

The Satu Mare wastewater treatment plant was designed for 155.047 inhabitants and an hourly flow of 3240 m2/h, and the last rehabilitation is being finalized through the project „The development and rehabilitation of wastewater sewer system in Satu Mare county" in which it has been realized an extention of biological step, regarding the removal of nitrogen and phosphorus.

The wastewater treatment plant is composed of the mechanical part: coarse bar screens, sand-clearing basin, grease filter, primary clearing tank and the biological part (carousel basins with anoxic anaerobic, aerobic areas, and secondary circular clearing tank). The primary sediments from the primary clearing tanks are pumped up in a buffer basin where they are mixed with the grease resulted from the grease filter and with the active dehydrated sediments, and with the aid of the mixers are hold in suspension. The four fermenters are used to stabilize the sediments mixed for 21 days, the temperature of the sediments is kept between 34-37 degrees C, the necessary environment of metagene bacteria for producing biogas. The fermented sediments is taken in the buffer basin where they will be mixed with the excess sediments and will be dehydrated with the aid of centrifugal boxes thus obtaining a type of sediment containing 35% dry matter and will be stocked on the drying beds. The biogas (containing CH_4, CO_2, H_2S) and obtained in the fermenters will be deposited in a gas collector with two membranes. The outer membrane is filled with air produced by the air blower the biogas will be filtered through sand and ceramics filters, to eliminate solid particles, then it will enter the cogeneration system, and will be transformed in electricity and thermal energy which will cover a part of the necessary energy for the wastewater treatment plant.

The Carei wastewater treatment plant was designed for the needs of 27.000 inhabitants with an hourly flow of 468 m^3/h. In this wastewater treatment plant there are no primary clearing tanks. The wastewater treatment plant is composed of the mechanical part (coarse bar screens, sand-clearing basin, grease filter) and the biological part (carousel basins with anoxic anaerobic, aerobic areas, and secondary circular clearing tank). Each of the 3 units of biological treatment is composed of anoxic reactors and aeration reactors, and the primary income of wastewater reaches the biological units mixed with the recycled sediments. The active sediments are retained in the secondary clearing tank and is diverted towards the distribution rooms of the biological reactors, where the active sediments are mixed with the primary sediments and are divided between 3 biological treatment lines. When the amount of sediments in the biological stage exceeds the allowed limit, a part of the sediments will be recycled in order to maintain an optimal dilution. The exceeding sediments are pumped in the dehydration station, formed by a filter press, and the dehydrated sediments are stocked on the dehydrated sediments decking, which is made of concrete.

The Negresti Oas wastewater treatment plant was designed for the needs of 14884 inhabitants and has an hourly flow of 434 m^3/h. In the present, the wastewater treatment plant is being under development due to the increasing number of connected inhabitants. The wastewater treatment plant is composed of two separate lines containing the mechanical part (coarse bar screens, sand-clearing basin, grease filter) and the biological part (basins with anoxic anaerobic, aerobic areas, and secondary circular clearing tank and the second line which includes the circular biological basin which is concentric to the secondary clearing tank. The exceeding sediments from both lines is mechanically stabilized by adding polymers in the tanks. From the tanks the sediments are transported in a buffer basin were are kept for 24 hours, then is dehydrated through centrifugal process and it is obtained a concentration of 25 % dry matter. The dehydrated sediments are taken with a front loader and deposited on sediments covered platforms, were they rest for 6 months until they reach 35% dry matter.

The Livada wastewater treatment plant was designed for the needs of 4984 inhabitants and has an hourly flow of 184 m^3. In the present, the wastewater treatment plant is being under development, the water is momentary by-passed directly into the Racta river. The wastewater treatment plant will be composed of two separate lines containing the mechanical part (coarse bar screens, a compact system of sand-clearing basin and grease filter) and the biological part (longitudinal basins with anoxic anaerobic, aerobic areas, and secondary circular clearing tank). The exceeding amount of sediments will be mecanically concentrated with polymers by means of mechanical units, then it’s evacuated in the buffer basin where is dehydrated by a centrifugal process, thus obtaining a 25% concentration of dry matter. The sediments will be deposed on the covered drying beds, where in six months will reach a concentration of 35% dry matter.

The Tasnad wastewater treatment plant is designed for the needs of 9673 inhabitants and has an hourly flow of 388 m^3. The station undergoes a process of reconstruction and the wastewater is momentary by-passed directly in the river.

The wastewater treatment system relies on a mechanical part containing coarse bar screens, a compact system of sand-clearing basin and grease filter. The biological treatment system relies on the process of extended aeration, nitrification and denitrification of active sediments, respectively the chemical and biological removal of phosphorus. The active sediments are thickened by means of a gravitational thickener which will work as a covered buffer tank, containing a peripheral mixing system, and a device used for removing the foam and a hydraulic ram for the evacuation of supernatant. The thickened sediments obtained from the secondary clearing tanks will be dehydrated with the help of filter preeses, thus obtaining a concentration of 35% dry matter, after which the sediments will be deposed on the drying beds.

The Ardud wastewater treatment plant is actually under reconstruction and it is designed for an hourly flow of 260 m^3 and it is designed to cover the needs of 5870 inhabitants. The wastewater treatment plant is composed from the mechanical part (coarse bar screens, a compact system of sand-clearing basin and grease filter) and the biological part designed on the basis of active sediments treatment through extended aeration, simultaneous nitrification and denitrification, respectively the chemical removal of phosphorus. The exceeding amount of active sediments are thickened by means of a gravitational thickener which will work as a covered buffer tank. The resulting sediments is the dehydrated with the help of filter presses, thus obtaining a concentration of 35% dry matter, after which the sediments will be deposed on the drying beds.

3. THE EFFICIENCY OF WASTEWATER TREATMENT PLANTS

The efficiency of wastewater treatment plants can be traced following the reduction of different amounts of particles present in the wastewater and implicitly in the sediments during the treatment phasis. In the first table there are illustrated the physio-chemical parameters of the influent (red column) compared to the physio- chemical parameters of the effluent (blue column).

There are presented only the functional wastewater treatment plants Satu Mare, Carei and Negresti. The Tasnad, Ardud and Livada wastewater treatment plants are not working at the moment, and undergo a process of reconstruction.

The physico-chemical parameters are expressed in yearly averages, namely 2015.

A considerable decrease of the waste water (influent) physical-chemical parameters can be observed in the table above, compared to the treated water (effluent) in all the 3 wastewater treatment plants mentioned before. After the development reconstruction of all the wastewater treatment plants, NTPA001 will be used.

Table 1. The comparison of physical-chemical parameters of the effluent and the influent and NTPA001 [16] in Satu Mare, Carei, Negresti-Oas wastewater treatment plants

Physio-chemical parameters	WWTP Satu-Mare		WWTP Carei		WWTP Negresti-Oas		Legal Admissible limits (NTPA001)	
	Influent	effluent	Influent	effluent	influent	effluent		
pH	7.47	7.43	7.19	7.40	7.11	6.88	6.5-8.5	SR ISO 10523-97
suspensions in mg/L	274.85	19.89	123.93	13.04	104.46	14.93	35	STAS 6953-81
CBO5, in mg O_2/L	142.42	11.48	78.15	7.43	71.18	9	25	STAS 6560-82
CCOCr, in mg O_2/L	370.18	50.31	200.07	29.81	176.24	42.89	125	SR ISO 6060-96
extractibile, in mg/L	5.16	1.84	5.6	1.46	3.8	1.52	20	SR 7587-96
ammonium, in mg/L	40.01	37.28	12.13	0.92	11.58	2.12	3	STAS 8683-70
total nitrogen, in mg/L	62.1	33.9	13.75	4.07	65.52	26.99	15	STAS 7312-83
total phosphorus, in mg/L	3.79	1.548	2.74	0.61	2.84	0.94	2	SR EN 1189-99
detergent, in mg/L	3.9	0.54	0.98	0.13	2.56	0.94	0.5	SR ISO7825/1-96
total cyanide,in mg/L	0.0286	0.0049	0.018	0.003	0.0094	0.002	0.1	SR ISO6703/1-98
total chrome, in mg/L	0.1812	0.0389	0.0527	0.0251	3.1415	0.0247	0.1	SR ISO 9174-98
zinc, in mg/L	0.123	0.0315	0.0473	0.0172	0.1057	0.0298	0.5	STAS 8314-87
nickel, in mg/L	0.0989	0.0118	0.0381	0.0077	0.1701	0.025	0.5	STAS 7987-67
lead, in mg/L	0.0317	0.0163	0.0172	0.0055	0.0311	0.0016	0.2	STAS 8637-79

copper, in mg/L	0.1349	0.0035	0.0166	0.0079	0.1055	0.0016	0.1	STAS 7795-80
sulphides and hydrogen sulphide, in mg/L	1	0.4604	0.6629	0.1681	0.8	0.3534	0.5	SR ISO 10530-97 SR 7510-97
sulphate, in mg/L	36.47	18.04	45.95	32.62	18.71	11.58	600	STAS 8601-70
phenol, in mg/L	0.0246	0.0102	0.0874	0.0225	0.5428	0.0385	0.3	STAS R 7167-92

The two parameters, BOD and COD are decreasing considerably after the biological stage, and thus placing themselves inside of the allowable legal limit (125 mg/L for COD and 25 mg/L for BOD). Ammonia nitrogen has in some cases a greater value in the influent than in the effluent, due to multiplication of bacteria [16]. The removal of the organic pollution varied between 76 and 87% for the COD and between 87% and 92% and for the BOD. It can be observed that in all cases the concentrations of heavy metals are well below the legal limit.

In the case of total phosphor the removal was varying in the range of 61% and 88% and total N removal was varying in the range of 46% and 70% respectively. The Nitrogen removal occurs by denitrification process and is an anoxic process that occurs in the presence of nitrites, nitrates and a minimum concentration of dissolved oxygen. The metabolism of nitrifying bacteria is sophisticated and characterised by its low energy yield. The nitrifying bacteria have a low specific growth rate and they are affected by a number of inhibitors. The increasing concentration of nitrogen substances in wastewaters resulted in the need for a gradual introduction of the second, biological level, which consists of nitrification and denitrification.

4. OPERATION COSTS OF WASTE WATER TREATMENT UNITS

Figure 1 presents the annual costs of the Satu Mare waste water treatment plant for the year 2015 (Figure 1). The largest investments refer to materials, especially electrical energy, given the fact that the amount of energy resulting from biogas through the cogeneration system covers almost a half of the power requirements of the plant. The reduced gas demand is due to the production of thermal energy from biogas, which is needed for heating buildings in winter and maintaining the temperature of fermenters between 35-37^{o} C throughout the year.

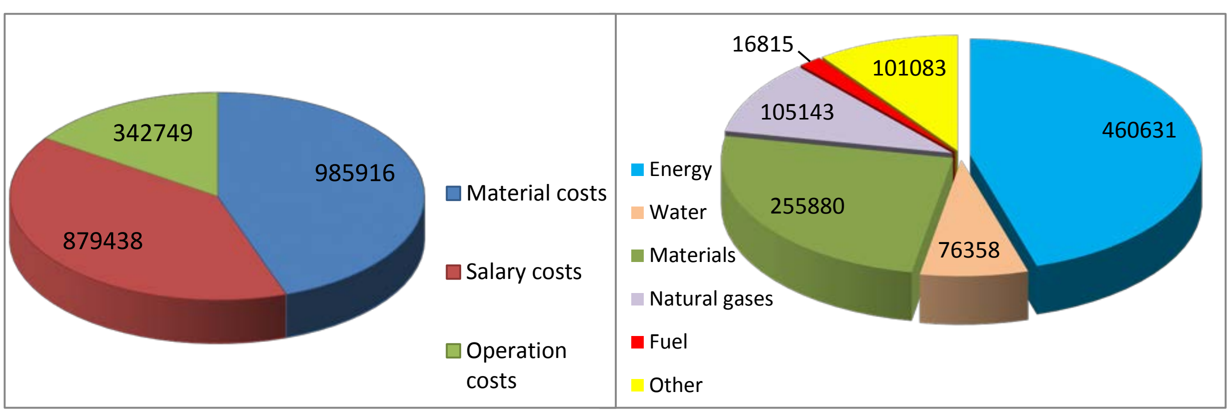

Figure 1. 2015 annual costs (in RON) for materials and overall, for the Satu Mare waste water treatment plant

The ratio is almost similar for the Carei waste water treatment plant, while at the Negresti-Oas plant operation costs are low because the unit is expanding.

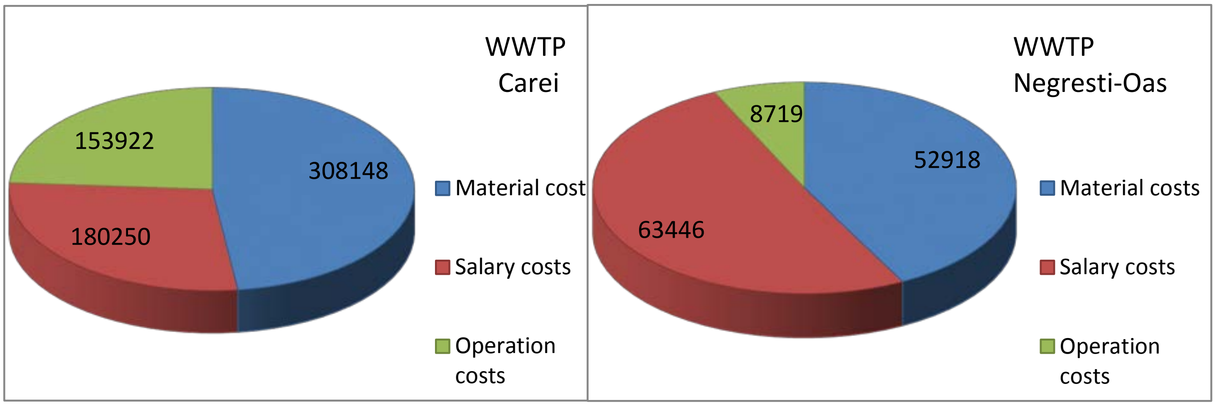

Figure 2. 2015 annual costs of the Carei and Negresti-Oas waste water treatment plants in RON

5. PRODUCTION AND EXPLOITATION OF SLUDGE RESULTING FROM SATU MARE WASTE WATER TREATMENT PLANTS

The output of sludge resulting from the Satu Mare, Carei, Negresti-Oas, Tasnad, Ardud and Livada waste water treatment plants totals 14,384 tons per year. It should be mentioned that this figure is an estimate, as four of the six plants are still being rehabilitated and only the design values were taken into consideration in these cases.

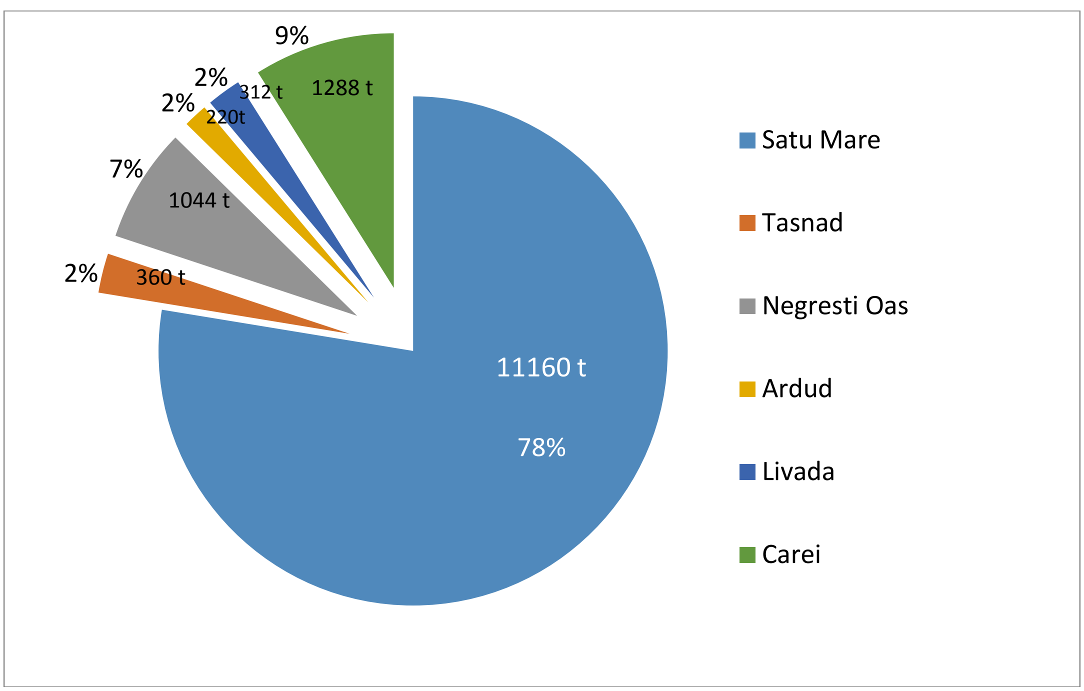

Figure 3. Distribution of sludge output in the six waste water treatment plants in Satu Mare county

The large amount of sludge obtained annually in waste water treatment plants determines plant operators to find increasingly viable solutions to reduce the quantity of sludge in view of clearing drying beds to be able to discharge fresh sludge. On the other hand, there are attempts to elaborate strategies to capitalise on sludge energetically.

At present, sludge is used in covering landfills, based on certain contracts with a landfill and provided that covers are within acceptable limits.

Thus, in agriculture sludge can be employed only if it is not contaminated with heavy metal or nitrogen compounds. The requirements for agricultural usage imply a level of dryness higher than 90%; moreover, the sludge must not be fermentable and it should be storable in silos until reemployment. The method by means of which fertilizer is obtained in agriculture is called composting. Composting is an aerobic process of bacterial decomposition through which biodegradable organic wastes are stabilised, eventually leading to the formation of compost. Composting is achieved in an inclined rotating cylinder, in which the supply with the raw material (sludge with wood flour) is made at one end and compost is discharged at the other end. Composting is advantageous because the resulting compost can be used as a basis for the mixture of several types of fertilizers, improving the structure of the soil by increasing the absorption capacity of the water and soil properties implicitly.

Incineration implies drying dehydrated sludge to eliminate waste water up to a final dried mass of 90-95%. The drawback lies in the relatively high costs of certain incinerators and their operation due to the use of filters that neutralise gases formed during incineration.

Co-incineration in cement plants involves the recovery of energy during the process of sludge treatment by using the methane produced in anaerobic fermentation, which generates heat and energy. Fermented sludge can be exploited by means of co-processing in cement plants, in equipment that meets power efficiency prerequisites upon the recovery of energy. As regards the exploitation of used sludge to produce energy, one can obtain more power from the employment of brute, unfermented sludge rather than by means co-incineration; costs depend on the quality of the sludge, the content of water and the transportation distance. In Romania there are seven cement plants authorised to process waste, as well as to accept sludge only in exchange for the payment of taxes that cover supplementary operational costs, which may depend on the level of humidity of the sludge and its calorific value.

Sludge dryers are a cheaper alternative than the above-mentioned ones, by means of which one can obtain sludge with a 90-92% content of dry substance. Technological sludge is stored in the infeed system of the dryer, where it is extruded and distributed evenly on the entire width of the drying belt, allowing for air to circulate through and, as a result of the slow running of the belt, the drying of the sludge. Due to the lack of movement and friction in the process of drying, no dust is created during the actual drying.

6. CONCLUSION

The study is a comparative presentation of technological and financial aspects regarding the efficiency of functional waste water treatment plants in Satu Mare county. The quality of the used water and sludge implicitly depends on the extent to which the physical-chemical parameters are reduced, in various stages of the treatment, between the influent and the discharge into the emissary. All the values are below the legal acceptable limit. The Carei and Satu Mare waste water treatment plants are completely functional; the one in Negresti-Oas is working on a new line, while the plants in Ardud, Livada and Tasnad are being rebuilt.

The largest costs of operation plants occur with respect to the purchase of materials and utilities, especially electrical energy.

After the constructions are finished, 14,384 tons of sludge will be produced every year, 78% of which in the Satu Mare waste water treatment plant alone, mostly with a 35% content of dry substance (in exceptional situations, 25% dried substance is obtained and subsequently up to 35% of the content is dried).

The last part of the paper presents the possibilities of sludge exploitation. Apart from the actual strategy of using sludge to cover landfills and the national strategy of employing sludge in agriculture, there are new methods such as the more expensive techniques of incineration and co-incineration in cement plants, as well as other methods like the use of sludge dryers.

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Reduction Of Total Cost Of Ownership By Reducing The Energy, Polymer Consumption & Maintenance

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Abstract
Cost control and a growing need for renewable energies: in this economy, finding the best solution to meet these expectations is a challenge every plant operator has to take. As energy costs are constantly raising, new technologies which reduce the energy consumption bring a quick return on investment. Advances innovations to reduce energy consumption were implemented in ANDRITZ Decanter: TurboWISE to improve efficiency and wear protection, TurboJet to improve energy, Easy Pond and Lamellar scroll to improve polymer consumption while thickening.
Also ANDRITZ has developed his own screw press for low maintenance costs which usually in competition with decanter technology.
New developments on automation lead to a better use of each equipment and participate in the reduction of total cost of ownership as our CentriTune system for decanters or our ScrewAutoBox system for screw press.

Keywords
Dewatering, thickening, energy reduction, polymer optimization, maintenance, centrifuge, screw-press.

1. INTRODUCTION

The total costs of ownership in waste water treatment plants (WWTPs) are the most challenging tasks and motivates plant operators to introduce new low energy consumption technology, decreasing polymer consumption and maintenance costs. Power efficiency and polymer optimisation of separation tools are prevailing issues that typically help to reduce the total cost of a plant and fit to sustainable development. New developments on automation can lead to a better use of each piece of equipment and contribute to the overall reduction of the total costs of ownership.

2. LOW POWER CONSUMPTION ANDRITZ SOLUTIONS

The separation of solid particles from a continuous liquid stream is a common task in many process industries, e.g. waste water treatment and the food industry.

Depending on the main objective of the separation task, it is the dryness of the solid rich stream (often termed cake), the cleanliness of the liquid rich stream (referred to as centrate) or the total capture of solids that is in focus.

The decanter centrifuge is the most common technology used in the world for the purpose of dewatering every type of sludge, such as municipal, industrial, recycled etc. Thus one of the targets is to reduce the power consumption of the decanter by keeping a stable product stream in terms of thickened sludge concentration or dewatered cake, capture rate and centrate quality.

ANDRITZ Separation has understood this need and as consequence, intensive research has been done. The main developments to reach this goal are the following:

- Reduction of the power loss from liquid and solid acceleration at the centrifuge outlets (High Hydraulic Pressure (**HHP design**));
- Recovering the kinetic energy of the liquid discharge from the centrifuge (**TurboJet** patent pending product) ;
- Optimising the liquid acceleration in the feed chamber (**TurboWISE** patent pending product).

The characteristic of the **HHP design** is the reduced discharge radius of the liquid and solids.

This reduces the loss of the kinetic energy and thereby the power loss for the separation process.

The reason for this behavior is that the hydraulic power consumption (power to discharges liquid and solid) of a centrifuge is proportional to the square of the discharge radius.

In addition to reduced power consumption, this innovative design has other important advantages.

Due to unique scroll design the ANDRITZ Separation Decanter can be operated with a very high hydraulic pressure during the sludge dewatering process. The result of this is:

- Reduction of sludge conveying torque by about 30% (the pressure supports the solid removal). This impacts are positively on the gear box life time or the gear box choice and consequently on the motor scroll drive size.
- Better centrate quality due to the increased "clarification volume";
- The machine is less sensitive to plugging (High hydraulic Pressure decrease drastically plugging situation);
- Higher capacity (no real scroll differential speed limitation) as hydraulic pressure impacts sludge extraction.

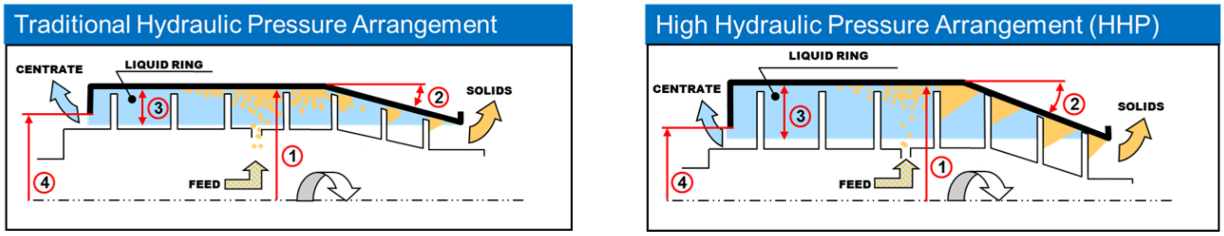


Figure 1. HHP design in ANDRITZ decanter

The **TurboJet** is a special weir plate design with exchangeable nozzles at the liquid outlet which is recovering the kinetic energy of the centrate by guiding the liquid discharge from the centrifuge in the opposite direction to bowl rotation.

The exchangeable nozzles form a liquid jet which creates a reaction force that supports the bowl rotation, and like this reduces the main drive power consumption.

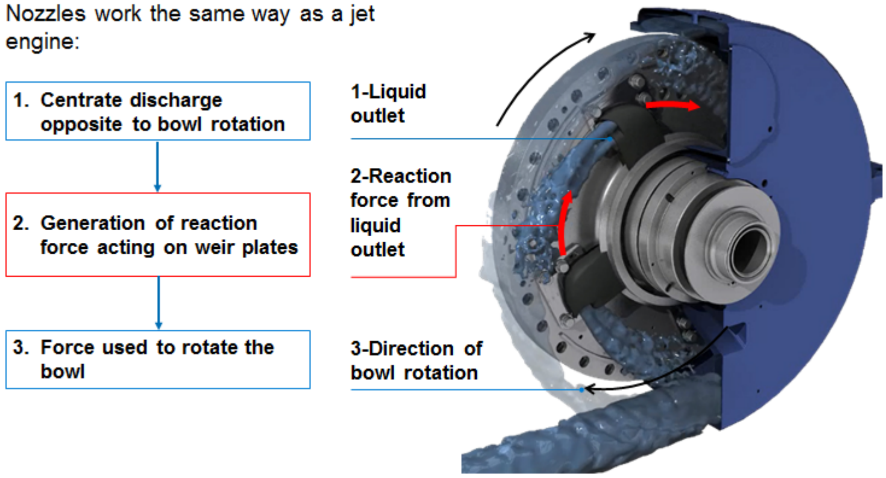


Figure 2. TurboJet operating principle

This product can be fitted to any ANDRITZ Separation Decanter and can also be retrofitted to nearly all brands of decanter. Due to the increase of efficiency, generally return of investment for customer is possible in less than 2 years!

TurboWISE - Standard feed chambers (feed distributor inside the machine) have a low efficiency and generate locally very high acceleration rate of the sludge. This may lead to high shear rates and breakup of flocculated sludge (reduction of clarification rate and loss of energy efficiency). The ANDRITZ TurboWISE system is a polyurethane (PU) insert in the feed chamber which ensures good and gradual acceleration of the feed. The purpose is to bring the non-rotating sludge smoothly to bowl rotation speed and distribute it evenly. Another positive effect of TurboWISE is the protection of the feed chamber which improves the life time of the scroll. These accelerators are easily interchangeable in the field with no need to cut the scroll. Replacement can be done through the orifices of the distributor while the machine is on site.

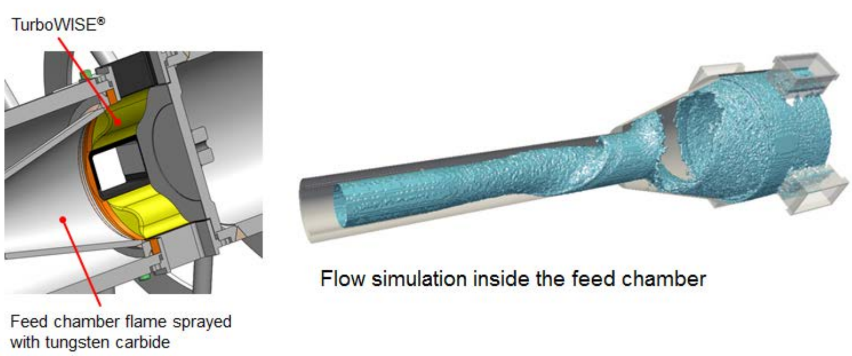


Figure 3. TurboWISE product

ANDRITZ Separation has continuously improved their decanters which led into a new decanter generation that include all these low energy consumption features. The improvement in power consumption on a typical sludge application is shown in figure 4 where the low power consumption decanter is compared to standard decanter.

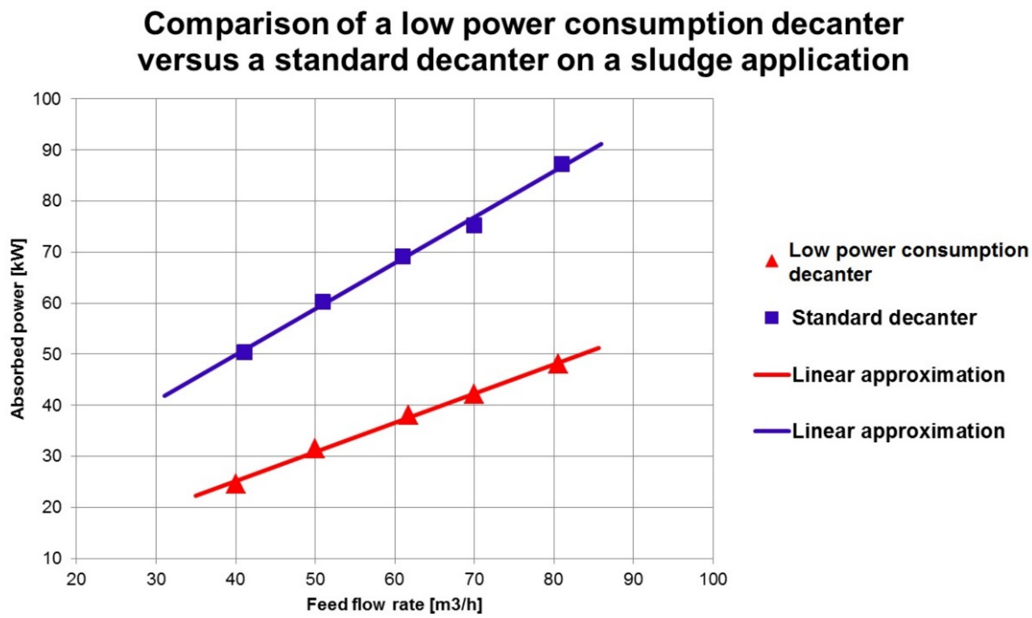


Figure 4. Comparison between low power consumption decanter and standard decanter on sludge application

Based on our vast experience in separation technology, ANDRITZ Separation also developed a new screw press (**C-Press**). The characteristics of this screw press are the low power consumption, the compact design and the very easy maintenance. Turnkey installation and mobile unit are also available.

Figure 5. C-Presse mobile unit

The important improvement in compact design is shown on the figure 6 where the new design is installed close to old one.

Figure 6. New design C-Press versus old design

The low power consumption **C-Press** has already been proven in several installations and gives benefits to customer.

3. REDUCTION OF POLYMER CONSUMPTION

The polymer consumption depends on several parameters like sludge origin, sludge concentration, type of polymer, performance target, centrifuge design, etc.…

It represents a real expense item in WWTP applications. ANDRITZ Separation developed different technologies to reduce the total operation cost by reducing the polymer consumption:

- **Polysave -** Automatic system for optimisation of the polymer dosage applicable for ANDRITZ dewatering and thickening units;
- Improve decanter performance by using **Lamellar scroll** (patent pending) design for thickening application with low polymer consumption or without polymer;
- **Easy Pond** system (patented design) to adjust pond level of a decanter during operation in order to optimise the decanter performance when variations in concentrations and feed flow rate occur.

The **Polysave** system applies and follows the operation instructions with automatic adjustment of the polymer pump and/or feed pump flow according to the real feed concentration measured during operation, within the pumps flow range.

Without having a permanent control of polymer consumption, the installation can suffer from a polymer sub-load/overload or polymer defect which leads to impact dewatering performance and generates additional operating costs.

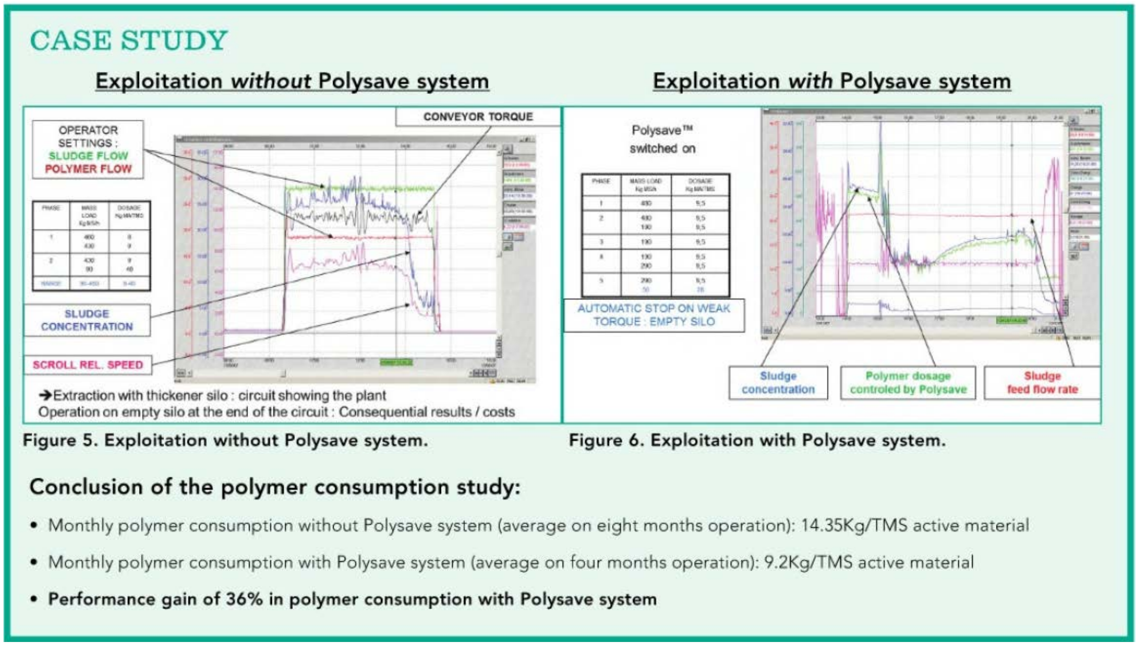


Figure 7. Case study with Polysave installation

Lamellar scroll - Another way to improve the polymer consumption is to work on the centrifuge design itself. ANDRITZ Separation developed a new lamellar scroll which is the combination of our High Performance (HP) scrolls with the proven lamellar clarifier technology.

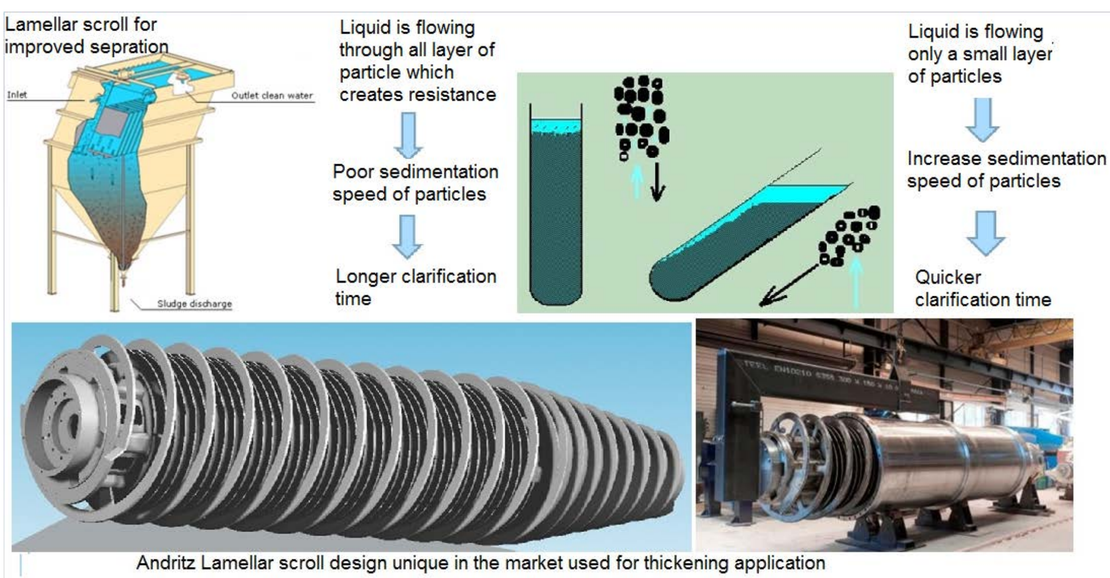


Figure 8. ANDRITZ lamellar scroll design

The advantages of the lamellar scroll are proven in several WWTP and a typical improvement is presented in the next figure.

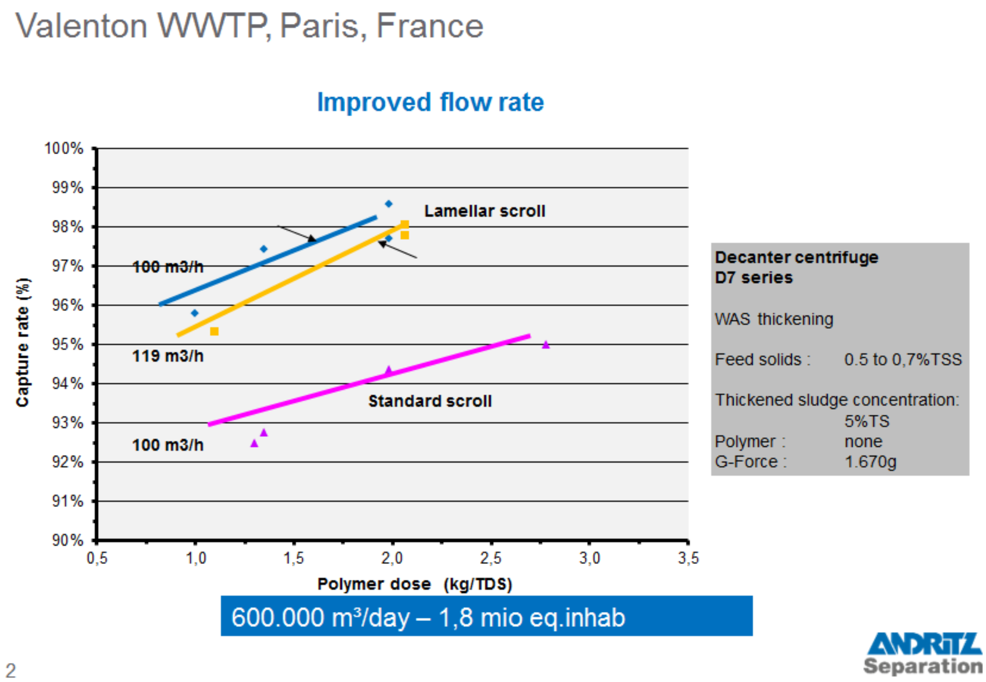


Figure 9. Case study with Lamellar scroll design

The **Easy Pond** system offers the possibility to change the pond level inside the centrifuge during operation. Variations in feed concentration or flow rate impact directly on the decanter performance and thus the reduction of the efficiency for the whole downstream bio-solids treatment process. This will increase plant costs and the human resources to manage. All these issues can be solved by integrating the ANDRITZ Easy Pond system. Fields tests with a large ANDRITZ Separation decanter (D12LL installed in Columbus WWTP) proofed that Easy Pond has more impact on thickened sludge concentration regulation than relative speed (see the figure 8).

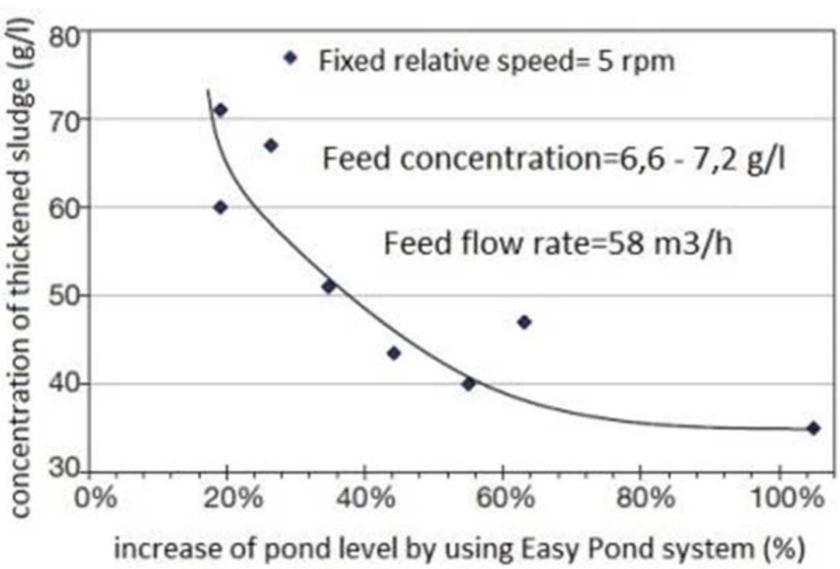
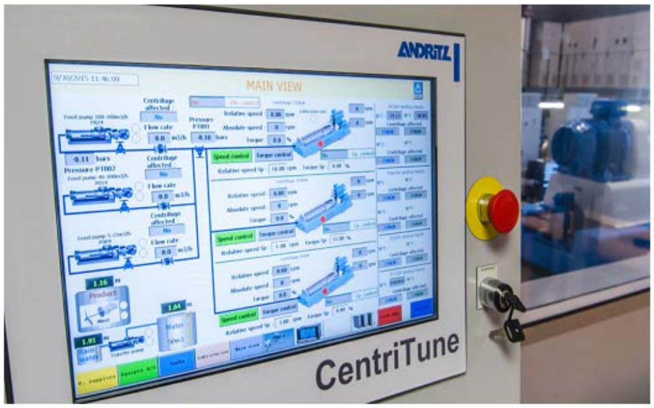


Figure 10. Action of Easy Pond system at fixed relative speed in Columbus WWTP

4. REDUCTION OF MAINTENANCE COSTS

New developments on automation lead to a better use of each equipment and participate in the reduction of total cost of ownership as our CentriTune system for decanters or our ScrewAutoBox system for screw press, preventing any mechanical failure or problem due to sensors and alarms, informing in advance Operators about the maintenance plans.



CentriTune panel

ScrewAutoBox panel

Figure 11. ANDRITZ control panels

New innovations on design as **TurboWISE** lead to a lower wear on scroll increasing its lifetime, decreasing the maintenance spare parts costs. TurboWISE system is designed to be replaced by operator on site.

ANDRITZ always focuses on easy maintenance, operation for all their equipment with easy access, on site replacement, cheap spare parts, and long life time of the full range of equipment.

5. CONCLUSION

The research and developments efforts of ANDRITZ Separation on decanter centrifuges and screw press allowed to reduce the energy consumption drastically over the last years. Furthermore the consumption of polymers has been strongly optimised by both technological progress and an increased level of automation.

ANDRITZ is your Separation specialist able to propose complete range of sludge dewatering equipment and the best solution considering project requirements.

CHAPTER V

STRATEGIES ON MEDIUM AND LONG TERMS IN SLUDGE MANAGEMENT AND TECHNOLOGIES FOR REDUCTION OF SLUDGE QUANTITIES

Difficulties In Establishing The Local Sludge Management Solutions

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Abstract
The paper describes the disposal and valorization routes of the wastewater treatment sludge management for a Romanian county. Five wastewater treatment plants are subjected to analysis in the view of the best sludge management solutions. The main routes in establishing the sewage sludge management were considered. The mid-term solution (2015 – 2019) for the wastewater treatment plants 1, 3 and 5 is land-filling as main option and the long term solution (2020-2040) of the sewage sludge management is co-processing at a cement factory in the county. For the other two WWTP 2 and 4, after the rehabilitation works and starting 2015, the sludge management solution is agricultural use. Difficulties in implementation this route are the lack of an agreement with the farmers and land owners for agricultural disposal of the sludge and the use of the sludge as a fertilizer. All the alternatives for sewage sludge management depend on two important factors: the quality of the sewage sludge (water content, heavy metals content, organic substances content) and the local conditions for land-filling, agricultural use and the presence of the co-incineration facilities. The transport of the sludge and the costs related to it represent an important decision factor in sludge management solutions.

