



Inclusion of Agriculture in Sustainable Wastewater Management in Bulgaria

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Abstract: There has been a fundamental modernization of the wastewaters management system in Bulgaria during the EU pre-accession and membership periods. Transition toward sustainable management of wastewaters has been associated with modern disposal of generated sludge from wastewater treatment plants and increasing agricultural utilization. Agricultural Utilization Wastewaters Management Chain emerged and gradually extended along with augmentation of the amount of produced sludge and its share effectively used in agriculture. Despite unprecedented changes in that new area there are few publications on potential and driving factors of agricultural utilization of sludge in the country. This paper tries to fill the gap and analyses the evolution and challenges of agricultural inclusion in sustainable wastewater management in Bulgaria. It is based on incorporation of the interdisciplinary New Institutional Economics methodology, official data and numerous in-depth interviews with representatives of the wastewater treatment plants, responsible authorities, farmers participating and not involved in sludge utilization, and other related agents. The study has found out that there has been a significant modernization of formal institutional environment (rules, regulations, standards, agencies) and incentives structure for agricultural sludge production, transportation, and utilization in recent years. Nevertheless, the potential for inclusion of agriculture in water treatment plants' sludge utilization has not been entirely used and policy target in the area effectively reached due to the significant transition and compliance costs for related agents, inadequate public information, training, and support, environmental and health risks, opposition of landowners, businesses, eco-groups and residents, and uncertain directions of policies development.

Keywords: wastewaters, sewage sludge, management, agriculture, Bulgaria

1. Introduction

There has been a constant enhancement of the water quality standards in European Union (EU) and around the globe. Since the accession of Bulgaria to the EU in 2007 there has been an enormous modernization of the system of water management in the country. Sustainable management of wastewaters requires their purification according to the EU standards before release in nature and/or further use in different social and economic sectors. The system of sustainable wastewater management also include as an important second component a proper treatment, storage and utilization of generated sludge from the water purification process (Golbiak & Rutkowska, 2023; Marin & Rusănescu, 2022; Rosiek, 2020).

As a result of introduction of EU norms and regulations and modernization of Wastewater Treatment Plants (WTPs) in Bulgaria there has been a significant increase in the amount of sludge in the past years. For instance, despite almost 10% of reduction of the wastewater discharged from WTPs there was registered more than three folds augmentation in the generated sludge since 2013 (HCH, 2024). The National Strategic Plan for the Management of Sludge from Wastewater Treatment Plants in Bulgaria (NSPMSWTPB) set a target for total elimination of permanently stored sludge by 2020 in line with the EU regulations in that area (HCHYY, 2014). Some of the most perspective ways for sustainable management of sludge component of the wastewaters identified in the country are utilization of the generated sludge in agriculture as fertilizer, for reclamation of damaged lands, and for composting (IAOC, 2023).

Widespread material utilization of sludge from WTPs in Bulgaria was not practice until 2005 while possible agricultural use had been experimented in research stations and farm fields (Marinova, 2008). Agricultural involvement in the wastewater cycle management was initiated in 2006, gradually extended, and reached 42% of the totally generated sludge amount in 2023 (IAOC, 2023). Nevertheless, still potentials for agricultural inclusion in the sustainable wastewater management are not fully explored in the country and real factors facilitating or restricting this process identified.

In EU and other countries there are numerous publications on different aspects of agricultural participation in sustainable wastewaters management (Delibacak *et al.*, 2020; Ekane *et al.*, 2021; Hudcová *et al.*, 2019; Iticescu *et al.*, 2021; Golbiak & Rutkowska, 2023; Golbiak *et al.*, 2023; Gulzar *et al.*, 2022; Marin & Rusănescu, 2022; Marzougui *et al.*, 2022; Muter *et al.*, 2022; Rosiek, 2020; Rosemarin *et al.*, 2020;

Seleiman *et al.*, 2020; Tesfamariam *et al.*, 2020). Most studies focus on environmental, technological, health safety and social dimensions while governance and economic aspects are largely ignored. With a very few exceptions (Bachev & Ivanov, 2021; Ivanov & Bachev, 2021; Ivanov *et al.*, 2020; Marinova, 2008] Sarov, 2020; Stankova *et al.*, 2021), in Bulgaria there are no in-depth studies on evolution and driving factors of the overall and agricultural utilization of generated waste from WTPs in recent years.

