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SLUDGE FROM WASTEWATER TREATMENT PLANTS IN BULGARIA – WASTE OR RESOURCE

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Abstract
Environmental pollution leads to significant economic losses, which arise from the costs of waste treatment and management. The need for sustainable management and effective prevention and control measures is essential to reduce these negative impacts and ensure long-term economic growth and social well-being. At the same time, waste represents an opportunity to generate economic value through recycling, composting and the use of waste as raw materials. The management of waste streams and the market for secondary raw materials presents both significant challenges and many opportunities for the modern world. Proper understanding, sustainable management and appropriate utilization of these resources can initiate a new model of interaction with the environment, which in turn can contribute to achieving significant economic and environmental benefits.
The object of this study is the sludge from wastewater treatment plants as part of specific waste streams, as well as their management activities and reporting values presented for a 10-year period within Bulgaria. The aggregates related to the sludge generation and recovery activities of the Wastewater Treatment Plants (WWTPs) in Bulgaria have been subject to a dynamic development during the last decade. The focus is on their recovery as a resource and not only as a waste.
The thesis that by proper treatment, sludge can be transformed into a resource that can in turn be used appropriately in various processes is discussed. This can reduce the need for primary resources and contribute to the sustainable development of particular economic sectors by, for example, favoring intensive farming/agriculture activities and the implications this brings.
The main objective of this paper is to classify the main types of waste streams and to look at the current status of sewage sludge and the opportunities for its reuse in the economic cycle. The main challenges and opportunities in the sector will be identified, as well as current effective management strategies and policies. An overview is also given of the legislative framework for sludge management in Bulgaria and the European Union, which plays a key role in regulating sludge recovery. It is essential to note that, under European legislation, sludge is safe where proper management is in place. With that being said, and in the light of the ongoing trends towards sustainable development, there is an increasing need to focus attention on this direction by applying specific sustainable methods for their recovery.
The report highlights the importance of sustainable sludge management, with a strong emphasis on the need to continue efforts for sustainable sludge management in Bulgaria and in general.
Key words: sewage sludge from wastewater treatment plants, agriculture, utilization, recycling, waste management
JEL code: Q12, Q15, Q19

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The provision of food for the population poses significant challenges for the agricultural sector. The continuously increasing demand for agricultural products is being addressed through the implementation of intensive farming practices, which are also associated with negative consequences such as environmental pollution. This leads to significant economic losses, including the costs associated with waste treatment and management. At the same time, waste represents an opportunity for generating economic value through recycling, composting, and its use as raw materials. In response to these challenges, the European Union's Green Deal, adopted in 2019, sets ambitious goals related to reducing greenhouse gas emissions, limiting the use of mineral fertilizers and pesticides, and increasing the area under organic farming by 2030 *(The European Green Deal, 2019)*. The need for sustainable environmental management through the implementation of effective pollution prevention and control measures is essential for mitigating these negative impacts and ensuring long-term economic growth and social well-being.

With proper treatment, waste can be transformed into a resource that can be utilized in various processes, including compost production, bioenergy generation, and secondary raw materials. This can reduce the need for primary resources and contribute to the sustainable development of specific economic sectors. The management of waste streams and the market for secondary raw materials presents both significant challenges and numerous opportunities for the modern world. Proper understanding, sustainable management, and appropriate utilization of these resources can initiate a new model of interaction with the environment, which, in turn, can contribute to achieving significant economic and environmental benefits.

In the context of the above, this study will examine the sludge from wastewater treatment plants (WWTPs) as part of specific waste streams that, through appropriate processing, can be utilized as a renewable resource in agriculture, specifically as a soil amendment for fertilization.

The primary objective of this study is to classify the main types of waste streams and to examine the current state of WWTP sludge as well as the opportunities for their reuse in the economic cycle. It will identify the main challenges and opportunities in the sector, along with current effective management strategies and policies.