Keywords
Sludge, management, co-incineration, agricultural use, land-filling.

1. INTRODUCTION

The disposal and valorization routes of wastewater treatment sludge are relatively limited and they are dependent on many factors, some of them independents by the possibilities of intervention of the water infrastructure operator:

- The technological endowment of the wastewater treatment plants, especially the sludge line, has an impact on the sludge properties;
- The quality of the treated wastewater - influences the properties of the sludge; this criteria mainly refers to the industrial wastewater discharged into the sewage system and consequently into the wastewater treatment plant;
- The local availability regarding the agricultural lands and the crops that are lent to sludge disposal;
- The availability of the land owners, farmers to accept the use of sludge as a fertilizer on the lands they exploit and own;
- The general properties of the land: topography, stratigraphy and quality indicators of the soils, surface water and underground water, sensitive zones, protected zones, vulnerable zones, etc;

- The availability of the surfaces designated to forestry plantation;
- The presence and the capacity of the landfills for domestic wastes;
- The facilities for incineration, co-incineration available in the area;

The analysis solutions, currently used in sludge management allow for the following routes:

- Disposal in solid wastes landfills;
- Valorization – agriculture use;
- Energetic recovery/valorization, co-incineration;
- Composting and fertilizer application.
- The paper explores/analyzes, using the study case of the sludge management in a Romanian county, the difficulties in implementing these options, based on the regulations of the National Strategy for wastewater sludge management (2012).

2. TECHNOLOGICAL EQUIPMENT OF THE WASTEWATER TREATMENT PLANTS

The five Waste Water Treatment Plants operated by the RO undergone major rehabilitation process, that affects both water line and sludge line.

In the following, the equipment of the sludge line for each of the five Waste Water Treatment Plants operated by the RO is described.

The quality and quantity parameters of the sludge generated in the Waste Water Treatment process, have represented the inlet data in establishing the solution for sludge management.

Wastewater treatment plant 1

The treatment technology foreseen in the Waste Water Treatment Plant is biological treatment with activated sludge, nitrification-denitrification process, phosphorous removal and aerobic stabilization of the sludge.

WWTP consists of the following technological objects for sludge treatment: buffer reservoir for excess sludge; sludge dewatering equipment that produces sludge with a 30 - 33% dry matter content; sludge compressor, polyelectrolyte unit.

Wastewater treatment plant 2

The technology consists of biological treatment with activated sludge, nitrification-denitrification process and phosphorous removal. The sludge line consists of the following processes:

- primary sludge concentration by gravitational settling;
- mechanical concentration of the excess sludge, by a concentrator – integrated screw press that increases the content in solids of the excess sludge from 0.8% to 6%. The chemical conditioning of the sludge is done by a completely automatic polyelectrolyte unit;

- mechanical dewatering of the digested sludge is performed by the existing installation and by two new filter press mechanical units, the polyelectrolyte preparation unit and the lime dosing control unit, to ensure a dry matter content of 35% of the dewatered sludge;
- disposal of the dewatered sludge on drying beds, for about 6 months. After this technological flow one expects to obtain a stabilized sludge with a 35% dry matter content.

Wastewater treatment plant 3

WWTP 3 consists of the following steps:

- Mechanical concentration of the excess sludge resulted in biological water treatment, by 2 screw-press concentrators, that increase the solids content of the excess sludge, from 0.8% to 6%. Chemical conditioning of the sludge in 2 polyelectrolyte units;
- Mechanical dewatering of the sludge in 2 filters press units, that increase the dry matter content up to 35%. The sludge cake will be treated with lime;
- Temporarily disposal of the dewatered sludge, on covered beds, for 6 months. Under this technological flow, the wastewater treatment plant will produce sludge with a 35% dry matter content.

Wastewater treatment plant 4

The proposed technology for the WWTP 4 consists of biological treatment with activated sludge, nitrification – denitrification process and aerobic stabilization of the sludge.

The processing flow of the sludge is identical with the one in the WWTP 3: concentration and mechanical dewatering of the sludge, temporarily disposal for about 6 months, respectively, producing sludge with a 35% dry matter content.

Wastewater treatment plant 5

The endowment and the technologies adopted for this plant are similar to the WWTP 4.

Conclusions

The start-up of the wastewater treatment plants, after rehabilitation is going to generate large quantities of sludge comparing to the present situation.

In terms of the quality of the sludge and considering the adopted technologies, one can expect a stabilized sludge with a 35% dry matter content.

This aspect will enable a sludge management by disposal; the other alternatives are still valid, but their efficiency will be reduced due to the high water content of the sludge, meaning: additional costs for transport, difficulties in disposal on the agricultural fields, reduced heating power, environmental impact.

3. ALTERNATIVES FOR SLUDGE DISPOSAL AND VALORIZATION SOLUTIONS

The predictive sludge production for the analyzed county, for each of the WWTP, a regional operator’s component, is presented in Figure 1.

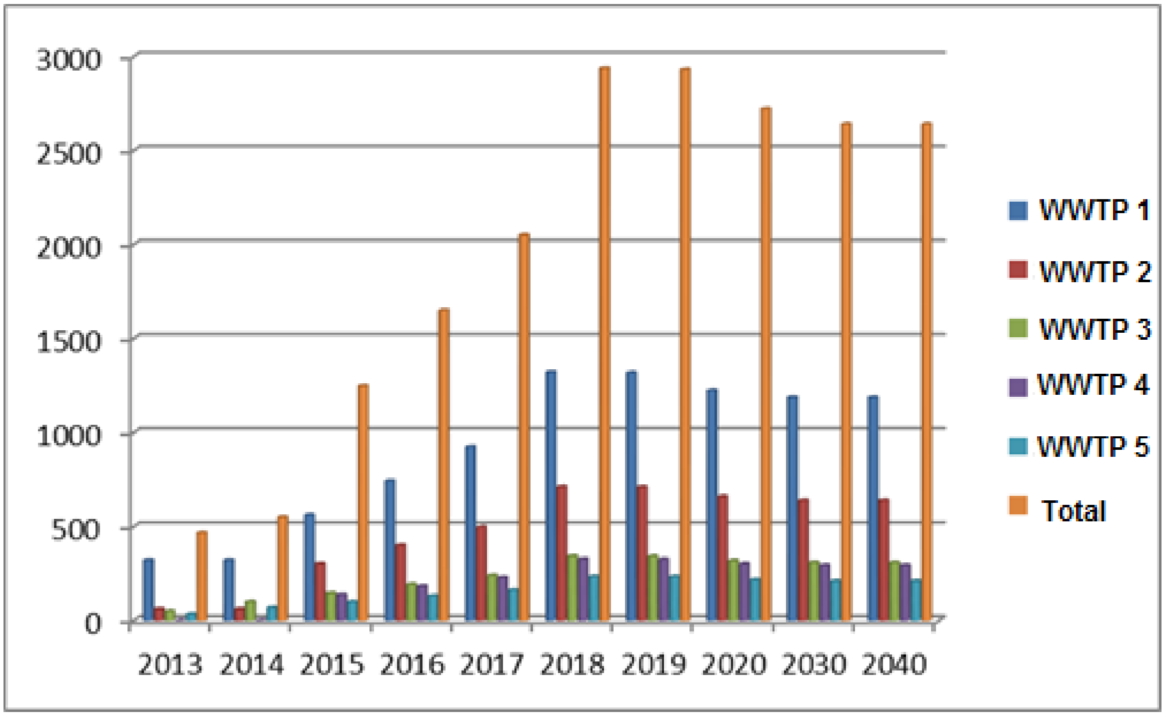

Figure 1. The predictive evolution of the sludge production for the analyzed county

In establishing the routes of the wastewater treatment plant sludge management, the following were considered:

- With respect to the local conditions of the county and considering the quality of the soil, the agricultural filed work in this county, the size of the agricultural fields and the restrictions regulated by the law, the agriculture could ensure a limited solution for sludge valorization, quantitatively; the national strategy sets for this region a maximum of 39.7% of the total produced sludge that could be disposed on agricultural fields; the maximum value accepted for this solution in the National Strategy is justified after analyzing the local conditions;
- The ecological landfill cannot ensure the disposal of the whole sludge produced in the wastewater treatment plants, if the present level of the dewatering process is maintained, referred to 35%; in the same time, it must be mentioned that for the WWTP 4 and WWTP 2 land-filling is not an effective option considering the great distance between the wastewater treatment plants and the landfill (Table 1).
- Assuming that the transportation of the sludge is performed with a 16 tones capacity sludge dump track, annually 19,632 km are completed for the entirely transportation of the sludge. Different distances and different sludge quantities for each of the WWTP are observed.
- For example, the WWTP 4, weighting 11% in the sludge production, with distances for the sludge transportation representing 22%, is located at the greatest distance from the landfill.
- The equivalent distance indicator that represents the unitary distance (km) traveled for the disposal of one tone of sludge, calculated by the ratio between the distances (km) traveled annually and the entire sludge quantity, indicates values ranging between 1.0 and 5.3.

This indicator has to be used in decision making for sludge management.

Table 1. The influence of the transportation distance on the sludge disposal

Parameters	UM	WWTP 1	WWTP 2	WWTP 3	WWTP 4	WWTP 5	Total
Produced sludge 35% DM	tones/an	3,488	1,829	971	839	660	7,788
The weighting of the sludge production	%	45	23	12	11	9	100
Distances to the landfill	km	14	28	17	42	8	
Travelled distances	km/year	6,104	6,401	2,063	4,404	660	19,632
The weighting of the travelled distances	%	31	33	11	22	3	100
The equivalent distance	km/tone	1.7	3.5	2.1	5.3	1	

- Incineration is not an option for the moment; there are no sludge incinerators in the area and the development and the operation of this kind of installation leads to financial and technical difficulties that the water regional operator is not able to commit to.
- Co-incineration in cement factories might be a solution, and that is because there are factories in the neighborhood, 60 - 70 km distance away: FCH – cement factory, that accepts sludge; the other possible routes don't provide the disposal of the entire produced sludge.

  Besides the advantages of the sludge co-processing in the cement factories, the risks associated with this process need to be taken into account. It has been demonstrated that every kind of sludge in any ratio with the raw material of the cement is not to be processed.

  The cement factories require two aspects regarding the quality of the co-processed sludge: (a) the quality of the final product to meet the standards of the cement producer; (b) an acceptable sludge heating power that the auto-combustion would be maintained.

  To relate with these requirements, the quality parameters of the sludge influenced by the WWTP operator are: the sludge water content and the volatile compounds content.

  Based on the processes foreseen in the wastewater treatment plants in the analyzed county, the sludge stabilization is accomplished up to a limit of 50% volatile substances content and a 35% moisture content, respectively.

  This product has a very reduced heating power, that can be increased only by reducing the water content, measure leading to an increase in the heating power according to the diagram presented in Figure 2.

  Accounting for 100 tones of sludge with a 50% dry volatile substance content, it might be noticed that decreasing the water content from 35% DM to 90% DM, once the sludge quantity is considerable reduced from 57 tones to 22 tones, the heating power of the sludge is also increased from 3.5 MJ/kg sludge to 11 MJ/kg, the produced sludge is a useful and attractive waste for co-processing (Figure 2).
- The production of the building materials is not a solution for the moment, considering that very small quantities of sludge are used in this process; as a result, this route will not be quantified, although the operator might use it, albeit not for the management of large quantities of sludge; it represents a solution in the alternative options, when management restrictions might limit the proposed routes.

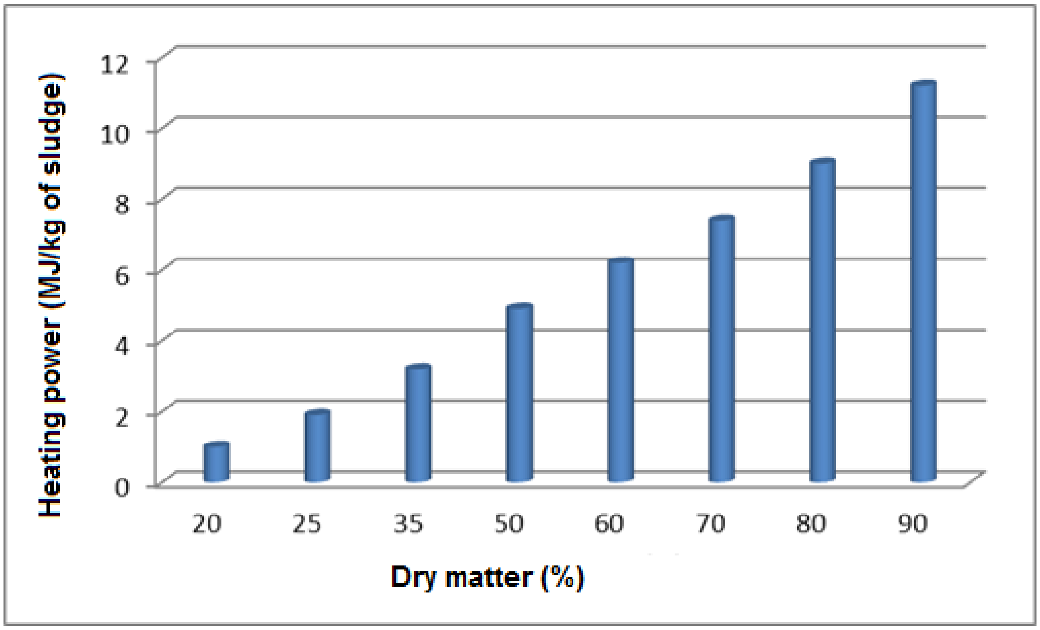

Figure 2. The dependence of the heating power on the sludge water content

- The use of sludge for forest plantation development is not going to be an alternative that the operator should choose as a solution for additional agricultural management of the sludge, when circumstances for different reasons as an agricultural option are not affordable.
- The willow plantations for energy have started to develop in Romania. Companies and farmers with enough experience continuously specialize in this field. In the county the energetic plantations have already been developed; farms for providing the stools needed in these plantations are available in the area. The energetic willow plantations need fertilizers to reach high productions; the fertilizers disposal is done initially when planting and once a year immediately after cropping; a production cycle lasts for 2 years in Romania, so that the disposal as fertilizers on a plantation can be accomplished only by two years. The sludge produced in wastewater treatment plants is a potential fertilizer in providing the nutrients. The optimal development of the energetic plantations should be completed by working together the farmer and the water operator; in this way an efficient development of this management route is achieved. There is no experience in the field in using the sewage sludge as a fertilizer on these plantations, but potentially it might be used.

4. SOLUTIONS PROPOSED FOR SEWAGE SLUDGE MANAGEMENT

The solutions proposed for sewage sludge management are briefly presented for the entire county (Figure 3). Aiming at developing multiple routes, when it is affordable and when different problems related to the technological endowment are generated, every time one route is not available another one should be a used, observing the indicator ratio proposed; these aspects follow up the conclusions resulted in the former chapter.

For each WWTP, the solutions are differentiated with respect to the following:

- For WWTP 1 the start up will be land-filling to the domestic wastes landfill starting 2015. The option is supported by the short distance comparing to the other WWTPs. After 2020, when land-filling is no longer accepted, a new route will be opened, co-incineration at the cement factory.
- For WWTP 2 the solution is agricultural disposal. For this plant and according to the conclusions in the former chapter, that the sludge transportation to the landfill has the highest specific cost and the whole quantity of the produced sludge is not going to be accepted, this route has not been developed, so that agricultural disposal is the only management solution.
- For WWTP 3 the management of the sludge starts with landfilling, similarly to WWTP 1. After 2020, when land-filling is no longer accepted, a new route will be opened, co-incineration at the cement factory.

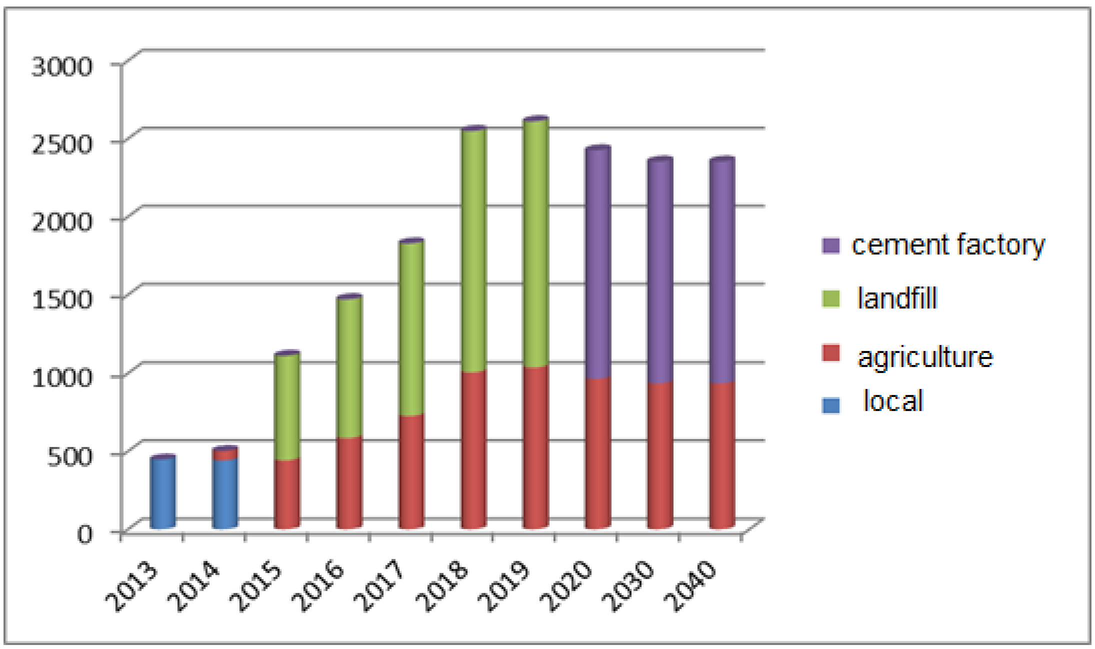

Figure 3. Solutions proposed for sludge management in the county

- For WWTP 4 a similar solution to WWTP 2 is proposed. All considerations mentioned for this plant are available in this case, too.
- For WWTP 5 a similar solution to WWTP 1 is proposed. All considerations mentioned for this plant are available in this case, too.

5. CONCLUSIONS

The sludge disposal solution for the five wastewater treatment plants operated by the RO is a combination that gathers the following routes: land-filling, agricultural disposal and co-processing in cement factories. With respect to the local characteristics of each of the wastewater treatment plant, to the local specific conditions of the county, to the necessity in ensuring a feasible management, the proposed solutions have been differentiated and customized so that to provide the best technical and economical efficiency (the best cost-effective solution).

The proposed solutions took into considerations the technological and operational evolution of these plants. Therefore the short term solution regarding the sludge management is the implementing of the existing solutions, the disposal to the existing landfills.

The mid-term solution (2015-2019) for WWTPs 1, 3 and 5 is to dispose the sludge to the regional landfill and the long term solution (2020-2040), is to co-process the sewage sludge at the cement factory FCH. The circumstances for sludge co-processing at the FCH factory are provided, since the agreement for the sludge co-processing is achieved. The operator should negotiate the detailed conditions for this cooperation and conclude the contract for the sludge delivery. For both alternatives it is important to notice that the transportation efforts are strongly dependent on the dewatering performances of the sludge (Figure 4). A decrease of the water content by 20% (from 65% to 45%) reduces the annual effort for the sludge transportation with 7000 km, a fuel economy of over 40%, respectively, that requires further analysis of the technical options in reducing the water content of the sludge. As a result of the above, the analysis of the dewatering solutions is recommended, solar drying being one of the possible option, with the disadvantages that it must be carefully analyzed in the Feasibility Study for the alternatives. This alternative needs wide areas for the solar installation, provides with an insufficient drying of the sludge and without an adequately sludge stabilization. Another disadvantage of this option is that the workers are exposed to no sanitary working conditions.

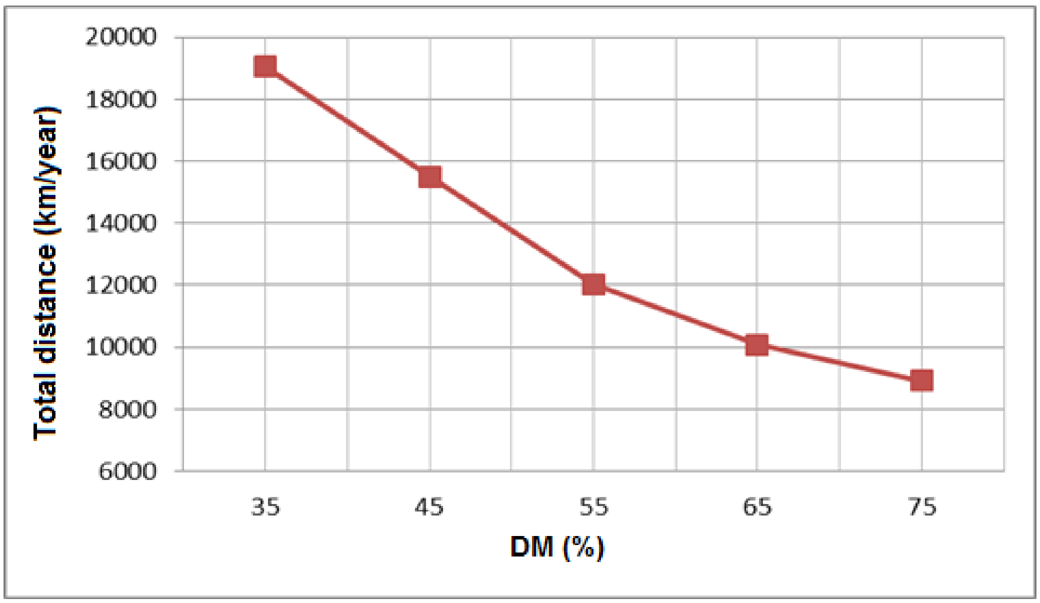

Figure 4. The transport efforts dependence on the sludge water content

For the sewage sludge from WWTP 2 and 4, after the rehabilitation works and starting 2015, the sludge management solution is agricultural use. This route could have difficulties in implementation because up till now there isn't any agreement/acceptance from the farmers and land owners regarding the agricultural disposal of the sludge and the use of the sludge as a fertilizer.

It must be mentioned that in the national strategy of the sludge management, in selecting the optimal solution, the economical criteria together with other criteria were taken into account. In this case, it is supposed that the identified solution in the national strategy is the optimal one for the RO, with the necessity of its re-approval, in the view of the relevant information that come into sight after the elaboration of the Feasibility Study and the National Strategy.

The recovery routes assume the implementation of further sludge treatment processes. In the case of WWTPs 1, 3 and 5, sludge drying is required (thermal drying for WWTP 1, solar drying for WWTPs 3 and 5) in accomplishing the quality needs of the sludge in the cement factories and in cutting the costs for transport and processing. One should note that through drying, the quantities of the transported sludge decrease, hence the transportation costs and the disposal costs are reduced, by the tariff levied by the manager of the cement factory.

The investments in solar systems and thermal systems for sludge drying, together with the operational costs depend on the plant capacity. The costs highlight the fact that the investment costs for the solar systems raise linearly with the plant capacity, and the investment costs for thermal systems are relatively constant up to a specific capacity of the plant (aprox. 50,000 equivalent inhabitants) and after this capacity increase rapidly. The operational costs are relatively low, increase slightly, almost linearly for the thermal systems and very fast for the solar systems. Therefore the solar systems are recommended for the small wastewater treatment plants up to 20,000 – 30,000 population equivalent.

In the case of the sludge produced in the wastewater treatment plants 2 and 4 it is recommended the sludge composting in the view of delivering a more attractive sludge for the interested farmers. One solution would be the use of semi-permeable membranes (Figure 5). The structure of the membrane enables an exactly moisture control providing its optimizing so that the degradation processes of the wastes meet the optimal conditions.

Figure 5. Platforms for sludge composting using semi-permeable membranes

The micro-porous structure of the membrane provides with a screen for microbes and pathogens removal. The membrane tests have shown that the microbes are reduced and destroyed over 99%, ensuring safety and sanitary working conditions for the workers and the neighborhood areas. The membrane conserves higher pressures than the atmospheric pressure in the confined zone, providing homogenous temperature and air circulation inside the wastes submitted to composting, for a control and optimal process. The pathogens contained in the wastes are destroyed during this process. The transport of the compost is more manageable, without any preventing measures as in the case of disposal and agriculture use. The good practices should be the same in the case of soils transportation. The compost could be disposed on the farmland without much caution, optimizing its transport and use. The disposal areas must be built and used in an optimal way with no impact on the neighborhood.

The recovery of the sludge at the cement factory is a good solution, but in co-processing the ratio of the sludge is reduced, to keep the quality parameters set in the process. This option is just an alternative option, without significant effects in sludge management.

The use of the sludge for development of the forest plantations is not a recovery route at this moment for large volumes of sludge; as a result of the analyzed data, in the past years no reforestations on large surfaces have been done in the county. The use of the fertilizers on the energetic plantations is not needed, but this practice has economic benefits by way of high wood production. The sewage sludge, by means of nutrients content could be a good substitute for chemical or natural fertilizers.

The disposal of the sludge can be done:

- initially when planting by incorporating the sludge in the soil;
- every two years, after cropping the energetic willow; the cropping of the willow is made in winter, when the moisture content of the willow stalks is minimum (30 – 40%); considering the willow grows very fast when the weather is getting warm and the access of the transport equipments, the disposal and the incorporation in the soil of the sludge could affect the growing of the plantation, the disposal of the sludge should be done immediately when the weather affords it; at present there are no definite procedures for the disposal of the sludge on these plantations and after cropping, so that to meet the regulations regarding soil incorporation.

The sludge can be disposed on these lands only after cropping the willow production; in Romania it is recommended cropping every two years; therefore, although multiple plantations are to develop, the sludge could be used in this route only once a year.

In conclusion, the alternatives for sewage sludge management depend on two important factors: the quality of the sludge and sludge processing technology in WWTP and the local conditions, specific to each of the WWTP.

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Sludge Management Strategy in S.C. RAJA S.A. Constanța

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Abstract
Given the high demand of energy for WWTP operation, RAJA is concerned in harnessing the energy potential of sludge and cover a percentage of energy needs by using biogas from anaerobic sludge digestion and producing electrical and thermal power through cogeneration units. Such a solution is now promoted by SC RAJA SA in Constanta South WWTP and has included it in the Feasibility Study prepared for accessing European funding. The solution consists in transporting the sludge from WWTP Constanta North and WWTP Eforie South to WWTP Constanta South and processing all the amounts here. Thermal Hydrolysis Process will be introduced prior to anaerobic digestion of sludge. Expecting results: increasing the digestibility of sludge by 20-30%, increasing biogas production by 30%; reducing sludge quantity and increasing sludge quality in terms of sanitation, reducing operational costs.

Keywords
Sludge management, energy recovery, thermal hydrolysis of sludge.

1. INTRODUCTION

SC RAJA SA Constanta is the largest regional operator in Romania in the field of drinking water supply and sewerage and operates in localities that are situated in seven counties.
In the field of wastewater, SC RAJA SA handles wastewater treatment in 15 WWTPs. Through Sectorial Operational Programme 2007-2013 financed by European cohesion funds 8 WWTP have been completely rehabilitated and modernized and 7 WWTPs were newly built (see Figure 1).

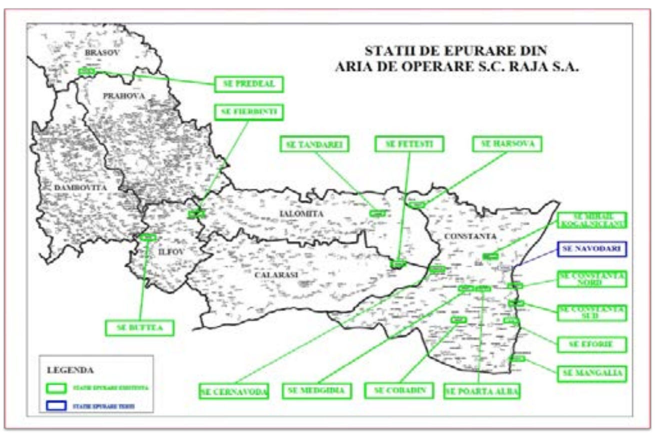


Figure 1. WWTP operated by S.C. RAJA S.A.

RAJA is also promoting a new project through Operational Program for Large Infrastructure 2014-2020; the project includes construction of 5 new WWTPs in rural agglomeration with less than 10,000 P.E.

2. SLUDGE MANAGEMENT

Sludge quantities

In order to manage the sludge issue, S.C. RAJA S.A. has drawn up a strategy for short, medium and long time, which provides a framework for planning and implementation measures to manage growing volumes of sludge from existing, rehabilitated and new WWTPs. It has been taken into account sludge quantity and quality generated in each treatment plant and also the local specificity of the station areas. Sludge quantities for existing facilities are detailed in Table 1.

Table 1. Sludge quantities and quality for existing WWTP

No.	WWTP	Sludge quantity		Dry solids	Notes
		m^3/day	m^3/year	%	
1	Constanta Sud	40	10560	25.2	registered data for WWTPs operation in year 2015
2	Constanta Nord	30	7920	25.9	
3	Eforie Sud	10	2640	26.1	
4	Mangalia	6	1584	25.2	
5	Cernavoda	1.2	317	24.5	
6	Poarta Alba	1.8	475	25.6	
7	Medgidia	19	4940	20	Designed parameters
8	M. Kogalniceanu	3.7	962	25	
9	Fetesti	16	4160	22	
10	Tandarei	3.1	806	20	
11	Harsova	3.5	910	25	
12	Fierbinti	1.7	442	20	
13	Cobadin	1.9	494	25	
14	Buftea	11.7	3044	25	
15	Predeal	4.46	1159	21	
TOTAL		**154**	**40413**	**20-26 %**	

For wastewater treatment plants proposed to be achieved through the next project, in the Feasibility Study the following quantities of sludge have been estimated (see Table 2).

Table 2. Sludge quantities and quality for designed WWTP

No.	WWTP	Capacity P. E.	Quantity (m3/day)	Quantity (m3/year)	Dry solids (%)
1	Corbu	62,000	summer – 6,027	2021,38	25-35 %
		44,000	winter – 5,378		
2	Baneasa	2,800	0,336	104,83	
3	Negru Voda	3,600	0,514	160,37	
4	Cazanesti	2,500	0,322	100,46	
5	Jegalia	3,000	0,387	120,74	
	Total	**55,900**	**7,59**	**2507,79**	

Sludge management strategy

In developing the strategy for sludge management at S.C. RAJA S.A. have been considered a number of issues, including:

- Legal requirements: compliance with European and National regulations;
- Specific features: sludge quantities and characteristics, soil characteristics;
- Protection of aquifers and vulnerable watercourses;
- Sludge management costs;
- Minimizing risks to health and environment.

Sewage sludge management at S.C. RAJA S.A. water company consists at the present time in the following:

- Aerobic or anaerobic stabilization, dewatering and storage in sludge deposit owned by the company - applies to almost all sludge;
- Use as fertilizer in agriculture - implemented at pilot level in 2015;
- Sludge drying and mixed storage together with household waste in municipal deposits - generally applicable in rural areas.

In the future the following variants will be used:

- Energy recovery with higher efficiency by using thermal hydrolysis (THP - Thermal Hydrolysis Process) and then sludge disposal or using as a fertilizer;
- Energy recovery through co-incineration in combustion plants (ex. Cement plant Lafarge);
- Use as fertilizer in agriculture.

3. SLUDGE THERMAL HYDROLYSIS

Thermal Hydrolysis Process (THP) is a technology for the treatment of sewage sludge prior to anaerobic digestion. THP is a process combining high-pressure boiling of sludge followed by a rapid decompression.

This combined action sterilizes the sludge and makes it more biodegradable, which improves digestion performance. Sterilization destroys pathogens in the sludge resulting in it exceeding the stringent requirements for land application (agriculture).

In addition, the treatment adjusts the rheology to such an extent that loading rates to sludge anaerobic digesters can be doubled, and also dewatering ability of the sludge is significantly improved.

Study case: WWTP Constanta South

Given the high demand of energy for WWTP operation, S.C. RAJA S.A. is concerned in harnessing the energy potential of sludge and covering a percentage of energy needs by using biogas from anaerobic sludge digestion and producing electrical and thermal power through cogeneration units.

Such a solution is now promoted by SC RAJA SA in Constanta South WWTP and has included it in the Feasibility Study prepared for accessing European funding.

The solution consists in transporting the sludge from WWTP Constanta North and WWTP Eforie Sud to WWTP Constanta South and processing all the amounts here.

Stage I – Sludge Homogenization - Primary sludge is mixed with excess and thickened / dewatered stabilized sludge. A homogenous mixture of sludge is obtained with 16-18 % DS and 40-50 % VS; it will be comprised of three types of sludge, as it is shown in Table 3 below.

Table 3. Sludge quantities and quality to be processed in WWTP Constanta South

Origin	**Sludge Type**	**Medium Quantity (t/day)**	**Dry substance (%)**	**Organic substance (%)**
Constanta North WWTP (AAO technology)	Dewatered and aerobically stabilized sludge	30	25%	55-62%
Eforie South WWTP (SBR technology)	Dewatered and aerobically stabilized sludge	10	25%	40-43%
Constanta South WWTP (AO technology)	Primary sludge + excess sludge (not stabilized)	1333	1%	47-56%
		250	5%	54-61%

Stage II – Thermal Hydrolysis – consists in three phases:

a) homogenization, fermenting and preheating up to 80°C – in the first tank (pulper);

b) thermal hydrolysis at 165°C and a pressure of 7 bars, for 30 minutes – in the second tank (reactor); the organic substance is solubilized (COD), mainly as volatile acids (the concentration may reach 50,000 mg/l);

c) the cooling of the sludge at 102 °C and the pressure drop to the air pressure level - in the third tank (flash tank); the pressure change leads to an additional lysis of the cells, which induces a further deep drop of the sludge thickness.

Stage III – Mesophyll Anaerobic Fermenting - the hydrolysed sludge is cooled down at 37-40 °C before entering the digester. For the mesophyll anaerobic fermentation –will be used the existing tanks.

Stage IV – Dewatering - Down to 35-40% DS – is done with the help of existing technology and equipment. The diagram in this case (including energy balance) is presented in Figure 2a.

Stage V – Drying (optional) – After dewatering the sludge is drying up to 90% DS through the use of a conveyer system – the conveyor belt is fed with a layer of homogenous sludge through which goes a drying air flow. The diagram in this case (including energy balance) is presented in Figure 2b.

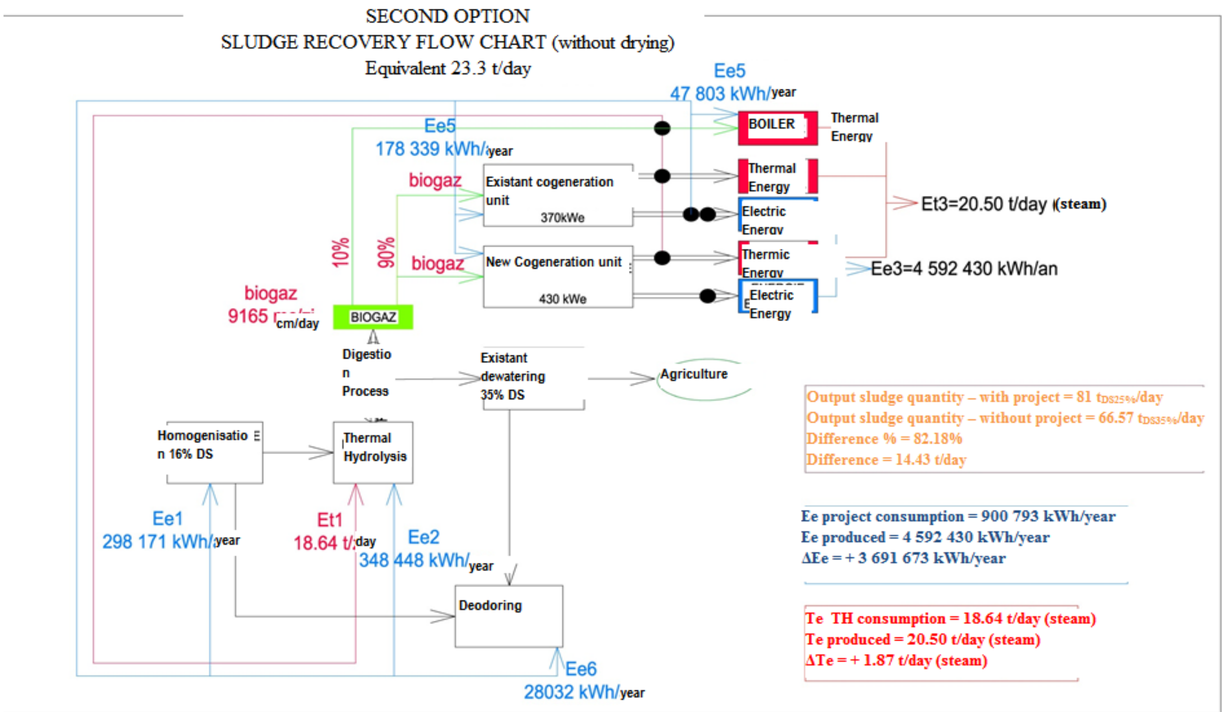


Figure 2a. Diagram for sludge processing in Constanta South WWTP (without drying)

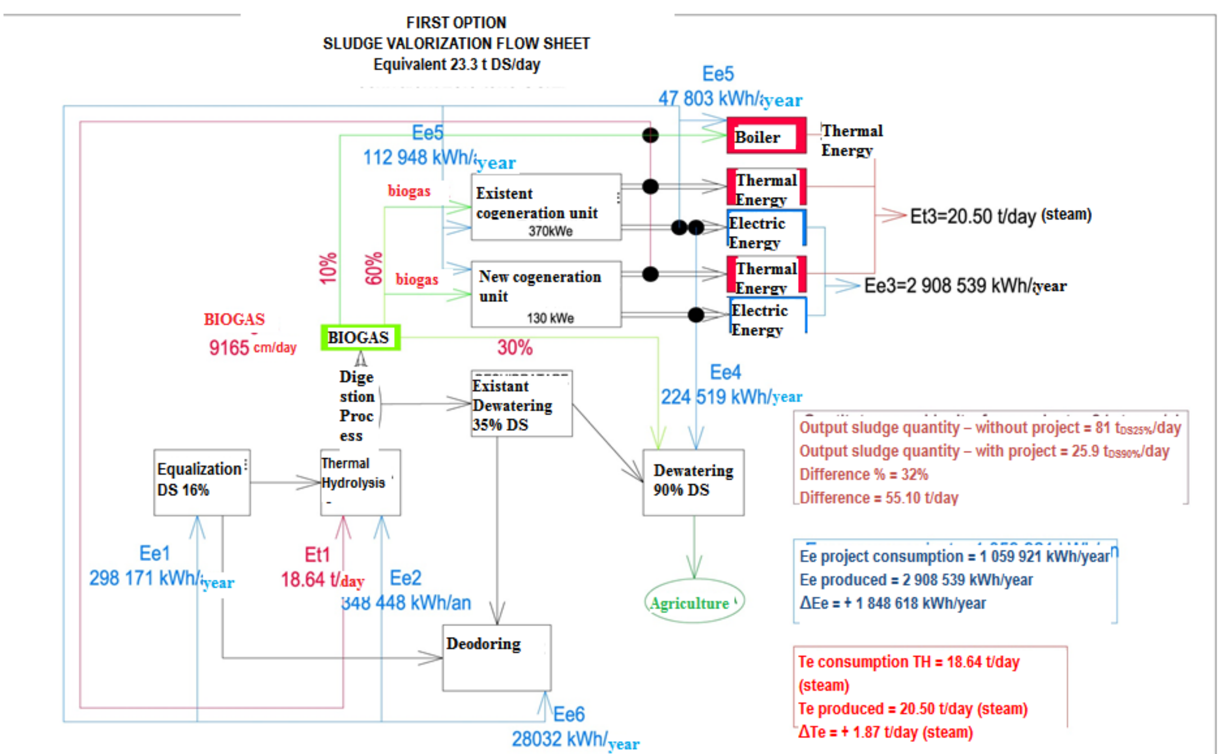


Figure 2b. Diagram for sludge processing in Constanta South WWTP (with drying)

4. CONCLUSION

Expecting results of THP implementation:

- Reducing by 20-60% the sludge quantity resulting at the end of the treatment process (it depends on the chosen technological solution - with or without drying);
- Increasing the digestibility of sludge in the digesting tank by 20-30%, due to the increase in the percentage of soluble organic matter and decrease in viscosity by THP;
- Increasing biogas production by 30-50%;
- Producing a larger quantity of biogas generates larger amounts of electricity and thermal energy in the cogeneration unit; within normal operation and load conditions, the thermal energy generated by the cogeneration units will cover the steam demand for the thermal hydrolysis process and for anaerobic digestion, and the electricity can cover up to 80% of the amount needed to operate the plant;
- Improving sludge quality, in order to use/recover it in agriculture – the result is a valuable biologic fertilizer with no microbiologic contamination risk;
- Reducing operating costs for the whole treatment plant (electricity costs, sludge transport and storage costs, environmental taxes, etc.);
- Compliance with the EU Directives on environmental protection, especially waste management – applicable to the wastewater treatment plant sludge.

Developing and implementing a strategy for sustainable sludge management is now a major goal for S.C. RAJA S.A.; that is why the company makes great efforts to ensure resources for achieving this objective.

Technologies For Reduction Of Sludge Quantities Within The Waste Water Treatment Plants

Mihălțan Pop Radu

Abstract
This work describes some ways to reduce the amount of sludge produced in sewage treatment plants and presents a summary of the technologies that can treat sludge from stations in three different sections of the sludge line. Within this work is also a presentation of the potential effects that these technologies may have on the sludge produced in the Alba Iulia treatment plant.

Keywords
Dehydration, centrifugation, incineration.

1. SLUDGE VOLUME REDUCTION WITH CENTRIFUGE TECHNOLOGY

This work presents the method of sludge quantity reduction with centrifuges, technology that is working at the waste water treatment plant in Alba Iulia.

The plant, having potentiality of 84000 PE, has a capacity up to 1437 m³/h of wastewater in dry weather and up to 2627 m³/h in rainy weather conditions. This plant receives mixed waters (it treats both domestic waste water, industrial and rainwater) and includes mechanical step, biological, eventually chemical ($FeCl_3$ against P peaks) and biogas production line.

Since its production in the plant`s processes, the sludge in used in order to obtain the biggest advantages for the plant, both if it is used and recirculated in the aeration basin for the biological stage or if it is used to be thickened and fermented to obtain biogas.

Regarding the sludge treatment for fermentation, in this step we find a first method of reducing sludge volume, namely sludge thickening in the gravitational thickener. The gravitational thickener is the circular basin where the sludge gets collected from the primary clarifier`s bottom (a solid content concentration between 3-10%) and where the sludge, under its own weight, gets thickened, becomes more dense and in this way its volume is first reduced (after gravitational thickening the sludge has a solid concentration varying in the range of 4-15%, 11.47% in media at Alba Iulia). From the gravitational thickener the primary sludge is pumped in the digester for fermentation. Moreover, depending on the solid content, the primary sludge gravitationally thickened can be pumped directly in a storage tank, through a by-pass, not being introduced in the digester.