This paper tries to fill the gap and analyses the evolution and challenges of the agricultural inclusion in sustainable wastewater management in Bulgaria. It also presents a successful business model, introduced by the biggest WTP in Sofia, for an effective inclusion of farmers in sustainable wastewater management utilizing 38% of the generated sludge in the country. The study is based on incorporation of the interdisciplinary New Institutional Economics methodology (Bachev, 2014; Bachev & Ivanov, 2021), and analysis of available official (statistical, report, etc.) data and numerous in-depth interviews with key representatives of the WTP, responsible authorities, and farmers participating and not involved in sludge utilization.

2. Evolution of Agriculture Involvement in Wastewaters Management in Bulgaria

Comparing to the pre-accession period to the EU there is approximately one tenth of the total amount of discharged wastewaters into water bodies in Bulgaria accounting 702951 million of cubic meters in 2022 (Figure 1). During the same period there was a considerable improvement in the wastewaters management in the country as the amount of discharged wastewaters without any treatment decreased almost 40% while its share in the total discharged wastewaters changed from 26,5% in 2006 to just below 17% in 2022. At the same time, the total amount of wastewaters discharged from WTPs increased by a little more than 15% and discharged wastewaters from WTPs with at least secondary treatment by 38%. Simultaneously, the share of total wastewaters discharged from WTPs augmented from 65,5% to 75,5% while the discharged wastewaters from WTPs with at least secondary treatment from 51,5% to almost 71%.

In 2023 the number of WTPs accounts for 179 (Table 1) associating two third of the total population off the country with sustainable public management of wastewaters. In addition, there are many WTPs of business enterprises, hotels,

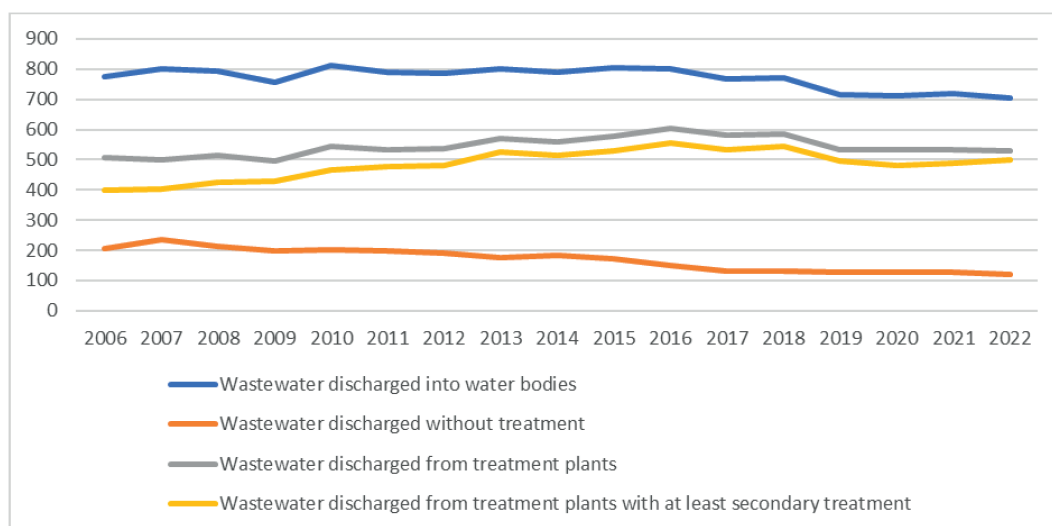


Figure 1: Amount of wastewater discharged in Bulgaria (millions of cubic meters)

etc. which are under private management of wastewaters. The number of modern WTPs has been constantly increasing during EU membership period most of them with public functions currently being with capability of more than 2000 equivalent resident (65% of the total number), 46% with secondary purification and 51% with tertiary purification.

Table 1: Number of wastewater treatment plants* in Bulgaria

Type	2018	2023
Total number	170	179
Population connected to the WTP (%)	63.9	67.2
Primary purification, number	4	4
Secondary purification, number	91	83
Tertiary purification, number	75	92
including Nitrogen removal	71	90
including Phosphorus removal	72	90

*Only stations that treat wastewater in settlements on behalf of the state government as public services.

Modernization of wastewaters purification in the country has been associated with enormous increase in the generated sludge from WTPs being in constant augmentation since 2013 and amounting more than 52 million tons dry matter in recent years (Figure 2). Furthermore, improvement of the overall wastewaters management in the country has led to more sustainable management of generated

sludge. In years before EU accession less than 9% of produced sludge in WTPs was sent for utilization while the share overpass 50% in recent years (Figure 3).

