FUTURE QUANTITIES OF SLUDGE FROM WASTEWATER TREATMENT PLANTS ON THE TERRITORY OF AP VOJVODINA

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Abstract

In the framework of the research, an assessment of the future amount of waste sludge that would be generated after the construction of the planned 200 waste water treatment plants (WWTPs) that should be built on the territory of Autonomous Province of Vojvodina in the Republic of Serbia was carried out. It is estimated that the annual production of waste sludge will be slightly more than 81 thousand tons (dry sludge) per year. The methods of sustainable use (circular economy of sludge) and the method of safe disposal of sludge resulting from wastewater treatment were also analyzed. Starting from the possible use in Anaerobic Digestion processes for recharging biogas, the residual sludge from Anaerobic Digestion is excellent for use in agriculture. Well-watered sludge can also be used in the cement production industry, or if the sludge is burned (to reduce the final amount of waste), the ash can be used in the construction industry for the production of bricks or concrete/mortar, and finally sludge has potential for possible use for recharging biofuel, bio-plastic etc. Finally, there is a real potential for the use of waste sludge in AP Vojvodina.

Introduction

Due to Serbia's need to reach the EU water treatment and protection standard and Water framework Directive goals, the construction of about 200 WWTPs on the territory of Autonomous Province – AP Vojvodina is planned. Wastewater contains a large number of different compounds, such as solid matter (350-1200 mg/l), dissolved matter (HPK 250-1000 mg/l), microorganisms, nutrients, heavy metals and micro-pollutants [1]. As a result of wastewater treatment, on the one hand, water that is safe for discharge to the water recipient is obtained, and on the other hand, waste sludge remains, which represents a mixture of water (in different ratios of 20-95%), living and dead microorganisms, organic matter , organic and inorganic chemical compounds [2]. This recharged sludge must be transferred so that it can be disposed of safely or it can be used for recharging energy, biofuel, bioplastics, as a fertilizer in agriculture, etc.

Waste sludge created at WWTP can be divided according to the type of technological process in which it was created into primary, secondary (or biological) and chemical. Raw sludge is sludge that has not yet undergone biological or chemical treatment to remove or reduce the concentration of solid and organic matter or pathogens. When sludge treatment is carried out, the so-called treated sludge (eng. biosolid) which can be classified by treatment, such as: (I) Aerobically digested; (II) Anaerobic digestion AD); (III) Alkaline stabilized; (IV) Composted; (V) Thermally dried.

Amount of sludge produced

Determining the amount of sludge that will be generated at the WWTP is very important for the design of the system for the reception, treatment and disposal of sludge and for the treatment of waste water [3].

The best approach for estimating the amount of sludge generated is to base it on data from similar plants (size, technological process, wastewater characteristics) and the expected amount of wastewater for treatment. The specific weight of the sludge can also be calculated using the following formula (formula 1 – wehere SS is: suspended solids) [4]:

$$Specific\ weight\ of\ sludge\ = \frac{1}{\left(\frac{\%\ SS\ in\ sludge}{Sludge\ density} + \frac{\%\ sludge\ water\ content}{1.0}\right)} \qquad (1)$$

Incorporation of solid materials is also known as solids capture. It is usually expressed in percentages to show the effectiveness of incorporation of solid materials in the body, which will then be treated in the following stages of the transformation. Solid matter loading [kgSS/day] can be represented by expressions 2 and 3 [4]:

$$Effluent\ SS\ load\ in\ sludge\ = Solids\ capture\ \times\ Influent\ SS\ load\ in\ sludge \qquad (2)$$

$$SS\ load\ in\ drained\ liquid\ =\ (1\ -\ Solids\ capture) \times\ Influent\ SS\ load\ in\ sludge \qquad (3)$$

Table 1 - Characteristics and quantities of mud produced by different processes [4]