The excess sludge resulting from the secondary clarifiers is homogenised in the homogenization tank, from here it passes through a second volume reducing method, the mechanical thickening, a process that is obtained using appropriate mechanical thickeners. At the entrance of the mechanical thickeners the excess sludge from the homogenization tank has a solid content between 0.73-2%, 0.9% in media at Alba Iulia and after thickening it has a solid content between 5-6%, 5.5 % in media at Alba Iulia.

From the mechanical thickeners the sludge is pumped in the digester where it is mixed with primary sludge gravitationally thickened and with the recirculated sludge, it ferments about 27 days at a temperature of 35^0 C for obtaining biogas used in a cogenerator for electricity/heat production and as fuel for heating boilers.

After fermentation, the digested sludge (solid content between 2.5-6.5%, 5.7% in media for Alba Iulia) is discharged into a storage tank from where it is pumped to the centrifuges for dewatering and volume reduction.

For reducing the digested sludge volume, at the Alba Iulia Plant are used mechanical dewatering units operating a physical separation of the solid fraction from the supernatant, with the final result of improving transport, storage and final disposal conditions.

The sludge dehydration is mechanical, performed by a (1+1) drying units with gravitational discharge of the supernatant (Figure 1).

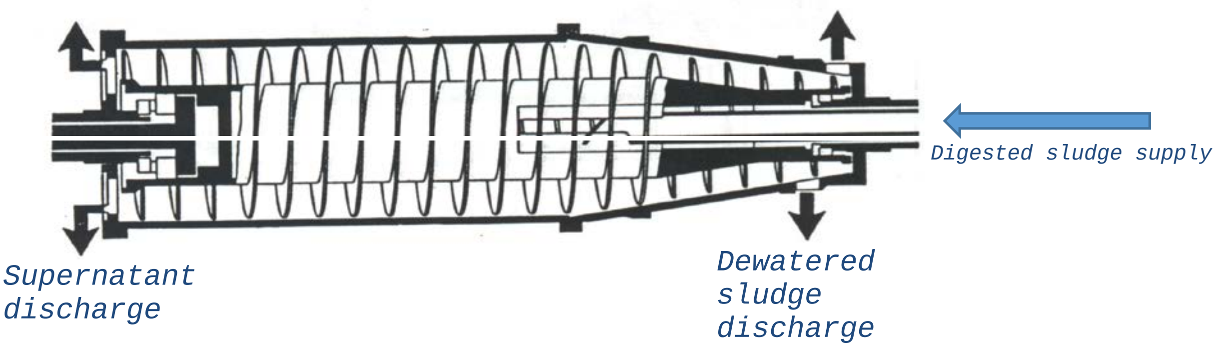
The dewatering equipment is composed of:

- (1+1) centrifuges for digested sludge dehydration with the capacity of Q=7 mc/h;
- 1 plant for (both granular and liquid) polyelectrolyte preparation with capacity of 1000 l / h;
- (1+1) polyelectrolyte dosing pumps with a max flow rate of 1000 l/h - dose the polymer/ water solution at the injection point of the dewatering equipment;
- 1 horizontal collecting sludge conveyor, L = 3.00;
- 1 diagonal conveyor for sludge discharge outside the dewatering building, eventually also conditioned with lime, L = 8.00 m.

Figure 1. Dehydration unit with gravity discharge of supernatant and sludge

The working principle of the centrifuge is completely different compared to other methods of sludge volume reduction. With centrifugation, the centrifugal force acts instead of gravity like in case of gravity thickener. In this case the centrifugal force created in a conical-cylindrical bowl ensures and increases the separation of the liquids from the solids parts of the sludge, at high rotation speed. The sludge particles are pressed against the rotating bowl and conveyed out of the centrifuge by a screw conveyor that rotates at a slightly different speed than the bowl. Then, through the system of screw conveyors under the centrifuges, the dewatered sludge is finally discharged into the sludge container.

2. CENTRIFUGE OPERATION PRINCIPLE



The feed enters the decanter at the intersection of the conical and the cylindrical part of the bowl through a central feed pipe in the hollow drive shaft. After leaving the feed pipe, the feed suspension is distributed into the rotating liquid in the bowl and smoothly accelerated to the full rotational speed. The centrifugal force makes the solids settle at the bowl shell. The screw conveyor continuously transports the solids toward the conical end of the bowl and through conical bowl part.

The separation takes place throughout the total length of the cylindrical part of the bowl, and the clarified liquid discharges at the large end where it flows over the rim of exchangeable and/or adjustable plate dams or power tubes. The solids are discharged from the small end by centrifugal force through outlet openings.

The decanter is driven by an electric motor. The motor shaft carries a drive pulley, and motive power is transmitted through V-belts to the bowl pulley to drive the bowl.

The torque measures the pressure of the sludge on the screw. This pressure creates torsion on the screw axis, which is measured to give the torque value. The higher the sludge pressure on the screw, the higher the torque.

Torque and relative speed are linked. An increase of the relative speed will lower the torque and the sludge will be extracted more quickly.

The supernatant resulted from dehydration is discharged by gravity in the underground supernatant tank. (Figure 2).

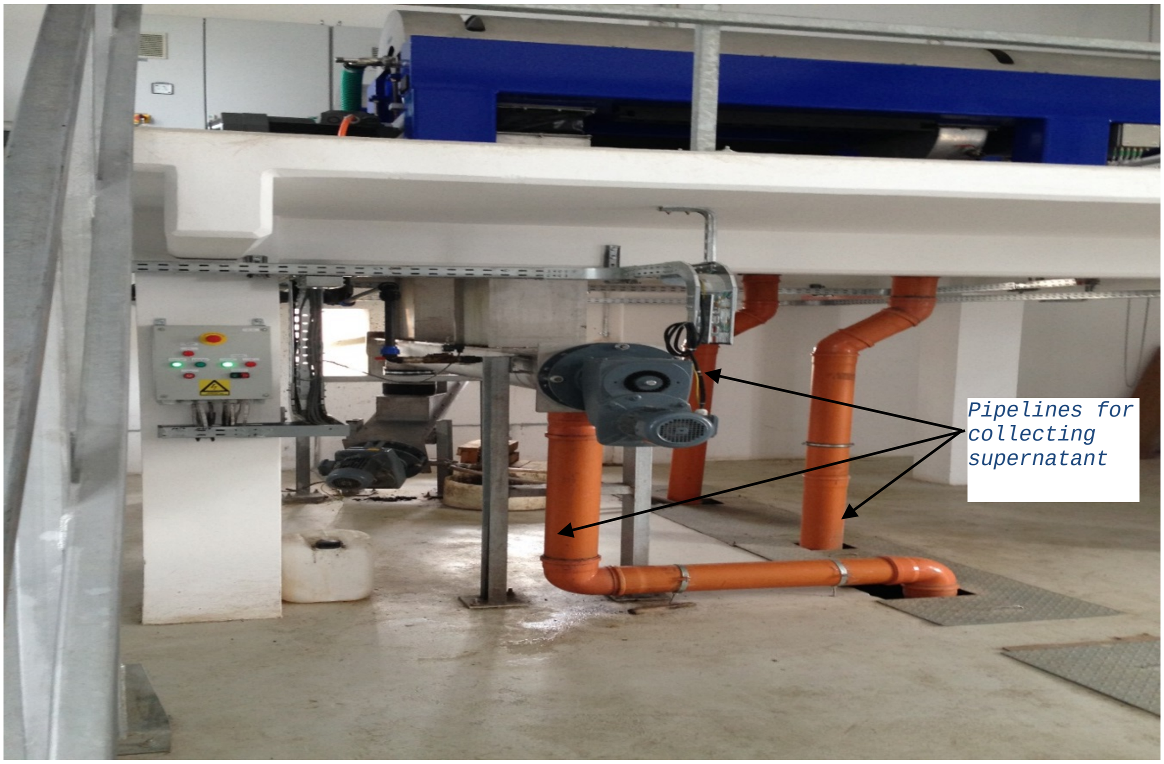


Figure 2. Supernatant collection system, by gravity towards the external supernatant station

The dehydrated sludge is discharged with two automatic screw conveyors in containers positioned outside the dewatering building. (**Figure 3**).

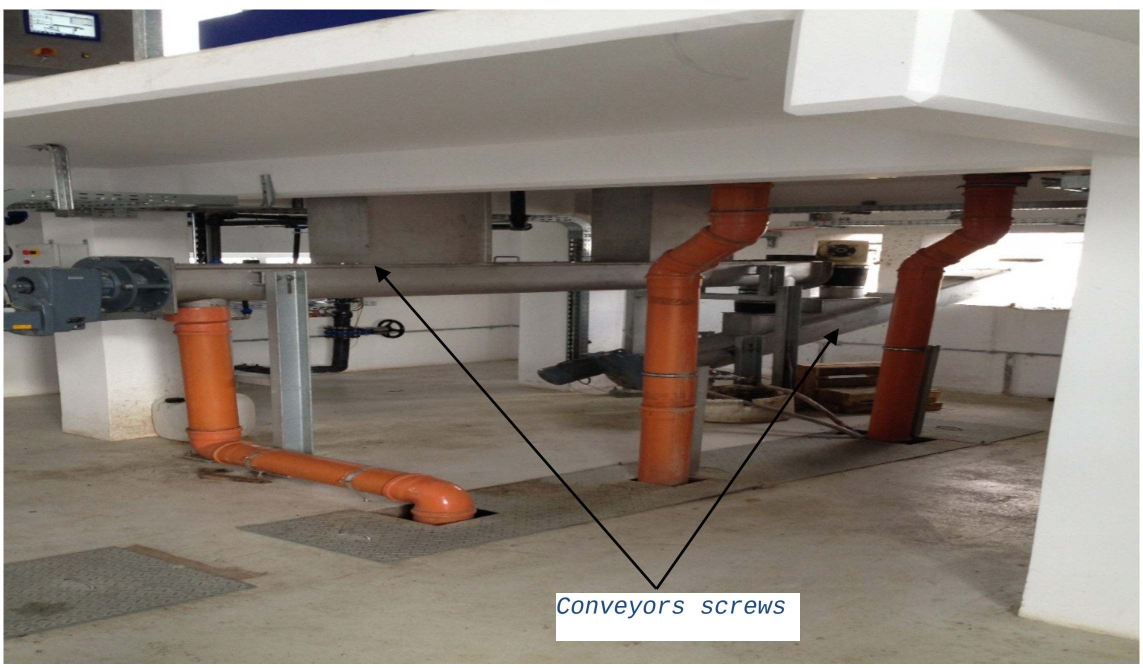


Figure 3. Screw conveyors for sludge extraction and discharge

Before starting the centrifuge are made analyses of the solid content for digested sludge from the storage tank. Its concentration should be in the range 2.5-6.5%. It is then set the necessary concentration of polymers, also post-evaluating the final result of the dewatering process, with analysis of the solid content of the sludge present in the external containers too. After the initial phase when the centrifuges are supplied with sludge and polymers at minimum flow, the flow of sludge is constantly increased from 2 mc/h until to a maximum of 9 mc/h.

Experimentally, after making a lot of analyses for the solid content of the digested sludge, it was concluded that the process of sludge fermenting in the methane tank and the supply program with fresh sludge of the methane tank have an influence on the concentration of digested sludge solid content collected in the storage tank that will supply the centrifuges. We noticed that in the second part of the day the sludge feeding the methane tank has a decreasing solid content concentration. For this reason was decided to reduce by 1 mc/h the feed rate of centrifuges during this second half the day, in order to be able to achieve always the wanted dewatered sludge solid concentration (28%).

Considering that during the sludge centrifugation is produced a considerable quantity of supernatant (~62 mc/day), it is necessary to have in this supernatant a maximum concentration of solid content of 0.2% (recommendation from the manufacturer), in order to reduce the solids and the eventual P and N charges coming back to the inlet of the station. On the other hand this will of reducing the solids in the supernatant of the dewatering treatment determines also a higher attention at the consumption of polymer for dehydration, since a bigger dose of polymer brings to a clearer supernatant but implies also higher operating costs for the plant.
In normal operation the concentration of the solid content of the sludge dehydrated with centrifuge and use of polymer is 28% (Figure 4); the difference up to the required 35% solid content is assured by the installation of the lime dosing system which is mounted between the centrifuge and the sludge containers.

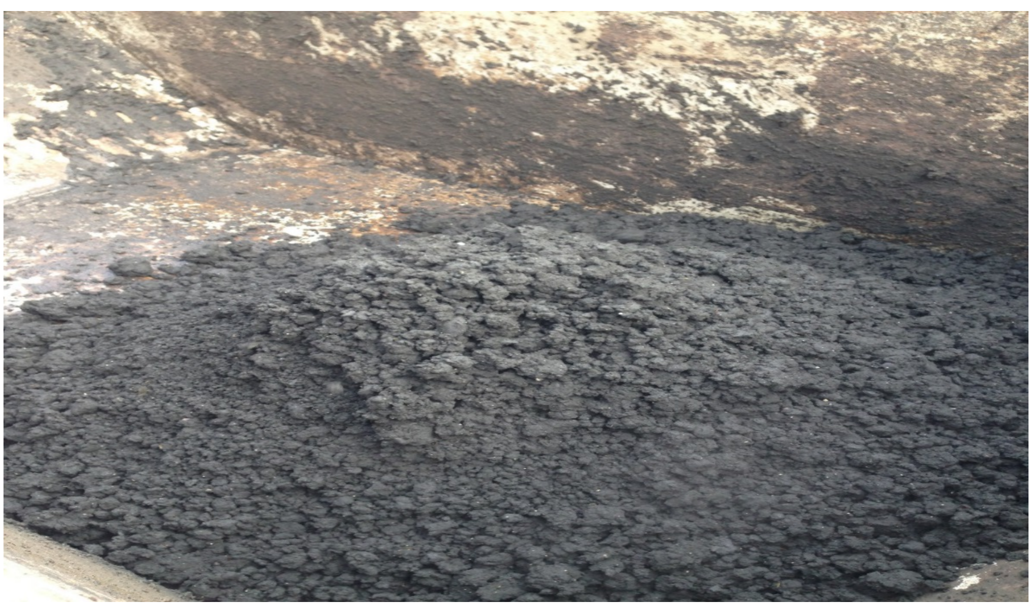


Figure 4. Dehydrated sludge with centrifuge, having 25% solid content

As a statistic in Alba Iulia in one day with the centrifuges were thickened 70.57 tons of 5.03% solid content digested sludge, obtaining 13.72 tons of 25.72% solid content dehydrated sludge, using 69.57 kilos of polymers.

As already said for obtaining a dehydrated sludge with a solid content from 28% to 35% after the centrifugal treatment, the sludge is conditioned with lime in powder. This process is assured by the lime dosing installation mounted between the centrifuges and the sludge container. Depending on the solid content of the sludge dehydrated with the centrifuge, value measured in laboratory and set in SCADA, the lime dosing of the sludge is automatically calculated by the PLC and applied at the rotary valve on the feeding silo, in order to obtain the wanted minimum 35% solid content (Figure 5).

Figure 5. Lime dosing installation

We analysed the evolution of the lime dehydrated sludge in a period of 7 days watching every day the solid content concentration of the same sample of sludge. This method consisted in analysing daily the solid content of the sludge. The conclusion after 7 days was that the sample which had in the first day 35% solid content, had after in the 7-th day the solid content of 82%. This made us to notice that the sludge treated with lime is in constant dehydration and consequently reduces its volume during the time. In the Alba Iulia station there is also a large concrete platform (partially covered and draining to the internal sewer) where the dewatered and conditioned sludge can be disposed and let further dehydrate during the time.

3. MEDIUM AND LONG-TERM STRATEGY

Another potential method to reduce the volume of sludge of the treatment stations, that we intend to implement in our company, is the wastewater treatment and purification with Eco-Tabs effervescent tablets. These tablets are a combination of minerals and chemicals that react with water and generate oxygen saturation, and of a mixture of 14 aerobic bacteria that are effective in removing organic matter, fats, oils.

These tablets are produced with the aim of reducing the values of parameters characteristic of treated wastewater required by the NTPA 001 (pH, TSS, BOD5, COD, ammonia, phosphorus, etc.) so that they may be within the legal limits. A potential effect of the treatment process with such pills is also the reduction of the amount of sludge produced by sewage treatment plants after wastewater treatment.

In this regard we chose inside the company a wastewater treatment plant that does not have parameters exceeding the NTPA 001 values in order to try a reduction of the sludge volume with this method.

The objectives proposed by the private company contacted are a minimum 75% of excess sludge quantity reduction and transport/elimination costs, maintaining/improving treated water indicators at the exit of the plant and reducing the total cost of the plant, together with lower consumption of polymers, $FeCl_3$, electricity (sludge line and aeration basin).

This procedure involves the manual application of tablets and Eco-tabs bags. This treatment is done directly in the biological reactor.

Now we are at the level of completing the formalities for the acquisition of this service.

In addition our company analyses also other possible and optimal ways that can be implemented in wastewater treatment regarding the reduction of the sludge volume produced and the increase of the efficiency of the treatment process with the lowest cost.

Modelling Of Combustion And Co-Combustion Processes Of Mineralized Sludge From Wastewater Treatment Plants

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Abstract
This paper presents the modelling of different solutions identified for the combustion and co-combustion processes of sludge from Wastewater Treatment Plants. There are evaluated the reference models for the combustion mechanisms of sludge and there are taken into consideration several possible solutions for increasing the efficiency of combustion and co-combustion processes and minimization of pollutant emissions as integration of afterburner systems, stratified combustion on grates and gas co-firing.
Preparation of mechanically dewatered sludge resulted after the methanogenic process is described, as well as the result of previous assessments of composition of emitted pollutants and their concentrations in the off gas resulted after the combustion processes in a fluidized bed reactor of Constanta South wastewater treatment plant sludge, results that were taken into consideration in the modelling of the identified solutions. The current research activities have been carried out under the framework of the development of innovation support services of Cluster MEDGREEN and are aiming the conceiving of an innovative technology for incineration of sludge and recovery of energy.

Keywords
Sewage sludge, combustion, modelling.

1. INTRODUCTION

In the current context of demographic development, with the tendency to population concentration in urban agglomerations, the problem of sludge management is becoming an important challenge for the sustainable development of the society.

Within the MEDGreen+ project there were identified different solutions for the improvement of combustion and co-combustion processes of sludge from waste water treatment plants.

During the study were, first evaluated the reference models for the combustion mechanisms of sludge from the wastewater treatment plants and were investigated different solutions for increasing the efficiency of combustion and co-combustion processes and minimization of pollutant emissions.

During the last years a substantial progress and diversity observed in the approach to the problems dealing with the development of sludge treatment processes in the wastewater treatment plants.

As it might be seen in Figure 1, the tendency of implementing sludge incineration is present in all EU member countries.

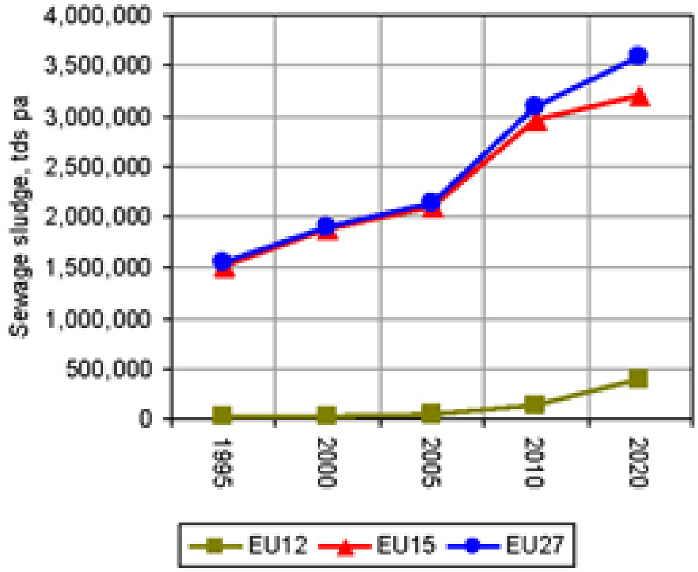

Figure 1. Tendency of sludge incineration in EU member countries

In the next paragraphs there are described the results of previous assessments of composition of emitted pollutants and their concentrations in the off gas resulted after the combustion processes in a fluidized bed reactor of Constanta South wastewater treatment plant sludge, results that were taken into consideration in the modelling of the identified solutions.

2. EVALUATION OF POLLUTANT EMISSION IN SLUDGE COMBUSTION

The Waste Water Treatment Plant (WWTP) from Constanta, Romania is a typical urban plant that is processing urban waste water. In the Southen area of Constanta, where the WWTP is processing the water, there is no *major* industrial factories, so the water is resulting mainly from households activities.

The sewage sludge is a sample of the mechanically dewatered sludge (ca. 70-75% moisture) resulting after methanogenic digestion process.

The samples were fed into a laboratory scale fluidized bed reactor with a 4 cm height quartz sand bed material (approx. 75 g), sieved in the nominal size range 315-400 μm.

The off gas that resulted from the combustion processes was analyzed with a non dispersive IR (ND-IR) spectrometer and with an FT-IR device in order to determine the CO and CO_2 and with paramagnetic measurement to determine the O_2 consumption.

The experiments were driven at different combustion temperatures 700, 800 and 900 °C to follow the influence of temperature change on the combustion process for single and multiple particles combustion processes for every type of sample.

For the sludge pellets it was performed a thermo gravimetric analysis (Figure 2) and a combustion test (Figure 3).

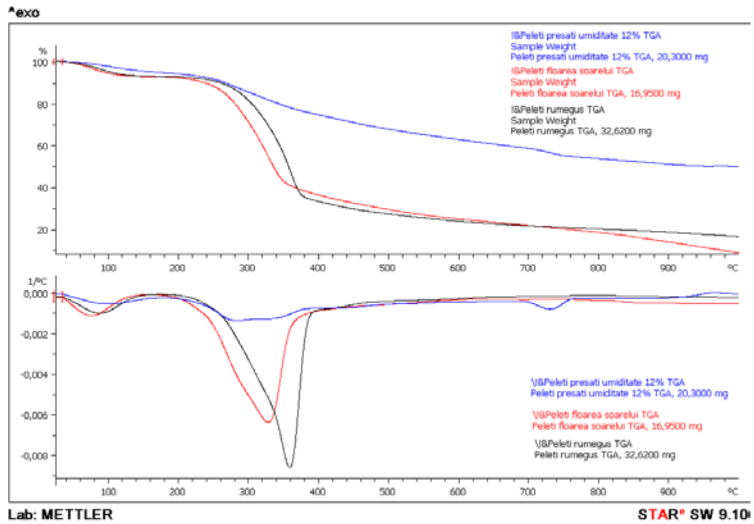

Figure 2. Thermogravimetric analysis for sludge pellets

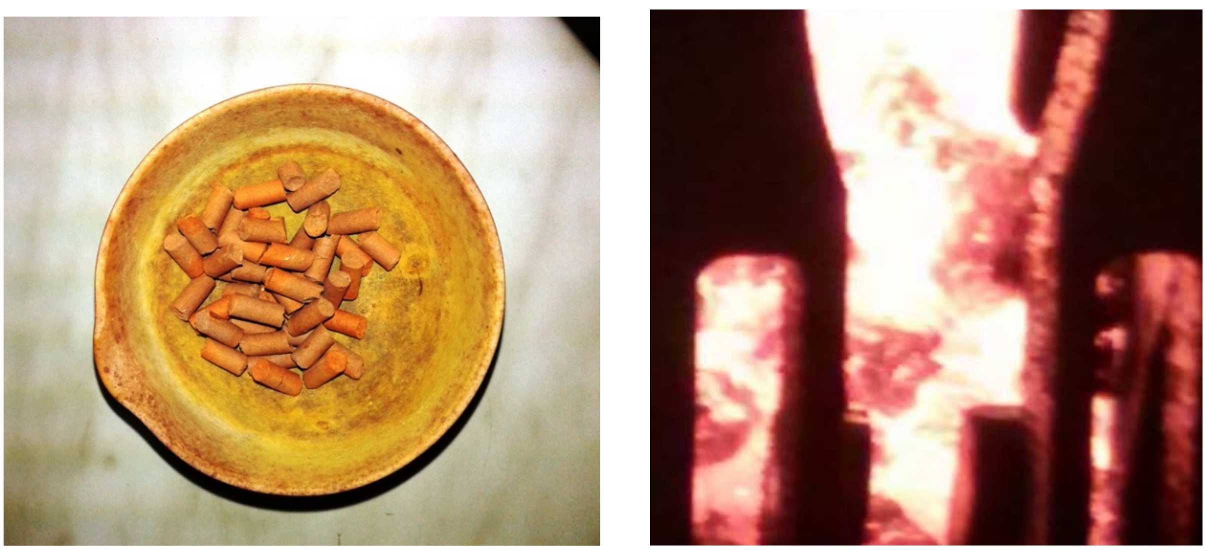

Figure 3. Ash Samples after combustion tests of pelletized sludge on grades

Results of the experimental work

The carbon content from the samples was determined based on the CO and CO_2 measured in the off gas. To have an „accurate" value for the measured concentrations, the raw data was corrected using a calibration graph. The real carbon concentration for every sample is calculated with carbon balance formula below using literature data, although literature data are varied and cannot reflect exactly the same composition of the sludge used for our tests.
Laboratory temperature and pressure: 1, 013 mbar; 296.25 K

$$\dot{V_{in}} = V_0 \frac{p_0 T}{p T_0}; \qquad (1)$$

$$m_C = m_{sample} \cdot c_{C_{in}} \qquad (2)$$

$$m_{C_{out}} = \left(\int_0^t c_{CO_2} \cdot \frac{1}{100} \cdot \dot{V_{in}}\, dt + \int_0^t c_{CO} \cdot \frac{1}{10^6} \cdot \dot{V_{in}}\, dt\right) \frac{p}{RT} M_C \qquad (3)$$

$$C_{balance} = \frac{m_{C_{out}}}{m_{C_0}} \cdot 100 \qquad (4)$$

The air flow used for every tested temperature is written below.
$\dot{V}_0$= 7. 71 Nl/min=1,285 * 10^{-4} m^3/s (volume flow used for 700°C)
$\dot{V}_0$= 7. 02 Nl/min=1.17 * 10^{-4} m^3/s (volume flow used for 800°C)
$\dot{V}_0$= 6.45Nl/min=1.075 * 10^{-4} m^3/s (volume flow used for 900°C)

For the wet digested sewage sludge from Constanta, Romania, the aim was to determine the influence of the high water content of sludge on its combustion process. The results showed more than 75% of the carbon is volatile and the combustion process is characterized by very low char carbon concentrations in the bed. The carbon balance made for this sludge showed that the highest amount of carbon (18, 56%) detected was at 900 °C temperature. Due to the high moisture of the sample the combustion test realized with this experimental set up the results were not similar with the literature data. In the following figure (Figure 4) are presented the results of the measured concentration of CO_2 and CO for single and multiple particles tests for the sludge at 700, 800 and 900°C.

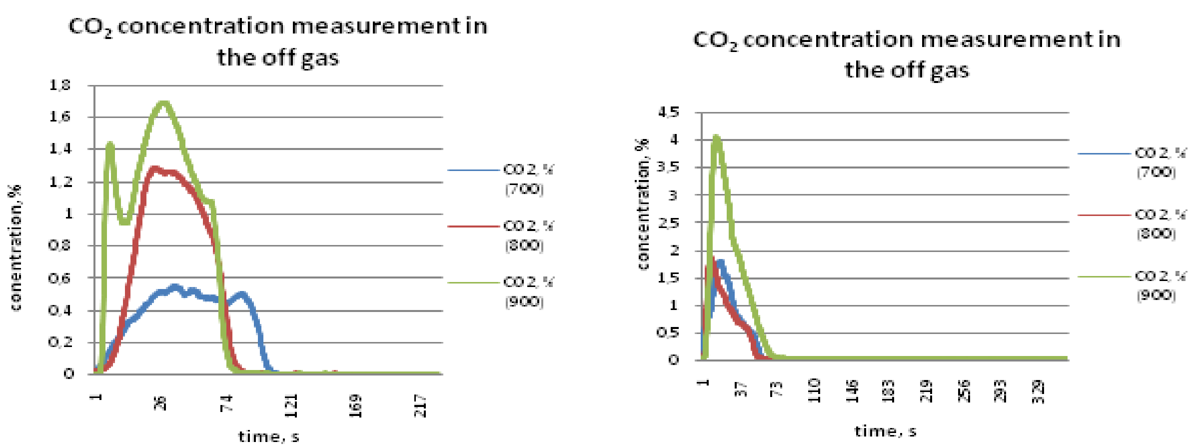

Figure 4. The CO_2 emissions for single (a) and multiple particles (b) tests for the Constanta South wastewater treatment plant sludge at 700, 800 and 900°C in combustion processes in a fluidized bed reactor [2]

3. MODELLING OF COMBUSTION AND CO-COMBUSTION PROCESSES OF SLUDGE

The research activities were started from the previous work presented above and during the work developed within the Cluster MEDGREEN research project and were conceived several solutions using innovative technologies for incineration of sludge and recovery of energy. There were taken into consideration the following solutions for increasing of the combustion and co-combustion processes efficiency:

- The first proposed solution is the integration of an afterburner system;
- The second proposed solution is the stratification of combustion process on grates;
- The third proposed solution is a gas co-firing process for the wastewater sludge.

Integration of an afterburner system

The proposed solution consists on the integration of an afterburner system to recover the fractions of ashes and unburned bottom ash and slag discharged together on the main grate. The grates burners system integrates a regulation mechanism grates to prevent of ashes melting and forming lumps at high combustion temperatures of approximately 1200 °C. Depending on the quality and properties of the sludge pellets and the frequency control mode scraping (cleaning grates), especially waste the incineration of low quality pellets, resulting significant fractions of unburned fuel, which contributes to reducing boiler efficiency. In order to implement the solution, the investigations have defined three constructive solutions which differ depending on the boiler size and ash flow.

Thus, the first solution is to ventilate the ash so that the combustion air is passed through the cavity of the ash providing oxygenation of the mass of ash allowing in this way favoring the process of post combustion and take-up of heat in the airflow, thereby ensuring as a "pre-heat" air.
The second solution is the recirculation of slag and ashes from the bottom of the furnace combustion zone or by the exhaust from the furnace, ensuring contact between flue gases and unburned fuel solid fractions. Recirculation devices may be different in shape design and size, and the recirculation of the ashes must be properly isolated.
A third solution consists in the implementation of cascade combustion systems where the unburned fuel fractions are passed from a main burner to a secondary burner. The main burner should be designed for a high λ. The secondary burner is sized for a lean λ. The air is circulated first, through the secondary burner, where combustion is carried out at a low temperature without the danger of melting the ashes and reduced frequency of scraping of the grate. Gases resulting from the combustion in the secondary burner are passed in the main burner where the combustion temperature is 1200 °C.

Stratified combustion on grates

For incineration of pellets of inferior quality, resulting from the processing of sludge from wastewater treatment plants, manure and waste biomass with high organic content, it is proposed the solution layering of the bed combustion by dividing the system of fuel into two subsystems of which one pellet of superior quality and second with pellets of inferior quality. In this way the combustion bed will be made up of layers interspersed.

The proposed solution consists of a layering procedure of the bed combustion by setting up two areas: (1) a core area, consisting of high-quality pellets, in order to maintain high-temperature combustion process and ensure supply of heat needed to stabilize the combustion process; (2) an area of lower quality fuel which to ensure the appropriate fuel incineration without affecting environmental protection rules.

From the point of view of construction, the implementation of the proposed solution has been achieved by doubling the fuel supply system using two separate circuits, to which the monitoring, control and control unit is made from the same PLC.

The proposed solution allows the incineration in suitable combustion process control for a wide range of lower fuel resulting from processing of sludge, biomass and manure. Performance from testing under real operating recorded, processed and compared with other similar systems and have found that the advantage constructive simplicity and low cost of investment and operation.

Co-firing process for the wastewater sludge

In order to neutralize these types of organic waste, one embodiment consists in processing the granulation and pelletization, followed by the incineration on grates which have fitted fuel gas nozzles.
In the case of the combustion of sludge pellets of inferior quality, and especially in the case of the combustion of sludge with a high degree of mineralization, we propose the integration of three nozzles for the fuel gas feed that will allow ensuring the combustion conditions and the thermal energy necessary for the stabilization of the combustion process.Thus, high quality fuel gas ensures maximum safety incineration conditions, by maintaining temperatures at higher values of 1200 ℃ and ensuring complete combustion.

From the point of view of construction, the implementation of the solution consists on the integration of a power supply system of the boiler with a flow of gas dimensioned, allows the combustion of sludge in suitable conditions.

4. ACKNOWLEDGEMENT

The results were obtained within the project "Development of innovative solutions materialized in products and services that should lead to increase competitiveness of the companies associated within the Cluster MEDGreen+", financing contract no. 1CLT / 800 027 / 03.06.2014, SMIS code 49755, financed through The Sectoral Operational Programme ”Increase of Economic Competitiveness”, 2007-2013, Priority Axis I, “An innovative and eco-efficient manufacturing system”, Main field D1.3, “Sustainable development of entrepreneurship”, Operation “Support for the integration of companies in value chains and clusters”, co-financed by European Development Regional Fund.

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Modelling Of Sludge Drying Processes In A Rotary Kiln

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Abstract
The paper presents the results obtained through research activities conducted for the development of a rotary dryer kiln concept for sludge drying in sewage treatment plants. The kiln is equipped with a triple shell horizontal rotating cylinder in which drying is achieved through direct contact between the hot gas flow and the sludge. Different solutions are currently being studied, as in co-current and counter-current flow, and the influence of different parameters over the entire process.

Keywords
Sewage sludge, sludge drying, modelling, rotary kiln.

1. INTRODUCTION

The management and disposal of sludge resulting from wastewater treatment processes is a major problem of the municipalities. The evolution of the quantities for the entire Romanian wastewater treatment sector is presented in Figure 1. This type of waste typically contains mineral and organic matter removed from the raw water, together with residues of any chemical treatment processes or industrial processes. If the biological fraction is higher than 30%, this type of byproduct cannot be discarded in natural environments without further treatment.

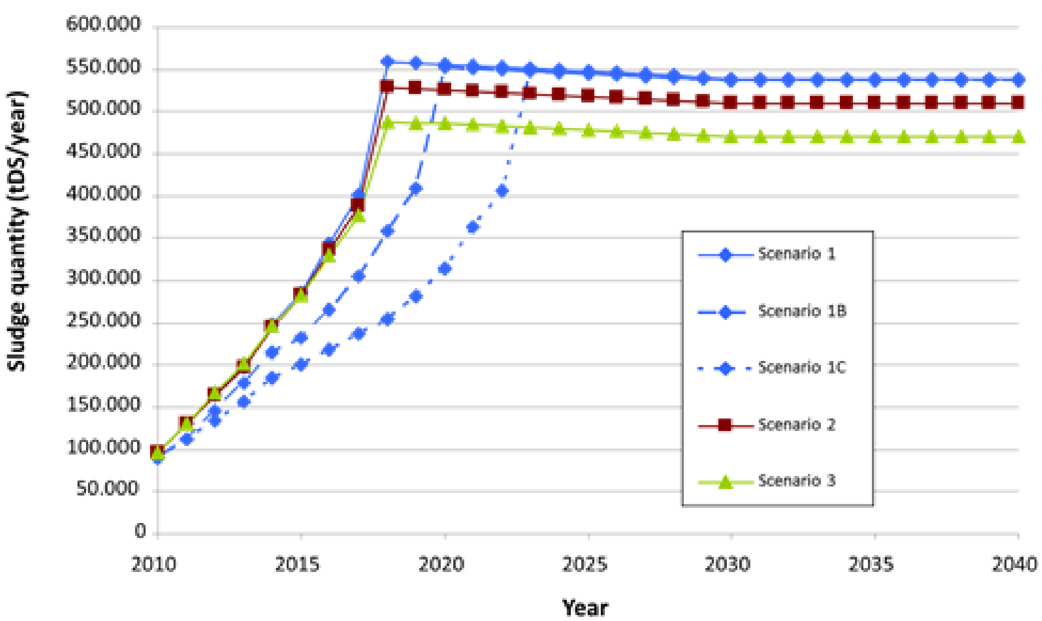

Figure 1. Estimation of total sludge quantities in the Romanian WWT sector

With the introduction of the new EU regulations regarding the landfill management, the main focus consists now in developing new innovative technologies with a minimum environmental impact, a better utilization of the existing landfill capacities, together with the reduction of volumes through recycling, exploitation of secondary resources and energy recovery. [1]

The typical raw sludge resulting from wastewater treatment processes has a concentration of 1-5% dry material. In order to implement further processing solutions, the dry material concentration has to reach a minimum of 60-90% (the final concentration depending on the processing technology - pelletizing, incineration). Therefore, an important step in the technological flow of sludge processing is the drying technique. The typical drying model is presented in Figure 2.

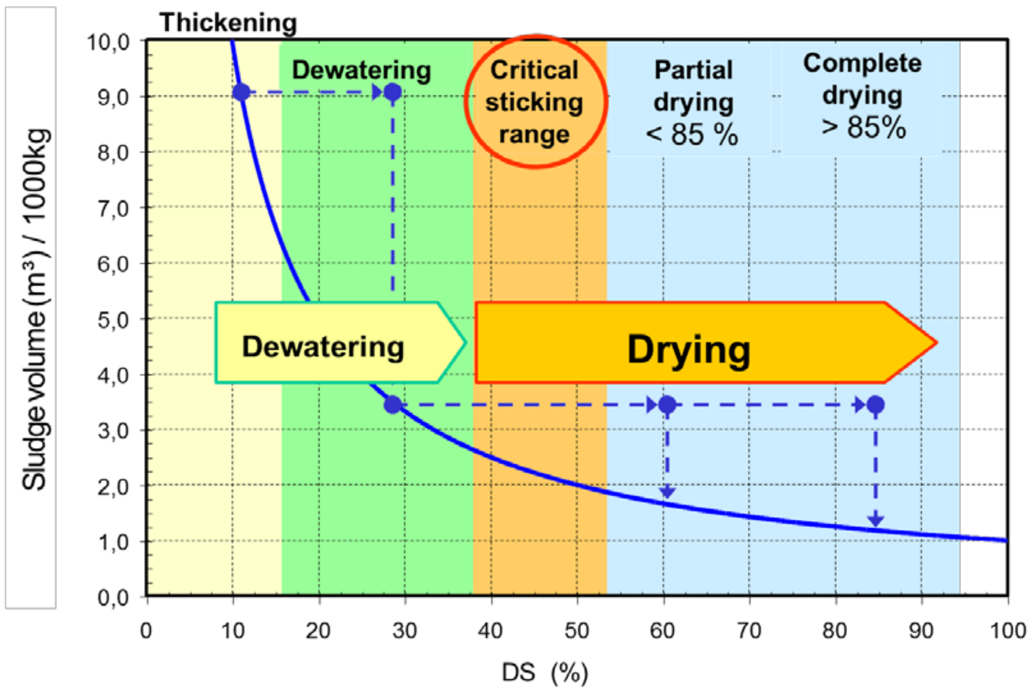

Figure 2. Sludge drying process [2]

At the moment , there are three technologies mostly utilized in sludge drying processes in order to reduce its water content: *belt dryers* - comonly used in smaller aplications, with a small to medium evaporation capacity, using heat with temperatures > 90°C and heating steam < 6 bar, *fluidized bed dryers* - common in larger applications, with a medium to large evaporation capacity, using heat sources >180°C or heating steam > 6 bar, and *drum dryers* for medium to large evaporation capacities, to make use of natural gas, biogas, or heating oil or if a granulation degree needs to be met (e.g.for fertilizer).

The drum drying process is one of the oldest processes for drying sewage sludges. Such industrial dryers are employed to reduce or minimize the liquid moisture content of the sewage sludge it handles by direct contact with a heated gas.

In some applications, dewatered sewage sludge is mixed in a mixer to a dry content of approximately 60% DS with material that has already been dried. [3]

2. ROTARY DRUM DRYERS APPLICATION

A typical rotary drum dryer usualy consists of one or multiple rotating cylindrical tubes, usually supported by concrete columns or steel frames. The dryer can be slightly sloped so that the discharge end that is lower than the material feed end in order to convey the material through the dryer under gravity or the material movement can be acheived with helical, transport fins. Material to be dried enters the dryer, and as the dryer rotates, the material is lifted up by a series of internal fins lining the inner wall of the dryer. When the material gets high enough to roll back off the fins, it falls back down to the bottom of the dryer, passing through the hot gas stream as it falls. This gas stream can either be moving toward the discharge end from the feed end, known as co-current flow, or toward the feed end from the discharge end, known as counter-current flow. The gas stream can be made up of a mixture of air and combustion gases from a burner, in which case the dryer is called a direct heated dryer. Alternatively, the gas stream may consist of air or another, sometimes inert, gas that is preheated. When the gas stream is preheated by some means where burner combustion gases do not enter the dryer, the dryer is known as an indirect-heated type. Often, indirect heated dryers are used when product contamination is a concern. In some cases, a combination of direct-indirect heated rotary dryers are also utilised in order to improve the overall efficiency. [4]

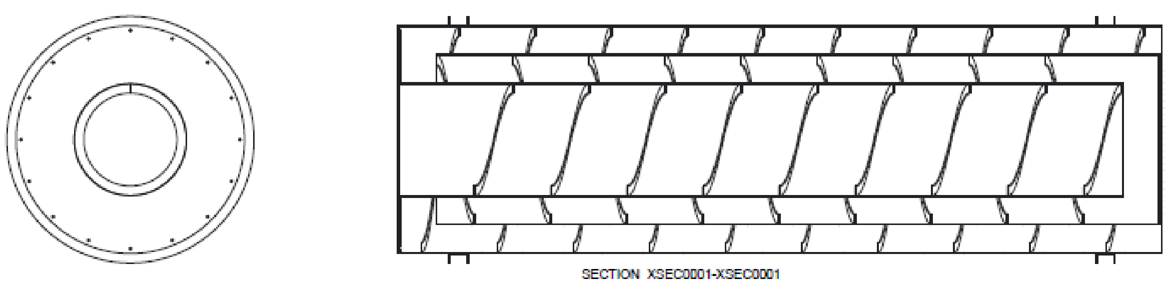

Figure 3. Triple shell drum

A rotary dryer usualy consist of a single shell or many, though any more than three drums is not usually necessary. Multiple drums reduce the amount of space that the equipment utilise. The drums are often heated directly by oil or gas burners.

The addition of a combustion chamber on the entry end helps ensure efficient fuel usage, and that homogenous drying air temperatures. As the material moves through the rotating drum, it is heated and the moisture is released.

Depending on the application, some dryers are costructed also with additional units for cooling, cleaning, shreding, and/or separation of the dry material. In some cases, when it is applicable, heat recovered from the exhaust gases may also be utilized.

In some rotary dryer applications, a higher economical efficiency can be acheived with the combination of other processes needed in particular. Such processes include cooling, cleaning, shredding, fractions separation, etc.

3. THE CONCEPT

The paper presents the results obtained through research activities conducted for the development of a rotary dryer kiln concept - Figure 3 - for sludge drying in sewage treatment plants. The kiln is equipped with a horizontal rotating cylinder in which drying is achieved through direct contact between the hot gas flow and the sludge. Different solutions are currently being studied, as in co-current and counter-current flow, and the influence of different parameters over the entire process.

The concept involves the design and construction of an integrated plant for drying and incineration of sludge from municipal wastewater treatment plants, in order to reduce the volume of waste to be disposed in landfills. The main scope is related to urban wastewater treatment sector, because the plant can be integrated into wastewater treatment plants, for processing, drying and incineration of sewage sludge. The instalation itself has other fields of utilization, in applications related to industrial processing, where waste is generated in aqueous suspension and cannot be discharged into the environment (food processing manure from farms, livestock and sludge resulting from unclogging lakes or swamp areas).