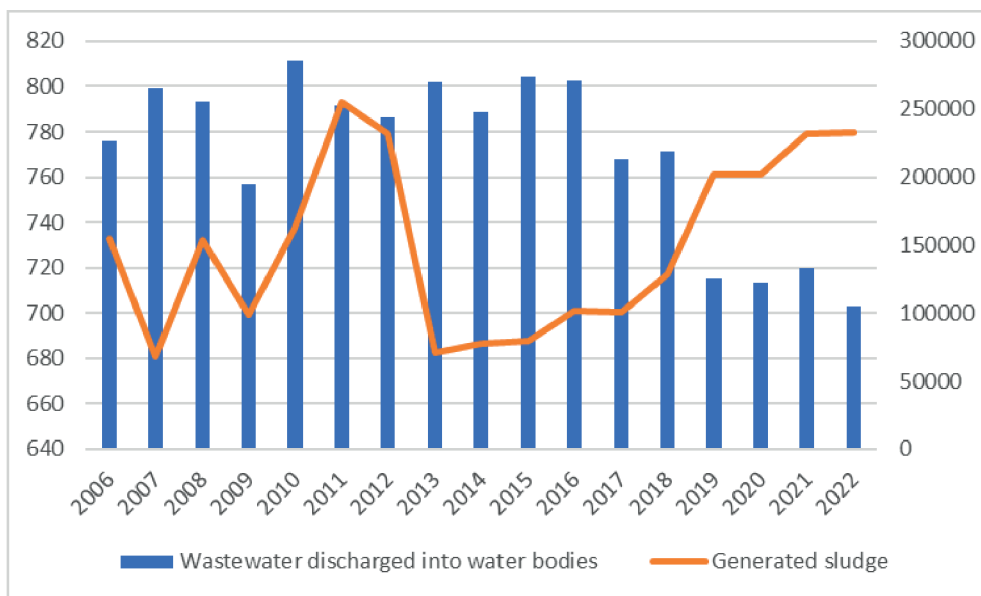


Figure 2: Amount of discharged wastewater and generated sludge from WTPs in Bulgaria (millions of cubic meters/tons dry matter)

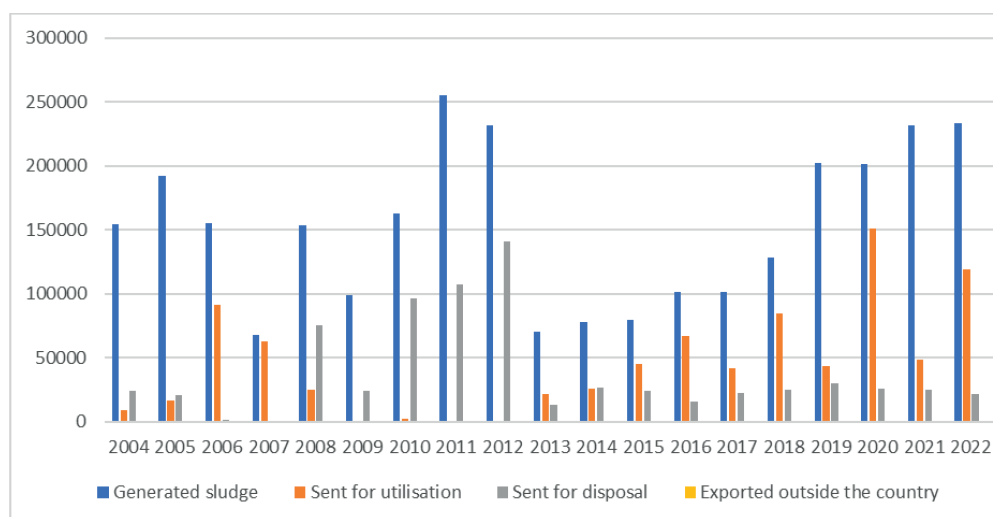


Figure 3: Amount of generated, utilized, disposed and exported sludge from WTPs in Bulgaria (tons dry matter)

In years before EU integration the main method for disposal of sludge from WTPs before was landfilling. Since 2006 there has been a significant augmentation of treated for safety, turned from waste into useful product, and effectively utilized sludge from WTPs in the country (Figure 4). Since 2015 the treated according to modern safety standards and included in the circular economy sludge from WTPs considerably overall disposed though landfilling and temporary storing amounts averaging 35384530 tons dry matter or 70% of the total disposed sludge in the country.