In order to achieve the above objectives, the following tasks are set in the development:

- to provide a classification of the waste streams including sludge from the WWTP;
- To review the legislative framework and current policies for the management of sewage sludge in Bulgaria and the EU;
- to provide statistics on the sludge generated by WWTPs by districts and years in the country and the methods of recycling and reuse of WWTP sludge;

- to draw conclusions on the opportunities, constraints and prospects for the sector in Bulgaria.

Classification of waste

In Bulgaria, the main types of waste streams can be classified according to different criteria, and the list of wastes is being supplemented and amended in accordance with scientific and technical progress. The main regulatory document governing this classification in Bulgaria is Ordinance No 2 of 23 July 2014 on waste classification, which provides a systematic approach to waste classification. This classification provides a framework for the management of waste, considering its origin, composition and potential hazard. It is an important tool for regulators, businesses and municipalities when planning and implementing sustainable waste management measures. *(Regulation No. 2, 2014)*

The main types of waste streams are divided into the following categories:

1. General waste categories, which includes municipal waste, construction and demolition waste, and manufacturing waste;
2. Specialized waste categories, combining hazardous waste – medical and veterinary waste, waste from electrical and electronic appliances;
3. The category by type of material, which includes metal waste, plastic waste, paper and cardboard waste, glass waste;
4. A category by origin that combines agricultural waste, mineral waste, water treatment waste and water treatment waste, where waste generated from wastewater treatment and sludge removal falls[1] .
5. Another category is waste from specific activities, which includes waste from food production and processing, waste from the chemical industry, waste from energy production.

The object of this work are sludges from wastewater treatment from settlements described according to the qualification of Ordinance No. 2 of 23.07.2014 on waste classification.

Sewage sludge is also subject to classification, which includes many aspects related to its origin, composition, level of treatment and recovery options. Distinguishing these in a proper way is complex but at the same time essential for the effective management and recovery of these sludges and minimizing their impact on the environment (*Regulation No. 6, 2000).*

[1] The sludge generated in a WWTP is an organic product that results from the treatment of wastewater after the settling of residual substances. It is generated by the separation of these residual products during the various stages in the wastewater treatment process and contains valuable agricultural constituents (including organic matter, nitrogen, phosphorus, potassium and, to a lesser extent, calcium, sulphur and magnesium).

First, the sediments can be separated by their origin. Urban sludge is generated from the treatment of wastewater from households, public buildings and commercial establishments. Industrial sludges originate from industrial plants such as chemical plants, the food industry and the textile industry. The classification also regulates cases where wastewater from different sources is treated together, these are so-called mixed sludges.

The second category covers sludges according to their composition. Organic sludges contain a high amount of biodegradable materials such as food residues and plant and animal materials. Mineral sludges, on the other hand, are composed mainly of inorganic materials such as sand, clay and metal oxides. Mixed sludges contain both organic and inorganic components.

The next classification is according to the level of treatment. Raw sludges are those that have not undergone further treatment after initial settling. Stabilized sludges have undergone a stabilization process, such as anaerobic digestion, to reduce the organic content and limit the growth of pathogens. Dewatered sludges are those where a significant portion of the water has been removed to facilitate subsequent treatment or disposal. Thermally treated sludges have undergone incineration or other thermal treatment, which further reduces their volume and destroys organic material and pathogens.

The fourth category addresses sludge recovery options. Some sludges can be used as soil improvers in agriculture after undergoing appropriate additional treatment processes. Others can be composted and used as organic fertilizer. There are also sludges that can be recovered for energy production by incineration or anaerobic digestion. Those that cannot be recovered are landfilled.

The hazard classification divides sludge into non-hazardous and hazardous. Non-hazardous sludges do not contain significant quantities of hazardous substances and can be recovered or disposed of with lower environmental risks. Hazardous sludges contain harmful substances such as heavy metals, toxic chemicals or pathogens that require special treatment and disposal.

Sediments can also be classified according to the origin of the contaminants. Some sludges contain a high level of biodegradable organic matter and are known as sludges with organic contaminants. Others contain heavy metals, minerals and other inorganic compounds and are classified as sludges with inorganic contaminants. There are also sludges with microbiological contamination which contain pathogenic micro-organisms and viruses and require special disinfection measures.