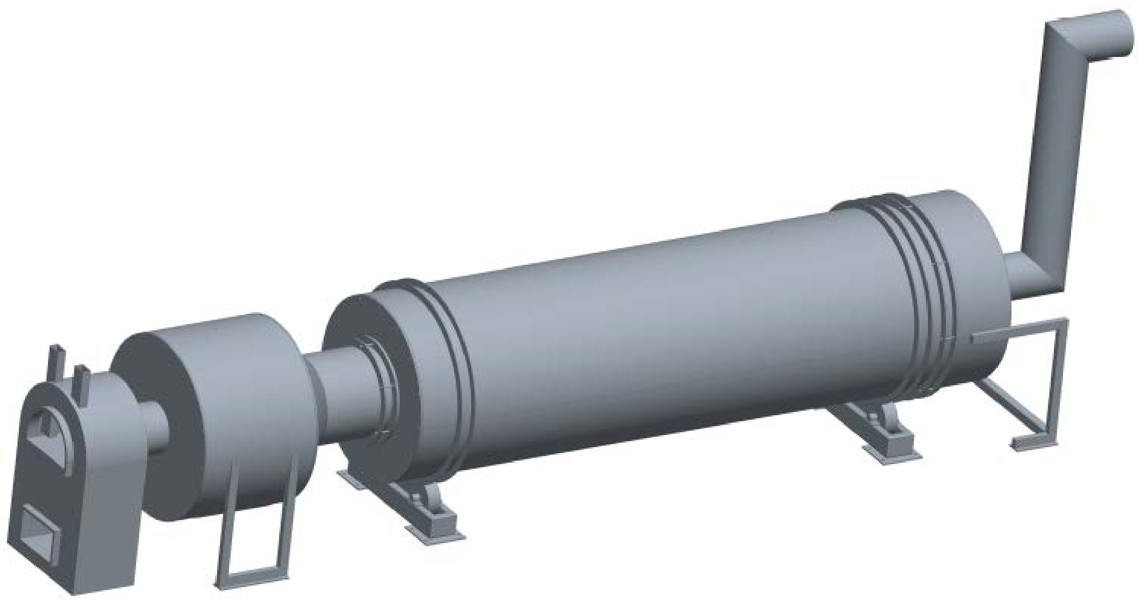

Figure 4. Rotary dryer kiln concept

Current solutions on the use of drying systems and incineration of sludge from sewage treatment plants usually consists of the collection and transport of sludge from several treatment plants to a central system, which can perform a preliminary stage drying and subsequently, the incineration of sludge in a classic combustion plants. There are systems in which the sludge is mixed with other municipal solid waste in a process that does not require sludge drying, and incineration is achieved by burning the mixture of waste.

The technical solution consists of achieving a compact installation dedicated to medium size treatment plants with capacities over 100,000 IE, hence after treatment, sludge quantities between 0.5-2 t/h. The objective of the concept is to provide a facility to handle sludge resulted from such plants, under standard conditions, with a humidity of 80%, to be incinerated with minimal costs, ensuring the reduction of the sludge volume to the level of ash, and with a minimum environmental impact. Thus, the amount of solid waste resulting from the purge is reduced by a factor of 1:8 and, at the same time, the waste products are biologically inert.

The concept consists of an installation comprising of a triple shell rotary kiln, in which sludge taken from wastewater treatment plant, with 20% DM and 80% humidity is inserted, and a stream of exhaust gases at a temperature between 300-400 ^{o}C flows in co-current, through the 3 cylinders, transferring the heat and gathering the water vapors from the sludge, resulting an output stream of dried sludge up to a content of 90% DM. The main feature of the installation consists in the gathering the dried sludge in an intermediate tank which is then transported and burned in the installation's combustion plant, equipped with a wood pellet burner, capable of co-incineration. The gases resulting from combustion are inserted into the rotary dryer, thus being the main source of heat required for the drying process.

Figure 5. Construction process

The advantages of this equipment consist of the following:

- It is compact, which enables integration into existing wastewater treatment plants;
- The resulting sludge after drying is utilized as an energy source, covering part of the energy for the drying process;
- The system allows subsequent recovery of energy from the combustion gases, which can be an additional source of income;
- The system allows recovery of the water content from sludge, through the condensation of

water vapors in the exhaust path;

- Reduce the costs of operation, storage, handling, and transport of sludge from sewage treatment plants;
- The ash from the incineration is the only waste resulting from the process, but with possibilities to be integrated in building materials, thus constituting a source of income, or can subsequently process in order to extract phosphates or nitrates;
- The system is fully automatic and reduces the involvement of the human factor to a minimum, only for surveillance;
- Investment costs are much lower than those for conventional drying installations, because it uses heat form flue gas at high temperatures;

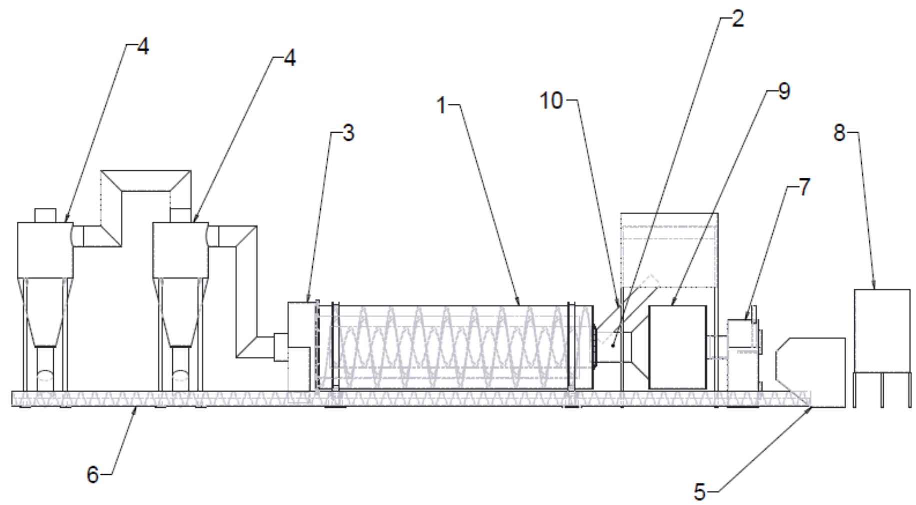

Figure 6. The installation main components

The pilot plant, aiming at the demonstration of the innovative concept, is currently in the latest stage of development and testing, at the Center of Engineering for Sustainable Development, of the MEDGreen Cluster. The construction process started with the manufacture of the main components of steel as follows: dryer (1) consists of 3 cylinders of steel, concentrically arranged and fixed so as to allow the movement of sludge from the cylinder with the smallest diameter, the cylinder the largest diameter, covering three successive passes. In order to move the sludge in each cylinder, guiding helical fins are installed, to provide displacement of the material by the effect of rotation of the assembly, driven by an electric drive system. The drive speed is controlled by a variable frequency drive that powers the electric motor. The drum assembly is coupled to two fixed components, the sludge intake (2) at the inner cylinder and the exhaust outlet (3) coupled tot the outer shell.

The two components have rotary joints which provide sealing through a labyrinth system. The gases resulting from the drying system are taken into a separation system with two cyclones (4) connected in series.

The collection of the dried sludge is carried at the lower side of the exhaust outlet, after the completion of the three passes. The dried matter is collected in a steel container (5) equipped at the bottom with a screw conveyor (6). With the conveyor screw, it will feed the sludge incinerator

(7). The incinerator is one of the innovations, consisting of a wood pellet burner, modified for granular biomass in the form of pellets, with dual feed path so that the feeding can be carried out simultaneously with biomass pellets (8) and dried sludge. From the construction point of view, the combustion system is provided with two screw conveyors, operated and controlled independently, depending on the dosage requirements. The burner's exhaust nozzle is connected to the sludge inlet of the rotary kiln dryer, through a pressure equalization chamber (9). The dryer's inlet includes the connection to the feeding screw (10) used for the feeding of wet sludge. The ash is collected in the ash pan of the burner and can be carried to a special container through a screw conveyor. [5]
The exhaust path allows a direct connection to a chimney or an energy recovery unit can be installed. The energy recovery can be achieved by condensation of water vapors and through a heat exchanger for exhaust gas energy recovery.

4 RESULTS

The first phase of testing was carried out only with the inner shell installed and a series of tests had been done in order to determine the transport capacity and the maximum load.
On the second phase, together with the installation of the triple shell, a series of tests had been done to determine, the rotation velocity. The relative humidity of the material was studied in order to avoid the material sticking. In order to further condition the resulting dry sludge, few pelletization technologies were tested.

Figure 7. Dry sludge and sludge pellets

Based on the results obtained in the testing phase, the following parameters had been established:

Rotation speed	1-5 RPM
Drive motor power	5,5 kW
Maximum processing capacity (wet sludge)	500 kg / h
Maximum dewatering capacity	60 %
Overall sludge volume reduction (after incineration)	1/5
Maximum co-incineration factor (pellets/sludge)	60/40
Inner helical transport fin pitch	400 mm
Maximum gas temperature at inlet	~400 ^oC
Average temperature loss Δt	60 %

Further tests are scheduled in order to gather information required for a larger application that will be designed for a processing capacity of 1000 kg / h.

5. ACKNOWLEDGEMENT

For a practical evaluation of this technology, an international research team has been involved in a package of activities under the project "The development of innovative solutions for products and services that could contribute to the competitivity enhancement of the companies associated in the Medgreen Cluster", that was financed under POS-CCE, Priority Axis I, "An innovative and eco-efficient manufacturing system", Main field D1.3, "Sustainable development of entrepreneurship", Operation "Support for the integration of companies in value chains and clusters", co-financed by European Fond for Regional Development.

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Benefits Of Sludge Treatment With Membrane Covers For Waste Water Plants, To Reduce Operation Costs And Provide Valuable Compost For Your Local Community

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Abstract
Biosolids-Composting for the Waste Water Industry are a very efficient solution to safe significant cost on sludge disposal, and also are able to produce an excellent compost product, which can be sold to agriculture operations, as a very sustainable natural soil improving product, allowing to save on fertilizer costs. So, the costing block of sludge disposal in a Waste Water Treatment Plant can be turned into a profit generating part of every operation.

For this composting process we will introduce a State of the Art Technology for organic waste treatment, using an ePTFE (expanded polytetrafluoroethylene) Membrane Cover, together with a positive aerated System to run a very efficient and emission controlled composting process, which is working in a very reliable way, all over the world, in many Waste Water Treatment Plants (WWTPs).

Qualitative process description of composting via encapsulation with an ePTFE (expanded polytetrafluoroethylene) Membrane Cover
The GORE® Cover system, a technology for aerobic waste treatment utilizing special laminates made by the membrane specialist Gore, is now in use in more than 150 plants in Europe in different design variants, for example, side wall, butterfly roof version or in combination with a loading tunnel, for composting of all organic matter or for mechanical-biological residual waste treatment. A breathable, semipermeable membrane cover is used to encapsulate the heaps during the rotting (decomposition) process. The encapsulated compost heap, sealed to the ground to avoid bypass streams of process gas and to provide for a certain backpressure, is supplied with oxygen at the base of the heap.

The GORE® Cover laminate forms a central component of the system. It is made of an especially developed, micro porous, PTFE -based GORE® membrane, which is laminated between UV-stable, mechanically high-strength fabric layers. Due to its specific membrane structure the laminate has semipermeable properties which enable an adequate climate in the heap:

- Water and windproof, it protects the rotting material from environmental impacts.
- Permeability characteristics for water vapor and air are tuned to ensure the necessary moisture control over the whole treatment time.
- Due to the positive ventilation, in a sealed system an insulation layer made of air is created, which produces uniform temperature distribution in the whole heap and ensures uniform sanitization of the decomposing material.
- Reliable odour and emission control due to membrane performance. Substitution of Biofilter.

The cover acts as a barrier against odors and other gaseous substances which escape from the decomposing material. During the rotting a fine condensate film forms on the inside of the cover, in which odorous and other gaseous substances dissolve and drip back into the rotting material. With a pore size of approx. 0.2 µm, at the same time it is also an effective barrier against spores and germs.

With its oxygen-controlled ventilation, the GORE® Cover system creates ideal rotting conditions. The short duration of the rotting process enables a high throughput rate per unit area. Measuring probes installed inside the heap monitor the oxygen supply and reaction temperature and control the ventilation period.

Keywords
Biosolids, composting process, emission controlled composting process.

1. INTRODUCTION

Since centuries the process of water treatment is improving globally and the quality of drinking water is getting better and better. Also connection rates are increasing, which leads more and more to a sustainable control of waste water. With this development an old question is becoming more important again. How to deal in a responsible way with the resulting sludge from the waste water treatment process? For managing the sludge, various practices established, whether it is for landfill or agriculture land apply, or with a synergetic approach to include energetic use or phosphor recovery.
Typical ways of waste water sludge disposal in Europe:

- Landfilling;
- Incineration;
- Agricultural utilization;
- Composting.

In the following paper we would like to focus on the composting solution and would like to introduce a very efficient technology as one possible option.

2. SOME DEFINITIONS

The term “Sludge” is in reference to the un-stabilized solids and usually refers to a specific process descriptor, such as primary sludge, waste activated sludge or secondary sludge. For general description, solids, residuals or another appropriate term is preferred.

The term “Biosolids” in this paper is generally used for sludge going into a biological treatment process with the intention of stabilization and hygenisation.
Possible stabilization operations are:

- Aerobic Digestion;
- Anaerobic Digestion;
- Lime/Alkaline stabilization;
- Long-term (lagoons, reed beds, etc….);
- Thermal (not incineration);
- Composting.

3. ADVANTAGE OF BIOSOLIDS-COMPOSTING

Biosolids-Composting (BS-Composting) for the waste water industry is a very efficient solution to save money on sludge disposal, and it also allows to produce an excellent compost product, which can be sold to agriculture operations, as a natural soil improving product, also allowing to reduce fertilizer costs. So the costing block of sludge disposal in a Waste Water Treatment Plant can be turned into a profit generating part for such operations.

Here we would like to introduce a State of the Art technology for organic waste treatment, using an ePTFE Membrane Cover together with a positive aerated System, to run a very efficient and emission controlled process, which is a proven way forward in many Waste Water Treatment Plants (WWTPs) globally.

Figure 1. State of the Art technology for organic waste treatment

Why composting? Good reasons for a smart solution:

- Creating a defined solution for the need of sludge-disposal, either as an additional WWTP-operation, or as an outsource operation
- Positive influence on community fees for WWT
- Significant reduction of disposal costs with the potential to produce a valuable product, which can be sold to the community. Dependent on the initial disposal costs, operations can become cost neutral.
- Most environmental friendly solution, compared to Incineration, Landfilling or Land Applying
- BS-Compost as a perfect and very valuable substitution of fertilizer for agriculture use. Best source against soil erosion and for sustainable soil improvements
- Natural recovery of Phosphor sources, re-used as a soil amendment

4. PROCESS DESCRIPTION OF COMPOSTING VIA ENCAPSULATION WITH AN EPTFE MEMBRANE COVER

The GORE® Cover system, a technology for aerobic waste treatment utilizing special laminates made by the membrane specialist Gore, is now in use in more than 150 plants in Europe, in different design variants, for composting of all organic matter or for mechanical-biological residual waste treatment. A breathable, semipermeable membrane cover is used to encapsulate the heaps during the rotting (decomposition) process. This cover is sealed to the ground or to a sidewall to avoid bypass streams of process gas and to insure some backpressure. Oxygen is introduced into the system from aeration channels.

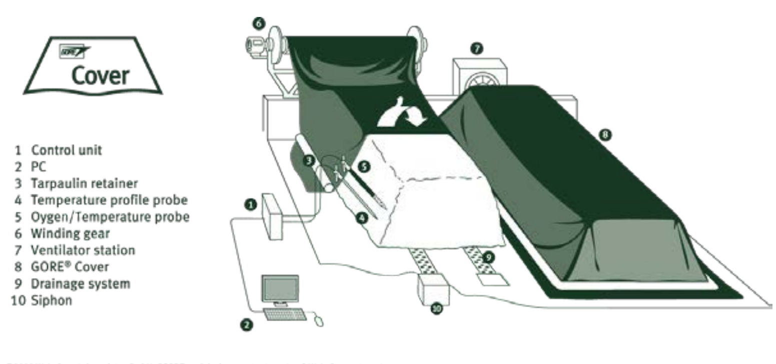

Figure 2. Potential design for using the GORE® Cover System in a composting process

The GORE® Cover laminate forms a central component of the system. It is made of an especially developed, microporous, PTFE[1]-based GORE® membrane, which is laminated between UV-stable, mechanically high-strength fabric layers. Due to its specific membrane structure the laminate has semipermeable properties which enable an adequate climate in the heap:

- Water and windproof, it protects the rotting material from weather impacts.
- Membrane permeability does allow the air and some water vapor to escape.
- Condensation effects insure a perfect water management for the process and a reliable odor and emission control. No Biofilter is needed.
- By positive aeration some overpressure under the cover is created, which produces a uniform air distribution across the heap, insures a homogeneous temperature profile and a uniform sanitization of the decomposing material.

A typical GORE® Cover process lasts eight weeks, divided into three phases. The rotting material remains in phase I for four weeks, followed by two weeks in phase II and two weeks in phase III. During these eight weeks is moved three times. The heaps are covered in phases I and II.

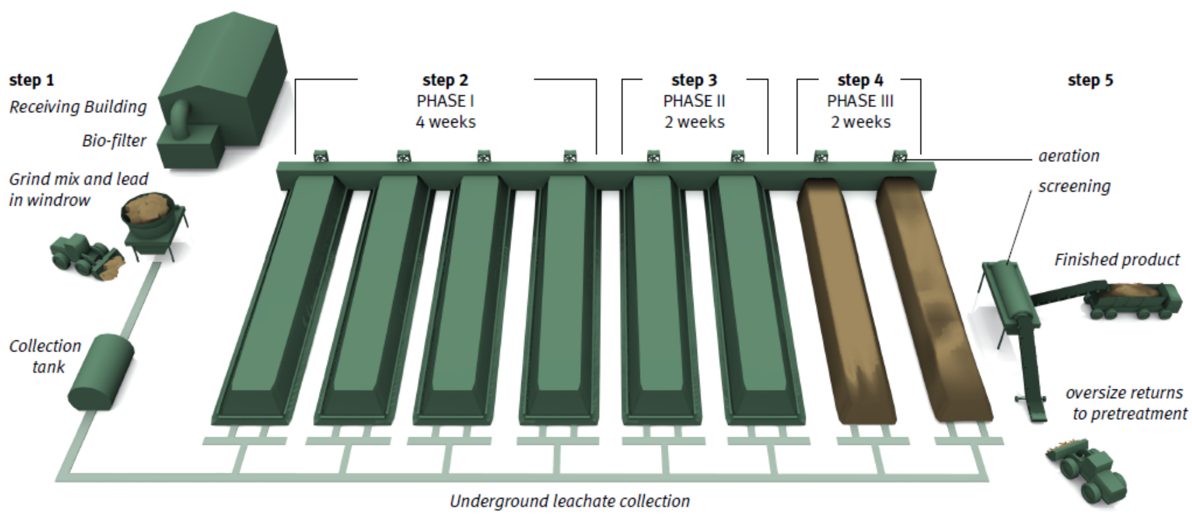

Figure 3. Schematic diagram of the GORE® Cover process

Most important, the cover acts as a barrier against odors and other gaseous substances which escape from the decomposing material. No additional filter is needed. During the rotting a fine condensate film forms on the inside of the cover, in which odorous and other gaseous substances dissolve and drip back into the rotting material, where they continue to be degraded bacterially. At the same time, with a pore size of approx. 0.2 µm, it is also an effective barrier against spores and germs.

With its oxygen-controlled ventilation, the GORE® Cover system creates ideal rotting conditions. The short duration of the rotting process enables a high throughput rate per unit area. Measuring probes installed inside the heap monitor the oxygen supply and reaction temperature and control the ventilation period at all times.

[1] Polytetra-fluoro-ethylene

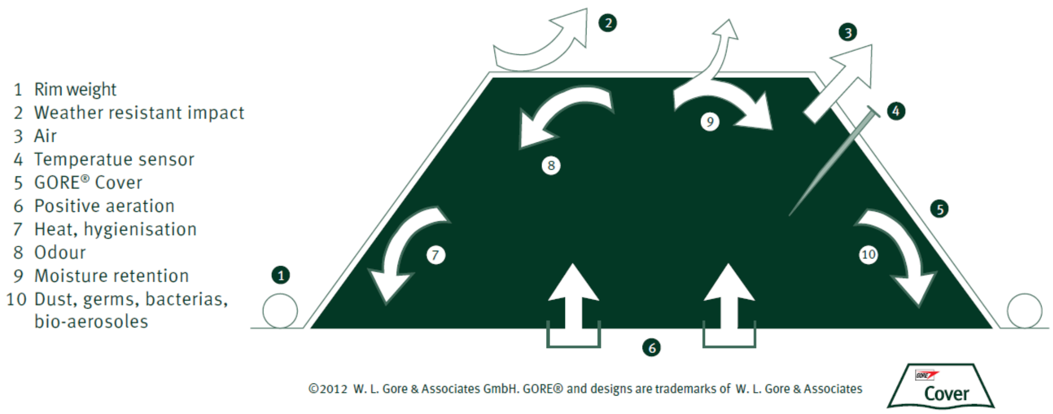

Figure 4. Schematic diagram of composting via encapsulation with semipermeable membrane cover

For composting of BS with the GORE® Cover technology following recommendations can be given:

- Input quality of BS for later agriculture use have to be in-line with local limits for heavy metal (EU Directive 86/278/EEC) and limits for organic micro-pollutants (EC [2000,2003] proposed limits)
- Green and woodwaste to be used as structure material
- Typical mix by weight is 1:1 or mix by volume is 1:3 (1 part BS, 3 parts of structure)
- Starting moisture level to be about 65%
- For a Class A, Rottegrad 5 compost quality an ideal treatment time would be:
    - 4 weeks intensive rot
    - + 2 weeks intensive rot
    - + 2 weeks maturation
    - + 4 weeks ageing time (in storage)

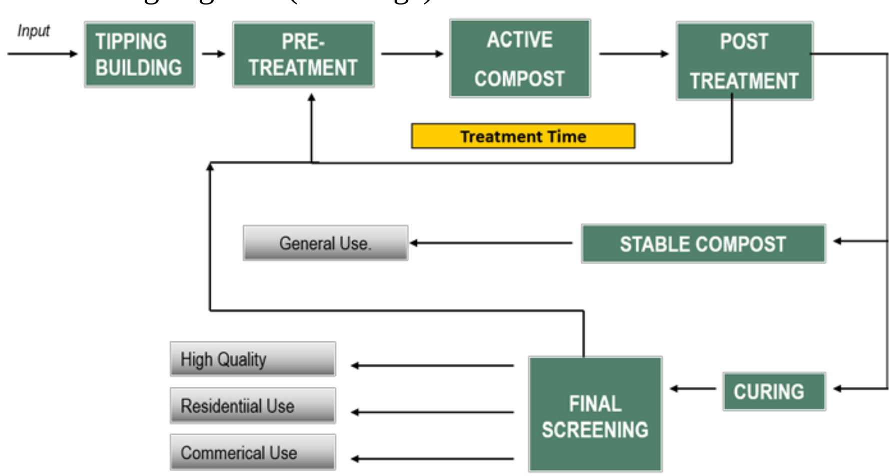

Figure 5. Typical process flow in a composting plant

Following criteria do define BS-Compost output quality in a specific way:

- County by Country specific "Class A-C" or "Rottegrad" definition
- Final moisture content
- Salmonella & E-Colli testing
- Local hygenisation achievement, 14 days temperature achievement > 55°C (or > 65°C or > 75°C over defined time)
- Available Phosphor and Nutrients in Compost
- €/ton sales value
- Be < critical heavy metal limits
- Be < critical salt limits

5. REFERENCES IN BIOSOLIDS COMPOSTING

Kirchbichl, Austria, 14.000 t/y of Biosolids/Foodwaste. Operation since 2009.

Within an expansion plan, the plant had to solve 3 items. Capacity increase on the existing footprint. Odors had to be controlled to best possible manner, due to odor complaints from neighbors and they wanted to fulfill the high quality standards for Austrian Compost. With their decision for GORE® Cover everything was achieved in an excellent way.
History:

- WWTP Kirchbichl in Austria is responsible for 13 villages in Tirol
- Community was founded in 1983
- In the early years of 1990 some first composting trials were done, due to the difficult sludge disposal situation in Tirol
- In 2000 a 5.000 m² rotting area was built with a solid roof construction. Open windrow composting with Turner.
- A Co-Fermentation was installed to also use food-waste to support the energy production
- The additional output from the Co-Fermentation had a positive impact on the compost quality
- Due to including the digestate into the following composting process, there is no extra hygenisation step needed. Necessary hygenisation is insured for the complete batch of the Biosolids/Digestate during composting.
- Due to emission calculations for a larger amount of BS to be treated, a decision was made for the use of 6 GORE® Cover system units in the intensive rotting phase.
- In 2008 an expansion of the composting area was permitted by the regulators.
- Planed process time:
    - 3 weeks intensive rot (Phase 1/GORE® Cover)
    - + 3 weeks intensive rot (Phase 2/GORE® Cover)
    - + 6 weeks maturation (Phase 3/open windrow turner)
    - + 6 weeks ageing in storage boxes
- Installation in 2009. Odour reduction with this new technology was significant
- Design for an input of 10.000 m³ of BS + 20.000 m³ of structure material = 30.000 m³ in total
- Total costs of the new intensive rotting area was about 2,3 MEuro (16.000m² property + asphalt + roof + construction costs + GORE® Cover process technology). Write-off for 150 kEuro/year.

- Results in 2014:
  - No odour claims from neighbors
  - Composting of 6.875t BS (23,5% dry matter)
  - Mixing of BS + woodchips + greenwaste + overs with turner on mixing area
  - under the GORE® System temperatures > 75°C are reached
  - stabilization and hygenisation reached on a constant bases (all batches)
  - Compost quality is Class-A (Austria / highest quality standard in EU)
  - Compost is selling for prices from 12,50 – 15,- Euro/m³
  - Total saving on the BS disposal costs is about 32 Euro/ton (2014) due to composting process

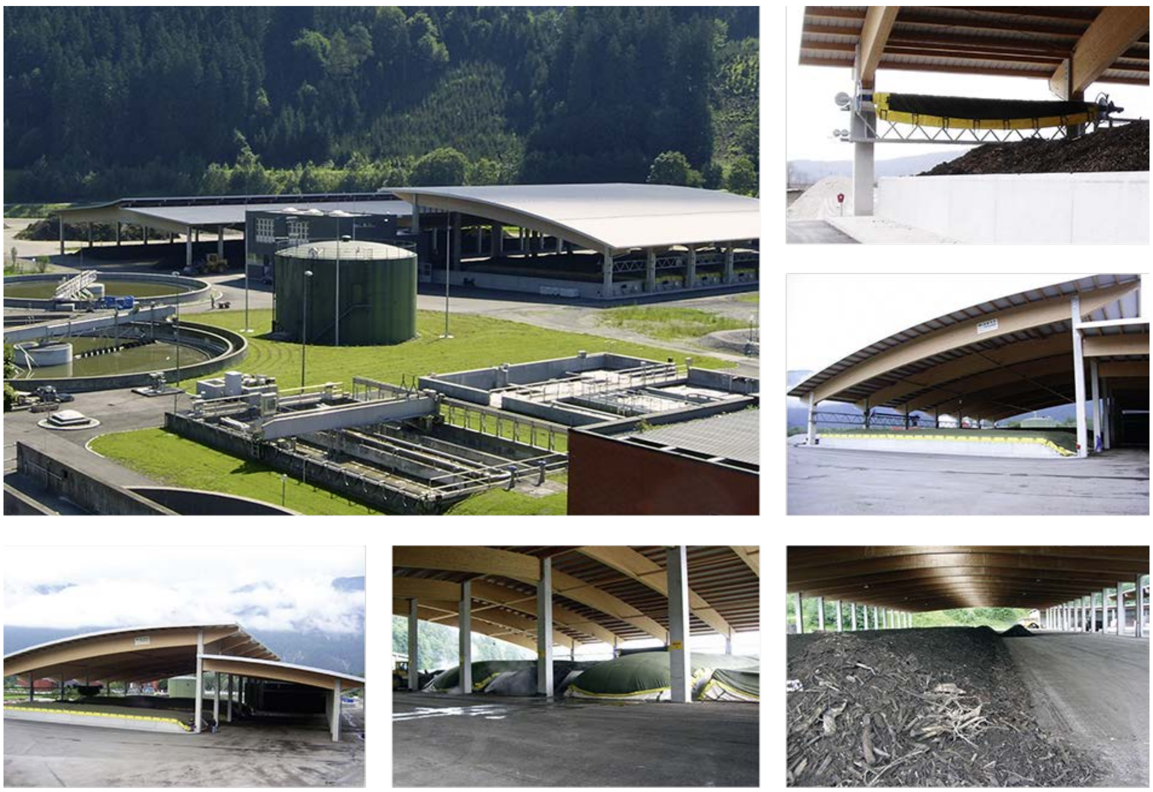

Figure 6. Pictures Kirchbichl

Moncton, Canada, 20.000 t/y of Biosolids. Operation since 2005.
Interest of customer was a valuable use of their WWTP Biosolids. Composting was the solution, looking for an easy and flexible technology, which can work under rough Canadian Winter conditions, to produce an excellent Compost Soil for un-restricted use.

History:

- Located in Riverview, New Brunswick Canada this 115.000 m³/day Wastewater Treatment Facility provides screening, grit removal, advanced chemically assisted primary treatment to meet provincial guidelines for effluent BOD (12.700 kg/day) and suspended solids (7.600 kg/day) utilizing three large circular flocculation type clarifiers with integral picket thickening, raw sludge dewatering via high solids handling centrifuges, lime stabilization of raw sludge and odour control facilities using wet scrubbers and biofilters.

- Effluent disinfection is not required under the current provincial regulatory agency Certificate of Approval. The current serviced population is approximately 100.000 with average daily flow of approximately 66 000 m³/day. The raw sewage BOD and TSS are 202 mg/L and 173 mg/L respectively (Austria is responsible for 13 villages in Tirol
- Before decision for GORE® Cover, extreme testing was done at lower -20°C for the composting performance
- In 2005 the Gore technology was purchased and installed
- WWTP Moncton is treating 20.000 t/y in 8 GORE® Cover windrows
- Process is for 8 weeks (4+2+2) and aging afterwards in storage area
- Compost is sold as “Gardener’s Gold”, Class-A quality Canada

Figure 7. Mix BS + structure material in Moncton **Figure 8.** Winter Testing Moncton

Fervosa, Spain, 35.000 t/y of Biosolids/Foodwaste/Manure. Operation since 2004

Plant started in 1992 for manure composting. In 1995 they added Biosolids and other organic materials. They faced odor problems. For 9 years they tried different solutions to solve the situation. In 2004 they started to use Gore system with positive results.

Figure 9. Sludge delivery Fervosa before mixing with structure

Figure 10. Fervosa plant, distance to next town

Los Angeles, USA. 200.000 t/y of Biosolids. Operation since 2015
Need to meet lowest regulations on VOC emission and pathogen reduction. After various up-front testing the GORE® Cover technology turned out to be the most efficient emission reduction technology for the strict Californian environmental laws. Second driver for the Composting solution was to find a cost effective way for their sludge disposal.

Figure 11. Plant design LACSD for first stage (200.000 t/y)

History:

- Initially a negative aerated static pile system was planned. Due to changing regulation on Ammonia and VOC emissions LACSD had to find a better emission control technology
- During intensive testing in 2007 the GORE® Cover technology turned out to be able to meet future emission requirements for California.
- Plan is to build a 1.000.000 t/year plant. Due to modular design in 5 stages
- One driver was from increasing tip fees for land apply and the knowledge, that such behavior will not be acceptable anymore in the future
- First stage for 200.000 t/year was built in 2014, 72 windrows with GORE® Cover
- Start-up finally took place in beginning of 2016
- Process time will be 8 weeks
- Output quality will be for Class-A compost

Figure 12. Mobile Winder in LACSD

Figure 13. First windrows going into operation for LACSD (total of 72, first stage)

6. EXPERIENCE IN ROMANIA WITH EPTFE MEMBRANE TECHNOLOGY

10 plants with Gore technology for the treatment of Organic Waste, Municipal Solid Waste (MSW) and RDF Production have been constructed in Romania since 2010.

Furthermore some new projects are in design stage or under approval right now.

7. TYPICAL PROJECT EVALUATION QUESTIONS

- What is current total amount of Biosolids in tons per year
- What is the output sludge type (primary, waste activated, return activated, anaerobically digested, etc.....)
- What is the actual disposal cost for sludge
- What is the local regulation on emission
- Distance to next neighbor
- How much space is available for a composting plant
- What kind of structure material is available in region
- Which marketing is possible for the final compost
- In case of already existing composting process:

  - What is material throughput, including structure material in t/y
  - What is the current mix recipe (Biosolids to bulking material) on weight basis or volume basis
  - What is the bulking material (hard wood chips, soft woods chips, shredded back, green waste, residential yard debris, grass, screened overs, etc….)
  - What is existing mixing equipment and mixing process
  - Actual treatment time in composting process
  - Achieved compost quality


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CHAPTER VI

EQUIPMENTS AND INNOVATIVE TECHNOLOGIES IN SLUDGE MANAGEMENT

The Baumgarte Sewage Sludge Treatment Concept; Thermal Processes For Sewage Sludge Treatment And Phosphorous Recycling!

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Abstract
Based on thermal conversion processes BAUMGARTE will present sustainable and environmental friendly sewage sludge treatment solutions.
On one hand, the latest BAUMGARTE development, under the trademark MEPHREC (TM) will demonstrate how Phosphorus can be recycled from sewage sludge. BAUMGARTE is in the process to build a pilot plant in order to demonstrate the practical realization of the MEPHREC (TM) concept. The presentation will show the concept of sludge thermal treatment incl. phosphorous recovery and will give an insight of the latest status of Pilot plant.
On the other hand, a sewage sludge mono-firing concept will explain another way of reliable and efficient thermal treatment process. It will be demonstrated that this energy conversation process is a reliable and efficient way by application of proven technologies.
Baumgarte, founded 1935, has a long-term history in the field of thermal residue treatment. Within the early 1960's the first units have been installed. Many realized projects illustrate the energy reliable, energy conversion concept and experiences.

Keywords
Thermal conversion processes, phosphorus recovery, sewage sludge mono-firing concept.

1. SEWAGE SLUDGE SITUATION AND OUTLOOK IN ROMANIA

Until today, Romania cannot fullfill European Applicable Standards with regards to drinking water supply, as well as sewage disposal.

Only 65% of Romania's population are connected to drinking water supply systems; with an even greater need to catch up in rural areas where the connection rate is as low as 33%.

For sewage disposal, the situation is similar, where at present only 52% of the sewage is collected with a treatment rate of only 30% (stage 1: mechanical Waste Water Treatment (W.W.T.), stage 2: biological W.W.T., stage 3: Physical or chemical W.W.T.). Sustainable processes for sewage sludge disposal or sewage sludge use are hardly applied. Reversely, this means that 70% of the municipal sewage is not treated which stands in contradiction to the European Guideline (1991) that requires a collection of municipal sewage by means of a public sewage system with a reasonable stage 2 treatment to ensure the removal of pollutants.

As a member of the European Union, Romania is entitled to incentives provided annually by various European Union Funds that shall enable, among other targets, the Romanian infrastructure to comply with European Standards. In terms of sewage collection, the target is 100%. European average rate is 94%, in 15 European Union Members the rate is 100%, in 5 countries the rate is below 30%.

The funds for sewage disposal accommodate 9.5 Billion Euro until 2018 of which 5.7 Billion Euro shall be invested into sewage disposal and – treatment and 3.8 Billion into the expansion of the public sewage system.

According to Germany Trade & Invest, there are still significant difficulties in Romania with regards to use of the funds with a retrieving quote of only 36,9% (2014, average in the period 2007-2013, according to the Romanian Ministry of European Funding). This circumstance represents one of the challenges in the current period from 2014-2020.

In the course of EU accession and previous accession negotiations, the sewage disposal sector has already improved significantly in terms of quantity and quality: the 2006 existing 751 sewage plants had almost doubled to 1.172 plants with an additional improvement of stage 2 (and partly stage 3) treatment of 50% compared to less than 30% in 2006.

The expansion of sewage plants inevitably lead to a significant increase of sewage sludge. Whereas in 2010 the amount of generated sewage sludge reached 100.000 tonnes, the forecast for 2018 expects that the amount will exceed 400.000 tonnes.

The Directive European Guideline for Sewage Sludge 86/278/EC also regulates the use of Sewage Sludge in agriculture and generally supported the application in the past, which lead to an average share of 45% of sewage sludge in agriculture in the European Union (1% in Romania).
However, long term soil examinations have brought to light not only an over fertilization, but more importantly, an increasing contamination with heavy metals, demonstrated radioactive traces and other harmful pollutants to human beings. These are mainly attributable to a generally increasing contamination of sewage sludge, that have caused tightening on allowable concentration, up to a very likely complete prohibition of agricultural use in e.g. Germany from 2017 onwards.

2. BAUMGARTE CONCEPTS

Baumgarte, founded in 1935, has a long history in the field of thermal residue treatment. Within the early 1960's the first units have been installed. Since then, many executed projects illustrate the plant reliability, environmentally friendly and sustainable sewage sludge treatment solutions in combination with Energy Recovery.
Especially for Sewage Sludge, Baumgarte is able to offer two Energy Recovery concepts:

1. Mono-combustion with fluidized Bed

The Mono-combustion represents an efficient mechanical/thermal partial dewatering and combustion in a fluidized bed combustor plant by means of evaporation/superheating of the sludge water and complete combustion of the organic substances/pollutants and a corresponding volume reduction by up to 99%. The inorganic pollutants are glowed and discharged as concentrated residues of the flue gas cleaning.
The auto-thermal incineration process is a proven and reliable environmentally friendly disposal concept that does not need additional fuel. The energy recovery from the sewage sludge is utilized in the process as well as for power generation, heat supply, etc.

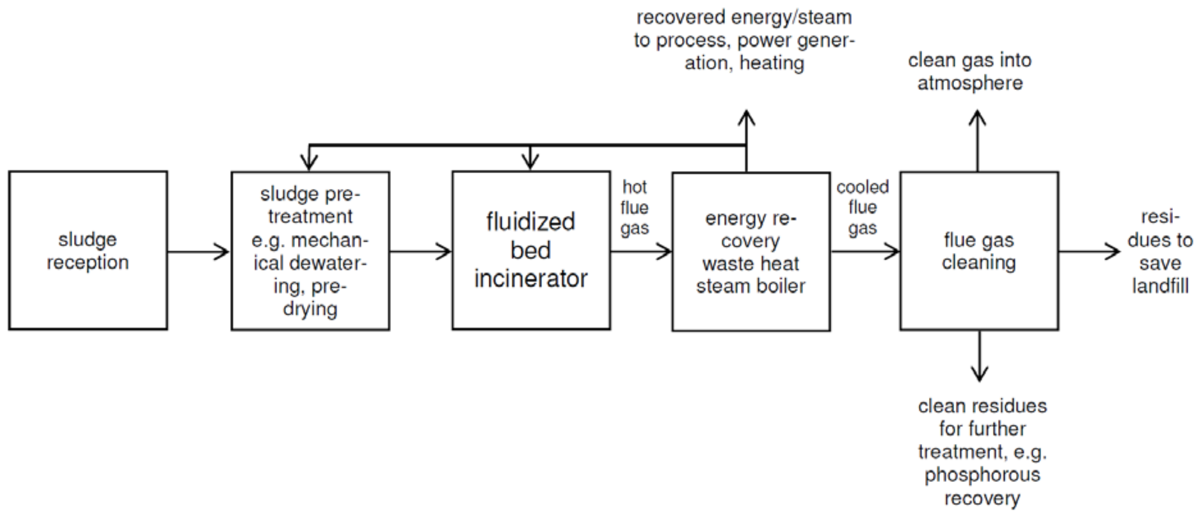

Figure 1. General System Block Diagram illustrates the process

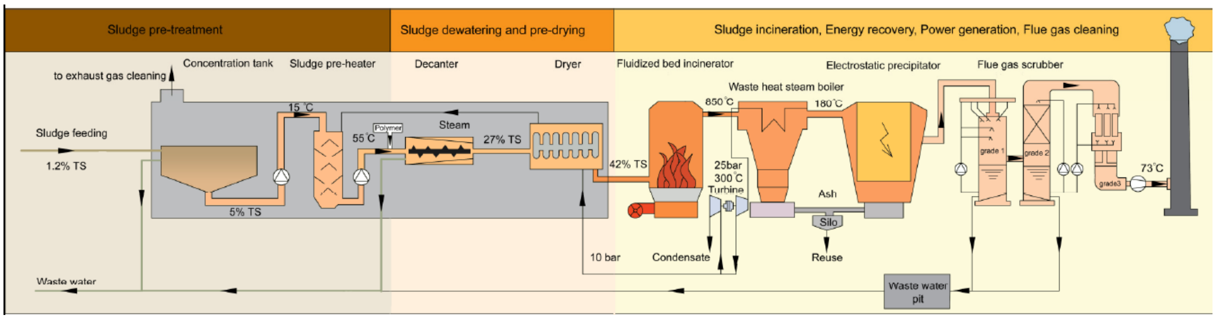

Figure 2. Exemplary plant process overview

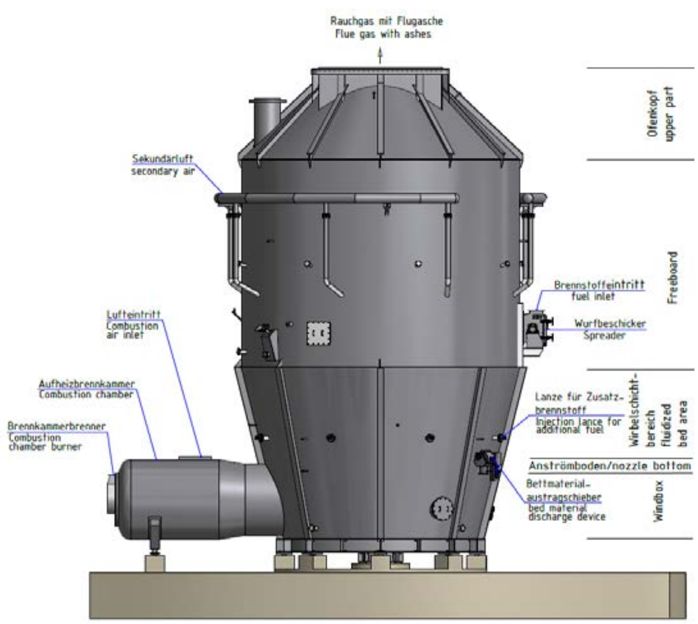

Figure 3. The Fluidized Bed Incinerator

The Fluidized Bed Technology is efficient, proven and reliable. These tailor-made solutions and concepts guarantee the flexibility to comply with individual customer needs.

Further, the emission limits (17.BImSchV / Directive 2000/76/EC) / local regulations are kept reliably.
Further Advantage: NO_2 - limits are kept without any NO_x reducing measures (e.g. SNCR)

2. MEPHREC (TM) Sewage Sludge Recycling with Phosphor recovery

The motivation for Baumgarte together with their partners to develop the MEPHREC technology is the globally rising interest in the limited resource phosphor.
Phosphor is a valuable mineral and an essential resource for mankind. Phosphor is ingested with our food and therefore ultimately extracted from the soil via agricultural plants. But global resources are decreasing and additionally, mainly to be found only in politically less stable countries that might impact the supply chain.
Knowing that sewage sludge contains up to 5% Phosphate (DS), makes it even more necessary to recover Phosphor from sewage sludge
In general, the Mephrec®- process or Mephrec®- reactor is a shaft furnace or cupola furnace.
Mephrec®-process means that during a metallurgical process, an oxygen melting gasification of P-containing materials such as sewage sludge (or sludge ash) is carried out.
For this purpose, briquetted sewage sludge is gasified. Ash components are melted at about 2000°C. The phosphorus-rich liquid slag is separated from the iron metal alloy.
After its solidification in a water bath it has a plant-available form. The fertilizer product is in conformity to the fertilizer ordinance.