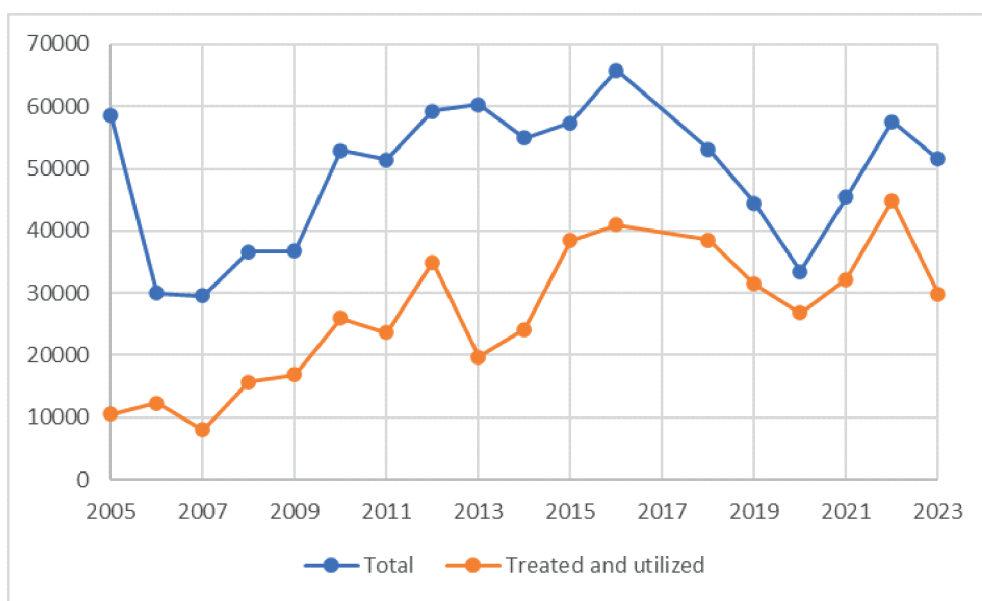


Figure 4: Amount of generated and treated/utilized sludge from WTPs in Bulgaria (tons dry matter)

The quality of produced sludge improved considerably as a result of improved treatments and strict quality control. Average concentrations of heavy metals and arsenic in sludge from WTPs varies every year and it has been a fraction of maximum permissible levels for all components (Table 2). The only exception was the average concentration of Chromium in sludge in 2007 which exceeded the allowed norm by 72%. All that made utilization of WTPs sludge possible in other sectors of economy increasing the sludge effectively used in circular economy.

The quality of sludge depends primarily on the characteristics of the treated wastewater, but also on the technologies applied for purification. Sludge must be

Table 2: Average concentrations of heavy metals and arsenic in sludge from WTPs in Bulgaria

	2005	2007	2010	2015	2020	2023	% maximum permissible
Nickel	48.77	43.07	55.05	37.9	46.67	39.3	10.8 - 15.7
Cadmium	4.12	2.21	3.84	4.1	1.85	2	6.2 - 13.7
Mercury	1.23	1.16	1.63	0.24	0.71	0.45	1.5 - 10.2
Lead	92.2	85.34	86.9	69.77	40.95	77	5.1 - 11.5
Chromium	344.63	859.87	97.14	149.98	89.55	61	12.2 - 172
Copper	153.4	228.55	253.02	238.69	312.71	296	9.6 - 19.5
Zinc	948.44	959.06	824.73	828.78	962.12	863.11	27.5 - 32
Arsenic	6.42	6.65	5.64	10.37	8.03	5.29	21. - 41.5

treated appropriately so that all fermentation processes are completed, there is no release of unpleasant odors, the spread of pathogenic microorganisms is not allowed, so that their safe and environmentally friendly management in nature is ensured and guaranteed. In addition to the amount of dry matter, the level of moisture of the sludge is critical for the utilization of sludge. Quality tests proved that in terms of organic content and heavy metal content, the sludge have been suitable for application in fertilizing agricultural lands. In terms of microbiological and parasitological indicators, the decontamination processes in some sludges have not completed, which is why they are suitable for direct application in agriculture and subjected to additional treatment with red California worms to produce biofertilizer.