As mixed sewage systems prevail in the country, which receive both domestic and industrial wastewater, part of the sludge generated by MSWWTPs is classified as “hazardous waste” within the meaning of *Ordinance No. 2 of 23.07.2014 on waste classification*. As the Sludge Ordinance does not allow for the recovery of sludge that is or contains hazardous waste, it is excluded as an option for agricultural use and is not of interest as a subject of analysis in the development *(Ordinance No. 2, 2014).*

In order to clarify the possibilities and limitations for the use of sewage sludge for fertilization in agricultural areas, a review of the current legislative and regulatory framework in the country was carried out.

Legislative and regulatory framework for the use of sludge from WWTPs

The legislative and regulatory framework for sewage sludge management is a leading and structurally determining factor for the functioning of various sectors in the country such as water, agriculture, waste management, etc. The main objective of the rules and regulations established for the management and subsequent utilization of sewage sludge is to regulate its use in a way that prevents harmful effects on soil, vegetation, animals and humans when it is used for fertilization.

In the European Union, sludge recovery is regulated by *Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture*.

It maintains its added value as the only legal regulatory instrument providing an EU framework for soil protection in the use of sludge in agriculture by setting a minimum level of harmonization to control pollution and health risks. At the same time, it provides the possibility for each country to build on national legislation with more stringent requirements. The Directive sets out how this type of waste should be managed, considering its valuable properties. It encourages use and recommends increasing the quantities to be used in agriculture if and only if they are used on areas where they do not have a negative impact on soil and agricultural production *(Directive 86/278/EEC, 1986).*

The main requirements set out in the document boil down to compliance with limits related to the content of heavy metals and biogenic elements (*cadmium, copper, nickel, lead, zinc, mercury, chromium*) in sediments and soils, as well as limits on the annual sediment load on agricultural land. It also provides for mandatory biological, chemical or thermal treatment of sludge before its use for fertilization *(Directive 86/278/EEC, 1986).*

The legislation prohibits the use of sludge in the following cases:

- when concentrations of heavy metals exceed specified limit values;
- on the soil in which fruit and vegetable crops are grown, with the exception of fruit trees;
- on grassland or forage land that will be grazed by animals or mown in the coming three weeks;
- less than ten months before the harvest of fruit and vegetable crops, when the crops are in direct contact with the soil and eaten raw.

In parallel with advances in the understanding of sludge properties, treatment and use, the broader environmental legislative and policy framework is changing significantly. There are wide variations in implementation, linked to the fact that sludge management depends on local conditions or policy choices by Member States. A similar example can be given with the heavy metal thresholds and parameters introduced by the Directive. Over time, seventeen Member States have reviewed and adopted stricter limits for both existing and additional pollutants. However, with the upgrading of technologies and methods for sludge treatment in wastewater treatment plants, their heavy metal levels have developed positively over time and have shown a significant decrease to a level below the limits set in the Directive.

The Directive applies in accordance with the waste hierarchy set out in the *Waste Framework Directive*. Its objectives are aligned with other environmental and health legislation and related policies outlined in the *Zero Pollution Action Plan* and the *EU Soil Strategy 2030 (EU Action Plan, 2022), (EU Soil Strategy, 2022).*

More broadly, Directive 86/278/EEC supports Europe's new sustainable growth agenda – the *European Green Deal* and EU policies on climate, health, circular economy, food security and the independence of fertilizer s, critical raw materials and energy. These policies influence sediment management policies differently depending on local conditions, for example agronomic soil needs, energy mix and available infrastructure.

The European Green Pact, on the other hand, aims to promote growth by moving towards a modern, resource-efficient and competitive economy. As part of this transition, several EU waste laws are subject to revision. One of the main building blocks of the European Green Deal is the *Circular Economy Action Plan (CEAP)*, which was adopted by the European Commission in March 2020. The EU's transition to a circular economy aims to reduce pressure on natural resources and create sustainable growth and jobs. The Action Plan introduces legislative and non-legislative measures targeting areas where action at EU level brings real added value, with one of the objectives sets being to ensure less waste *(CEAP, 2020)*.