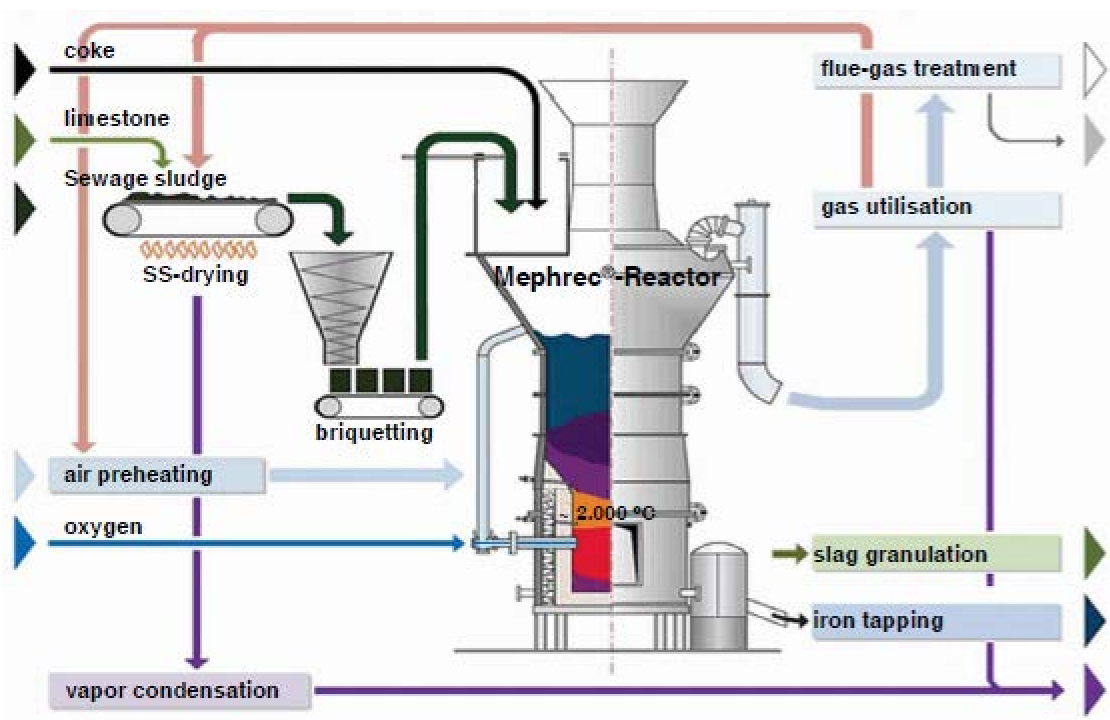

Figure 4. Schematic process

The process can be characterized by a simultaneous material and energy recovery from sewage sludge.

The material recovery is achieved by utilizing the in-process waste heat for drying the sludge to approx. 85-90% Dry Substance (DS) as the preliminary stage for briquetting.

The Energy Recovery from Raw Gas as a resulting by product from the process can be utilized in e.g. a waste incineration plant, etc.

This highly environmental friendly technology stands for products that are free of any organic pollutants and extremely low in heavy metal content in the produced slag (especially Cd, U and TI).

Its easy combination and/or integration into other processes underlines its high process flexibility as well as its High plant-availability of the slag's phosphate (>90% P_2O_5-lemon soluble).

In addition to the use of a MEPHREC System on the area of wastewater treatment plants, where the sewage sludge is produced directly, it can easily be integrated behind a sewage sludge mono incineration plant, before respectively inside waste incineration plants, or at sites with phosphorus-containing waste, just to specify some examples.

The pilot plant in Nuernberg, which is promoted by the German Federal Ministry for Education and Research in the ERWAS program under the title ERWAS - Collaborative project KRN-Mephrec: sewage sludge recycling region of Nuremberg, examines and gives evidence about the technical feasibility, economic viability and environmental sustainability of the Mephrec® method in industrial scale, in order to have a technological alternative for the use of sewage sludge to meet the domestic demand for high-quality phosphorus fertilizer, according to energy and environmental aspects and European regulations and legislations in the future.

INWAFERM - A High Efficient Cost Effective Technology

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Abstract
Inwatech Ltd. an experienced company in engineering, constructing and operating activity created a special unit INWAFERM.
Inwatech offers integrated approach from project preparation, through implementation to operation.
Thanks to its compact design flexibility to fit into any sludge treatment technology KAVINWA 60 unit types has been developed taking into account the ease integrality, because the footprint, energy use and fit of the system. INWATECH constructs flat type digesters facilitating the digestion of feedstock with very high thickness and organic content.
The digesters of Inwatech are also well suited for fermentation of sewage sludge. For perfect biological degradation and gas yield - beside cost effective operation - we emphasize to focus on the mixing mechanism. A case study about INWAFERM technology applied at Kazincbarcika Waste Water Treatment Plant and a lot of reference of design are also presented.

Keywords
Sludge, digester, biogas, efficiency.

1. TECHNOLOGY BACKGROUND

In the passed 15 years from the foundation of Inwatech Ltd. by engineering, constructing and operating activity Inwatech Ltd. has generated a well structured knowledge and practice data base. By this structure and content unique background we created unit to unit our INWAFERM.

2. FLEXIBILITY

Inwatech's customers are all over from various agricultural sectors, as well as from industries and municipalities, that require the utilisation of the widest variety of biosolids and sludge.
INWAFERM's clever design layout and the applied equipment provides excellent robustness, technological safety and flexibility.

3. SUSTAINABILITY

Inwatech offers its extensive experience in optimising energy consumption and biosolid/sludge based renewable energy production. Our digesters bring ecological and economical viable solutions. Solutions for reducing energy costs and CO2 emissions. Inwatech delivers substantially more than just technology. Inwatech offers integrated approach from project preparation, through implementation to operation.

4. UNITS

KAVINWA 60 unit types, thanks to its compact design flexibility to fit into any sludge treatment technology, because the footprint, energy use and fit of the system has been developed taking into account the ease integrality. The equipment to be treated material (substrate) is mechanically pre-treated in such a way that the maximum particle size of 2 mm with liquid organic mass using cavitation impact material size 20-30 microns, homogeneous state.

INWAFERM digester is an innovative digester type of attractively low investment and operational costs, yet allowing the application of the most versatile feedstock. Inwatech constructs flat type digesters facilitating the digestion of feedstock with very high thickness and organic content.
Mixing mechanism - created to enable to reach the best level of biological and temperature homogeneity
Cost-effective, low energy demand tank mixing and heating system
Integrated biological biogas treatment for H_2S removal with polishing step BIOGINWA
Integrated variable volume biogas buffer at top of the reactor
We apply proven, self-developed components including Inwatech's state of the art control equipment which is easy to integrate into existing systems. Our past experience also covers all necessary equipment to treat and convert biogas into energy, in whatever form it is required (electricity, heat, bio methane, steam). Inwatech's digesters are also well suited for fermentation of sewage sludge.

5. FOCUS ON MIXING SYSTEM

For perfect biological degradation and gas yield - beside cost effective operation - we emphasize to focus on the mixing mechanism.
The MIXING SYSTEM is designed based on experiences, live tests and the latest modelling proceedings bases for a wide variety of substrate mixes.

BIOGINWA is a self designed biogas treatment unit, which complies to the local gas treatment regulations, beside supplying the gas engines with an appropriate clean biogas.

6. CASE STUDY ABOUT INWAFERM TECHNOLOGY APPLIED AT KAZINCBARCIKA WASTE WATER TREATMENT PLANT

Location of the project: Kazincbarcika, Hungary
Biological treatment technology: Contiseq SBR Technology
Sludge treatment scheme:

CONTISEQ BASINS

↓

PRIMARY SLUDGE-EXCESS SLUDGE HOMOGENISATION TANK

↓

MECHANICAL THICKENER

↓

THICKENED SLUDGE BUFFER TANK

↓

INWAFERM MESOPHILIC SLUDGE DIGESTION → **CHP UNIT**

↓

DEGASING TANK

↓

DEWATERING

Sludge treatment stage input data:

EXCESS SLUDGE FREIGHT	kg/d	**1824**
EXCESS SLUDGE QUANTITY	m3/d	198
PRIMARY SLUDGE	kg/d	**1629**
PRIMARY SLUDGE QUANTITY	m3/d	58
VOLUME OF MIXED EXCESS SLUDGE	m3/d	256

PRIMARY SLUDGE-EXCESS SLUDGE HOMOGENISATION TANK VOLUME: 340 cm

MECHANICAL THICKENER CAPACITY: 20 cm/h

DRY SOLIDS CONTENT OF THICKENED SLUDGE: 5,80 %

THICKENED SLUDGE BUFFER TANK VOLUME: 150 cm

INWAFERM MESOPHILIC SLUDGE DIGESTION

TOTAL DRY SOLIDS LOAD	kg/d	**3453,00**
TOTAL DRY SOLIDS CONTENT OF MIXED SLUDGE	kg/d	5,80%
VOLUME OF MIXED SLUDGE	m3/d	60
ORGANIC CONTENT OF MIXED SLUDGE	%	**70,9%**
TOTAL ORGANIC LOAD	kg/d	2449
DESIGN VOLUMETRIC ORGANIC LOAD	kg/m3	***1,70***
REQUIRED VOLUME	m3	**1440**
PROVIDED VOLUME	m3	**1500**
PROVIDED RETENTION TIME	d	**25,2**
PROVIDED VOLUMETRIC ORGANIC LOADING RATE	kg/m3	1,63
ORGANIC SOLIDS CONTENT OF DIGESTED SLUDGE	%	53,9%
ORGANIC SOLIDS CONTENT OF DIGESTED SLUDGE	kg/d	1175
TOTAL VOLUME OF DIGESTED SLUDGE	m3/d	**60**
TOTAL SOLIDS CONTENT OF DIGESTED SLUDGE	kg/d	**2180**
ORGANIC SOLIDS DEGRADATION	kg/d	**1273**
SPECIFIC METHANE PRODUCTION	Nm3/kg VSS	**0,47**
METHANE CONTENT OF BIOGAS	%	***60%***
PRODUCED BIOGAS	Nm3/d	**997**
HEAT VALUE OF BIOGAS	MJ/d	**20587**

In Kazincbarcika WWTP it was build an INWAFERM digester of 1500 mc with a build in the digester roof gasholder of 1000 mc. The diameter of the digester is 20 m.

With a biogas production of 1000 N cm/day it was build a cogeneration unit with a CHP engine that produces 125 kW /h.

7. REFERENCE OF DESIGN

2010-2012. Zöldforrás Energia Ltd. Szeged Complete farm biogas plant Capacity:1.100 kW Biogas: 10.000 Nm3/d	**2008-2009. Csenger-Tej Ltd. Csenger** Complete farm biogas plant Capacity: 536 kW Biogas: 4800 Nm3/d
2010-2011. Körös-Maros Biofarm Kft. Gyula Complete farm biogas plant Capacity: 499 kW Biogas : 4800 Nm3/d	**2014. Balassagyarmati Biogáz Erőmű Kft.** Complete biogas plant Capacity: 1000 kW Biogas : 8200 Nm3/d
2013. Pannónia Zrt. Biogáz erőmű Gas Handling and storage 700Nm3/h capacity	**2010-2013. ÉRD and Region Wastewater Treatment** and construction of sludge treatment facilities, biogas utilization Capacity: 500kW Biogas : 2700 Nm3/d
2011-2013. Békéscsaba urban waste water treatment plant Wastewater Treatment and construction of sludge treatment facilities, Biogas utilisation Capacity: 250kW Biogas: 2.640 Nm3/d	**2012-2014. Mosonmagyaróvár urban waste water treatment plant** Wastewater Treatment and construction of sludge treatment facilities Capacity: 250kW Biogas : 2050 Nm3/day
2014. Kazincbarcika urban waste water treatment plant Capacity: 250kW Biogas : 1000 Nm3/d	**2014- Siófok urban waste water treatment plant** Capacity: 150+250kW Biogas: 2092-3788 Nm3/d* *szezonban és szezonon kívül
2007-2008. Soproni Sörgyár Rt.(Heineken HU ZRt.) Complete with a new anaerobic pre-treatment, a full line of biogas facility Capacity: 2.700 m3/d biogas: 3.800 Nm3/d	**2008-2009. Rauch Hungária Kft. Budapest** Complete with a new anaerobic pre-treatment, a full line of biogas facility. Capacity: 1.000 m3/d 40.000 LEÉ, 3,5 t KOI/d Biogas: 1130 Nm3/d

2003-2004. Hungrana Kft. Szabadegyháza Complete with a new anaerobic pre-treatment, a full line of biogas facility Capacity: 7.800 m3/d,336.000 LEÉ Biogas: 12.000 Nm3/d	**2007-2008. Dudayack Zrt Csepeli Papírgyára** new anaerobic pre-treatment, new aerobic degree, a full line of biogas facility Capacity: 3.500 m3/d,133.000 LEÉ Biogas: 5.200 Nm3/d
2012-2013. **Hamburger Hungária, Dunaújváros** Anaerobic wastewater pre-treatment, biogas recovery Capacity: 4800m3/day80.000 LEÉ Biogas : 7000 Nm3/day Reference of construction	**2010-2012. Zöldforrás Energia Ltd. Szeged** Complete farm biogas plant Capacity:1.100 kW Biogas: 10.000 Nm3/d
2008-2009. Csenger-Tej Ltd. Csenger Complete farm biogas plant Capacity: 536 kW Biogas: 4800 Nm3/d	**2010-2011. Körös-Maros Biofarm Kft. Gyula** Complete farm biogas plant Capacity: 499 kW Biogas : 4800 Nm3/d
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2012-2014. Mosonmagyaróvár urban waste water treatment plant Wastewater Treatment and construction of sludge treatment facilities Capacity: 250kW Biogas : 2050 Nm3/day	**2014- Siófok urban waste water treatment plant** Capacity: 150+250kW Biogas: 2092-3788 Nm3/d* *szezonban és szezonon kívül
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2003-2004. Hungrana Kft. Szabadegyháza Complete with a new anaerobic pre-treatment, a full line of biogas facility Capacity: 7.800 m3/d,336.000 LEÉ	**2007-2008. Dudayack Zrt Csepeli Papírgyára** new anaerobic pre-treatment, new aerobic degree, a full line of biogas facility Capacity: 3.500 m3/d,133.000 LEÉ

Biogas: 12.000 Nm3/d	Biogas: 5.200 Nm3/d
2012-2013. **Hamburger Hungária, Dunaújváros** Anaerobic wastewater pre-treatment, biogas recovery Capacity: 4800m3/day80.000 LEÉ Biogas : 7000 Nm3/day	**2014. Kazincbarcika urban waste water treatment plant** Capacity: 250kW Biogas : 1000 Nm3/d

Biogaz plant operating experience

2010-2012. Zöldforrás Energia Kft. Szeged Capacity: 1.100 kW Biogas: 10.000 Nm3/d	**2008-2009. Mil-Power Kft. Paks-Földespuszta** Kapacitás: 1200 kW Biogas: 10.000 Nm3/d
2011. Csanád Gazdaségfejlesztési Kht. Biogas Plant-Biogas Mixing Technology Service	**2011. Pilze-Nagy Kft.** Biogas Technology to carry out repair services Replacing the damaged gas storage
2013. Bicsérdi Arany-Mező Zrt. Biogas plant Gas Treatment 400Nm3 / h capacity, delivery and installation Digester submersible mixer	**2013. Green Balance Kft. Biogas plant** Replacing the damaged gas storage
2012. Aufwind Schmack Első Biogáz Szolgáltató Kft. Installation of submersible mixers fermenter	**2010-2013. ÉRD és Térsége Szennyvíztisztító és biogáz hasznosítás** Capacity: 500kW Biogas: 2700 Nm3/d
2007-2008. Soproni Sörgyár Rt. (Heineken HU ZRt.) Complete with a new anaerobic pre-treatment, a full line of biogas facility Kapacitás: 2.700 m3/d Biogas: 3.800 Nm3/d	**2008-2009. Rauch Hungária Kft.** Capacity 1.000 m3/d 40.000 LEÉ, 3,5 t KOI/d Biogas: 1130 Nm3/d

Thermal Treatment Of Sludge

Peter Rottenmanner*

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(E-mail: *peter.rottenmanner@andritz.com)*

Abstract
Transport and disposal of municipal sludge is causing a lot of costs and emissions – and space for disposal is getting more and more reduced. With dewatering and especially drying of municipal sludge the volume of sludge to be transported can be dramatically reduced. But not only volume reduction is done – also a valuable fuel - pathogen free, if dried properly - is produced. This fuel can be used for example in cement factories, but dried sludge (where allowed) can also be used as a fertilizer.
Depending on available heat sources and final purpose of the sludge (after drying), different technologies can be used to dry the sludge. In the presentation these drying technologies will be presented as well as a way to minimize the use of primary energy for sludge drying by using biogas produced on the WWTP and/or waste heat (hot water, low pressure steam or exhaust air).

Keywords
Sludge Drying, energy source, granulate quality.

1. INTRODUCTION

Producers of sludge do not want to run into any risks related to disposal or final use of sludge. In addition, for both municipalities and also industrial companies the costs for transport of sludge, as well as costs for disposal, are significantly growing and permissions for new disposal areas are more and more difficult to get.
Therefore a proper dewatering and thermal treatment of the sludge can lead to significant benefits for the operating company.
This article is introducing and concentrating on four different drying technologies as well as the possibilities to use the necessary thermal energy for drying of the sludge in an efficient way. These four drying technologies (see Figure 1) are drum dryer, fluid dryer bed, paddle dryer and belt dryer.

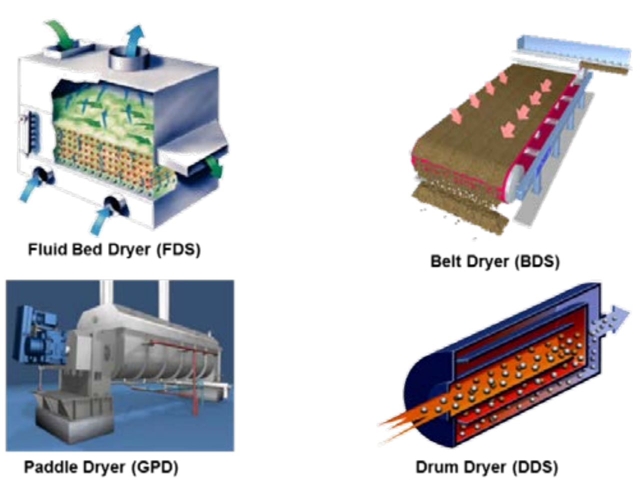

Figure 1. Drying technologies

These drying technologies convert the sewage sludge into a product which is free flowing, can safely be stored and easily transported – at the end of the drying process - a product suitable for further use is available. All four introduced drying technologies ensure full drying of the sludge (to dry substance contents ≥ 90 %). Furthermore the final product is fulfilling EPA 503 Regulations for Class A requirements (concerning pathogen reduction).

2. THE RIGHT DRYING TECHNOLOGY

Some factors directly influence the decision for the most suitable drying equipment.
- Operating costs;
- Product quality;
- Available space;
- Capital costs.

The operating costs are a main factor to decide for the most suitable drying technology – and amongst those the energy costs are a significant portion of the sludge treatment costs. Therefore the use of waste energy or cheap energy is preferred compared to the use of costly primary energy.
In principle you have to differentiate between direct and indirect heated dryers (see Figure 2). For the belt dryer sometimes also a combination of those two heating systems makes sense – see below.

Direct heated dryers use
- Natural gas;
- Biogas;
- Diesel.

Indirect heated dryers use
- Thermal oil;
- Middle or low pressure steam;
- Hot water;
- Flue gases.

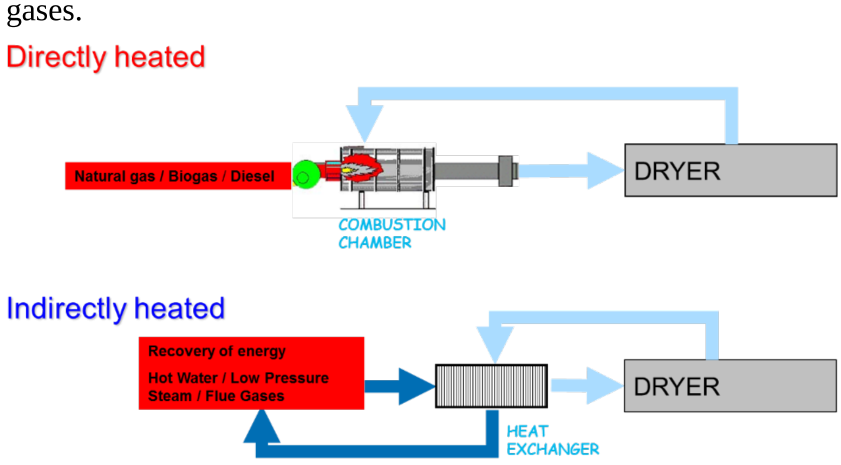

Figure 2. Heat supply to dryers

Amongst the four mentioned drying technologies, drum dryers request the highest drying air temperature ($\geq$ 350°C), most drum dryer installations are directly heated with primary energy like natural gas or Biogas.

Fluidized bed and paddle dryers typically are indirectly heated drying systems powered by thermal oil or steam.

The requested temperature level for fluidized bed dryers is between 130 – 250°C, whereas the paddle dryer requests temperatures of 170 – 230°C.

Belt dryers can use low temperature heat sources like low pressure steam, hot water or flue gases.

Of course also primary energy can be used, but clearly the possibility of using low temperature heat sources is a main advantage of a belt drying installation.

Typically the drying air temperature in the belt dryers is between 95 – 135°C – depending on the available heat sources.

As the specific evaporation capacity per m^2 of belt is mainly defined by the drying air temperature, the knowledge about available heat source(s) is necessary already in the designing phase.

In addition due to safety reasons the maximum allowed drying air temperature is defined by the sludge to be treated.

3. BELT DRYER DIRECT AND INDIRECTLY HEATED

As mentioned before, the belt drying system is able to use both direct and indirect heat sources at once.

If the use of gas engine cooling water (to produce “green” electricity from Biogas - which is subsidized in many countries) is possible, this waste energy use can significantly reduce the necessary additional primary energy amount – see case study below.

Assuming a yearly dewatered sludge amount of 35.000 t (dewatered to 25 % dry substance content) and full drying (to $\geq$ 90 % dry substance content) of the sludge, the use of engine cooling water (figures depending on the type of gas engine used!) from a gas engine can reduce the necessary natural gas consumption by approx. 10 % - and this energy is free of charge!

Theoretically in addition also the flue gases from the gas engine can be used as heat source, but the characteristic of the flue gases (dew point!) have to be respected during the designing phase.

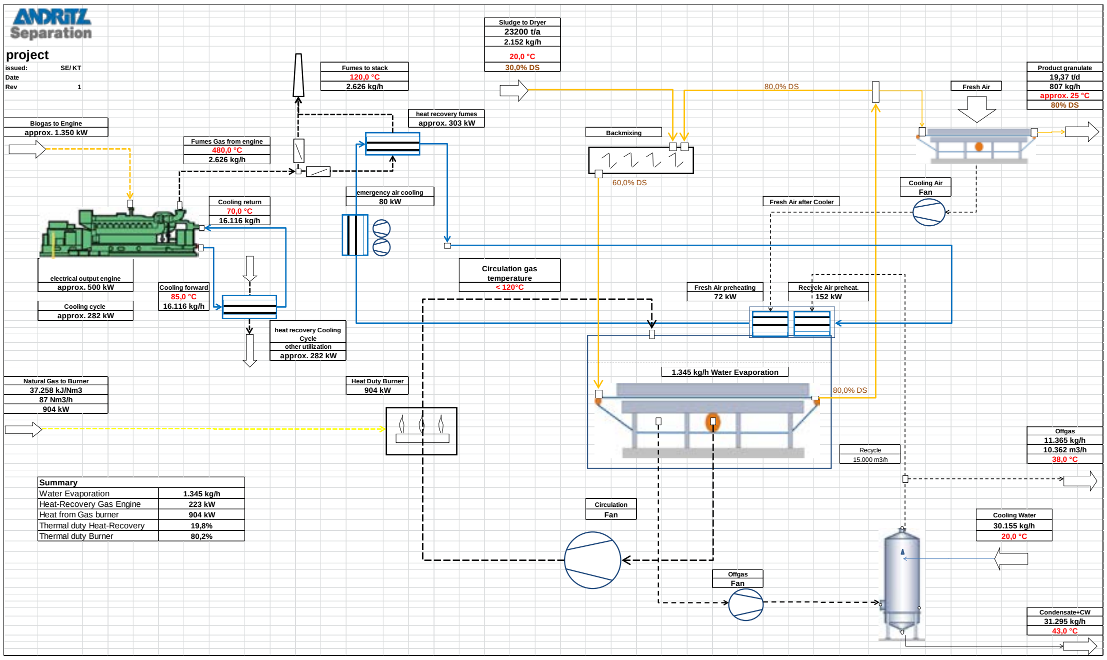

Figure 3. Mass balance for a belt dryer showing use of waste heat

4. QUALITY OF PRODUCED DRIED SLUDGE

Depending on the final use of the product, operators request specific particle size distributions.

For example automatic fertilizer spreading machines request even particle size distribution (to avoid blockages), whereas for landfilling or composting the sizing of the final product is of minor importance.

Figure 4. Sample pictures of dried sludge

5. EMISSIONS CAUSED BY THE DRYING SYSTEMS

One of the characteristics of sewage sludge are the entrained odours, therefore the dryers are operated in a way, that no odorous air is extracted to the environment, the complete quantity of exhaust air has to be treated in the exhaust air treatment equipment.

The design of the exhaust air treatment is depending on local regulations; the bandwidth of necessary equipment can be from (simple) Bio filter to RTO (Regenerative Thermal Oxidizer) and a lot in between.

The exhaust air volume to be treated differs from the drying technology in operation, for Fluid bed dryers and paddle dryers the amount of air to be treated is significantly smaller as for drum dryers, the highest exhaust air volume has to be treated, when belt dryers are used.

6. DRYER SIZES, APPLICATIONS

All four drying technologies provide a wide range of capacities and applications. The most significant key parameters are the hourly water evaporation capacity and the specific thermal and electrical energy consumption.

Belt dryer:
Typical water evaporation capacity from 500 – 10.000 kg per hour per drying line, the particle size distribution of the dried sludge can be influenced by additional equipment like crusher and sieve.

Drum Dryer:
High capacity Dryers with water evaporation capacities from 4.000 – 12.000 kg per hour per drying line, the drum dryers also produce the most homogeneous product, perfectly usable as fertilizer.

Fluidized Bed Dryer:
Water evaporation capacity from 1.000 – 11.000 kg per hour per drying line, the fluidized bed shows a high flexibility in case different sludge properties have to be treated.

Paddle Dryer:
Water evaporation capacity from 500 – 4.000 kg per hour per drying line, the paddle dryers are compact in design and enables besides full drying partial drying of sludge (dry substance content from 70 – 90 %).

7. FINAL USE OF DRIED SLUDGE

Some of the possibilities (incineration in a cement kiln, landfilling, as well as use as fertilzer) for the final use of dried sludge are shown in Figure 5.

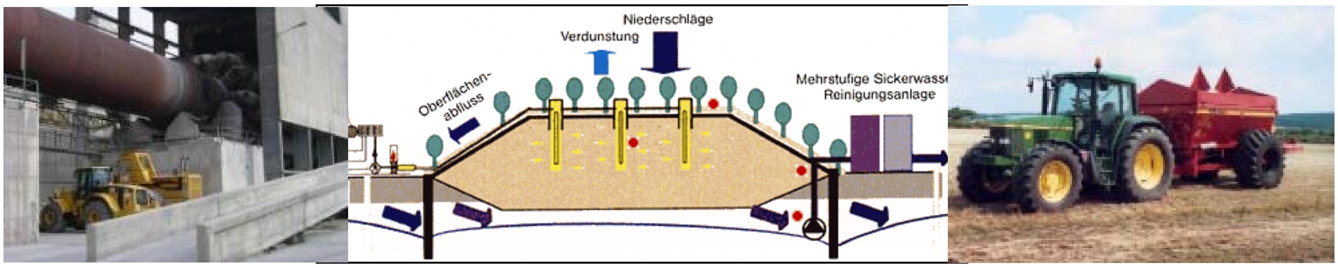

Figure 5. Sample pictures of dried sludge

8. CONCLUSION

Thermal Treatment of sludge enables the operator to convert waste to product, and the ANDRITZ Separation dryer portfolio ensures that the customers can choose the most suitable drying technology for their application. Significantly, more than 100 references worldwide show the wide experience and know how.

ANDRITZ is your Separation specialist able to propose complete range of thermal sludge drying equipment and the best solution considering project requirements.

Valorization and Reuse of Biological Sludge

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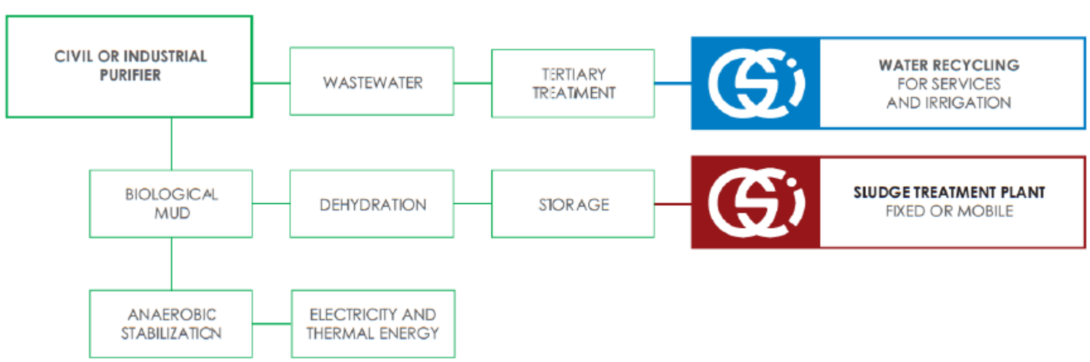
Abstract
Each purification plant of wastewaters has to be considered as a productive center of environmental and agronomic resources. A monitoring of specific chemical and microbiological parameters and of operatives ones allows to direct the reuse of waters and sludge. The reuse of waters in the agricultural sector can be direct to the irrigation or fert-irrigation, in the industrial sector can be direct to the treatment/washing/ cooling and, in the civil sector can be direct to the not-potable use. The reuse of sludge allows to give a good contribute to the soil both in the direct use and as integration in the compost production and soil corrective. A good management of the recovery of sludge can be obtained from a "Global Management Service", linking the activities of "the transformer", of the "producer" and of the "user".

Keywords
Treatment, Agriculture, Composting, Other applications.

1. OUR MISSION

"A waste is a complex chemical product and as such, must to be treated in accordance with the laws"
O.S.I. Eco Service is a Consulting and Global Service Company, specialized in the treatment of wastes. The company has the purpose to spread the concept of a new way to reuse sludges and wastewaters originated from purification plants, both civil and industrial ones. In the following scheme **(Scheme 1)** are showed the two different lines of treatment for water and sludge.



Scheme 1. Treatment's line for water and sludge

Tertiary Treatment System of purified waters

Our delivery of technologies consists in: accelerated decanting systems, sand filtration, activated carbons, and osmosis and ultra-filtration processes, depending on the quality of purified waters, as the case may be. (**Figure 2)**.

Our consultancy delivery consists in the following services:

- management of treatment plant for a defined time period;
- technical assistance with accredited analytical tests of waters in treatment's phases;
- technical assistance during the phases of the reuse in agriculture or in services as washings, cooling, etc.

In this way we can consider a purification plant as a production center not only of energy but also of recoverable matter.

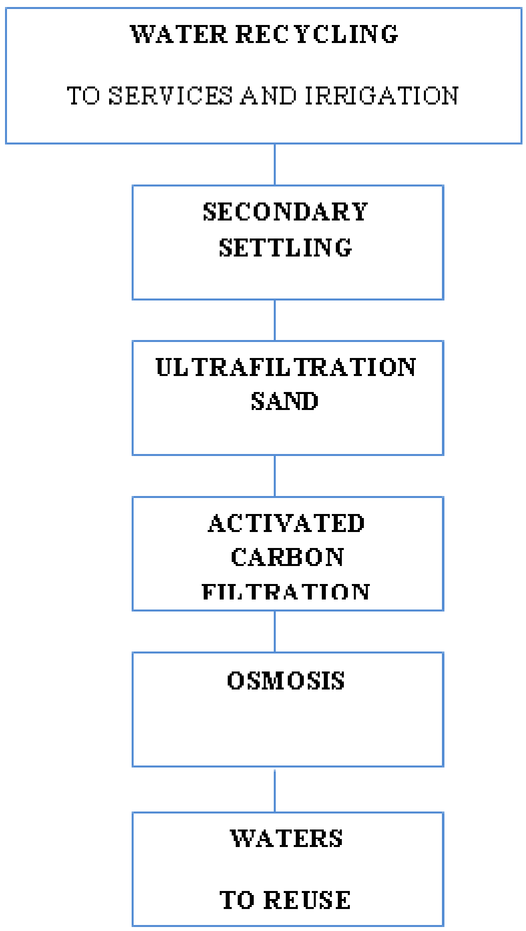
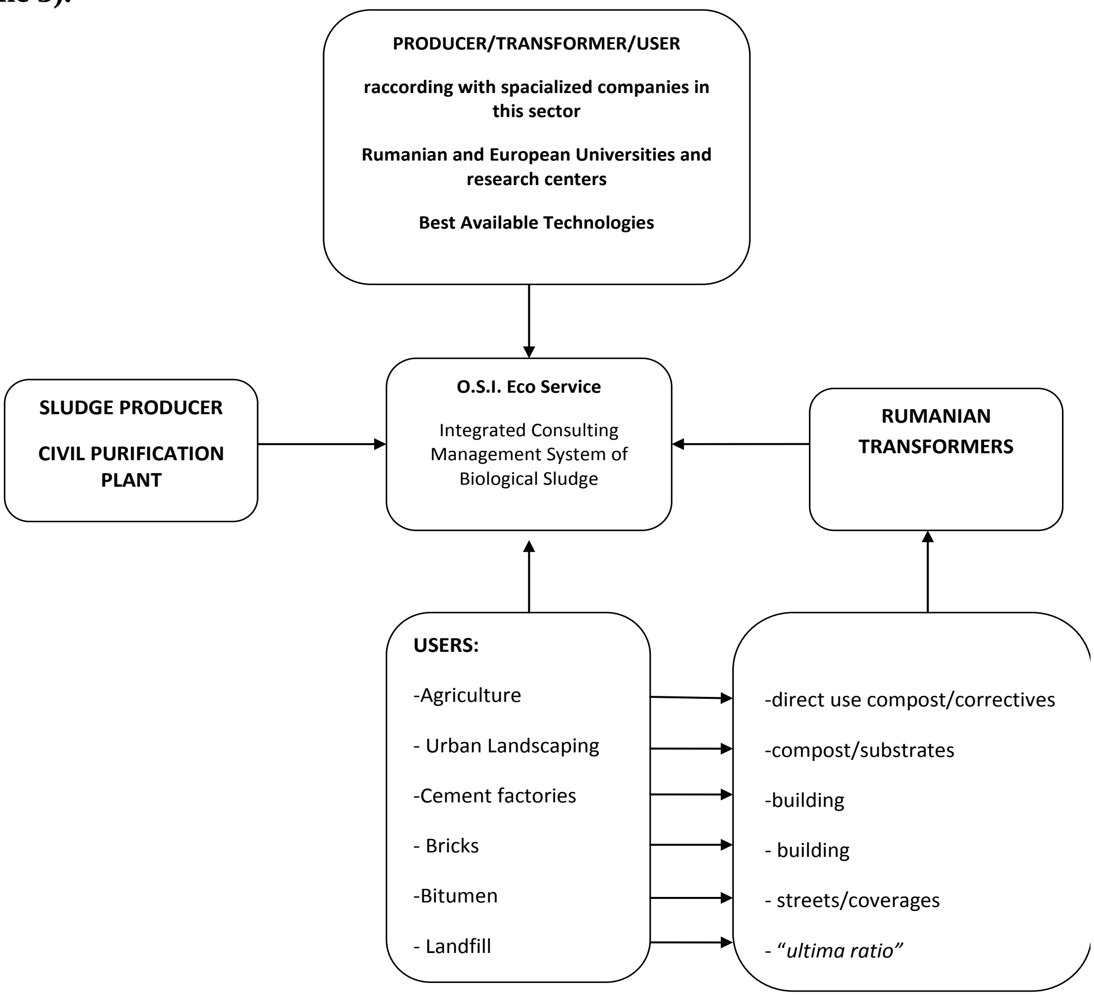


Figure 2. Tertiary Treatment of water

Treatment of sludge

Through the valorization and reuse of biological sludge it could be achieved a big reduction in the quantities of sludge destined to final disposal (landfilling, incineration). Each civil water purification plant has its own kind of sludge, a specific treatment for conditioning, use or disposal and thus its specific sludge process solution. Research on a case by case basis is necessary and preparatory to the solution. Our mission is to relocate technological and management processes with specific applications of valorization and reuse of biological sludge in agriculture and composting in each purification plant geographical area. The producer of sludge (purification plant) has to provide a site to deposit the sludge in order to stabilize and sanitize it. During the treatment phases a certified laboratory provides its support to analyze the sludge as requested by the law (e.g., in respect of its composition of pH, C.E.C., heavy metals, organic carbon, total phosphorous (P), total nitrogen (N), etc). Regarding the sludge treatment, our activities are included in the Consulting Management System of Biological Sludge showed in the scheme below **(Scheme 3).**



Scheme 3. Consulting Management System of Biological Sludge

OSI Eco-Service technology deliberables:

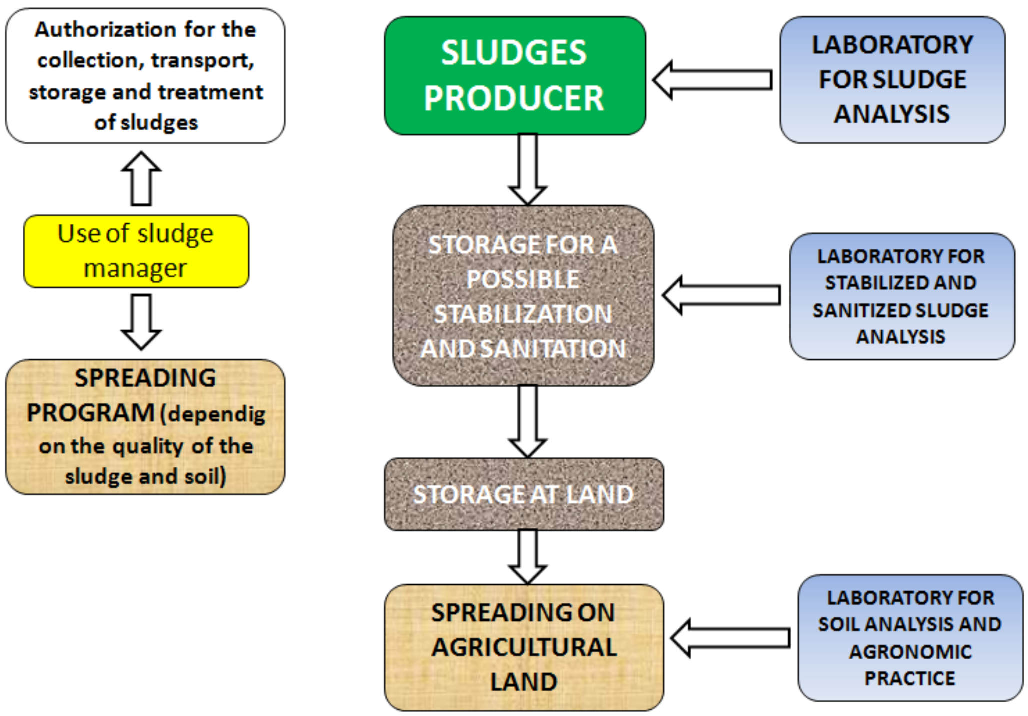
- plant line for treatment of stabilization, dehydration, inertisation and sanitation of sludge in order to prepare them for later use or for a disposal;
- fixed plant that depends on annual production of sludge;
- mobile plant located on truck or on equipped sites, as authorized for sludge treatment and the use of skilled personal;
- total plants of aerobic and anaerobic compost production;
- total system of air purification.

OSI Eco-Service consultancy deliberables:

- monitoring of accredited laboratories of sludge reuse process;
- training of the staff working with the sludge;
- technical assistance and management of the treatment plant for defined periods;
- technical assistance and management for the reuse of treated sludge both directly in agriculture and in composting;
- technical assistance and management for aerobic and anaerobic composting plants (mixed composted soil improver, green composted soil improver, universal soil improver, substrates);
- technical assistance for Quality and Accretitated Certification for processing and products.

2. PROCESS OF SLUDGE MANAGEMENT FOR THE TOTAL USE IN AGRICULTURE (FROM WASTE TO WASTE)

When sludge reaches a good level of maturation, its spreading on land, on an agricultural soil, will be the last phase of the whole analysis and treatment process. The same analysis conducted on the sludge must be conducted also on the soil where such sludge will be spread. The manager of the process must be authorized according to the law for the collection, the transport, the storage and the treatment of sludge. He also has to draw up a detailed spreading program, depending on the quality of the sludge and soil, the cultures, the period of the year, etc. This spreading program has to regard also the equipment and the ways of spreading (means of transport, quantities/day, capacity, spreading speed, etc). The full process of sludge treatment (destined to agricultural reuse) is illustrated in the scheme of process below **(Scheme 4)**.