Before 2005 agricultural utilization of WTPs sludge was not reported in the country despite that there were research experimentations as well as field trials at few farms. Almost three quarters of generated sludge was landfilled (permanently disposed) while remaining amount temporary stored or used for reclamation of agricultural, forests and other lands (Figure 4). Since 2006 agricultural involvement in wastewaters sustainable management and related sludge utilization started and gradually increased comprising between 20% to almost 58% of the totally generated sludge in the country in different years. New methods of WTPs sludge utilization like composting also emerged in 2013 and augmented taking a particular fraction of the all sludge in certain years – e.g. 36% in 2022.

At the same time, the quantities of the landfilled sludge from WTPs significantly declined during that period being 2-4% in recent years. The later development has been a result of the policies for reduction and entire abatement by 2020 of the harmful for environment practice of permanent disposal of generated sludge

in the country. However, due to impossibilities of many WTPs to find sustainable utilization of generated sludge in other sectors of economy and practiced “temporarily storing strategy” the share of temporary disposed sludge in the country increased considerably in recent years.

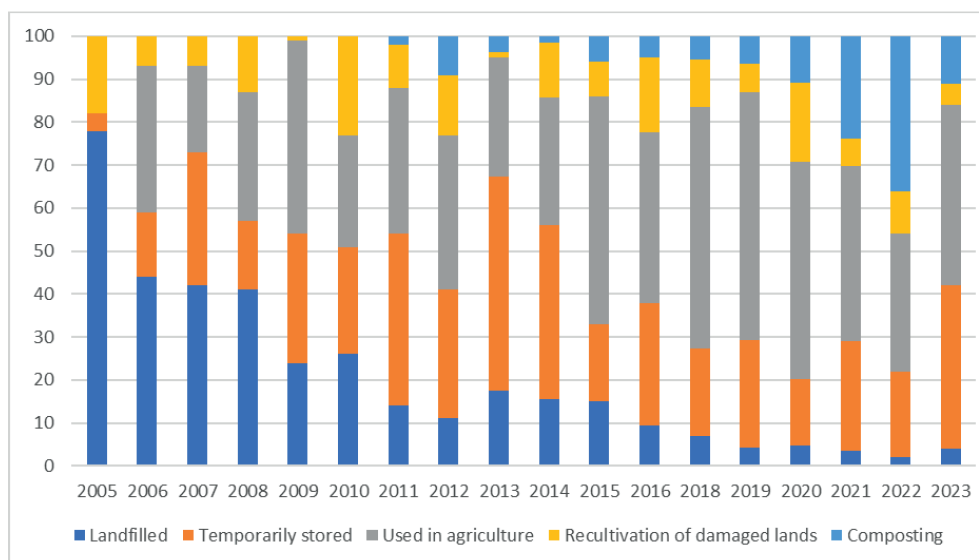


Figure 4: Share of sludge management activities in Bulgaria (percent)

The biggest producer of WTPs sludge in the country is in Sofia region accounting for between 38% (2023) and 61% (2022) of the total generated amount (Figure 5). All WTP Sofia sludge has been effectively utilized in agriculture as a fertilizer. Other WTPs utilizing occasionally generated sludge in agriculture in some years are these in Haskovo, Ruse, Burgas, and Vraza.

Some portion of generated sludge has been used for strengthening and stabilizing eroded terrain and landslide areas, for reclamation of forest terrain, for leveling the terrain of landfills, old mine deposits, etc. In different years these are the sludges from the WTPs in Burgas, Haskovo, Targovishte, Vratsa, Varna, Blagoevgrad, Pazarjik, and Silistra. Another fraction of the sludges are utilized by other methods such as composting, etc. in Pleven, Plovdiv and other treatment plants.