In the context of the *Green Pact* and circular economy requirements, an assessment of the Circular Economy Action Plan has been carried out. It establishes the relevance of the Directive and highlights the effectiveness of using sludge in agriculture as a basic and significantly cheaper alternative to incineration. The use of sludge in agriculture is strategically considered in the context of sustainable development, zero pollution and climate change in EU policies. The importance of flexibility is underlined, given that sludge management is highly dependent on local conditions. The assessment also points to the lack of data on the use of sludge in agriculture and ongoing research on this issue *(The European Green Deal, 2019).*

Bulgaria's national legislation on the use of sewage sludge in agriculture, which is constantly being developed and refined, is part of the country's environmental policy and is harmonized with the European one. In 2007, when Bulgaria was accepted as a member of the EU, it started to comply with the requirements and regulations of the EC. In this regard, the regulation has been introduced through relevant normative documents in key areas, and to align with the European standards after the country's accession to the EU, a *National Strategic Plan for the Management of Sludge from Wastewater Treatment Plants in Bulgaria for the period 2014 – 2020* has been adopted *(NSPMSWTP, 2014).*

The requirements of Directive 86/278/EEC have been introduced into our national legislation by means of *an Ordinance on the procedure for the recovery of sludges from wastewater treatment through their use in agriculture*. It applies to sludges from sewage treatment plants and wastewater facilities in urban and other areas with a similar composition to municipal water. It defines: the procedure and method for the recovery of sludge through its use in agriculture and for the recovery of sludge in land reclamation; the requirements for producers and users of sludge intended for recovery in agriculture in a manner that ensures that its application will not have a harmful effect on soil, vegetation, animals and humans; the procedure for reporting on the sludge recovered; the permitting regime for the use of sludge from GSSW; and the methods for sampling and testing sludge and soils (*Regulation, 2017*).

In line with European legislation, Bulgaria has also adopted a *National Strategic Waste Management Plan*, the latest version of which is in force for the period 2021–2028. As a result of the implementation of the program, a plan is set to provide infrastructure for the recovery of sludge from MSWTPs, reducing greenhouse gas emissions and to have an electronic system up and running for the products offered from treated sludge from MSWTPs for use in agriculture and for the reclamation of disturbed land. The set target is expected to be realized by 2040 (*NWMP, 2021).*

The institutional framework also includes other government policies, programs, plans, and instruments that legislate both the management and the options for the subsequent utilization of sludge in agriculture and other industries.

Such regulatory requirements are contained in official documents, the main part of which is related to environmental management legislation through *the Environmental Protection Act (EPA, 2023)*, water through *the Water Act (Water Act, 2000)*, soil through *the Soil Act (Soil Act, 2018)*, agricultural land through *the Agricultural Land Conservation Act (ALCA, 2024.)*, waste through *the Waste Management Act (WMA, 2024)*. It regulates the application of penalties and sanctions for non-compliance with established conditions in the use of sludge from WWTP in agriculture.

Generated and recovered sludge from WWTPs in Bulgaria

The generation and subsequent recovery of sewage sludge in Bulgaria is an important aspect of waste management and sustainable development. As required by legislation, the EEA publishes annual reports on the management of sewage sludge. On the basis of this information, *Annex 1* to this report shows the quantities of non-hazardous sludge generated by WWTPs by territory for the respective Regional Environment and Water Inspectorates (REWIs), ranked in descending order of the responsible population for each respective region for 2023.

In the context of the published data, between 2012 and 2022[1] in Bulgaria an uneven trend of increasing amounts of generated non-hazardous sludge from WWTPs is reported. The main reason for this is the expansion of the network of WWTPs in the country, from 85 active WWTPs providing data in 2012 to 100 in 2022. However, the upward trend continued until 2016, including the peak in reported sludge generation, with a total of 65742.65 tons/dry weight (wt) from all WWTPs.

In 2020, there is a significant decrease in the values of sludge generated with a total amount of 33 473.35 tons/dry wt. Over the next few years, the values start to increase significantly, almost doubling in 2022 to a total of 57 514.55 tons/dry wt.