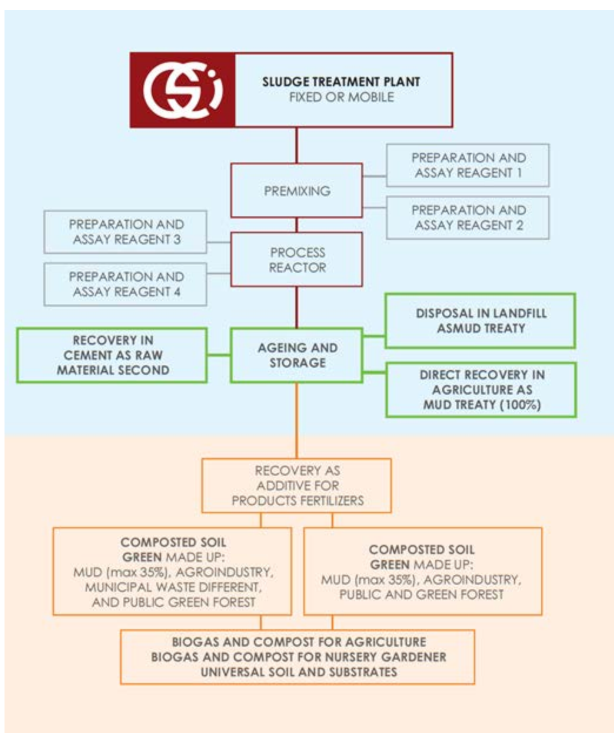
Scheme 4. Scheme of process of the direct use in agriculture

3. PROCESS OF COMPOSTING AND PRODUCTION OF CORRECTIVE FERTILIZERS (FROM WASTE TO PRODUCT)

Another possible reuse of produced sludge from purified plants, in addition with organic wastes (before direct to landfill), is the composting in order to produce different kind of composted soil improvers and corrective fertilizers:

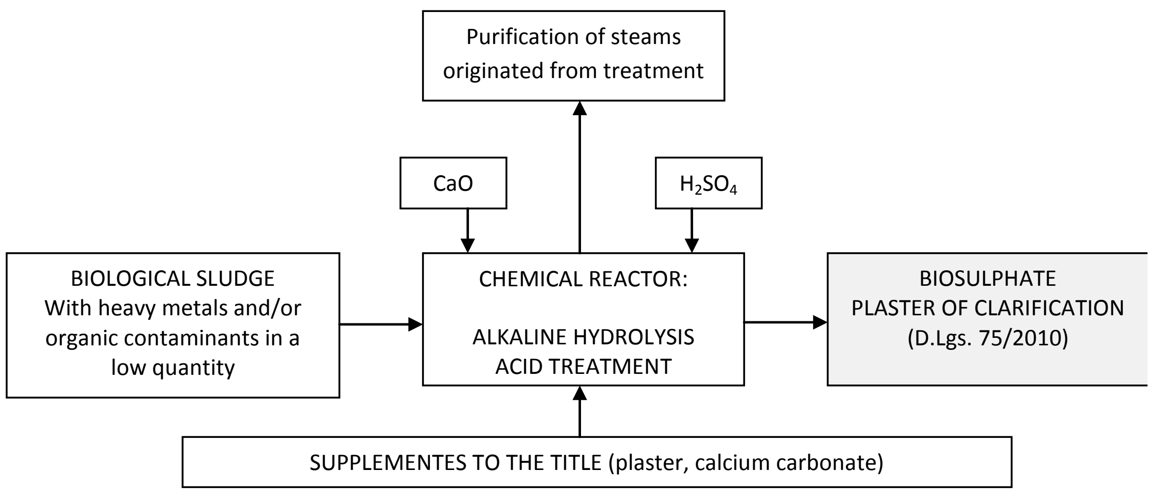
- green composted soil improver: obtained from a controlled process of transformation and stabilization of organic wastes made by refuse from green ornamental maintenance, refuse from cultures, sludge, etc;
- mixed composted soil improver: obtained from a controlled process of transformation and stabilization of organic wastes made by organic fraction of urban solid wastes from differentiated collect, wastes from animals, wastes from agro-industrial activities, wood, sludge and natural textiles processing;
- peaty composed soil improver: obtained from mixed peat (>50%) and green or mixed composted soil improver.

In the figure **(5)** is highlighted the composting process with the final production of the soil improvers described above. Firstly sludge is treated, as the Romanian Order No. 344/2004 requires, with the quicklime, as the reactive base, in a percentage depending on the characteristics of the started sludge. This kind of treatment expected various processes: chemical stabilization, inertization and igienization. After this applications the treated sludge has to be direct in the right way of direct use in agriculture, in cement factories, in the production of bricks, in landfill or in the recovery processes for the use in agriculture (direct spreading, composting, production of corrective fertilizers).



Scheme 5. Scheme of sludge's treatment and possible destinations

The use of compost, as a soil improver, in an agricultural soil provides many benefits to the soil itself and to the crops because it transforms organic fresh matrices from different origins into an homogeneous and stable material that maintains good quantities of humified organic susbstance with a low fermentability; also the quality of obtained compost depends on the characteristics of materials started to composting, expecially for the lowest levels of polluting substances and of foreign materials. Its biological richness allows to increase the mineralization of organic compounds in the soil to improve the general plant's assimilation of nutrients. The corrective/organic fertilizers is another solution to treat sludge/waste and make them an important and useful product; they are obtained from mixed sludge/compost/inorganic fertilizers. The Scheme (6) shows the production of corrective fertilizers (example: bio sulphate).



Scheme 6. Production scheme of corrective fertilizers (ex: bio sulphate)

CASE HISTORY N.1: PRODUCTION OF CORRECTIVE / ORGANOMINERAL FERTILIZERS

(https://www.youtube.com/watch?v=s5Fvvg1tYJ0)

Plant: Agrisistemi/Hera S.p.a.- Plant of Cervia (Rimini), Italy
Power plant: 70.000 ton/year of input material:
100% biological sludge
Bio sulphate production: about 80.000 ton/year

CASE HISTORY N.2: PRODUCTION OF COMPOST

(http://www.sep-compost.it/index.html)

Plant: S.E.P. Pontina Ecological Society S.r.l.- Pontinia (LT), Italy
Power plant: 60.000 ton/year of input material:
70% differentiated urban collect
20% green wastes
10% biological sludge
Production of compost: about 20.000 ton/year

CASE HISTORY N.3: PRODUCTION OF SLUDGE TO THE DIRECT USE IN AGRICULTURE
Plant: ECOTRASS Carvico Bergamo, Italy
Power plant: 35.000 ton/year of input material:
100% biological sludge
Production of treated sludge to the direct use in agriculture: about 37.000 ton/year

4. ECONOMIC ADVANTAGES FROM THE USE OF SLUDGE IN AGRICULTURE

The reuse of biological sludge in agriculture represents an important collective advantage from an economic/energetic/environmental point. Thanks to this application, the manager of purification can provide a good and cheap disposal system, the users connected to the purification plant benefit of this lower price and the farm satisfies nutritional requirements of the cultures, reducing the need of chemical fertilizers. Phosphorous, not renewable substance, represent an essential element for the grow of cultures and the use of biological sludge in agriculture allows a reintroduction of this element into the soil without further costs. Assuming the reuse of biological sludge in agriculture produced in Lombardia (Italy) (about 168.000 tons of dry substance/year), is possible to estimate the equivalent recovery in fertilizers elements, as showed in table **(7)** and the relatives economic advantages in table **(8):**

BIOLOGICAL SLUDGE (168.000 tons d.s.)	**% d.s.**	**Elements in tons**	**Equal to tons**	**of equivalent fertilizer**
NITROGEN (N)	3.0	5.040	10.950	of urea (N=46%)
PHOSPHOROUS (as P_2O_5)	2.5	4.200	9.130	of triple superphosphate (P_2O_5=46%)

Table 7. Relationship between quantities of used sludge and recovered elements (Lombardia)

EQUIVALENT FERTILIZER	**TONS**	**COST €/TON**	**TOTAL COST €**
UREA	10.950	300-500	3.285.000-5.475.000
TRIPLE SUPERPHOSPHATE	9.130	400-600	3.652.000-5.748.000
TOTAL		€	6.937.000-11.223.000

Table 8. Economic advantages

5. ENVIRONMENTAL ADVANTAGES FROM THE USE OF SLUDGE IN AGRICULTURE

The reuse of biological sludge in agriculture leads to a great intake of organic substance that contrasts effectively the process of desertification and offsets the losses of organic substance due to intensive monocultures. This application also represents an important carbon sink thanks to the immobilization of the carbon in the form of humus with a slow release of CO_2. Finally, it's possible in this way, a great reduction in the CO_2 emission, contrary to that occurs during the combustions and the energy consumption in the preliminary dehydration of sludge.

6. ENERGETIC ADVANTAGES FROM THE USE OF SLUDGE IN AGRICULTURE

The use of biological sludge in agriculture allows to save energy to dry sludge and to produce fertilizers, as showed in table (9). (EPT = Equivalent Petroleum Tons; 1 EPT= 41.86 GJ).

EQUIVALENT FERTILIZER	TONS	ENERGY CONSUMPTION EPT/TON	TOTAL ENERGY CONSUMPTION EPT
UREA (46%)	10.950	1.80	19.718
TRIPLE SUPERPHOSPHATE (46%)	9.130	0.36	3.286
TOTAL		EPT	23.004

Table 9. Energetic advantages

7. STUDIES TO EVALUATE THE POSSIBLE NEGATIVE IMPACTS DUE TO THE USE OF BIOLOGICAL SLUDGE IN AGRICULTURE

Ineris (French Public Entity)

- Study lasting 70 years;
- Global calculated level risk is compatible with health rules;
- Risk contribute due to surfactants and phthalates has to be considered not significant.

London Imperial College (EWA Workshop)

- Evaluation of microbiological impact: the concentration of illness due to the consumption of products grown on soil treated with sludge results really unlikely.

Province of Pavia, Italy (Study about metals concentration)

- Study lasting 50 years;
- The different use of fertilizers makes to think that there isn't a direct influence on the concentration of heavy metals on the soils;
- The content of dioxins in the soils results about 10-20 times lower than limits of the law (D.M. 471/1999).

ERSAF (Research copybooks n. 61, 02/07, ch. 4°)

- There are not found differences between a treated soil with sludge and others soils regarding to the accumulation of heavy metals in the soil.

C.R.P.A. Reggio Emilia, Italy

- Study lasting 18 years;
- Agronomical use, also extended, of biological sludge leads not to an accumulation of organic contaminants neither of harmful heavy metals;
- Agronomical use of biological sludge increase the quantity of organic substance (+13%), of total nitrogen (+15%) and of phosphorous (+83%) of the soil itself .

Arizona University: dangers due to the dissemination of aerosols during the process of distribution of sludge

- Microbiological risk of aerosol's inhalation for the workers who distribute sludge is lower than who work at the purification plant.

8. PORTFOLIO - PROJECTS AND MANAGEMENT

1. T.T.L.: Authorized mobile plant for inerting wastes from pharmaceutical companies, city gases and papermills;
2. CONSORTIUM 1: authorized platform for treatment of non-hazardous liquid and solid waste;
3. CONSORTIUM 2: extension of CONSORTIUM 1 platform to new CER codes and organizations of micro waste collection;

4. Authorized plant for production of expanded clay with use of waste (ARIANO IRPINO - ltaly);
5. Gypsum supply from flue gas neutralization process for ENEL power plants;
6. Gasification plant from 200 KWh to 50 KWh for biomass, wood chips and husk;
7. Line piant for handling wood chips Vs gasifiers;
8. Participation to plant for synthetic diesel fuel planning from biomass;
9. Optimization of sludge treatment processes for agricultural re-use;
10. Planning of platform for 100,000 tons of hazardous and not hazardous waste on behalf of GAIA (Colleferro, FR, ltaly) like ordered by ltalian Environmental Ministry for Municipality of Beijing;
11. Expert assistance for the management plant area consortium of Development Industrial Frosinone system consortium area of Development;
12. Expert assistance and management of wastewater treatment plants of different ASl industries in Frosinone (ltaly);
13. Expert assistance and management of two incinerators of energy recovery plants of 12 MW in Colleferro also with emission monitoring and ash and slang characterization and disposal;
14. Recovery of slag producend during incineration with consequent recovery of energy in ITALCEMENTI concrete plant (Sardegna - ltaly);
15. Skilled support in researching for biomass and energy recovery incinerators and emission monitoring in BIOMASSE ITALIA (Crotone -ltaly);
16. Optimization in compost production (20.000 tons/year) from FORSU (60000 tons/year) and realization of monitoring planes according with Compost Giude Lines 75/2010 in PONTINIA;
17. Lines for the use of compost in SEP, Pontinia:
- MIX with biological sludge;
- MIX with green;
18. Skilled chemical support for ACEA - Rome Municipal Energy Environmental Company - in appling Directive 86/278 l EEC for sludge use in agricultural field (Council of 1986/06/12 about environmental protection with particular regard to the soil using sludge from purifier);
19. Chemical assistance in process and application of laws about compost recovery from organic waste and other materials;
20. Applying compost Vs degraded areas and environmental remediation; Abban Cells, concrete, landfills;
21. Incinerators ash and slag Reuse Vs cement plants;
22. Dry and wet separation with separation of water percolation for SEP company;
23. Colleferro landfill optimization for waste distribution in storage cells;
24. RSU re-use project with gasification plants in Romprest, Bucharest;
25. Mobile inertizing plants for inorganic sludge from electroplating of 15000 tons and subsequent disposal in landfills for VIDEO-COLOR (Frosinone, Italy);
26. Mobile plant to neutralize the zinc oxide from industriai Pharmaceutics (CHEMI);
27. Mobile plant pilot for solvent recovery c/o ABBOTI spa APRILIA;
28. Re-use paper sludge vs cement and brick production;
29. Draft composting plants Vs community areas;
30. Agronomic plans enhancement of sludge and compost with components of enrichment of natural inorganic mineral and agricultural areas and South Pontine Rome;
31. Process lines for tertiary water reuse treatment - epicresi ASl Frosinone;
32. Lines of industrial water recycling industry pickling iron (SLM Ceprano);
33. Recovery of pickling sludge in a plant for the production of bricks;

34. lnvestigation grant authorization SMAE Southern Company expanded clay of Ariano Irpino to the use of organic waste in the production of expanded clay;
35. Applied research with Prof. Liberti for the best application in waste SAME;
36. Application management project refining OFMSW before filling the biocells clor SEP;
37. Environmental monitoring in landfills and biogas recovery (ICQ);
38. Design and application of the recovery of biogas at landfill of San Nicola La Strada (Ce) – ICQ – Rome;
39. Implementation of the Chemical Laboratory at the landfill MAD Roccasecca;
40. Development ICQ Ltd. as a partner in the field of energy recovery;
41. Design and construction of worm farming to organic sludge of paper mill;
42. Draft installations polyfunctional mixing, harmless, inert, sanitizing various types of sludge and waste into account the quality and the final destination;
43. Projects of recovery of paper, cardboard and plastics as a function of reuse as
Cartiere, RDF, granulation;
45. Project to leverage food production lines (bakery) across the IFS;
46. Research and analysis project hair to contaminated areas - area Campania - Abruzzo - in collaboration University of Rome Tor Vergata.

9. RESEARCH PROJECTS IN PROGRESS

1. Enhancement biowaste and green waste for the production of Universol molds;
2. Enhancement of biological Sludge.

Digestion And Composting As A Way To Use The Energetic And Material Potential Of Waste Water Sludge

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Abstract
Untreated sludge from waste water treatment can cause a number of problems such as large demand of storage volume and odour trouble. But in the waste water treatment sludge a potential of energy and a material potential is incorporated. With biological processes such as digestion and composting the mentioned problems can be solved and the material and energy potential can be used. Effects and benefits of both mentioned processes will be described. Strabag Environmental Plants has a long lasting experience in the design and erection of plants which contain digestion and composting process steps. Characteristic features of Strabags plant and equipment design will be explained.

Keywords
Sludge digestion in LARAN® Loop Reactor, energy production, tunnel and membrane composting.

1. OBJECTIVES AND EFFECTS OF WASTE WATER SLUDGE TREATMENT

Without further treatment sludge from mechanical-biological waste water treatment create a number of problems. Some of them are a large demand of land for storage, odour problems, especially in warm season and high costs for transport due to the big amount of water and organic parts.

Sludge from mechanical-biological waste water treatment contains a potential which can apply to an energetic and material use. By use of this potential with biological treatment, the above mentioned problems can be reduced significantly. Biological treatment processes, which can be implemented in existing installation relatively easy, are digestion and composting of waste water sludge.

With sludge digestion the following effects can be reached:

- Reduction of sludge mass, due to biological degradation of the organic components in the sludge;
- Production of biogas, which can be used for electrical and/or thermal power production
- The properties for sludge dewatering will be improved, which results in higher solids concentrations in the sludge and less flocculation aid consumption;
- Sanitation of the sludge, in case of thermophilic process conditions.

By means of a composting step the following effects can be reached:

- Mass reduction of the sludge due to biological degradation of the organic components under aerobic conditions;
- Mass reduction of the sludge due to drying and water reduction by the aeration air;
- Sanitation of the sludge by self heating due to biological degradation processes under

aerobic conditions;
- Creation of a product which can be sold in case boundary values of chemical parameters will be met.

A combination of digestion and composting of waste water treatment sludge is possible as well.

The following chapters contain a short summary of the figures about the possible effects and a description of the technical solutions provided by Strabag.

All calculations are based on a sludge production given in the following table (*table 1*):

Table 1. Characteristics of waste water treatment sludges

	Solids mass [g/PE*d]	**Suspended solids concentration (SS) [%]**	**Volatile solids concentration (VS) [% of SS]**
Primary sludge	40	4 (static thickened)	70
Excess sludge	45	6 (mechanical thickened)	67
Mix of sewage sludge	85	4,8	68,4

2. CHARACTERISTIC VALUES FOR SLUDGE DIGESTION

According to the above mentioned sludge production values the following biogas and energy production can be assumed (table 2). Biogas can be used for production of thermal energy by combustion in boilers with an efficiency of about 90% or as fuel for CHP units to produce electrical and thermal energy at the same time. The efficiency for electrical energy production is calculated with 38% and with 42% for thermal energy production.

Table 2. Possible energy production with digestion of waste water sludge

	Specific biogas production [Nm³/PE*a]	**CH4-concentration in biogas [vol-%]**	**Specific energy content of biogas [kWh/PE*a]**	**Thermal power production (combustion only) [kWh/PE*a]**	**Use as fuel for CHP-units**	
					Electrical power [kWh/PE*a]	**Thermal power [kWh/PE*a]**
Primary sludge	4,8	63	30,3	27,3	11,5	12,7
Excess sludge	4,9	60	29,7	26,7	11,3	12,5
Mix of sewage sludge	9,8	61,5	60,0	54,0	22,8	25,2

The produced electrical energy can substitute a part of the energy demand of the whole waste water treatment process and can so save operational costs of the installation.

Beside the energy gain, a major effect of sludge digestion is the reduction of mass by degradation of organic parts of the sludge and a big improvement of the dewatering characteristics of the sludge. The chart shows the reduction of the sludge volume from the raw sludge to the digested and dewatered sludge. First big reduction results in mechanical thickening of excess sludge from approx. 0,7 % SS to 6 % SS. Primary sludge is thickened to 4 % SS in the primary clarifier already. Degradation of organic matter in the digestion step will reduce the volume by approx. 1 % only. But the improved de-watering characteristics allow to dewater the digested sludge to a dry mater content up to 32 % with a flocculation aid demand of 4 g/kg dry mater only. This results in a reduction of the sludge volume down to 3 % in comparison to the original, untreated sludge (*diagram 1*).

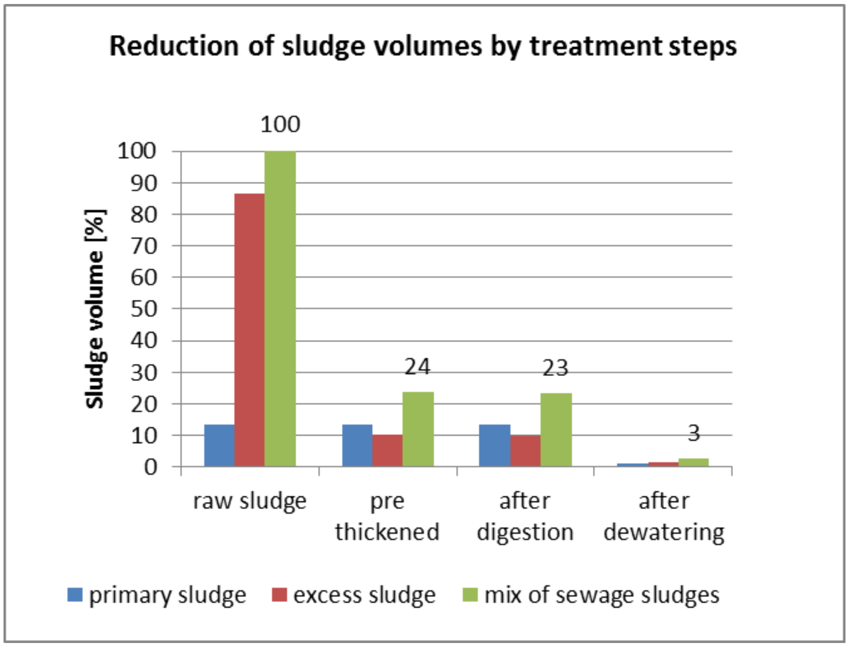

Diagram 1. Reduction of sludge volumes by treatment steps

For calculation of the volume of a digestion tank a retention time of 20 days shall be assumed. For the pre-thickened sludge this results in a necessary volume of 35 l/PE. For a treatment plant for 50.000 PE the volume of the digester need to be 1.750 m³.

To keep the digester at the process temperature of about 37°C, thermal energy of 25 kWh/PE*a are necessary. This is equal to the produced thermal energy by a CHP-unit running with the produced biogas (see table 2).

3. EQUIPMENT FOR SLUDGE DIGESTION

The core equipment for sludge digestion is the digestion tank. With the LARAN® Loop digester Strabag provides a proved and tested system. It is characterised by the following features (*see figure 1*):

- High efficient mixing system with biogas injection and draft tube to create the loop flow and secondary mixing system with external pump and tangential jet nozzles to create a rotating movement (bottom sludge recirculation). This rotation transports the solid material in the middle of the digester where it will be removed constantly (*see figure 2*).

- No rotating equipment, therefore no wear and no maintenance work inside the digester necessary. Digester can be in operation for many years without interruption.
- Draft tube can be designed with double wall and can serve as heat exchanger. External heat exchangers for digester heating are possible as well.
- Included feature to block H_2S formation by adding some air in the injected biogas. That will lead to lower H_2S concentrations in biogas.

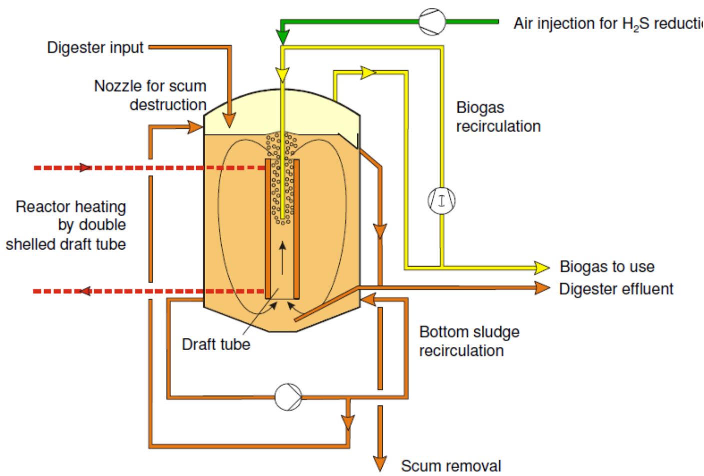

Figure 1. Principle of LARAN® Loop digester mixing device

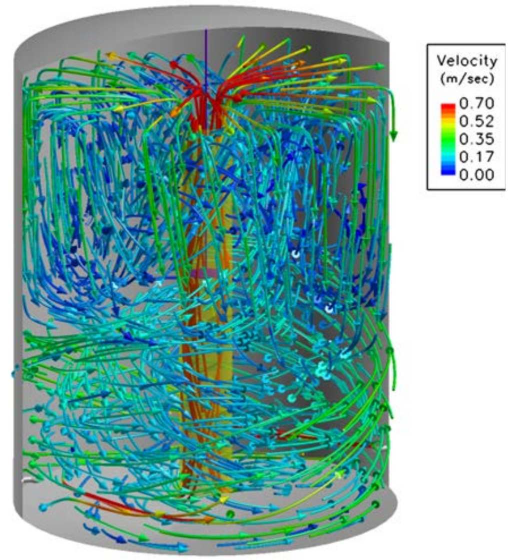

Figure 2. Visualisation of mixing flows in combined gas injection and bottom sludge recirculation

LARAN® Loop digesters can be built of concrete or of steel. The volume of one digester can vary between 500 m³ and 10.000 m³ for steel digester and 12.000 m³ for concrete.

Existing equipment for sludge thickening and sludge storage can be used furthermore with some small modifications.

4. REFERENCES FOR DIGESTION PLANTS

Strabag has built a number of plants for waste water sludge digestion. Some selected references are:

- Waste water treatment plant Iasi/Romania (retrofitting of an existing plant)
- Sludge digestion for waste water sludge in Brest/Belarus as part of the waste digestion facility;
- Waste water treatment plant Stavenhagen/Germany (*figure 3*);
- Waste water treatment plant Radeberg/Germany (co-digestion with bio waste).

Figure 3. WWTP Stavenhagen/Germany, digesters

5. CHARACTERISTIC VALUES FOR SLUDGE COMPOSTING

The normal process of waste water sludge composting consists of the following steps:

- Mixing of the dewatered sludge with some structural material in order to make the passage of air through the pile possible. Mixing is done in special machines which are fed by wheel loaders.
- Intensive composting step in closed composting tunnels or in concrete boxes which are covered with a semi permeable membrane:
    - Filling the tunnels or boxes with wheel loader;
    - Closing the tunnel gates or cover the pile with the membrane;
    - Start aeration;
    - Depending on process and installed measuring devices monitoring and control of the process by temperature, pressure and oxygen measurement;
    - In tunnel composting watering of the compost pile is possible to create optimal conditions for biological processes;
    - Stop aeration, open gates or remove membrane;
    - Removal of the compost out of the tunnels or the boxes by wheel loader.
- Curing of the material in open windrow composting to finish the biological processes. The windrows shall be set up on an area which is covered by a roof for rain and sun protection but no walls are necessary.
- Post processing of the compost, which mainly means sieving to remove larger parts of structural material to get a compost with defined particle size.

As a precondition, the waste water sludge has to be dewatered to a solids concentration of at least 20% as a minimum. Solid concentrations of 25% to 30% reduces the volume of sludge quite a lot and also the handling and mixing of the sludge is much easier. A good mixing of the sludge with structural material is essential to make sure all material is under aerobic conditions and biological

processes are possible and equal in the whole pile.
A reduction down to 45 to 50 % of the original mass of the sludge can be reached by composting (*see diagram 2*). Though a mass reduction of about 45 % will happen in intensive composting step and another 10 to 15% reduction is carried out in curing step. Within that 75 to 80% are based on loss of water with the aeration air. A part of only 20 to 25% are based on biological degradation of the sludge. The volume is reduced of about the same portions.

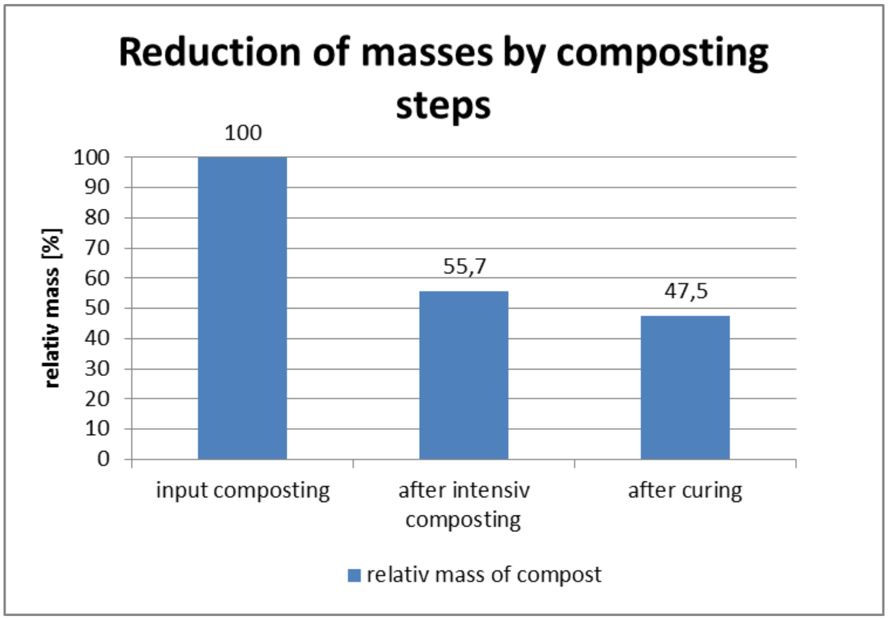

Diagram 2. Reduction of masses by composting steps

For intensive composting step in tunnels, a retention time of 3 to 4 weeks is assumed. For curing another 3 to 4 weeks time shall considered. Based on the above mentioned sludge production a space of 140 m² per 10.000 PE is necessary for intensive composting and another 60 m² per 10.000 PE for curing. In this space is not included approx. 20% surplus composting space for not useable area while filling and emptying. Space for storage of raw sludge, structural material, mixing and sieving equipment is not included as well.

For aeration a flow of 6 m³ air per hour and per cubic meter of pile shall be provided. This is necessary first for sufficient oxygen supply for biological processes and second to carry out enough water from the sludge/compost.

The result of the sludge composting process is a marketable product which can be used in agriculture and for landscape construction. It has good properties for soil improvement and as a fertiliser.

6. EQUIPMENT FOR SLUDGE COMPOSTING

Depending on several plant specific factors such as available space, available heating power, necessity of exhaust air treatment in order to meet limit values and quality parameters for compost, Strabag is able to provide two several composting processes which are closed tunnel composting and composting in boxes with membrane covering.

Tunnel composting equipment

In the tunnel composting process, the composting takes place in concrete tunnels which are 20 to 30 m long and from 4 to 5 m in height and width. Tunnels will be closed by moveable gates (*figure 4*). Number of tunnels parallel is not limited and results from the mass of waste water sludge to be treated.

Figure 4. Compost tunnels with gates, view from filling hall, Mondercange/Lux

Tunnel composting provides the following advantages:

- Complex ventilation system with reuse of air;
- Heating of air and therefore temperature control is possible;
- Temperature for sanitation can be reached and maintained specifically;
- Oxygen content in exhaust or reused air can be measured and controlled;
- Pressure drop in the compost pile can be measured as an indicator of aeration capability;
- Watering of the compost pile is possible to ensure optimal conditions for bacteria growth and to reach the desired water content in the compost ;
- Due to several measurements a complex logic can control the process in order to achieve best results in compost quality;
- Closed system with collection of exhaust air. Tunnel gates are air tight;
- Exhaust air treatment is possible by acid scrubber and bio filter and therefore no odour emissions will occur.

Membrane composting equipment

For composting in boxes with membrane cover dimensions up to 50 m long and 10 width are possible as a maximum (*figures 5 and 6*). Smaller dimensions of boxes are beneficial for logistics. According to the maximum height of pile for waste water sludge composting, boxes are up to 1.8 m high.

Figure 5. Membrane winding machine, composting plant Hunedoara/Romania

Figure 6. Maximum sized composting box for membrane composting, Hunedoara/Romania

Composting in boxes with membrane cover is characterised by the following:

- Low invest costs for buildings (no closed tunnels, no hall structure around) and for equipment (no tunnel gates, less pipework for aeration, less measurement equipment);
- No watering of compost pile possible;
- Measurement of temperature und oxygen is possible, but just at a certain point of the pile
- Composting process is partly influenced by outside conditions (temperature, solar irradiation, precipitation);
- Ventilation air can be used just once. Exhaust air is passing the semi permeable membrane at the whole surface covered. No collection of exhaust air and no treatment are possible.

Simple control of aeration is possible to maintain temperature and oxygen content. But no direct heating can be done.

7. REFERENCES FOR COMPOSTING PLANTS

Strabag has built several composting plants so far:

- Composting plant Brixlegg/Austria for waste water sludge composting, open windrow composting in halls;
- Composting boxes with membrane covering Hunedoara and Mehedinti/Romania;
- Tunnel composting plants for bio waste and household waste, e.g.:
  - Kutno, Piotnowo and Kielce/Poland;
  - Leipzig-Gröbern/Germany;
  - Schöneiche/Germany;
  - Mondercange/Luxembourg;
  - Lille/France;
  - Lorient/France
  - Ljubiljana/Slovenia.

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CHAPTER VII

ECONOMICAL AND ENVIRONMENTAL ASPECTS IN SLUDGE MANAGEMENT

Sewage Sludge Sanitation Treatments, Uncertainties And Risks, Legislative Requirements

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Abstract

Pathogenic organisms present in urban wastewater are, in a great measure, removed in treatment plants by primary sedimentation - free bacteria and those associated with various host cells adhere to the solid particles and settle with them, being accumulated in the primary sludge. Further on, biological treatment provides inactivation or destruction of pathogenic species, through the conditions in the aeration basins and the interspecific relationships among microorganisms, as competition and predation. Also, part of the pathogenic organisms adhere to sludge flocks and are eliminated with excess activated sludge. Various sludge treatment methods have been developed and have led to satisfactory results in terms of sanitation and migration control of biological contaminants into the environment. Although wastewater treatment processes provide a strong control of epidemic outbreaks, a complete elimination of all pathogenic organisms cannot be assured by conventional treatments applied to wastewater and the resulting sludge.

Regarding the pathogen load, current national and European legislation does not provide a list of indicator organisms for pathogen loads and the limits required for the safe usage of sludge in agriculture, however countries in the European Community have expressed their concern regarding the transfer of pathogens by using sludge as a fertilizer and recommended new amendments for Directive 86/278 /EEC, including clear specifications on the appropriate treatment of sludge, in order to protect human and environment health.

Therefore, it becomes necessary to signalize the areas of uncertainty concerning the risk of transmitting pathogens in the process of sludge recycling and the importance of updating the legislative provisions, in light of technical and scientific progress.

Keywords
Migration contaminants, sludge sanitation, pathogens, areas of uncertainty.

1. INTRODUCTION

The implementation of projects focused on the construction of sewage systems and wastewater treatment plants (WWTP) took place with the development of science and the understanding of the causes and manner of transmission of many diseases that can cause epidemics. The development and the expansion of these systems aimed, firstly, at the need to protect human health and the environment.

Wastewater treatment processes are generating sludges (primary, biological, mixed sludges) that include, in a greater or lesser measure, various microorganisms which are present in the wastewater influent. The pathogen loads of wastewaters that reach a municipal wastewater treatment plant are variable and are influenced by many factors such as the type of the sewer network (combined or separate), the number of connected inhabitants, the health of the population connected to sewers, the nature of activities carried out by operators connected to sewers (slaughterhouses, meat processing industry, dairy industry, conditioning and processing of vegetables and fruits, etc.) [1]

The type of wastewater treatment plant, the climatic variations of the WWTP's site, the WWTP's operation mode determine, in turn, a variation in pathogen load within the sludge generated at various stages of wastewater treatment. Some of the organisms will settle inside primary clarifiers, due to their high affinity for the solid suspended particles, some will reach the biological stage, where their survival rates differ depending on the strength of species to environmental conditions, their ability to live together outside the host organisms, the system retention time, the composition of the activated sludge microfauna that act on pathogenic organisms via „competition and predation" mechanisms.

Therefore, the municipal WWTP sludges contain pathogen loads large enough to raise the issue of disease spreading risks on the treatment line. Scientific text-books present data that vary from one study to another, as regards the degree of contamination with pathogens of untreated WWTP sludge (this variability is due to the many factors that influence microbiological load, plus the fact that laboratories use different sampling, identification and organisms counting techniques). The different ways to express the results (either by reporting to liter, gram or kilogram of dry matter or kilogram of raw sludge) makes it difficult to compare data presented in various studies. Approximate values, extracted from French scientific textbooks, related to the pathogen loads in untreated sludges, are shown in Tables 1, 2 and 3.

Table 1. Urban WWTP untreated sludges - Load in pathogen viruses [1]

Organism	Load	Sludge type
Enterovirus	max. 3200 PFU/l	Untreated sludge
	110 PFU /l	Biological sludge
	1700 PFU /l	Mixed sludge
VHA	100-1000 / kg d.m.	Unspecified
Adenoviruses	0-46000 TCID50	Unspecified

d.m. = dry matter
PFU = plaque forming unit
TCID50=median tissue culture infective dose; that amount of a pathogenic agent that will produce pathological change in 50%of cell cultures inoculated. Expressed as $TCID_{50}$/ml.

Table 2. Urban WWTP untreated sludges - Load in pathogen bacteria [1]

Organism	Load	Sludge type
Salmonella spp.	30 MPN/l	Primary sludge
	100-1000 g d.m.	Primary sludge
	4 log CFU g d.m.	Biological sludge
	max. 1000/l	Mixed sludge
Salmonella typhi	11000-19000000/l	Untreated sludge
Pseudomonas aeruginosa	3300 g d.m.	Untreated sludge
Listeria spp.	53-28000 MPN/g d.m.	Biological sludge
	<7 la 50000 MPN/g d.m.	nămoluri netratate
Listeria monocystogenes	5,1-6300 MPN/g d.m.	Biological sludge
Campylobacter spp.	1,5-4,4 log/100 ml	Biological sludge
	194 la $4{,}2 \times 10^4$ MPN/100 ml	Untreated sludge
Shigella spp.	7 log/g s.u	Untreated sludge
Mycobacterium spp.	1489-3173/g d.m.	Biological sludge
Staphylococus aureus	150 MPN/g	Primary sludge
Clostridium perfringens	5,7 log CFU/g	Untreated sludge

Yersinia spp.	6 log/g d.m.	Untreated sludge
Klebsiella spp.	7 log/g d.m.	Untreated sludge
MPN = most probable number CFU = colony forming units		

Table 3. Urban WWTP untreated sludges - load in parasites (protozoa and metazoa) [1]

Organism	Load	Sludge type
Helminths	1000-1000/kg	Primary sludge
	0 viable eggs/10 g d.m.	Biological sludge (extended aeration)
	2/10 g d.m.	Biological sludge
	24/10 g d.m.	Primary sludge
	44 la 77/10 g d.m.	Urban sludge
	65-120 viable eggs/g	Untreated sludge
Cestoda	0-1000 eggs/l	Primary sludge
Nematoda	2-45 viable eggs/g d.m.	Untreated sludge
	10-10000 eggs/l	Primary sludge
Toxocara sp.	10-50 eggs/kg	Biological sludge
	10-100 eggs/g d.m.	Primary sludge
Trichuris sp.	10-50 eggs/kg	Biological sludge
	12-55 eggs/100 g d.m.	Untreated sludge
	100 eggs/g d.m.	Primary sludge
Hymenolepsis sp.	10-50 eggs/kg	Biological sludge
	0-12 eggs/100 g d.m.	Untreated sludge
Taenia sp.	100 eggs/100 ml	Untreated sludge
Ascaris spp.	50-100 eggs/kg	Biological sludge
	100-1000 eggs/g d.m.	Primary sludge
	38/10g	Untreated sludge
Giardia sp.	6,3 viable cysts/10g d.m.	Thickened primary sludge
	100-10000 cysts/l	Primary sludge
	7,4-113000/g d.m.	Mixed sludge
	2700-14300/g d.m.	Biological sludge
Cryptosporidium sp.	16,5/g d.m. (0,8-119/g d.m.)	Mixed sludge

Regardless of the detected contamination level, the results of numerous studies confirm the existence of pathogens in urban sludge and, hence, their potential risks related to their use in an untreated form for crop fertilization. Globally, and at European level, risk studies were conducted in order to determine the effects on human health associated with land application of sludge (such analysis could form the basis of further laws able to mitigate the potential hazards brought to public health and environment).

Although epidemiological research did not reveal a direct link between the agricultural use of sludge and direct human contamination, the microbiological risks related to the use of sludge in agriculture are nowadays recognized and the caution principle is worldwide applied, given the great variety of pathogens and their conveying paths (such as prions, unconventional infectious agents, [2], [4].)

2. SLUDGE PROCESSING: UNCERTAINTIES AND RISKS

Given the potential risk posed to human health by the agricultural use of WWTP sludge, worldwide strict laws are today implemented in order to ensure the prevention and the reduction of sludge harmful effects on environment and public. At European level, the agricultural use of sludge is regulated by Directive 86/278/EEC, which is transposed into Romanian law by Order 344/2004, which defines the technical regulations on environmental and soil protection.

These technical rules do not provide limits for the sludge pathogen loads or indicator organisms, but ensures the risk mitigation by accepting only treated sludge for use in agriculture. According to law, sludge „treatment” means: "Biological, chemical or thermal processes, long-term storage or any other appropriate procedure able to significantly reduce its fermentation capacity and all health risks resulting from its use on farmland. "

The applying of different types of treatments such as aerobic and anaerobic stabilization, use of lime, dewatering, composting, etc. can provide a substantial decrease of pathogen loads, but a complete sterilization is difficult to obtain, the efficiency of these treatments being dependent on the initial contamination degree, the species resistance and the operating conditions.

The effectiveness of a treatment focused on pathogens is measured by the logarithmic load decreasing rate, but also by the blocking effect of the subsequent development capacity of pathogenic species. Moreover, the legal provisions of the Agency for Environmental Protection of the United States (US EPA) include the parameters related to the effectiveness of sludge stabilization and sanitation treatmenta and the one related to the potential for attracting vectors (organisms that carry pathogens to or from the sludge stored after treatment), vectors that may contribute to the spread of surviving germs or other germs able to recolonize the treated sludge.

Therefore, in order to ensure an effective treatment of sludge, most often there is need to couple two or more types of treatment methods, able that lead to an extended decrease of pathogenic organisms loads.

2.1. Conventional treatment

The treatment methods that are able to decrease the digestion level and destroy 99% of pathogenic organisms are considered to be „conventional” [5]. According to scientific textbooks a conventional sludge treatment must achieve at least a 2 $\log_{10}$ decreasing of pathogens number, this being proven by a reduction in the load of the indicator organism, that is Escherichia coli [3].

Moreover, the maximum permissible concentration of E. coli remaining into one gram of dry matter of sludge must be below 10^5 [7] or the fecal coliform density must be below the value of $2x10^6$ MPN/g d.m. [6]. Sludges treated via conventional processes, shown in table 4, still feature a high potential for contamination by persistent pathogenic organisms, fact which leads to restrictions in the use of such sludges on farmlands.

Table 4. Pathogens load decreasing rate reached by means of conventional processes (Godfree and Farell, 2005)[9]

Process	Logarithmic decreasing		
	Coliform bacteria	Entero-viruses	Parasites
Mesophilic anaerobic digestion	From 0,5 to 4	From 0,5 to 2	0
Aerobic digestion	From 0,5 to 4	From 0,5 to 2	0
Composting	From 2 to > 4	From 2 to > 4	From 2 to > 4
Drying	From 0,5 to 4	From 0,5 to > 4	From 0,5 to > 4
Lime treatment	From 2 to > 4	> 4	0

2.2. Advanced treatment methods

Treatment methods that can provide an almost complete elimination of all pathogens are considered to be „advanced". Hence, a sludge treated this way should be Salmonella free and must feature a load decrease of at least 6 $\log_{10}$ for all pathogenic organisms, that is a 99.9999% destruction of initial loads [5] and the maximum permissible concentration of E. coli remaining in a gram of dry matter of sludge should be below 10^3 [7]. In a report drafted by E. G. Carrington for the European Commission (EC 2001) a series of advanced treatment methods are proposed (shown in Table 5), methods which may ensure the reduction of pathogens down to an "insignificant" level which should pose a minimal risk to human health and environment.

Table 5. Advanced sludge treatment - decreasing of pathogen contamination risk [3]

Procedure	Parameters
Composting in heaps/ricks	Sludge maintained at 55°C, for 4 hours, betweeen each of the 3 shiftings, followed by a maturation period for composting completion
Composting in aerated heaps and in composting vessels/tunnels	Sludge maintained at 40°C for at least 5 days of which at least 4 h a day at min 55°C, followed by a maturation period for composting completion`
Thermal drying	Heating up to at least 80°C for 10 minutes, with humidity decreasing below 10%
Thermophile digestion (aerobic and anaerobicc)	Treatment at 55°C for a minimum period of 4 h between feedings, at a cell retention time that muts suffice for sludge stabilization
Thermal treatment pasteurization), followed by digestion	Sludge maintained for minimum 30 minutea at 70°C, followed by mesophile digestion at 35°C (at retention time of 12 days).
Lime treatment (CaO)	Sludge and lime are mixed in order to reach a pH of at least 12 and a minimum temperature of 55 °C for 2 h, after mixing

The report states that, next to assessments made, other processes such as mesophilic anaerobic digestion, lime treatment and various storage methods, cannot ensure a fully pathogen free sludge.