Most of the utilized sludge in agriculture is from the WTS in Sofia comprising from 73.7% to 100% of the total in different years (Figure 6). Only few farms have been effectively using sludge as fertilizer on their agricultural lands. For instance, in Sofia region in 2018 the generated and temporary stored (from 2017) sludge was

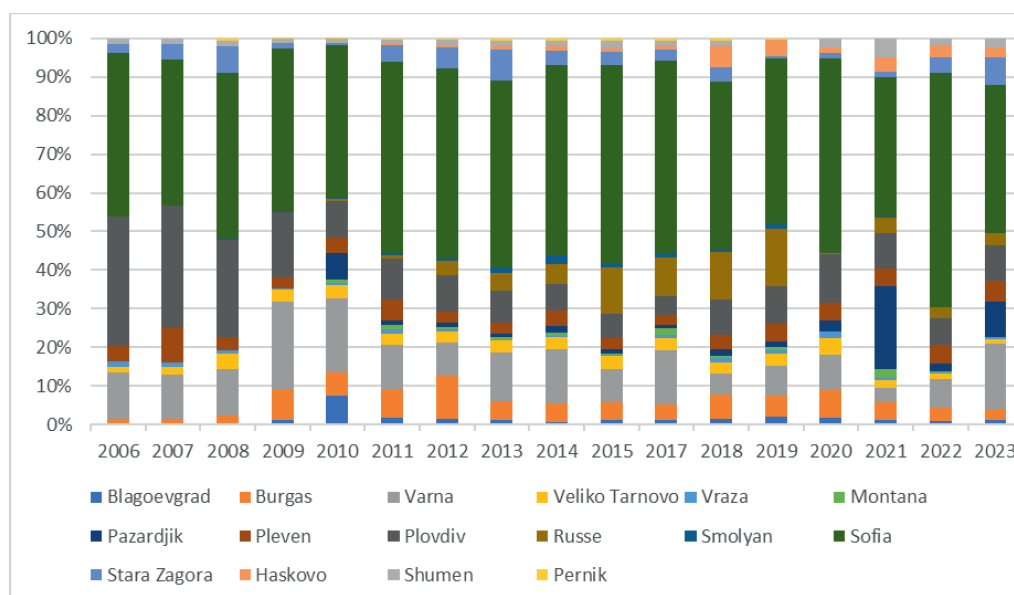


Figure 5: Share of generated sludge from WTPs in different regions of Bulgaria (percent)

utilized on 2170 ha of arable lands of seven farms located in the area of Stolnik, Zhelyava, Chepintsi, Negovan, Novi Han, Chelopechene, Krivina, Kubratovo and Benkovski (IAOC, 2023). A total of 38440 tons of sludge were spread on the indicated areas averaging of 17.7 tons per ha. Similarly in 2015 and 2016 annually

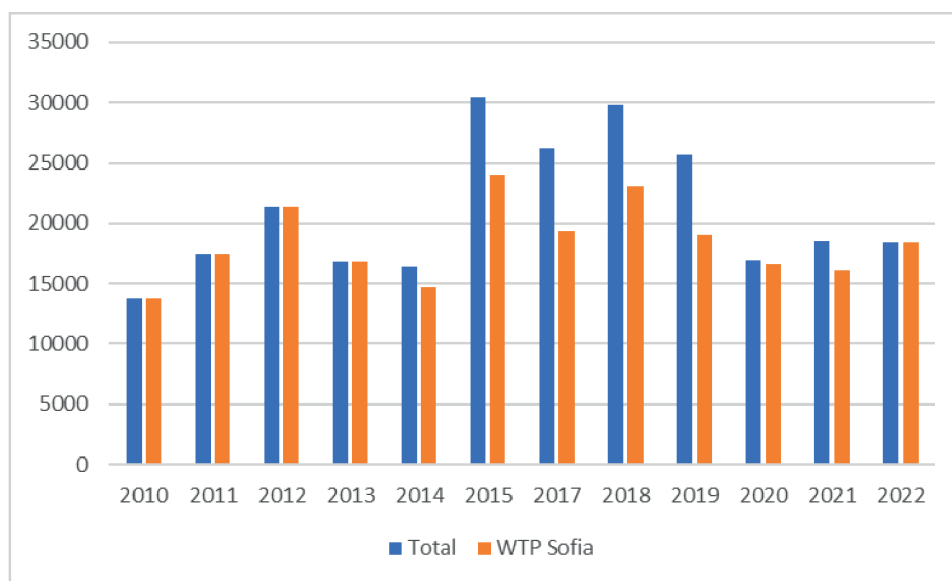


Figure 6. Utilized sludge from WTPs in Bulgaria and from WTP in Sofia (tons dry matter)

utilized in agriculture sludges in Sofia region comprised 19358 tons used by seven farms on 1030 ha located in Chelopechene, Negovan, Chepintsi, Podgomer, Lokorsko, Svetovrachene and Kremikovtsi, averaging of 18.8 tons per ha.