Technological process in WWTPs	Karakteristike proizvedenog mulja iz otpadnih voda		
	SS content (%)	Sludge mass (gDS/ES·day)	Sludge Volume (L/PE·day)
Activated Sludge			
• Primary Sludge	2 – 6	35 – 45	0.6 – 2.2
• Secondary Sludge	0.6 – 1	25 – 35	2.5 – 6.0
• Total	**1 – 2**	**60 – 80**	**3.1 – 8.2**
Activated sludge with extended aeration	0.8 – 1.2	40 – 45	3.3 – 5.6
Aerated lagoon	6 – 10	8 – 13	0.08 – 0.22

Production of primary sludge

The amount of sludge generated during the primary treatment depends primarily on the efficiency of the removal of suspended solids (SS) in the primary settling tanks. The typical efficiency in removing od SS in primary flocculation machines is 60 to 65%. the trace of SM removal can be related to the time of hydraulic retention or the surface overflow of the primary clarifier (engl. primary clarifier).

Production of activated sludge

In the activated sludge process, important variables in the quantification of the produced sludge are: the amount of removed substrate (COD or BOD), the mass of microorganisms in the system and non-biodegradable inert SS. The calculation of the net growth of biomass and the amount of waste activated sludge (WAS) is carried out using expressions 4 and 5 [5]

$$P_x = Y(S_0 - S) - k_d X \qquad (4)$$

$$WAS = P_x + I_0 - E_t \qquad (5)$$

P_x -net growth of biomass expressed as volatile solid substances (VSS, kg/d); Y -gross yield coefficient (kg/kg); S_0 - Influent substrate (COD or BOD kg/d) ;S - Effluent substrate (COD or BOD kg/d);k_d- Coefficient of endogenous decomposition (d-1);X-Biomass at the aeration pool (MLVSS, kg).

Solids Retention Time (SRT), also known as sludge age, is a very important parameter in the process of biological purification with activated sludge. SRT represents the average retention time of sludge in the system and is represented by taxes.

Results and discussion

Quantity of sludge rechargeed from WWTPs in AP Vojvodina

Management of sludge produced at WWTPs represents one of the most difficult problems to be solved. Sludge produced at WWTP represents only a few percent of the volume of processed waste water (after dewatering and condensation), but its treatment and disposal make up to 50% of total operational costs. To calculate the (theoretical) amount of sludge that will be produced as a result of wastewater treatment, we will use the data from table 1.

Table 1 – WWTPs capasity in EP – Population equivalent by regions in AP Vojvodina [6]

Region	Total capacity [EP]
West Bačka	388.200
North Bačka	280.000
North Banat	237.620
South Bačka	879.500
Middle Banats	214.300
South Banatska	394.000
Srem	403.900
Total	**2.797.520**

Table 2 – The amount of sludge produced from WWTPs in AP Vojvodina by regions

Oblast	Total capacity [ES]	Sludge production i WWTPs [tons dry sludge]	
		daily	annually
South Bačka	879.500	70	25.550
South Banat	394.000	32	11.680
North Bačka	280.000	22	8.030
North Banat	237.620	19	6.935
Middle Banat	214.300	17	6.205
Srem	403.900	32	11.680
West Bačka	388.200	31	11.315
Total	**2.797.520**	**223**	**81.395**

The value of waste sludge in the context of the circular economy

Increasing the amount of sludge from wastewater treatment is a global problem in the context of population growth and adequate sanitary protection. Although sludge is considered waste, it can be used as a source of energy or resource, thus replacing an equivalent amount of material and/or energy that should otherwise be provided from non-renewable sources. The treatment and disposal of sludge is very important for the protection of the environment, because of possible organic pollutants, heavy (and toxic) metals and pathogens that can linger in the sludge, which can cause health problems.