However, in the UK [7], besides the methods listed in Table 5, is also mentioned the mesophilic digestion followed by a second digestion step, in order to ensure a minimum retention

time of 14 days. Advanced treatment methods have been developed in recent years, among these being referred to a number of pre-treatment methods conducted before the mesophilic digestion, with the main role in increasing the biogas production efficiency, but can also the reduction in pathogens such as: thermal hydrolysis (Cambi process), gamma or beta rays irradiation and the US disintegration. The deactivation of pathogens by means of these treatment methods is not yet systematic and depends on the initial sludge load in pathogens and also on the compliance to treatment conditions, especially in referrence to the „temperature-application duration" tandem (retention time). The stabilized and sanitized sludges are subsequently stored in special warehouses or platforms until the moment of their spreading on lands. The long-term sludge storage is a method that is significantly reducing the risk of contamination with pathogens, but the efficiency of this process is dependent on the type of stored sludge and environmental conditions [1]. Among these factors the scientific literature [1] states:
- The degree of sludge dewatering, the lack of humidity being a factor that hinders the development of micro-organisms;
- The presence of nutrients necessary for microorganisms, some of bacteria and pathogens (fungae) having nutritional requirements which can not be assured by treated sludge;
- The treated sludge microflora, the saprophytic bodies acting on pathogenic organisms either through direct predation or by secretion of inhibitory substances;
- Sludges chemical composition and their treatment carried out prior to their storage;
- Temperature achieved in the sludge deposit, which directly determines the survival time of microorganisms. Studies conducted on the pathogen concentration after certain periods of sludge storage highlighted the inactivation ability and the ability to decrease the pathogens density, especially bacteria and viruses that are less resistant, providing that a minimum four months storage period is ensured. The parasites (helminths in particular) are more resistant and are not inactivated unless sludges are effectively treated and the storage duration exceeds nine months. The effect of storage on different types of sludge are briefly shown in the table no. 6, extracted from the report issued by ADEME, the French Agency for Environment and Energy Management, "Base scientifique de l'évaluation des risques sanitaires relatifs aux agents pathogènes":

Table 6. Results of studies related the storage of various types of sludges (ADEME, 2007) [1]

Treatment prior storage	Salmonella spp.	Enteroviruses	Helminths	Giardia spp.
Sludge-extended aeration	Fast neutralization (NANCIE 2000) Isolated even after 7 storage days (Cardiegues 2000)	Increasing during storage (NANCIE 2000)	No viable parasite detected during storage (NANCIE 2000) Viable eges conc. ranged between <1-9,6 eggs/4g d.m.	Increasing during storage (NANCIE 2000)
Digested sludges	Concentration keeps stable after 1st month and afterwards decreases under 8 MPN/10 g d.m. (NANCIE 2000)	Undetected (NANCIE 2000)	Undetected (NANCIE 2000)	-
Dehydrated digested sludges	Isolated after 7 day storage period (Cardiegues 2000)	-	No influence on the nematoda eggs density has been seen during a	Number of cysts increased

Treatment prior storage	Salmonella spp.	Enteroviruses	Helminths	Giardia spp.
	Full neutralization after 16 storage weeks but load has re-increased to 2,2 MPN/g in the 52nd storage week, after a rainy period (Gibbs 1997)		2 months storage period (Cardiergues 2000). The above mentioned concentration not significantly affected ny storage (Gantzer 2001)	during the studied period (Thiriat 1998)
Thermally dried sludges	Undetected (NANCIE 2000)	Undetected (NANCIE 2000)	Undetected (NANCIE 2000)	-
Sludges treated by hydrated lime	Undetected (NANCIE 2000)	Undetected (NANCIE 2000)	Undetected (NANCIE 2000) (Gantzer 2001)	Initially number of cysts decreases, afterwards stagnation occurs (Thiriat 1998)
Sludges treated by lime	Fast neutralization (NANCIE 2000)	Undetected during the 9 mths period (NANCIE 2000)	No viable parasite detected during the 9 mths storage (NANCIE 2000)	-
Composted sludges	Undetected during the 9 mths period (NANCIE 2000)	Undetected during the 9 mths period (NANCIE 2000)	Undetected during the 9 mths period (NANCIE 2000)	-

3. THE EFFECT UPON THE DECREASING OF MICROBIAL LOADS BY A LONG-TERM STORAGE OF IASI WWTP SLUDGE IN THE TOMEȘTI LAGOONS

The sludge from the Iasi WWTP was stored during period 1995-2006 in an unincorporated area nearby Tomeşti commune, in lagoons arranged on an 5 hectares area. At the time the Iasi WWTP was using a conventional mechanical-biological treatment line, with suspended active sludge, able to process a maximum flow of 2,1m^3/s. Primary and biological sludges that were resulting from the treatment process were stabilized in two mesophilic anaerobic digesters (the only functional ones from a set of 8 existing digesters - the refurbishment of sludge line was completed in 2010).

The two anaerobic digesters had available only 2/3 of their total volume of 8000 cubic meters, and, hence, at a production of about 3600 tonnes sludge/day they could provide an average retention time and therefore a low rate of decreasing of organic matter and pathogenic organisms.

Sludge treated this way was pumped in liquid form towards the Tomeşti lagoons until 2006, when the lagoons were decommissionned and the reclamation of land commenced (in order to return it to the Tomeşti Commune). Phytoremediation was chosen as reclamation method, because plants are able to reduce moisture contents in the soil, and also contributing to humification and soil formation from sludge. Moreover plants are able to extract heavy metals from the stored sludge. Due to the *Institutul Național de Cercetare pentru Pedologie, Agrochimie și Protecția Mediului București*, I.C.P.A., (National Research Institute for Soil Science, Agrochemistry and Environmental Protection Bucharest), certain balance and environmental impact studies were conducted, in order to determine the sludge's physical, chemical and biological properties and also for the adjacent soils, before and during the phytoremediation process.

Figure 1. Location of the Tomești lagoons – Marking of observation and sampling point

Regarding the potentially pathogenic microflora loads, the preliminary study [10] sought to isolate and identify the microorganisms with epizootic and epidemiological implications.

Tests conducted on fresh and digested sludges (and subsequently stored either on dehydration platforms inside the WWTP or in the Tomeşti lagoons), revealed a $2\log_{10}$ reduction in the number of viable coliform bacteria within the stored sludge's surface layer (0- 20 cm) and also a regrowth in the number of viable coliform bacteria within depth layers (development maybe favored by the high moisture in depth strata and by the lack of action coming from temperature and sunlight, fact which favored the decreasing of loads within in the surface layers).

Table 7. Sludge samples – contamination degree with potential pathogen microflora –Iași WWTP [10]

Sludge type	Coliform bacteria	Fecal coliform	Salmonella	Sulphite reducing bacteria
	MPN/g	MPN/g	MPN/g	MPN/g
Primary sludge (clarifier no. 3)	1,0 x 10^4	1,0 x 10^4	absent	1,0 x 10^3
Excess active sludge	1,0 x 10^4	1,0 x 10^4	absent	1,0 x 10^2
Fermented sludge (digester)	1,0 x 10^4	1,0 x 10^4	absent	1,0 x 10^2
Fermented sludge (inner storage platforms) Layer 0-20 cm	1,0 x 10^2	1,0 x 10^2	absent	absent
Fermented sludge (inner storage platforms) Layer 30-50 cm	1,0 x 10^4	1,0 x 10^3	absent	1,0 x 10^3
Fermented sludge (Tomești lagoons) Layer 0-20 cm	1,0 x 10^3	1,0 x 10^3	absent	-
Fermented sludge (Tomești lagoons) Layer 0-20 cm	1,0 x 10^3	1,0 x 10^2	absent	1,0 x 10^2

Analysis of potentially pathogenic microflora in Iasi WWTP sludge revealed its significant decreasing after sludge being stored on platforms (such decreasing varies depending on the sludge moisture content and the storage duration). By comparing with the above mentioned definitions for advanced and conventional sludge treatments, the fecal coliform load (around 10^3) and the absence of Salmonella genus microorganisms of the genus, allows to consider the sludge from the Tomeşti lagoons to be closer to the category of advanced treated sludges, with the reserve given by the small number of tests conducted and the errors resulting from other factors, such as the sampling methods, the sampling season, etc.

Studies conducted by I.C.P.A. Bucharest were also aimed on the effect brought on the microflora specific to the soil treated with sludge, compared to the microflora from the adjacent land. Microbiological tests carried out on sludges and soils sampled from various depths were aimed to determine the loads bacterial and fungal structures, the taxonomic composition of microbial communities [11]. It was found that as moisture content was decreasing moisture content and the soil formation was progressing, the pathogenic microflora was beginning to be substituted by a compost specific microflora, in the case of sludge from drying platforms (recent storage) and subsequently by the one specific to soil, in the case of Tomeşti lagoons sludge (where phytoremediation was carried out in the past 10 years). The sludge contents, rich in organic matter, is affecting the relationship between the main groups of organisms that are found in the specific microflora, the fungal populations being superior or equal to the fungal heterotrophic bacteria populations, compared to soils where bacterial populations are dominant.

Table 8. Bacterial microflora in soils and sludge samples drawn from the witness drilling and from the drilling executed at the sludge deposit [11,12]

Sample	Depth cm	Species and genera of bacteria identified on the Topping medium (in order of frequency)	Viable cells x10^6/g d.m.
2005			
Soil witness borehole	0-20	Pseudomonas pseudogleyi, Pseudomonas sp., Arthrobacter simplex, Bacillus circulans, Actinomyces sp.	475
Sludge deposit borehole	0-20	Pseudomonas fluorescens, Pseudomonas spp., Bacillus polymixa, Bacillus circulans, Arthrobacter globiformis	13949
2014			
Soil witness borehole	0-20	Arthrobacter globiformis, Bacillus megaterium, Pseudomonas sp., Arthrobacter citreus, Bacillus sphaericus	50,9
Sludge deposit borehole	0-20	Pseudomonas sp., Arthrobacter globiformis, Bacillus circulans, Actinomyces sp.	98,4

Table 9. Fungal microflora in soils and sludge samples drawn from the witness drilling and from the drilling executed at the sludge deposit [11,12]

Sample	Depth cm	Fungal species and genera identified on Czapeck medium (in order of frequency)	Viable cells x10^3/g d.m.
2005			
Soil witness borehole	0-20	Paecilomyces marquandii, Mucor racemosus, Aspergillus sp., Penicillium citrinum, Penicillium griseofulvum, Fusarium sp.	145
Sludge deposit borehole	0-20	Micelii sterile incolore, protozoare	32
2014			
Soil witness borehole	0-20	Gliocladium catenulatum, Scopulariopsis sp., Aspergillus ochraceus, Verticillium sp.	60,6
Sludge deposit borehole	0-20	Penicillium pulvillorum, Gliocladium catenulatum, Scopulariopsis brevicalis, Oidiodendron sp., Cladosporium micrococcus, Penicillium janthinellum, Chaetomium globosom, Fusarium oxysporium	593,7

Given the possibility of pathogens transfer from stored sludge towards environment, the groundwater quality in the storage area has been considered. In 2014, on samples taken from observation boreholes located in the area of Tomeşti sludge lagoons, tests of microbiological quality of groundwater in the area were carried out, in order to verify the influence of stored sludge. In order to assess the sanitary quality three indicators were chosen: total coliform bacteria, Escherichia coli and intestinal enterococci, the last two being exclusively associated with fecal pollution.

As it can be seen from the table below, in tested samples the colonies of E.coli and intestinal enterococci did not develop, this being proof that the risk of groundwater contamination with pathogens from sludge stored on long periods is minimum. Total coliform bacteria have been detected (at low density), a group of bacteria that are widespread in nature, such bacteria being found in human or animal feces but also in soil, vegetation and surface waters.

Table 10. Microbiological tests of groundwaters from observation boreholes - Tomești lagoons

Sampling location	Microbiological indicator	Testing method	Result
Borehole no.3	Escherichia coli	ISO 9308-3/2004	0 MPN/100 ml
	Intestinal Enterococci	ISO 7899-1/2004	0 MPN/100 ml
	Total Coliform	EPA 9223 MF	135 CFU /100 ml
Borehole no.4	Escherichia coli	ISO 9308-3/2004	0 MPN/100 ml
	Intestinal Enterococci	ISO 7899-1/2004	0 MPN/100 ml
	Total Coliform	EPA 9223 MF	110 CFU /100 ml
Borehole no.5	Escherichia coli	ISO 9308-3/2004	0 MPN/100 ml
	Intestinal Enterococci	ISO 7899-1/2004	0 MPN/100 ml
	Coliform bacteria	EPA 9223 MF	138 CFU /100 ml
Borehole no.6	Escherichia coli	ISO 9308-3/2004	0 MPN/100 ml
	Intestinal Enterococci	ISO 7899-1/2004	0 MPN/100 ml
	Total Coliform	EPA 9223 MF	140 CFU /100 ml
Borehole no. 7	Escherichia coli	ISO 9308-3/2004	0 MPN/100 ml
	Intestinal Enterococci	ISO 7899-1/2004	0 MPN/100 ml
	Total Coliform	EPA 9223 MF	138 CFU /100 ml
MPN = most probable number CFU = colony forming units			

Tests conducted on pathogenic microflora and soil specific microflora showed that the sludge subjected to mesophylic fermentation (though the process is carried at variable parameters compared to those imposed for a proper treatment) and stored for a long time (about 10 years) is no longer a hazard in terms of contamination by pathogens. Moreover, due to the reducing of humidity and the ongoing soil formation the qualitative and quantitative differences of soil and sludge microorganisms is considerably decreasing.

4. UNCERTAINTIES AND RISKS

The performing of advanced treatments can be an important way to prevent the transmission of various diseases, by harnessing the WWTP sludge. But the variety of factors that may influence the operation of WWTPs, the various capacity of different methods for removing or inactivate certain pathogens, the influence of environmental factors during storage or farmland spreading, are all elements that increase the risk of survival or reactivation of pathogens. A precise definition of each treatment process based on its performance and validation/standardization of control and monitoring methods could reduce the uncertainty regarding the reached quality of treated sludge.

The methods and techniques of sampling, and the determination and counting the indicator organisms or pathogens in treated sludge are still in a development and standardization stage, and the inactivation mechanisms are still insufficiently understood, this generating some uncertainty as regards the effectiveness of different types of sludge treatments. The currently used indicator organisms (Escherichia coli and Salmonella spp.) are vegetative bacteria and are not robust enough in order to be representative for the strength and behavior of all pathogenic organisms of interest. For example, determinations carried out after drying process lead to an unexpected increase of the E. coli concentration. On the other hand the thermal inactivation could allow the development of viable organisms but with no vegetative cells which can be determined through cultivation, hence leading to difficulties in the determining of the real quality of treated sludge [13].

The resilience of pathogenic organisms raises issues regarding the impact that may come from potential redevelopment/reinfection in treated sludges. There is need to establish a differentiation between "pseudo" stabilization processes and those that ensure full stabilization. For example, the inactivation mechanisms that occur in the anaerobic digestion processes are still partially understood. In addition, the appearance of mutagenic bodied and/or bodies resistant to antibiotics, the determination of new organisms (E. coli O157:H7) or unconventional infectious agents (i.e. prions, of which transmission paths, inactivation and concentration processes are still little known), make that the real quantifying of contamination risks via sludges through the use of sludge to become difficult.

The survival of pathogens in treated sludges and their re-development in certain environmental conditions can lead to transfer contamination in soil, water or air. The conveying of microorganisms depends on a large number of biotic and abiotic factors including the microorganism's size, its physical characteristics (vegetative form or its resistance), the soil's texture and structure, its pH, humidity, temperature, oxygen availability, the presence of UV rays, water flow rate, the phenomena of antagonism, competition and predating. For example, viruses have a greater ability to be transferred to the ground through their property to adhere to particles and the organisms that feature resistance forms (Clostridium spp. Eggs, cysts of parasites) are more adapted to resist environment.

Table 11. Survival time in soil and on plants surface [2][14]

Organism type	Soil		Plants	
	Absolute max	Max	Absolute max	Max
Bacteria	1 year	2 months	6 months	1 month
Viruses	1 year	3 months	2 months	1 month
Protozoa cysts	10 days	2 days	5 days	2 days
Helminths eggs	7 years	2 years	5 months	1 month
Absolute Maximum = maximum survival time in special conditions (i.e. very low temperatures or very well protected places) Maximum = maximum survival time in normal conditions				

The agricultural use of sludges poses infection risks in relation to vegetable cultures too, as long as the wastewaters generated by fruits and vegetables washing also can convey phytopathogenic organisms. For example, in the UK studies conducted by Carrington et all. (1998) have identified the risk coming from the potato cyst nematode (Globodea spp.) which infests the seed potatoes (the land laws require the verification of the presence of such cysts). Given that there are no satisfactory methods for detecting of viable cysts in soil, the UK have resorted to the banning of sludge as fertilizer on lands where seed potatoes are cultivated. [3]

Another aspect that opens new questions in relation to the appropriate treatments (able to mitigate the impacts on environment and human health) is the increasing of sludge toxicity next to modifications induced by certain sanitation treatments.

Recent ecotoxicity studies indicate that some sanitation methods applied to sludges can induce changes in their composition fact that can disrupt the soil microflora, affect biodiversity and inhibit the growth of vegetation and fauna [15].

Current methods of assessing the pathogen contamination risks related to the agricultural use of sludges are limited by the impossibility to define the risk resulting from the inhalation of soil particles and bio-aerosols (only risks related to direct infectious contamination are taken into account), by the use of dose-response relationship and the omitting of the existence of an acquired immunity or a genetic infection predisposition of some individuals, by the lack of feasible exposure scenarios and some scientific data regarding certain ways of transfer of infectious agents.

5. LAW PROVISIONS

The current national legislation, aligned with European legislation, does not state any restrictions related to indicator organisms and limits of contamination levels in pathogenic organisms for WWTP sludges, regardless of the recycling method.

Nevertheless, countries in the European Community expressed their concern regarding the transfer of pathogens, especially through the use of sludge as a fertilizer and the risk this procedure is posing to human health. Therefore the Directive 86/278/EEC was amended with new provisions among which clear specifications regarding the appropriate treatment of sludges in order to protect human health and the environment when sludges are used as agricultural fertilizer.

Order 344/2004, that is transposing into national law the European Directive 86/278/EEC, although is not including limits for pathogenic organisms, it enforces double protective measures for mitigating the disease risks next to the use of sludge in agriculture. On one hand it admits the farmland use of treated sludges, so to significantly reduce the number of pathogens, and on the other hand it limits the use of sludge only to those crops of which products are processed/cooked before being consumed or those whose parts do not come into direct contact with the ground and are harvested after a great period of time after the sludge spreading. [16]

Reducing the health risk linked to the agricultural use of sludge has been a continuous concern and, worldwide, has led to the development of guidelines, good practice codes, standards and rules which, in some states, require limit values for the sludge microbiological quality indicators, values shown in the table below.

Table 12. Standards for pathogens maximum concentrations in WWTP sludge [13,16]

Country	Salmonella	Other pathogens//indicator organisms
Denmark*	absent	Fecal Streptococci fecali < 100/g
France	8 MPN/10 g d.m.	Enterovirus 3MPCN/10 g d.m. Helminths eggs 3/10g d.m.
Finland (539/2006)	Undetected in 25 g	Escherichia coli < 1000 UFC
Italy	1000 MPN/g d.m.	
Luxembourg		Enterobacteria 100/g Worm eggs, potentially contagious - absent
Poland	Sludges not to be used in agriculture if Salmonella is present	
Norway	Undetected in 50 g	Viable helminths eggs -absent Fecal Coliform < 2500/g d.m.
*only for sludges subjected to advanced treatments MPN = most probable number UFC = colony forming units		

The United States legislation provides two quality classes for WWTP sludges, depending on used treatments, treatments for which operating parameters are specified in order to ensure a proper sanitation. For the Class A sludge, which can be sold, packaged and spread in gardens, the regulated pathogens content is the one below detection level: that is, Salmonella below 3 MPN / 4 g dry substance, Enteroviruses under 1 PFU / 4 g dry substance and viable helminth eggs under 1 in 4 g dry substance or the concentration of fecal colifom to be less than 1000 CFU/g d.s. For Class B sludge, which can be applied to agricultural land, forests and public lands the law says that the density of bacteria and enteroviruses must be decreased down to a level shown by the presence of fecal coliform at a rate of $2x10^6$ MPN / g d.m. [2 3]

In a manner similar to the one presented by the DMA law and the British Code of Practice for use of sludge in agriculture "The application of HACCP Procedures in the Water Industry: biosolids treatment and use on agricultural land", requires that sludge used in agriculture must meet the requirements able to ensure the reducing of contamination risks pathogenic defined by an agreement between users (British Retail Consortium) and the sludge producers (UK Water Companies) entitled "Safe sludge Matrix", and which defines two types of treatment (conventional and advanced), which can provide the decreasing of pathogens contents, quantified by means of the Escherichia coli and Salmonella concentrations.

The recent working papers of the European Commission related to the amending of Directive 86/278/EEC, entitled "Working document on sludge and biowaste, 21 september 2010, Brussels" include references to the enforcement of new restrictions in order to limit the risk of pathogens transmission via agricultural use of sludge.

Among these the next are mentioned as indicator organisms for sludge sanitation: Salmonella (absent in 25-50g) or the reduction in E. below $5x10^5$ CFU / g (wet weight) of treated sludge.

However, the developing of new molecular detection and quantification techniques, featuring a much higher sensitivity, should make easier to monitor the effectiveness of sludge treatments by focusing the tests directly on pathogenic organisms [17].

6. CONCLUSIONS

In order to ensure the re-introduction of sludge in its natural cycles it is essential that the results of numerous scientific studies to be translated into clear law provisions, able to define and validate various types of sludge treatments, as to ensure an efficient sanitation and to mitigate the negative effects on human health, flora and fauna, and, as well, the long-term effects on the soil, groundwater and surface water quality.

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Possibilities For Sewage Sludge Management By Energetic Reuse

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Abstract
Someş Water Company aims to become a significant player in energy production and, in accordance with principles of sustainability and sustainable development, to create its own circuit of sludge management which is environmentally friendly and in tune with the national and European legislation.

Keywords
Electric energy, sustainable development, sludge management, environment.

1. INTRODUCTION

The development of drinking water distribution systems, together with the waste water collection and treatment systems will determine the increase of processed sludge volume and consequently the increase of energy consumption related to treatment of waste water and sewage sludge.

2. LEGISLATION

Current legislation, as per GD no. 188 dated February 28, 2002 (updated) approving norms regarding the conditions of discharging waste water into water bodies, annex 1, art. 2, para. 13 defines sludge:

- "sludge = residual sludge, treated or not treated, originating from waste water treatment plant", and as a process stage: "sludge – the final stage of water treatment, including products of metabolic activity and/or raw materials, intermediate products and finished products of industrial operations".

Law no. 211/2011, with subsequent modifications, regarding the status of waste, and Directive 2008/98/CE of the European Parliament and Council, dated November 19, 2008 regarding waste and repealing certain Directives, exclude waste water, consequently the sludge resulted from treating such water, from their scope, however annex no. 2 to GD no. 856/ 2002 (updated), regarding the management of waste and approving the list of waste, including hazardous waste [1] also mentions sludge, as follows:

Table 1. Types and descriptions of waste [2]

Waste code	Type and description of waste
19	**Waste originating from waste treatment stations, from ex-situ waste water treatment stations, drinking water treatment stations and industrial water treatment stations**
19 02 05*	sludge resulting from physical-chemical treatment, with hazardous substances contents
19 02 06	sludge from physical-chemical treatment other than specified in 19 02 05

Waste code	Type and description of waste
19 05	waste from aerobic treatment of solid waste
19 05 01	uncomposted fraction from municipal waste and similar
19 06	waste from anaerobic treatment of waste
19 06 03	liquid stage from anaerobic treatment of municipal waste
19 06 04	digested stage from anaerobic treatment of municipal waste
19 06 99	unspecified waste
19 08	waste from waste water treatment stations, not specified elsewhere
19 08 05	**sludge from municipal waste water treatment**

National waste management strategy 2014-2020, approved by Government Decision no. 870 on November 6, 2013, specifies that sludge should be used by applying best practices, such as to prevent it from being disposed to waste storage, as much as possible”. Anaerobic digestion plants are able to process municipal waste, as well as sludge originating from waste water treatment stations, and have the processing capacity according to the demand in their area.”[3]

Waste management strategy at county level for 2014- 2020 in Cluj County provides:

1. proper management of sludge originating from waste water treatment plants, complying with strategic principles and minimising the impact on environment and human health, prioritising the use in agriculture in accordance with legal provisions.

2. composting, which may have various usages, depending on quality (agriculture, restoration of damaged areas etc.), with a “Regional platform for organic waste composting” owned by the Local Council of Dej city, financed by the EU through PHARE /2004/016-772.04.01.04.01.01 “Investment scheme for waste management small projects” with an annual processing capacity of the composting station of 5000 m^3.

The Masterplan assumed by Someș Water Company specifies the solution of “Using the sludge as fertiliser in agriculture, and as a complementary solution the storage on an authorised compliant platform” (Chapter 7), in compliance with the Directive 86/278/CEE, on agricultural use of sewage sludge.

Currently the Company’s solutions for sludge disposal are:

- disposal to storage;
- agriculture use as fertiliser.

Both have minimal costs, not requiring additional tariffs to population. Present expenses for storing sludge in ecological storages are at 10-15 euro/tonne, while in other countries these exceed 100 euro/tonne.

Sludge transportation must comply with European and national regulations in force (measures established by GD no. 788/2007 enforcing measures for the application of European Parliament and Council Regulation (CE) no. 1013/2006 regarding the transfer of waste, GD. No. 1061 on September 10, 2008 regarding the transport of hazardous and non-hazardous waste on Romanian territory).

New compliant waste storage facilities may accept sludge for storage up to 10% of their capacity, and sludge storing in ecological facilities will cost, in 2017, 80 RON/tonne, and in 2018 – 120 RON/tonne, representing the fees collected for inert and non-hazardous waste taken for final disposal in storage (in compliance with Law no. 384 on December 24, 2013 approving the Gov. Ordinance no. 31/2013 modifying and completing the Gov. Emergency Ordinance no. 196/2005 regarding the Environment Fund to ANNEX No. 1).

Romania in its transition to a “green economy” is recording a low performance due to high storage ratio (above 70%) compared to recycling or energy recovery incineration ratios.

Sludge from waste water treatment may have a humidity level less than 65 % as per Order of Minister of Environment and Water Management no. 757/26.11.2004 approving the technical norms for waste storage (updated), para. 4. Operation and monitoring, point 4.2.1.5.

Sewage sludge may be used in agriculture only in compliance with the following:

National regulations:

- Order no. 344/708 issued in 2004 by the Ministry of Environment and Water Management approving the norms regarding the protection of environment and in particular of soil, when sewage sludge is being used in agriculture, with subsequent modifications and additions;
- GD no. 964/2000 approving the Action plan for protection of water bodies against pollution with nitrates from agricultural sources, with subsequent modifications and additions.

European Union’s regulations:

- Council Directive no. 86/278/EEC regarding the protection of environment and in particular of soil, when sewage sludge is being used in agriculture, with subsequent modifications and additions;
- Directive no. 91/676/EEC regarding the protection of water bodies against pollution with nitrates from agricultural sources;
- Directive no. 2004/35/EC regarding environmental responsibility, and Directive 2008/50/EC of the European Parliament and Council regarding the quality of air, and a cleaner air in Europe.

The farmer must take into account the provisions of Order no. 352/2015 issued by Ministry of Agriculture and Rural Development and no. 636/2015 issued by the Ministry of Environment and Water Management published in Official Journal no. 363 on May 26, 2015 approving the norms for eco-conditionality within the support schemes and measures for farmers in Romania, and to obtain the permit for agriculture use.

For sewage sludge to be used in agriculture:

- dewatering process is a precondition for an economical transport and potential storing/disposal.
- continuous control of sludge and soil to comply with maximum values for:
    - heavy metal concentration in soil where sludge is applied,
    - heavy metal concentration in sludge,
    - maximum annual amounts of heavy metal that may enter soil with agricultural destination.

The topic of sludge use in agriculture is extremely discussed at EU level, as well. In almost 30 years the standards and requirements in the Directive have not been revised or updated. Some member states apply restrictions, imposing more severe limits, arguing a higher level of heavy metals, persistent organic polluters and pathogens in comparison to other states [4].

In the ex-post evaluation of the document "Proposed Directive of European Parliament and Council to revise objectives in Directive 2008/98/CE regarding waste", sewage sludge is between a recycling directive and a directive at the end of life. This allows for recovery of sludge on agriculture land in clearly defined sanitary and environmental conditions, to support recycling of nutrients and organic matter by applying sludge on agricultural land. There are however issues for agricultural application of sludge since the use of inappropriate sludge might raise doubts regarding the food quality in various member states, thus preventing free circulation of goods. Sewage sludge directive falls under the application of free circulation of goods legislation, Art. 100 ECT (Common market) and Art. 235 ECT (articles essential for Treaty objectives). [5]

3. WHAT CAN BE DONE?

Waste water treatment operators are responsible for developing, according to local circumstances and recommended approach, compliant possibilities for sludge disposal and opportunities for reuse, as well as supporting the "existing sludge markets".

A cost-benefit analysis, namely an economical analysis, was performed to determine the profitability of investments in energy production.

In our case the sludge may be considered biomass. As per national legislation, two green certificates are granted for 1 MWh of energy produced and delivered to the national energy system using biomass fuel.

An additional green certificate is granted:

- in case of biomass installations based on energy crops
- in case of biogas installations if using high efficiency co-generation.

The green certificate is the title attesting the production of electric energy from renewable sources. The certificate can be transacted, aside from the energy it represents, on a market regulated by law (Law no. 220/2008, Art. 2, point h).

For the period 2008-2025, the transaction value of green certificates on the markets specified in Art. 10 Para. (1) ranges between 27 euro/certificate; and 55 euro/certificate.

The value of green certificates would represent an additional revenue to the producers for "clean" energy delivered into the network.

The number of green certificates issued per month by the transport operator is calculated as multiplying the amount of energy delivered and the number of green certificates which the operator would receive per each MWh produced and delivered to the network or to consumers.

$$GCR = E * 30\ days/month * GCN * GCP$$

where:

GCR – green certificates revenue;

E – energy produced and delivered to the network in 24h (MWh);

GCN – green certificates number obtained by the energy producers for energy from renewable sources, in case of biogas and biomass 2 green certificates per each MWh produced and delivered, and an additional certificate if the energy is produced by biomass installations using energy crops.

GCP – green certificate price (Euro)

For a biogas co-generation installation with a power of 200 kW, operating at full capacity, 1 MWh will be produced in 5 hours. Setting the certificate price at 50 euro, this gives:

GCR = 4.8 MWh/day * 30 days/month * 3 green certificates * 50 euro/certificate

GCR = 21600 euro/month

In other words, the revenue resulting from transacting green certificates is of 21,600 Euro per month for a 200 kW generator, without considering the profit accrued by actually selling the energy, or used for own purposes.

4. SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT

The concepts of sustainability and sustainable development are two relatively new concepts emerged together with the globalisation concept.

Globalisation is the modern term used to describe the changes in societies and world economy resulting from increasing international trade and cultural exchanges.

The term of “sustainability” originates from forestry, designating procedures which balance the production capacity of forests with the volume of harvested wood such as, on long term, to increase the harvested volume without affecting the forests. Thus there can not be harvested more trees than those replanted.

The basic principle of sustainability was defined in 1987, extensively and very effective, by the UN Commission chaired by former Norwegian prime minister Gro Harlem Brundtland as follows: “A sustainable society seeks to meet the needs and aspirations of the present generation without compromising the ability to meet those of the future, where each individual has the opportunity to develop freely, in a balanced society in harmony with the environment.”

The concept of sustainability is a nonsense if it does not include the concept of quality of life. The latter has no perspective if it is not combined with the concept of sustainability. All three elements are important in order to speak about sustainable development at global level. For this reason, international bodies in the last 15 years defined sustainable development as the “improvement of quality of human life and at the same time considering the capacity of maintenance and support of ecosystems in which we live”.

Sustainable development aims to define a stable theoretical framework for decision making in any situation involving a relation human-environment, either the natural, economical or social environment [6].

Economical environment is defined as a system based on production and ruled by economical laws [7]. The relation between the economical system and the natural environment has to be reconsidered. For that purpose it should be accepted that the economical system belongs to the environment and, consequently, should be approached on the basis of the same material and energy laws.

The concept of economical process reduced to its two sides – production and consumption – enabled a limited approach of development. This concept does not take into consideration essential factors which contribute to environment degradation [6], [7].

The stage following consumption is one of the main causes of pollution. The operation of economical system requires ever increasing amounts of material and energy resources. Used energy transforms irreversibly into non-recoverable energy [6], [7].

Following the consumption stage, material transformed into products and then turned into waste is only partially recovered as the process operates with losses.

The stage prior to production is incorrectly perceived in the current economical concept, since it is been approached only from the point of view of extracting resources without considering the effects of dislocation from the natural environment and without considering the fact that many resources are finite and non-replaceable on Earth [7].

5. ENERGY CROPS PRODUCING BIOMASS

Using energy willow for recycling sludge from waste water treatment plants

People involved in growing, studying and researching energy of willow say that it has two fields of use:

- energy purposes;
- environment improvement.

When it used for energy purposes the results are fast considering the material satisfaction, however the improvement of environment conditions is more important in the context of sustainable development. In Nordic countries is unconceivable to discharge treated waste water into emissary. Willow plantations (cultivars adapted to harsh conditions) are established downstream of waste water treatment stations, producing a rich crop of biomass, usable for energy purposes.

In Romania such plantations were established downstream of waste water treatment plant in Miercurea Ciuc as a collaboration between the regional water operator Harviz SA, the municipality of Miercurea Ciuc and Kontrastwege SRL company.

Based on experience accrued by the above mentioned association, using sludge with dry mass proportion of 8-10% in amounts ranging from 10 to 50 t/ha the following conclusions were drawn:

- fertilisation with sludge during the first year is not recommended;
- best results were achieved when applying sludge during the vegetative stage, with quantities of 20-25 t/ha;
- quantities of 10 t/ha had no significant effect, while the effect was negative for quantities above 30 t/ha. [8]

Using Paulownia hybrid plantations for sludge recycling at Huedin waste water treatment plant

Paulownia Clona in Vitro 112® and Paulownia Cotevisa 2 are hybrids adapted to European pedoclimate conditions and were created by multiple consecutive hybridisations in laboratory, after 20 years of research and studies on experimental plantations, creating the fastest growing tree in the world.

These trees have the fastest growing rate (in 4 years they grow as tall as fir trees in 75-80 years or beech and oak in 35-40 years) producing 70% wood and 30% biomass. It has hard essence wood, caloric power of 4211 Kcal/kg, produces a quality timber up to 6 m in length, without nodes, semi precious, with wide range of uses. These hybrids can withstand temperatures from -30 to + 45 °C, regenerate by vegetative propagation at least 3 times, so after planting can be harvested 3 times in 15 years, producing significant revenue for the investor.

Figure 1. Paulownia plantation at 2 years

Figure 2. Paulownia plantation at 6 years

This tree can also be used for soil stabilisation (has pivoting roots and reaches down to 9-12 m). Given its fast growth (in 5 months since planting reaches 2-3 m in height and 8-10 cm in diameter) is most efficient for protection forests. It is a melliferous tree (a mature plantation on 1 ha can generate a production of 700-900 kg og honey) and has a large CO2 absorption capacity – a mature plantation on 1 ha can absorb 1200 t of CO2 which is found in solid form in the wood in amount of 49% [9].

Someș Water Company – Huedin subsidiary is running an experiment with Paulownia Green International SRL company in Cluj Napoca, a company renting an area of about 150 ha in Bicalat (Huedin area) from which 15 ha are planted with Paulownia hybrids.

Someș Water Company – Huedin subsidiary will apply sludge with no heavy metals or below the allowed limits, from Huedin waste water treatment plant, on about 13 ha, hoping to positively affect the tree growth by reducing the harvesting period from 5 years to 4 years, thus producing 4 crops in 15 years instead of 3 foreseen crops.

The amount of dry sludge required for a good growth is of 7 kg/m2 in year I, 10 kg/m2 in year II, 15/m2 kg in year III and 30 kg/m2 in year IV, amounting to 18 tonnes of sludge with 80% humidity per hectare (one hectare comprises around 600 trees).

Total amount of sludge resulting for year I is of 234 tonnes, for year II of 335 tonnes, for year III of 500 tonnes, and 1000 tonnes for year IV, which would solve the problem of sludge management at Huedin WWTP.

If this collaboration gives positive results for Paulownia Green Internaţional SRL, the company intends to extend the collaboration to the 100 ha of land designated for Paulownia crops.

At Huedin WWTP investments are in progress, namely a solar dewatering platform for the sludge, in order to reduce the weight of transported sludge.

If this experiment will succeed, Somes Water Company aims to:

- expand this program by purchasing agricultural land (degraded or partially degraded) with areas sized to the current sludge production level for each of the 8 waste water treatment plants of the company;
- establish similar energy crops;
- sell crops to timber industry;
- purchase power generators, sized to the level of wood and biomass production from the energy crops and consequently producing eco-friendly electric energy.

The costs related to land purchase, crops, power generators etc., will be covered by energy production and green certificates received for biomass energy, as well as by timber revenue.

With this approach Someș Water Company intends to become a significant player in production of energy in accordance with principles of sustainability and sustainable development, to create its own circuit of sludge management which is environmentally friendly and in tune with the national and European legislation.

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Municipal Sludge Amendments Effects On Growth And Physiological Parameters Of Ocimum Basilicum L. Plants

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Abstract

In order to assess the fertilization potential of municipal sludge for Ocimum basilicum L., a series of morphological and physiological parameters were investigated in a pot experiment with basil plants grown on different substrates, 100% eroded soil, 100% sludge and a mixture of eroded soil 15% + sludge 85%. The height and the fresh mass of plants increased significantly in plants grown in mixture (33.64 cm) compared to the other variants (20.56 cm on eroded soil and 20.64 cm on sludge). Similarly, the numbers of leaves and of lateral stems were higher in sludge amended substrate, while the number of abscised leaves was higher in 100% sludge grown plants. Leaf morphological indices such as mean area and perimeter recorded higher values in the mixture grown plants, however, the plants grown on sludge and sludge mixture exhibited foliar necrotic areas. The growth of the basil plants was accelerated in the mixture, as these plants reached the flowering stage before the other variants which, after the same period of time, were still in the vegetative phase. From a physiological standpoint, the values of the chlorophyll fluorescence ϕPSII and Fv/Fm were not significantly altered suggesting minimal impact on the status of the plants of the different characteristics of the substrates. Meanwhile, the chlorophyll content, was higher on sludge grown plants and significantly so in mixture grown plants compared to degraded soil grown plants. The results suggest that a higher yield of basil can be obtained when grown on eroded soil amended with 15% sludge compared to eroded soil alone.

Keywords
Biosolids, basil, chlorophyll fluorescence, eroded soil.

1. INTRODUCTION

The development of the collecting and treating systems of municipal waste water resulting from domestic, economic or industrial activities, by a growing number of wastewater treatment plants is a reflection of modernization and welfare of the contemporary society. The large quantities of municipal sludge (approx. 10.000.000 tones / year in Europe) results from waste water treatment plants and need special measures for sustainable management and disposal (Salado, 2010; Kelessidis and Stasinakis, 2012). Thus the Sewage Sludge Directive 86/278/EEC encourage the use of sewage sludge in agriculture, as it is the most viable method of reusing this waste, because it contains high amounts of macronutrients and also regulate its use in such a way, as to prevent harmful effects on soil, vegetation, animals and man.

Due to legislative restrains, that aim to ensure the safety of the citizens, as well as to protect the environment, the methods used in the treatment of the wastewater lead to increasingly higher quality of sludge (Fytili and Zabaniotou 2008; Smith 2009).

At European Union (EU) level, there are countries in which the greatest percent of sludge disposal is for agricultural use, for example in the year 2012 Spain, Germany and United Kingdom were the largest sludge producers (2577.2, 1844.4, 1078.4 thousands tones dry matter of which

74.5%, 29.3% and 78.2% were used in agriculture). In other countries such as Hungary, Greece and Romania, despite the fact that they produce considerably amounts of sludge, its utilization in agriculture is limited (157.7, 118.6, 48.4, thousands tones dry matter total production of which 9.5%, 11.8% and 4.1% are used in agriculture). Even though in 2013 the total production of sludge increased in Romania to 172400 tones dry matter, only 8000 tones (4.65%) dry matter were used in agriculture (Eurostat, 2016).

The reasons why in some countries of the EU the agricultural use of sludge is limited are the lack of awareness about the benefits of using agricultural, fear of contaminating the land with heavy metals, the costs of sludge transport on agricultural land and costs of monitoring the quality of sludge and of the land on which it is used.

Most scientific papers show positive effects of sludge on improving plant yield because of the macro nutrient content in the sludge (Cornfield et al., 1976; Vaca et al., 2011; Özyazıcı, 2013; Chrysargyris and Tzortzakis, 2015), but also of the better physico-chemical properties of soils on which they are used, by altering the bulk density of the soil, aeration and stabilization of eroded soils (Holz et al., 2000; Ros et al., 2003; Gu et al., 2013; Mihalache et al., 2014). There are also articles that show some negative effects, concerning the increase in heavy metals in plants and soils, pathogens and esthetic alteration of environment through smell (Singh and Agrawal, 2007; Mazen et al., 2010; Vaitkute et al., 2010; Collivignarelli et al., 2015). Regarding the physiology of plants cultivated in sludge amended soils, there are relatively few reports in the literature (Singh and Agrawal, 2010).

Ocimum basilicum L. is a widely used medicinal and aromatic plant, well known for the volatile oils and phenolic compounds synthesized. Research indicate that basil can be grown on municipal sludge (biosolids) amended substrates (Zheljazkov and Warman, 2004), showing an increase in biomass, while producing an essential oil free of contaminants. Since increasing agricultural land areas are affected by erosion (Darie and Ionita, 2013), the current paper aimed to evaluate whether basil can be successfully grown on eroded soil, in the presence of sludge amendment and to quantify the physiological performance of basil plants cultivated on a highly eroded soil, amended with municipal sewage sludge.

2. MATERIALS AND METHODS

Experimental conditions

The experiment consisted of growing *Ocimum basilicum* L. plants in laboratory controlled conditions in various substrates. The basil cultivar used was “Aromat de Buzau”, seeds were obtained from the Agricultural Research and Development Station at Buzau, Romania.

For the growth of basil plants, 4 L (15 cm height x 18 cm diameter) plastic pots were used. The variants were: S – sludge 100%; ES – eroded soil 100%; ES+S – eroded soil 85% + sludge 15% (v/v). The air dried, 2 years old sludge was obtained from the Dancu Municipal waste water treatment plant in Iasi, Romania. The concentration of heavy metals did not exceed the maximum admissible values for agricultural use (data not shown). The soil was collected from an agricultural land situated at 46°20'29.0"N 27°41'44.6"E in Vaslui County, Romania and was represented by a loamy chernozem (Florea et al., 2012) highly eroded by agricultural practices and environmental conditions. The physiochemical characteristics were assessed at the County Office for Soil and Agrochemical Studies – Iasi (Table 1). Prior to usage, the soils and the sludge were sieved through a 0.1 cm mesh size sieve. For each variant, 3 pots were used, and were field with 100% eroded soil, 100% sludge and a mix of 15% sludge + 85% eroded soil. The sludge was thoroughly mixed with the soil on a volume basis.

Table 1. Physiochemical properties of the eroded soil and sludge used in experiment

Eroded soil	pH	EC uS/cm	N total %	P ppm	K ppm	Humus	CaCO3 %
	8.05	221.4	0.068	41	97	1.24	9.34
Sludge	pH	E.C. uS/cm	Nt% d.s.	P2O5% d.s.	K2O% d.s.	O.M.	U%
	6.96	6280	4.83	2.43	0.51	26.6	29

Each pot was seeded with 10 basil seeds. The plants were thinned at 4 individuals per pot after 1 week. The pots were kept at constant temperature regimes, between 22° C (night) and 25° C (day). Artificial light was supplied by 4800K fluorescent tubes for 14 h each 24 h. The atmospheric humidity was relatively constant, around 50%. Plants were irrigated twice a week with distilled water.

Morphometrical assessments

For each variant, 12 individuals were assessed for stem height, number of leaves, number of lateral stems, root length, number of abscised leaves. Also area, perimeter, length and width of the leaves were assessed by ImageJ, an image processing program developed by National Institute of Health.