Surprisingly, population numbers do not seem to have an impact on the total amounts of non-hazardous sediment generated, which inevitably raises questions in its wake.

The only variable that tends to increase its share in each subsequent year and is independent of the other variables is the share of RIEW Sofia, which in 2014 is 49.22% for 54 939.34 tons/dry wt of non-hazardous sludge generated, compared to 60.96% for 2022 with almost the same amount of sludge generated of 57 514.55 tons/dry wt.

According to European legislation, under proper management, sludge from MSWW is safe waste for nature and human health. In fact, there are several options for the recovery and disposal of this type of waste stream. Some of these are long-standing practices, for example, their reuse as fertilizer and soil conditioner on agricultural land and reclamation on non-economic land. Another already well-established sustainable method is their use for fertilizer and biogas production, which has been introduced in Bulgaria since 2018. The oldest and most inefficient method, which has the most negative environmental and health impacts, and which still occupies a significant share in management activities is sludge disposal. In the context of the data summarized in *Annex 2* of this paper, in the 10-year period considered (2012-2022), there is a positive trend in the reduction of the share of landfilled sludge, which in 2014 occupied 15.42% of the total amount of treated sludge, and in 2022 this amount melts to 2.52%.

Significant growth in the share of sludge used in agriculture has been observed over a 4-year period with a progressively increasing share from 29.78% in 2014 to 56.13% in 2018 for all activity categories combined. However, in the last 2 reporting years, there has been a decline with 18,616.29 tons/dry wt. of sludge recovered in agriculture or 32.37% of the total being reported for 2022, which is one of the lowest values for the ten-year period under consideration.

[1] The EEA has not provided public data on sludge management from WWTPs for 2017.

Over the past four years, there has been a positive shift in the development of fertilizer and biogas production activities, with a 7-fold increase in its figures between 2018 and 2022, reaching an impressive 34.84% in 2022.

Conclusion

The analysis of statistical information on sludge generated and subsequently recovered from WWTPs shows that the amount of sludge has been increasing over the last ten years. In the context of the circular economy strategy, there is a trend to reduce landfilling and increase recovery methods through agricultural application and reclamation. There has been significant progress in the sustainable recovery of this waste resource, but there is also a perceived need for further efforts to improve technologies and increase the environmental and economic benefits of these processes.

Data for the first few years of our study indicate that landfilling was the preferred method of sludge disposal. During the period under review, the trend regarding the quantities of sludge applied to agriculture has been maintained, with the waste from the RIEW Sofia being the determinant of this quantity. These form the picture of sludge use at national level, as over the years the reported data from other treatment plants that utilize their sludge in this way is scarce. The information from the Sofia WWTP dominates the overall picture on sludge management in the country with 60.96% for 2022 of the total amounts of non-hazardous sludge produced.

A large part of the non-hazardous sludge in Bulgaria – 80.09% in 2022 – meets the necessary conditions in terms of its quality composition for fertilization in agriculture and satisfies the legal requirements of Directive 86/278/EEC, but only 32.37% of it is actually recovered in the soil.

A high proportion of sludge is stored temporarily on the drying fields of the treatment plants. Although they have analytically proven good quality character-ristics, no environmentally sound use has been found for them.

Achieving higher performance on sludge use in agriculture is a process of establishing and implementing a strong legislative national policy. In this context, it can be concluded that Bulgaria has a modern legislative and regulatory framework for the safe use of sludge in agriculture, which is based on modern European standards.