The circular economy represents the antithesis of the previous linear model of the economy, which implies the uncontrolled exploitation of natural resources and the flow of materials from the factory through the user to the landfill.
According to the Ellen MacArthur Foundation (EMF), the circular economy is: reconstructive and regenerative by design and aims to make products, components and materials maximally useful and valuable at every moment [7]. Because of the legislation that limits the disposal of sludge at the landfills, as a method of sludge removal, many researchers have tried to find ecologically sustainable ways to reuse sludge. The European Commission considers that "as waste becomes a resource that returns to the economy as raw material, then much greater priority must be given to reuse and recycling" [8]. The reuse of sludge as a raw material in various industries represents an excellent way of managing waste, having in mind the concept of circular economy. Taking into account the fact that the organic components of the sludge are a significant resource in terms of energy and nutrients that are waiting to be used, a study carried out in 2015 by the International Solid Waste Association (ISWA) [9] shows that in the context of the circular economy, the benefit of energy and fuel recharged from waste is that they can replace other energy resources and limit the associated CO_2 emissions.
Nutrients reuse
Considerable amounts of nutrients (approximately 0.5–0.7% phosphorus and 2.4–5.0% nitrogen) are found in sludge, in the form of proteinaceous materials that can be used for fertilizer production. The return and recycling of phosphorus is considered a possible pilot, i.e. case where it can be "proven that circular principles function in practice" [7]. Crystallization is a process that is used to recover phosphorus from WWTP in the form of struvite (NH_4MgPO_4). In the research [10], referring to municipal waste water, TSS from 26-30 kg/EP/year. and tangential fraction from the appropriate fermentation of celluloid mud, it is estimated that 0.07 – 0.15 kg/EU/year can be produced. struvita, which corresponds to income from 0.05 – 0.11 €/EP/year.
Construction material
Complexes of organic carbon and inorganic composites from mud represent the source of valuable materials that can be transformed into products such as artificial lightweight aggregates, clay, bricks and glass by means of thermal processing. For the production of bricks and cement, mud can be used directly without burning. Supplying sludge in its raw form to cement production can be an alternative to existing methods, eliminating some expensive and energy-intensive phases of sludge treatment/disposal. Even more important is that environmentally harmful waste can be turned into a safe and stable product.
Biogas
The primary source of energy at the WWTP is biogas produced by AD reactors, with a content of methane (50–70%) and carbon dioxide (30–50%), as well as some trace nitrogen, hydrogen, hydrogen sulfide and water vapor. AD is one of the most used technologies for the production of biogas at WWTPs. Taking into account that biogas can be used to recharge electricity and heat energy, water vapor and other purposes, its production and maximum utilization are of essential importance.

Conclusion

When it comes to wastewater treatment in AP Vojvodina, the situation is very bad. About 20% of total wastewater (municipal + industrial) is treated, and waste sludge is deposited in landfills. Since there is no legal regulation related to the treatment and disposal of sludge, there is no way to use it efficiently and safely, especially in agriculture.
Because of the EU accession tasks, Serbia must make great efforts in water management, and waste water treatment plays perhaps the most significant role.

As part of the effort to improve the current situation, the study "Investigation and development of the AP Vojvodina waste water collection and treatment model" [6] was conducted, which considered the settlements behind which the WWTP will be built, as well as the required size, treatment technology, etc. The construction of 200 WWTPs for the territory of Vojvodina is planned. As shown in table 2, the planned WWTP should be sufficient for the treatment of 2.8 million PE, which is considered sufficient considering the growth of population and industry in the next 30 or so years. Based on these parameters and the data from table 3, it is estimated that the annual production of waste sludge will be slightly more than 81 thousand tons (dry sludge) per year.

When it comes to the EU, data on the use of waste sludge and the technologies used vary widely. It is estimated that in 2008, more than 10 million tons of dry sludge was produced in 26 EU countries, of which 36% was used in agriculture. However, 5 out of 26 countries (Germany, England, France, Italy and Spain) contributed as much as 75% of the total amount of sludge production [11].

It can be concluded that there is a real potential for the use of waste sludge in AP Vojvodina. Starting from the possible use in AD processes for recharging biogas, the residual sludge from AD is excellent for use in agriculture. Well-watered sludge can also be used in the cement production industry, or if the sludge is burned (to reduce the final amount of waste), the ash can be used in the construction industry for the production of bricks or concrete/mortar, and finally sludge has potential for possible use for recharging biofuel, bio-plastic etc.

Of course, not all applications are equally economically profitable in the case of the Republic of Serbia (even regionally), so a detailed LCA analysis is necessary to select the most profitable use, and this is beyond the scope of this advice.

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