Physiological measurements

Fresh mass and dry mass of entire plants were gravimetrically determined for 6 weeks old plants.

Chlorophyll fluorescence was evaluated by measuring Fv/Fm and ϕPSII on 3 leaves (from the lower, middle and upper regions of the plants) from 3 individuals each per treatment, using a pulse modulated fluorometer FMS2 (Hansa Tech Ltd.). Fv/Fm was measured following a 20 minutes dark adaptation of leaves using provided clips. ϕPSII was measured at normal light regime.

Assimilatory pigments were measured with a non-destructive portable chlorophyll content meter (CCM 200 Plus, Opti-Sciences Ltd.) that measures optical absorbance, the readings being expressed as CCI units.

The statistical analyses conducted were represented by analyses of variance among treatments and the Tukey post hoc test at $p<0.05$, the results being expressed as means and standard errors.

3. RESULTS AND DISCUSSIONS

The different cultivation substrates influenced all the morphometric indices analyzed. The height of the basil plants recorded the highest values in the case of sludge amended substrates, where the increase was of 163% compared to plants cultivated on 100% eroded soil and 162% compared to plants grown on 100% sludge substrate. Similarly, the fresh mass of plants was highest in plants grown in soil-sludge mixture, with values increased with 520% and, respectively, 443% compared to eroded soil and sludge grown plants. Root lengths of plants were longer in the case of plants cultivated on eroded soil amended with 15% sludge than those of plants from other variants (Table 2).

Table 2. Morphometrical parameters of basil plants cultivated on different substrates

Substrate / Parameter	Height (cm)	Fresh weight (g)	Root length (cm)
Eroded soil	20.56±0.53	1.75±0.18	5.83±1.09
Eroded soil + Sludge	33.64±0.55*	9±0.1*	7.33±0.33*
Sludge	20.64±0.96	2.03±0.53	4.33±0.6

(*-significant differences from control plants at $p < 0.05$)

Leaf morphological indices, leaf area, perimeter, maximum width and maximum length, were significantly increased in mixed substrate grown plants. Leaf area and leaf perimeter recorded values of up to 428% and, respectively, 198% compared to other treatments (Fig. 1).

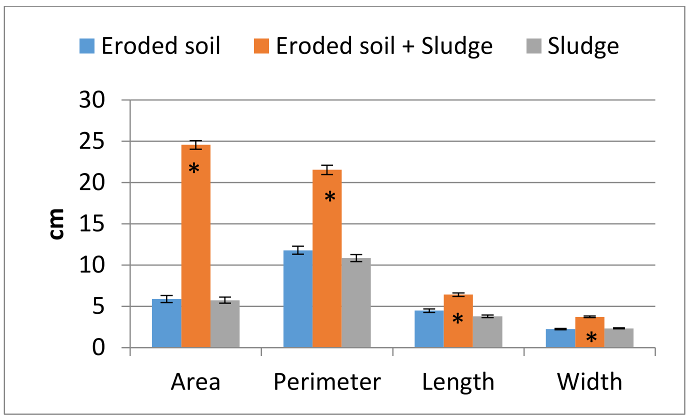

Figure 1. Morphological indices of basil plants cultivated on different substrates
(*-significant differences from control plants at $p < 0.05$)

The increase in values of morphological parameters and, hence, in plant yield, may be explained by much higher contents of nutrients in sludge and sludge mixture compared to eroded soil alone. Similar results were obtained for other species, under sewage sludge treatments, with significant positive influences on similar parameters (Costa et al., 2010; Özyazıcı, 2013), but also for basil (Kashani et al., 2013). Some species may be sensitive to the toxic effects of sludge amendments, with reductions in root lengths and other morphological traits (Vaitkutė et al., 2010; Oleszczuk et al., 2012), however such effects were not recorded for basil grown on the analyzed sludge.

Regarding the number of leaves and lateral stems, a significantly increase was obtained in the case of plants cultivated in mixed substrates compared to the other variants (Fig. 2).

Also the number of abscised leaves was grater for plants grown in the mixed substrates compared to the ones cultivated in eroded soil (250%), but lower than the ones form sludge substrates (33%). We can assume that, the high content in macronutrients from sludge stimulates organogenesis in basil plants, but also induces leaves senescence (Marschner, 1995).

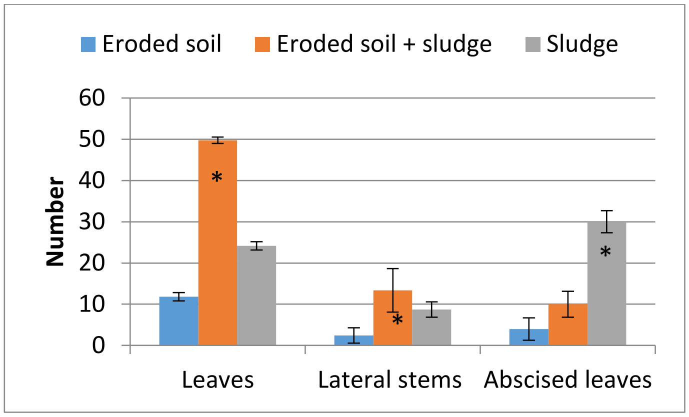

Figure 2. Number of leaves and stems of basil plants cultivated on different substrates (*-significant differences from control plants at $p < 0.05$)

Water content was higher in plants cultivated on sludge and the dry matter was lowest in the same plants even though the values are not statistically significant (Table 3).

The water content in plants is very important for the normal development of the physiological processes and is known to be higher in parts of a plant with intense metabolic activity like meristems or leaves.

The increase in water content in the plants cultivated on sludge may be attributed to an intense activity of organogenesis, as these plants had the highest number of abscised leaves and formation of new leaves in consequence (Shipley and Vu, 2002).

Also it reveals a better absorption of water through the radicular system because of the low density of the substrate.

Table 3. Physiological parameters of basil plants cultivated on different substrates

Substrate/ Parameter	Water content (%)	Dry matter (%)	Chlorophyll contents (CCI units)
Eroded soil	85.95±0.53	14.05±0.53	9.81±0.54
Eroded soil + sludge	85.7±0.2	14.3±0.2	13.74±0.82*
Sludge	86.19±0.14	13.81±0.14	12.8±1.25

(*-significant differences from control plants at $p < 0.05$)

The chlorophyll fluorescence values show similar values for maximum yield of PSII (Fig. 3) among treatments. The quantum yield of PSII, expressed as Fv/Fm parameter (Fig. 3) records slightly lower values for the treatment consisting of sludge mixture, however a not significant decrease compared to the other variants.

Another photosystem related parameter, chlorophyll contents, indicates that the sludge treatments lead to elevated amounts of assimilatory pigments (Table 3).

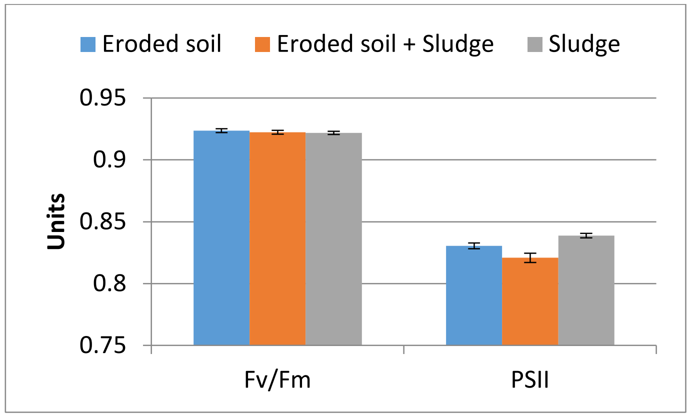

Figure 3. Chlorophyll fluorescence parameters of basil plants cultivated on different substrates (*-significant differences from control plants at $p < 0.05$)

The positive effects on plant growth of elevated nutrient contents in substrates have been reported, thus recommending the sludge for fertilization. However, concerns on the toxicity of sludge towards plants have been expressed (Oleszczuk and Hollert, 2011; Adamcova et al., 2016) and testing is required. One parameter that reflects certain toxic influences on the physiology of plants is chlorophyll fluorescence, which may be used to assess the efficiency of the photosystem II and therefore of the photosynthetic capacity of plants (Baker and Rosenqvist, 2004). Parameters such as Fv/Fm and PSII (maximum quantum yield of PSII and quantum yield of PSII) were reported to variate in the case of sludge amendment (Augustynowicz et al., 2009), showing possible toxic effects. Similarly, the effect of sludge amendment was shown to exert beneficial effects on the physiology of plants (Han et al., 2004) and also the physiological response of plants assessed through chlorophyll fluorescence measurements may be species - specific (Tan et al., 1999). The data obtained for basil shows that, at the level of photosystem II, the effects of sludge are minimal, further underlining the lack of toxicity of tested sludge towards basil.

Increased chlorophyll contents in sludge amended plants may be the result of higher nitrogen levels in substrate. Although some species may display reduction of chlorophyll contents under sludge amendment, this may be due to metal toxicity (Singh and Agrawal, 2007). A positive correlation between nitrogen levels and chlorophyll amounts of leaves has been shown for several species (Mazen et al., 2010; Zhang et al., 2013) and occurs due to the fact that nitrogen is included in the structure of chlorophyll molecules (Martinez and Ramos, 2015).

Other research regarding the beneficial effect of utilizing sewage sludge for the fertilization of crops in Romania, sustain its usefulness, especially for the high amounts of macronutrients which improve soil quality, that leads to greater yield. For Instance, Vasilica Stan from the University of Agricultural Sciences and Veterinary Medicine, Bucharest, in a two year study, 1994-1996, reported an improved yield (199.9%) of maize cultivated on a soil amended with 10% sludge compost (Stan, 1996). Also, Ailincai et al., (2011), conducted a five year-crop rotation, winter rape-wheat-maize-sunflower-wheat, on an experiment located at Podu-Iloaiei Agricultural Research Station, Iaşi County, obtained increased yield of winter rape (187%) by using 40 tonnes/ha of sludge. Thus, the sewage sludge from Romania waste water treatment plant can be used, with very good performances, for the fertilization and soil conditioner for the land with agricultural purposes, especially for the growth of higher crops but also for some medicinal plants like basil, that are cultivated for the production of the essential oils.

4. CONCLUSION

The tested, air dried municipal sewage sludge, can be used for growing *Ocimum basilicum* with positive, fertilizing, effects on plant growth and yield, in conditions of growth on eroded soils. The sludge exerts little toxicity on plants, mainly manifested through leaf necrotic areas, but the investigated physiological parameters were not affected. Further testing may be conducted to optimize sludge dosage in order to improve eroded soil properties for basil crop fertilization.

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Usage In Agriculture Of Sludge Generated In Wastewater Treatment Plants. The Experience Of S.C. Apa Canal 2000 S.A. Piteşti

Petrică Negru*

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Abstract
The activity consisting in the disposal/valorization in agriculture of dewatered sludge – sludge resulted during the wastewater treatment in the Wastewater Treatment Plant Pitesti – has as a legal basis the provisions of Joint Order no. 344/707/2004 issued by the Minister of Environment and Waters Management and Minister of Agriculture, Forests and Rural Development. The Order had translated into Romanian legislation the CEE Directive no.86/278/CEE regarding the protection of the environment and especially of soils when using sludge from wastewater treatment processes in agriculture, directive published into the Official Journal of the European Community (JOCE no. L 181 /4th of July 1986, with the subsequent modifications and completions).
The dewatered sludge obtained within the Wastewater Treatment Plant Pitesti is used as fertilizer in agriculture only for cereals crops.
There are presented the history and experiences of valorization of sludge in agriculture of S.C. APA CANAL 2000 S.A. PITESTI.

Keywords
Sludge, land, plant.

1. THE HISTORY OF SLUDGE SPREADING FOR AGRICULTURAL PURPOSES BY SC APA CANAL 2000 SA PITESTI.

PHASE I. EXPERIMENTS PERFORMED WITHIN THE AGRICULTURAL RESEARCH AND DEVELOPMENT INSTITUTE PITESTI – ALBOTA

In the period 2003 – 2008, the Agricultural Research and Development Institute Pitesti-Albota alongside with S.C. APA-CANAL 2000 S.A. Pitesti performed a series of experiments on the agricultural plots belonging to the Institute, experiments aimed at using in agriculture the dewatered sludge from Pitesti Wastewater Treatment Plant Pitesti. The results of these experiments are detailed in the book with the title "Usage in agricultural acid soils of sludge resulted from urban wastewater treatment. Impact upon the environment".
Year 2008 – Sludge was spread on a surface of **5 ha – S.C. Grimar - Bradu**

- Pedology and agrochemical study for assessing agricultural lands suitability to spreading sludge from Wastewater Treatment Plant Pitesti no. 227/28.05.2008;
- Spreading permit no. 1/30.05.2008 – recommendation 20 tonnes dry substance/ha;
- The quantity of sludge valorized in agriculture was of **100 to dry substance**.

Year 2009 – Sludge was spread on a surface of **50 ha – Stolnici – MOSIE lot – S.C. BARAC HADAS S.R.L.**

- Pedology and agrochemical study for assessing agricultural lands suitability to spreading sludge generated in the Wastewater Treatment Plant Pitesti no. 492/11.02.2009;
- Spreading permit no. 1/ 17.03.2009; recommendation 15 to dry substance/ha with the obligation to monitor the physical-chemical parameters subsequent to sludge

spreading for monitoring the quality of soil, underground water and plants – annual frequency;
- The quantity of sludge valorized in agriculture was of **577 tonnes dry substance.**

PHASE II. INTENSIFICATION OF SLUDGE SPREADING ACTIVITY BY MEANS OF EXTENDING THE SURFACES

Year 2010 – Sludge was spread on a surface of **100.9 ha – Stolnici –Filfani Rail Station Area– S.C. Agrototal Prodcom S.R.L.**
- Pedology and agrochemical study for assessing agricultural lands suitability to spreading sludge generated in the Wastewater Treatment Plant Pitesti no. 332/10.07.2010;
- Spreading permit no. 1/08.09.2010 with the obligation to monitor the physical-chemical parameters subsequent to sludge spreading for monitoring the quality of soil, underground water and plants – annual frequency;
- The quantity of sludge valorized in agriculture was of **1,537 tonnes dry substance.**

Year 2011 – Sludge was spread on a surface of **3 ha – Stolnici – Mosie lot – S.C. Barac Hadas S.R.L.**
- Pedology and agrochemical study for assessing agricultural lands suitability to spreading sludge generated in the Wastewater Treatment Plant Pitesti no. 1032/16.08.2011;
- Spreading permit no. 1/08.09.2010 with the obligation to monitor the physical-chemical parameters subsequent to sludge spreading for monitoring the quality of soil, underground water and plants – annual frequency;
- The quantity of sludge valorized in agriculture was of **68 tonnes dry substance.**

Year 2012 – Sludge was spread on a surface of **74 ha – Stolnici – Mosie lot – S.C. Barac Hadas S.R.L.** (2nd spreading for 50 ha + 24 ha first spreading)
- Pedology and agrochemical study for assessing agricultural lands suitability to spreading sludge generated in the Wastewater Treatment Plant Pitesti no. 1032/16.08.2011;
- Spreading permit no.1/08.09.2010 with the obligation to monitor the physical-chemical parameters subsequent to sludge spreading for monitoring the quality of soil, underground water and plants – annual frequency;
- The quantity of sludge valorized in agriculture was of **634 tonnes dry substance.**

Year 2013 – Sludge was spread on a surface of **40 ha –Stolnici – Mosie lot (15 tonnes/ha, 600 tonnes dry substance) S.C. Barac Hadas S.R.L.**
- Pedology and agrochemical study for assessing agricultural lands suitability to spreading sludge generated in the Wastewater Treatment Plant Pitesti no. 1032/16.08.2011;
- Spreading permit no. 1/08.09.2010 with the obligation to monitor the physical-chemical parameters subsequent to sludge spreading for monitoring the quality of soil, underground water and plants – annual frequency;
- The quantity of sludge valorized in agriculture was of **600 tonnes dry substance.**

Year 2014 – Sludge was spread on a surface of **40 ha –Stolnici – Breazu lot (15 tonnes/ha, 545 tonnes dry substance) S.C. Agrostar Farmex S.R.L.**

- Spreading of chemical reagents on a surface of 120 ha for correcting the soil's reaction, upon the recommendation of OSPA Arges.
- Pedology and Agrochemical Study on monitoring the soils on which sludge generated in the Wastewater Treatment Plant Pitesti was spread no. 3979/18.03.2014;
- Spreading permit no. 1/31 07.2014;
- Sludge was spread on a surface of **12 ha – Stolnici – Mosie lot – S.C. Agrostar Farmex S.R.L. Pitesti (15 tonnes/ha, 180 tonnes dry substance);**
- The quantity of sludge valorized in agriculture was of **725 tonnes dry substance;**
- Area where sludge was spread in year 2009. Spreading permit no. 2/30.10.2014, November.

Year 2015 – Sludge was spread on a surface of **28 ha on Mosie lot.**

- Pedology and Agrochemical Study on monitoring the soils on which sludge generated in the Wastewater Treatment Plant Pitesti was spread no.3979/18.03.2014;
- Spreading permit no. 1/ 09.02.2015;
- Disposed sludge quantity: **392.63 tonnes s.u** (15 tonnes/ha);
- Area where sludge was spread in year 2009 (12 ha in 2014 + 28 ha in 2015).

Table 1. Centralizing table

Year	Location	Surface ha	Disposed Quantity (tonnes/dry substance)	Observations
2008	S.C. Grimar Bradu	5	100	Achieved
2009	Stolnici – Mosie	50	577	Achieved
2010	Stolnici – Filfani	100.9	1537	Achieved
2011	Stolnici – Mosie	3	68	Achieved
2012	Stolnici – Mosie	74	634	Achieved
2013	Stolnici – Mosie	40	600	Achieved
2014	Stolnici – Breazu	40	545	Achieved
	Stolnici – Mosie	12	180	Achieved
2015	Stolnici – Mosie	28	392.63	Achieved
TOTAL quantity disposed in the period 2008-2015			**4633.63**	

NOTE: all determinations performed regarding the quality of soil, underground water and plants are within the maximum admissible limits foreseen by legislation in force.

2. VALORIZATION IN AGRICULTURE OF SLUDGE PRODUCED IN THE WASTEWATER TREATMENT PLANT PITESTI

The contraction of the industrial activity at the economic level led to the substantial reduction of the treated sludge' pollution degree with heavy metals.

The contracted land surface on which S.C. Apa-Canal 2000 S.A. Pitesti is valorizing the sludge produced during the wastewater treatment is of 150 ha, is located at a distance of approximately 100 km from Pitesti and belongs to SC Agrostar Farmex SRL Pitesti.

Preparatory activities:

Since the sludge obtained within the Wastewater Treatment Plant Pitesti falls under the category of non-hazardous waste and is to be used as fertilizer in agriculture, with observance of the provisions contained within Joint Min. Order no. 344/707/2004, soil sampling and testing was performed on an annual basis in order to verify the soil quality. Sampling is performed by specialized personnel and the samples are analyzed in the company's laboratory that is licensed by RENAR.

The parameters analyzed are the ones set in Order no. 344/2004, as follows:

- Heavy metals (Cd, Cu, Zn, Ni, Pb, Mo, Co);
- Agro-chemical parameters.

The results of the parameters analyzed in the soil samples fell within the limits permitted by Joint Min Order no. 344/707/2004.

Sludge that does not comply with the quality requirements is discharged as hazardous waste.

After the sludge quality was analyzed, a request was submitted to the Office for Pedology and Agrochemical Studies (OSPA) in order to perform the basic Pedology and Agrochemical Study for new lots and for monitoring the lots on which sludge was spread in the previous years.

The Pedology and Agrochemical Study performed by OSPA consists in performing soil analyses in licensed laboratories (heavy metals, pH, etc.) that represent the basis for justifying the recommendation regarding the sludge quantities to be spread on those agricultural land plots. The OSPA recommendations can be identified in the sludge spreading history. In the last 3 years, the sludge quantity recommended by OSPA was of 15 tonnes/ha.

Based on the Pedology and Agrochemical Study the endorsement from DGA Arges was obtained.

In the period 2008 – 2015, a number of 6 spreading permits were obtained.

For obtaining the Spreading Permit, the following documents were submitted to the Environment Protection Agency Arges:

- Pedology and agrochemical study with the recommendation of spreading 15 tonnes/ha;
- Quantities of sludge generated and quantities of sludge supplied in order to be used in agriculture;
- Sludge composition and characteristics – according with the testing reports;
- Type of treatment performed – dewatering;
- Sludge user identification data – SC Agrostar Farmex SRL Pitesti, SC Barac Hadas SRL;
- Data on the location of the agricultural land plots on which sludge is to be spread – layouts.
- Probable period for sludge spreading: March-April and September – October.
- Type of crop: corn, wheat, sorghum.

For transporting the sludge generated in the Wastewater Treatment Plant Pitesti to those specific agricultural land plots in that period a number of 3 transport companies were selected, fulfilling the following conditions: at least 5 vehicles, minimum capacity of 20 cm, non-hazardous waste transportation license, transport license.

Sludge spreading was performed using a manure spreading vehicle attached to an 80 hp tractor, with subsequent high depth incorporation. The spreading time upon incorporation was of 1-2 days. The land preparation was followed by seeding.

After plants rising, the environment parameters' monitoring was performed as follows:

- Soil monitoring – pedology and agrochemical study for post-spreading monitoring is performed by OSPA by means of soils sampling and performance of analyses for heavy metals and pH. frequency: once per year.
- Underground water monitoring – underground water analysis, using samples from the area where the spreading was performed. Frequency: once per year.
- Plants monitoring – biologic material sampling in different development phases. For corn and sorghum crops, 3 biologic material samples were taken in different vegetation stages. The sampling was performed both for the experimental plot and the control lot. Parameters monitored were the heavy metals (Cu, Cd, Cr, Ni, Zn, Pb, Mo, Co).

3. RESULTS

Table 2. Expenditures with sludge valorization in agriculture in the period 2013 - 2015

No.	Disposal year	Disposed sludge quantity tonnes/ dry substance	Total expenditures RON	Disposed sludge quantity tonnes/ raw substance	Price /tonnes/ dry substance RON	Price /tonnes/ raw substance	Price euro/ tonnes/ dry substance	Price euro/ tonnes/ raw substance
1	2013	600.00	154,212.55	1150.0	257.02	134.09	58.41	30.47
2	2014	724.98	243,591.35	2439.0	323.58	99.87	73.54	22.69
3	2015	392.63	136,860.14	1,006.7	125.92	49.11	28.61	11.16
			534,664.04	4,595.7				

A major factor in reducing the expenditures/to dry substance is related to the cost of sludge transport. Its influence in the expenditures is of 20%, so it can be stated that a lower distance from the sludge storage to the land on which the sludge is to be spread will diminish the costs substantially.

Advantages related to sludge usage in agriculture.

- Sludge is used as a fertilizer – contribution of macro and micro-elements necessary for the plants.

- Reduction of chemical fertilizer quantities used, thus reducing the production costs.

- Improvement of soils reaction due to the pH. Since its value is around 7.6, nutrients access is improved. In case of a lower pH, the heavy metals are soluble in the soil.
- The organic matter content improves the aerial-hydric regimen of soils, by increasing the water retaining capacity and by reducing the soil's compaction degree.

Assessing The Environmental Impact Of Wastewater Treatment Sludge Using Life Cycle Assessment Methodology

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Abstract
The 21st century began with the world facing a water quality crisis, due to the continuous population growth, urbanization, land use change, increased living standards and poor water use practices and wastewater management strategies. According to UN Water, if the present unsustainable trends of water use and management continue, by 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could live under water stress conditions. The present global environmental issues drive societies to develop new sustainable ways of using the natural water resources and managing waste. The proper management of sewage sludge represents a growing problem world-wide since studies show that sludge production will continue to increase the following years. The current challenge for the waste water treatment plants managers is to find and implement cost-effective and innovative techniques and solutions for sludge treatment, while addressing the environmental concerns. Recycling and use of the sludge in order to eliminate it, but also to recover energy are the preferred options for sustainable development, rather than incineration or landfilling. This paper describes the methodology that will be used in order to evaluate and quantify the impact that the tailored for the Romanian wastewater sector.

Keywords
Life cycle assessment, sewage sludge management, environmental impact.

1. INTRODUCTION

As global population and consumption are continuing to increase, it is becoming very important for us to have a wise use of resources and minimise the detrimental impacts that we have on the environment around us. We need good and correct information to guide decisions that are aimed at reducing environmental impacts. That would include design decision, purchasing decisions and policies decisions. When we are making this kind of decisions, good intentions are not enough. The decision needs to be supported by good science. Simply stating that a product has recycle content or is recyclable is not enough. We need to have a quantified assessment of the actual effects of those characteristics of the environmental footprint of that product system.
The wastewater treatment consist in a complex of mechanical, physical, chemical and biochemical processes. This processes have as a result a primary effluent– the treated water and a number of by-products consisting in the materials resulted in the separation process. From a quantitative perspective, the most important by-product that results from the wastewater treatment process is the sludge.
According to the National Policy for Sewage Sludge Management, Romania faces a fourfold increase in sewage sludge in the following decade. [1] Currently, most of the sludge produced by the Romanian wastewater sector is disposed by landfilling or applied directly to agricultural land, but considering the fact that sewage sludge represents a source of energy and nutrients, it is possible to utilise it as raw material for industrial processes and energy production.

According to EU negotiations, by December 31, 2018, Romania has the obligation to enter into full compliance with EC Directive 91/271 / EEC. All cities with more than 2000 inhabitants should be served by wastewater treatment plants (WWTPs), and so the sludge production will increase.
The available data on the current situation regarding the sludge management in our country are synthesized in the National Wastewater Sludge Management Plan.

Choosing a suitable sludge management technology should be a decision-making process based on environmental, economic and societal constrains.
The increased awareness of the importance of environmental protection, and the possible impacts associated with products, both manufactured and consumed, has increased interest in the development of methods to better understand and address these impacts. One of the techniques developed for this purpose is life cycle assessment. [2] The Life Cycle Assessment (LCA) is a decision support technique used in order to assess the environmental performance or to identify the system with the best performance through a comparative analysis of different scenarios. Basically, what an LCA study does, is to compile and evaluate the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.
There are four phases in an LCA study, as presented in the figure 1 below: the goal and scope definition phase, the inventory analysis phase, the impact assessment phase and the interpretation phase, that can have direct applications, according to the initial purpose of the study.

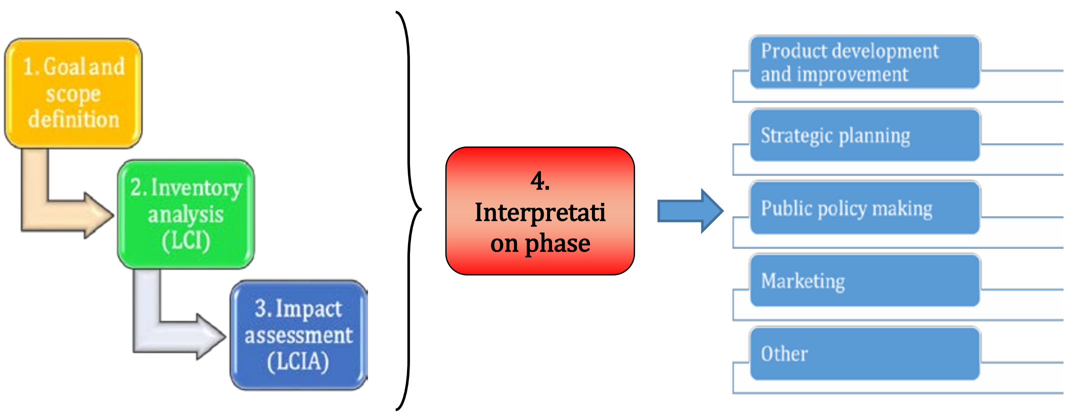

Figure 1. Fundamentals of Life Cycle Assessment

The steps of the Life cycle that will be analysed in the ongoing study presented by this paper are: sludge production in WWTP; sludge anaerobic digestion; digested sludge transport from the WWTP to the drying and pelletizing plant; transportation of the sludge pellets to the end-user, in order for the final product to be incinerated and transformed in energy; the consumption of energy, water, raw materials and other materials; emissions and waste resulted after the incineration.

2. LIFE CYCLE ASSESSMENT METHODOLOGY

The scope of an LCA study clearly states and defines from the beginning the system, boundaries, data requirements, assumptions and limitations. The scope should be defined in detail to ensure that the whole analysis is compatible with and sufficient to address the stated purpose. All data boundaries, methodology, data categories and assumption should be clearly stated and should

include geographical extent (local, national, regional, continental and global) and time (product life, tome horizon of processes and impacts). During goal definition in LCA, the following must be clearly stated:
- the intended application – sludge management in WWTP
- the reasons for carrying out the study – integrated evaluation of different sludge management scenarios in order to determine the proper solution, based on datasets
- the intended audience – WWTP managers and end users of the final product.

The system studied is wastewater sludge management and the function of the system is the treatment of sludge resulting from the municipal wastewater treatment plants in Romania. The functional unit that will be used for the comparison of the treatment systems is 1 ton of sludge from WWTP of urban area.
Waste water from both municipal and industrial source is treated at the wastewater treatment plant. The resulting sludge is pre-treated after which is subjected through different stabilisation/ treatment alternatives. The system boundary for the study starts at the point where the sludge is released from the pre-treatment processes. Two different system products will be analysed: (1) untreated, dewatered sludge (directly from the thickening system of the municipal wastewater treatment plant) and (2) digested sludge from the anaerobic digesters.

Different scenarios (Figure 2) will be taken into account for applying an LCA study, with the first two scenarios depicting the existing situation in the two Constanta municipality WWTP, while the remaining scenarios are alternatives to the existing ones. The environmental impacts of these scenarios would be analysed and compared to determine which of them is the most feasible.

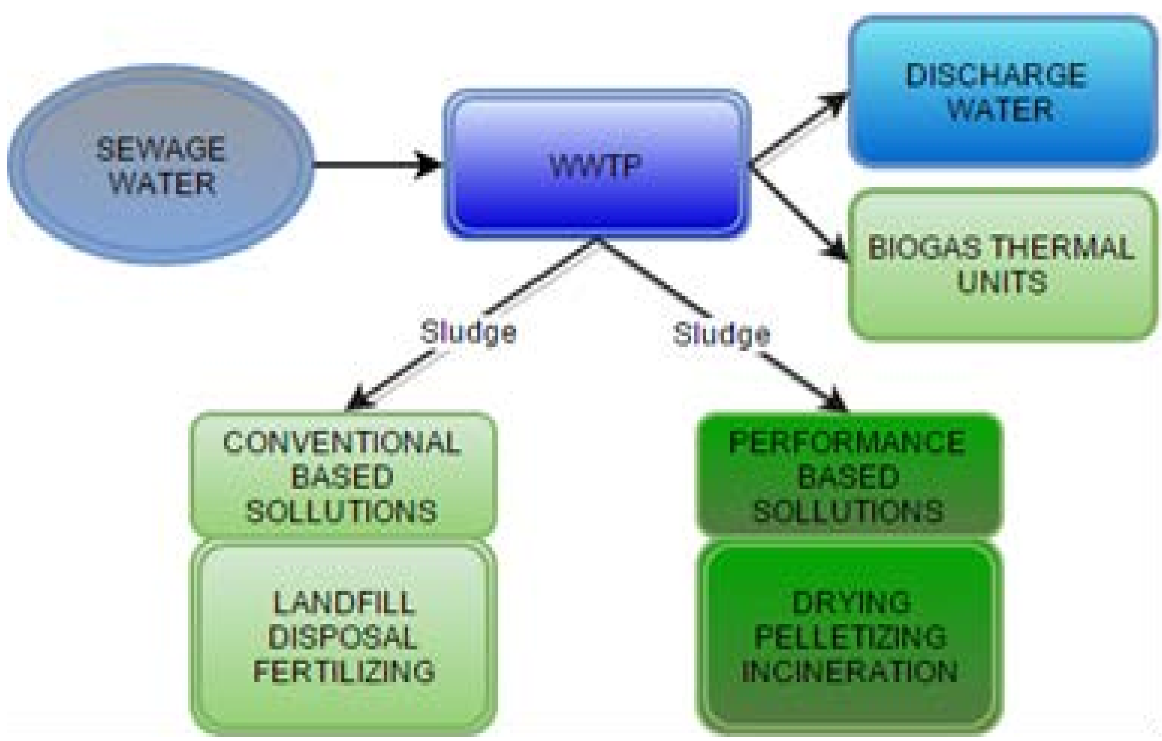

Figure 2. Sludge management options considered and the products that would be analysed

The fundamentals behind the choosing this options can be described as it follows:
- these scenarios can offer sustainable ways for treating municipal solid waste as they offer the possibility to exploit the nutrient and energy content of sludge as well as reducing pollutant emissions;
- they offer the possibility to reduce the sludge volume up to 80-90%;
- possibilities of valorisation of sludge can be obtained through incineration or combustion (sometimes co-combustion) with energy recovery or by anaerobic digestion with energy recovery from the methane produced in that process. Both are sources of renewable energy.
- drying and pelletizing the sludge offers the possibility to use high-efficiency pellet boilers for the incineration process;
- The scenarios have been chosen based on the research activities conducted by a team of researchers involved in the project "Development of innovative solutions materialized in products and services that should lead to increase competitiveness of the companies associated within the Cluster MEDGreen+", financing contract no. 1CLT / 800 027 / 03.06.2014, SMIS code 49755, financed through The Sectoral Operational Programme "Increase of Economic Competitiveness", 2007-2013, Priority Axis I, "An innovative and eco-efficient manufacturing system", Main field D1.3, "Sustainable development of entrepreneurship", Operation "Support for the integration of companies in value chains and clusters", co-financed by European Development Regional Fund. Based on the results from this project, with the LCA approach, it would be possible to identify the best system to treat wastewater sludge together with the key parameters influencing their environmental impacts.

After identifying the purpose of the analysis, next step is to quantify the energy and raw material inputs and also, the environment releases from each stage of the cycle. The third stage is the impact analysis – assessing the impact on the human health and the environment, referring to the energy, raw material inputs and the releases quantified by the inventory. The final stage of the LCA evaluates the opportunities to reduce the energy consumption, material inputs or environmental impact, at each stage of the product's life cycle. This step represents the so-called improvement analysis.

The quality of an LCA study depends highly on the availability of input data for constructing an LCI. Completeness, representativeness and accuracy were identified as three aspects of data quality, and representativeness could be further defined in temporal, geographical and technical terms. However, collecting a site-specific input dataset could be prohibitively time and resource-consuming. As a consequence, most of the LCA studies rely heavily on existing emission and operational data for target systems. (3)

3. USING OPENLCA. BASIC OVERVIEW

This chapter presents the OpenLCA first steps in conducting an analysis on sewage sludge management with the purpose of identifying current data gaps. OpenLCA is a free, professional Life Cycle Assessment (LCA) and footprint, open source software with a broad range of features and many available databases, created by GreenDelta since 2006.
The software as well as any models created can be shared freely, as long as the database license allows it. OpenLCA can be used for a number of different applications, for example: LCA, Life

Cycle Costing (LCC), Social Life Cycle Assessment (S-LCA); Carbon & water footprints; Environmental Product Declaration (EPD).
Initially, openLCA does not contain any data, therefore the 'navigation' section on the left (Figure 3) will be empty. OpenLCA offers us the possibility to either create a new, empty database, or to import an existing one.

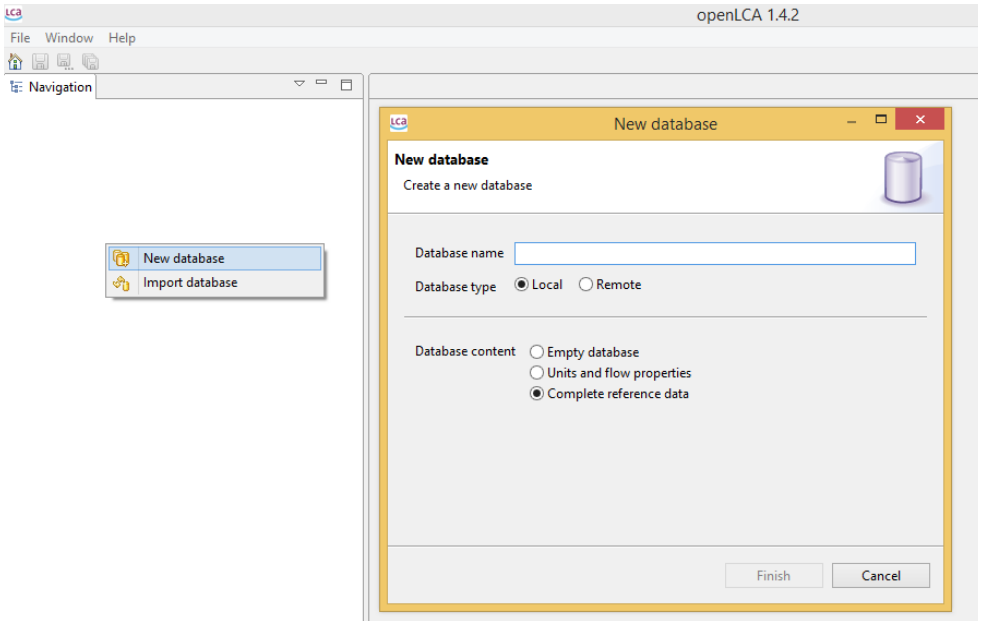

Figure 3. Creating or importing a new database in openLCA

At the first stage of this study there will be used the European Lifecycle Database. The Joint Research Centre of the European Commission provides the ELCD database (http://lca.jrc.ec.europa.eu/lcainfohub/datasetDownload.vm), as a free, public database in ILCD format.

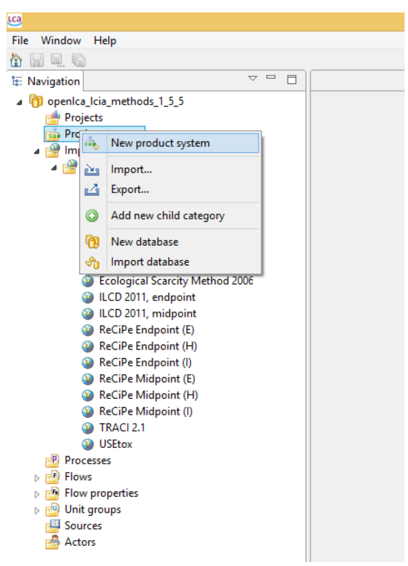

Figure 4. Creating a new product system in openLCA

Core of any LCA modelling is the modelling of the life cycle of the product under study. In openLCA (as in ISO 14040), the life cycle model of a product is called product system, and there are different ways for creating and completing product systems (Figure 4), depending on the database and user preferences. The first possibility is to create the product system from the process. (Figure 5).

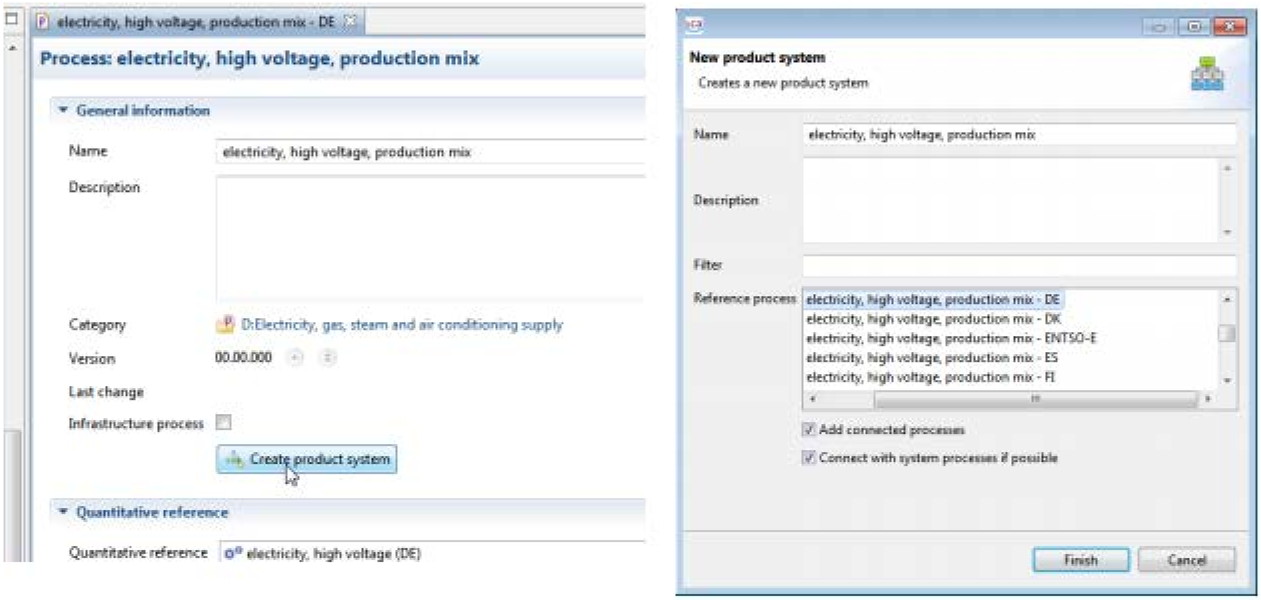

Figure 5. Creating a new product system from a process

The product system contains all the information about the scenario that is going to be assessed. Furthermore, we need to define the processes involved in the analysed system, the flows, with the possibility to edit and modify our flow properties and process parameters.

Another important feature in conducting an LCA study is the impact assessment method and their impact categories.

The most common impact categories that can be found in the different impact assessment methods available for openLCA are presented in the table below.

Table 1. Availability of impact categories per method

Methods	**A**	**CC**	**RD**	**EC**	**EU**	**Eph**	**HT**	**IR**	**LU**	**Od**	**Old**	**PM/ RI**	**PO**
CML (baseline)	Yes	Yes	Yes	Yes	-	Yes	Yes	-	-	-	Yes	-	Yes
CML (non-baseline)	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes

Cumulative Energy Demand	-	-	-	-	Yes	-	-	-	-	-	-	-	-
eco-indicator 99 (E)	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes	-	Yes	Yes	-
eco-indicator 99 (H)	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes	-	Yes	Yes	-
eco-indicator 99 (I)	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes	-	Yes	Yes	-
Eco-Scarcity 2006	-	-	Yes	-	-	-	-	-	-	-	-	-	-
ILCD 2011, endpoint	Yes	Yes	-	-	-	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes
ILCD 2011, midpoint	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes
ReCiPe Endpoint (E)	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes
ReCiPe Endpoint (H)	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes
ReCiPe Endpoint (I)	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes
ReCiPe Midpoint (E)	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes
ReCiPe Midpoint (H)	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes
ReCiPe Midpoint (I)	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes
TRACI 2.1	Yes	Yes	Yes	Yes	-	Yes	Yes	-	-	-	Yes	Yes	Yes
USEtox	-	-	-	Yes	-	-	Yes	-	-	-	-	-	-

A – Acidification
CC – Climate change
RD – Resource depletion
EC – Ecotoxicity
EU – Energy use
Eph – Eutrophication
HT – Human toxicity
IR – Ionising radiation
LU – Land use
Od – Odour
Old – Ozone layer depletion
PM/RI – Particulate matter/ Respiratory inorganics
PO – Photochemical oxidation

4. CONCLUSION

Environmental assessment of a sludge management scenario and its feasibility represents a very complex process having as main constrains the lack of datasets and the scale-up difficulties. However, although a certain number of simplification and assumption have to be made, environmental assessment using LCA can be used as base for decision making processes, an instrument for applying research activities in industrial processes.
The final goal of the LCA study will be to identify the best system to treat the wastewater sludge together with the main parameters that influence their impact on the environment. There will be conducted further and more complex investigation on options as anaerobic digestion, drying, pelletizing and incineration, investigations that could lead to the optimal sludge management in terms of recovery of material and energy in order to obtain economic and environmental advantages.

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