3. Factors facilitating and restricting agricultural involvement in wastewaters management chain

As a results of unprecedented improvement of wastewater management during EU membership of Bulgaria the contribution of the Secor “Agriculture, Forestry and Fishery” increased both comparatively and absolutely in terms of share in the wastewater discharged into water bodies and the share in effective utilization of generated sludge in circular economy (Figure 7).

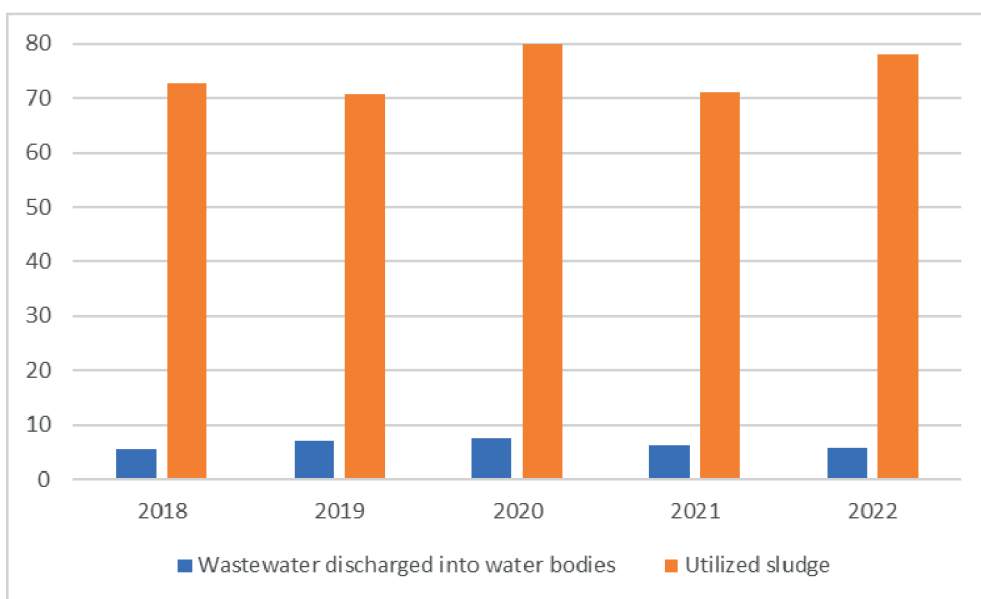


Figure 7: Contribution of Agriculture, Forestry and Fishery in discharged wastewaters into water bodies and in sludge utilization in Bulgaria (percent)

Nevertheless, the targets for the full elimination of landfill disposal of sludge from WTPs by 2020 set up by the NSPMSWTPB was not reached. At the same time, there has been a huge progress in introduction of modern methods for sludge disposal in the country. What is more, the agricultural utilization of sewage sludge in Bulgarian has been overpassing significantly the average EU level for the period 2011-2022 averaging 57.4% comparing to the 32.6% for EU (Figure 8).