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Annex 1: Amount of non-hazardous sludge in Bulgaria for the period 2012 $ 2022

Amount of sludge, tons/dry weight (wt)		2012		2014		2016		2018		2020		2022	
REWIs	Sofia	29 168,14	49,22%	27 039,60	49,22%	32 959,00	50,13%	23 101,00	43,57%	16828,393	50,27%	35 058,00	60,96%
	Plovdiv	5 620,00	9,48%	3 824,52	6,96%	3 206,40	4,88%	4 810,00	9,07%	4249,59	12,70%	3 984,49	6,93%
	Varna	5 146,84	8,69%	7 612,09	13,86%	9 227,20	14,04%	2 899,32	5,47%	3089,159	9,23%	4 226,24	7,35%
	Burgas	6 541,34	11,04%	2 745,50	5,00%	2 653,75	4,04%	3 319,94	6,26%	2368,625	7,08%	2 052,42	3,57%
	Ruse	2 090,53	3,53%	2 815,00	5,12%	6 555,00	9,97%	6 614,46	12,48%	136,226	0,41%	1 538,67	2,68%
	Stara Zagora	3 173,80	5,36%	2 014,88	3,67%	1 924,40	2,93%	2 061,40	3,89%	530,332	1,58%	2 294,44	3,99%
	Pleven	1 679,00	2,83%	2 216,20	4,03%	1 684,00	2,56%	1 996,02	3,76%	1519,445	4,54%	2 871,20	4,99%
	Blagoevgrad	882,38	1,49%	302,75	0,55%	749,75	1,14%	777,95	1,47%	567,482	1,70%	490,64	0,85%
	Pazardzhik	724,68	1,22%	889,81	1,62%	548,00	0,83%	841,26	1,59%	962,01	2,87%	1 053,00	1,83%
	Pernik	248,19	0,42%	302,83	0,55%	336,46	0,51%	240,59	0,45%	-	-	-	-
	Veliko Tarnovo	1 655,06	2,79%	1 811,69	3,30%	2 123,00	3,23%	1 499,68	2,83%	1474,789	4,41%	773,52	1,34%
	Haskovo	400,83	0,68%	667,00	1,21%	586,93	0,89%	2 810,36	5,30%	464,23	1,39%	1 812,66	3,15%
	Shumen	755,94	1,28%	850,40	1,55%	966,33	1,47%	876,22	1,65%	760,438	2,27%	931,05	1,62%
	Vratsa	390,00	0,66%	49,45	0,09%	433,91	0,66%	606,53	1,14%	522,632	1,56%	206,07	0,36%
	Montana	364,37	0,61%	523,29	0,95%	1 250,70	1,90%	356,54	0,67%	-	-	202,96	0,35%
	Smolyan	419,98	0,71%	1 274,33	2,32%	537,82	0,82%	209,08	0,39%	-	-	19,19	0,03%
Amount of non-hazardous sludge, total tons/dry wt		59 261,08		54 939,34		65 742,65		53 020,35		33 473,35		57 514,55	
Existing WWTPs providing data		85		87		97		100		75		100	
												Source: EEA	

Annex 2: Treated sludge by activity operations in Bulgaria for the period 2012 – 2022

Sludge amount, tons/dry wt	Sludge management activities	2012		2014		2016		2018		2020		2022	
	Deposed	-	0,00%	8 472,15	15,42%	6 180,02	9,39%	3 740,87	7,05%	1 604,60	4,79%	1 447,34	2,52%
	Temporarily preserved	-	0,00%	22 292,74	40,58%	18 679,01	28,39%	10 763,01	20,28%	5 119,98	15,30%	11 453,75	19,91%
	Used in agriculture	-	0,00%	16 363	29,78%	26 229,46	39,87%	29 797,00	56,13%	16 929,34	50,58%	18 616,29	32,37%
	Reclamation of disturbed landscapes	-	0,00%	6 964,36	12,68%	11 439,70	17,39%	5 908,75	11,13%	6 228,84	18,61%	5 957,70	10,36%
	Organic composting with red Californian worms for bio-fertilizer	-	0,00%	847,09	1,54%	3 263,99	4,96%	-	0,00%	-	0,00%	-	0,00%
	Production of fertilizer and biogas	-	-	-	-	-	-	2 874,00	5,41%	3 590,58	10,73%	20 039,48	34,84%
	Total	0,00		54 939,34		65 792,18		53 083,63		33 473,35		57 514,55	
Amount of treated sludge		0,00	0,00%	32 646,60	59,42%	47 113,17	71,61%	42 320,62	79,72%	28 353,37	84,70%	46 060,81	80,09%
												Source: EEA	

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