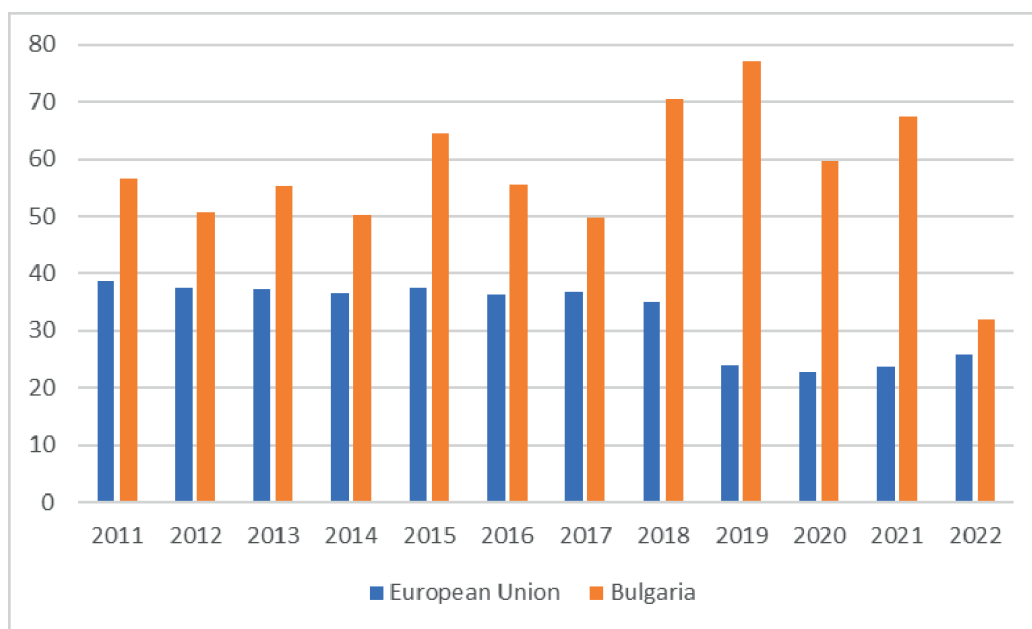


Figure 8: Share of agricultural utilization of sewage sludge in the EU and Bulgaria (percent)

Utilization of sludge from WTPs as a fertilizer has been a major form for effective sludge disposal in Bulgaria while other modern methods applied in other EU countries have been less used. Therefore, the factors affecting agents' behavior in the Agricultural Utilization Wastewaters Management Chain (AUWMC) are to be identified and their importance evaluated in order to understand the evolution and prospects of agricultural participation in sustainable wastewater management in the country.

AUWMC in Bulgaria is associated with “transformation of sludge from waste into good” (useful product) and includes several major actors – (1) WTPs, (2) companies transporting WTP sludge, (3) farms utilizing sludge as fertilizer, (3) buyers of farm products produces with sludge utilization (Table 3). Other important actors also regulate, license, control and/or support effecting development of this specific chain such as – Ministry of Environment and Waters, Ministry of Health, Ministry of Agriculture and Food, Regional Environmental and Water Inspections (REWI), Bulgarian Food Safety Agency (BFSA), accredited laboratories for sludge and soil tests, research and educational institutions, agricultural advisory service, private consultancy, and technology and equipment providing companies, etc.

Table 3: Factors for agricultural sludge production, transportation and utilization chain in Bulgaria

<i>Critical factors</i>	<i>WTPs processing</i>	<i>Sludge transportation</i>	<i>Farms application</i>	<i>Farm produce marketing</i>
Formal regulations and restrictions	Clear regulations Strict procedures and standards Mandatory public licensing	Clear regulations Strict procedures and standards Mandatory public licensing	Clear regulations Strict procedures and standards Mandatory public licensing Limited new permits	Clear regulations for marketing and final use
Motivating factors	Long-term EU, national and regional strategies Special public support programs Easy costs transfer to water consumers New markets and business opportunity Public and community pressure Improved corporate public image Restrictions for temporary storage and landfilling Increased accumulation of generated sludge	New markets and business opportunity Limited competition	Positive long-term production and economic effects Logistical and material support by WTPs Free sludge supply and delivery Ineffective enforcement of formal standards and procedures Increasing mineral fertilizers, irrigation water and labor costs	Better quantity-quality-pricing ratio Easy distribution as mass rather than branded commodity
Demotivating factors	High investment and costs of compliance High costs for special treatments	High investment and compliance costs Absence or few customers High dependency	Long, complicated and costly licensing and testing procedures High transportation costs Multiple uncertainties and risks Need for precise management Difficulties for smaller farms Impossibility for use in all crops Results depending on production conditions and crops Inadequate training and info No CAP support Opposition of landowners, businesses, communities, etc. Uncertainty for policies development	Lack of comprehensive, reliable and accessible information Consumer rejection Low price Restricted export possibilities

In-depth study of the specific AUWMC has found that there are diverse critical factors facilitating and/or restricting agricultural inclusion in wastewaters

management in Bulgaria. Identified factors are institutional, behavioral, technological, economic, social etc. and quite specific for the main actors of AUWMC. They eventually determine the evolution, present stage and prospects of agricultural utilization of WTPs' sludge in the country.

Since 2007 entire EU laws have been applied in Bulgaria including environmental and food safety regulations. Therefore, modern institutional environment for sustainable WTPs sludge management exists in the country consisting of rules, regulations, standards, agencies, etc. related to production, storage, transportation and utilization of sludge, including in farming sector.

The European Directives related to utilization of sewage sludge in general and in agriculture were adapted in Bulgaria in 2004 through a number of documents, the main among them being the Ordinance on the Procedure and Method for the Utilization of Sewage Sludge through the Use in Agriculture – OPMUSSUA (Regulation, 2017). OPMUSSUA determines the procedure and method for the utilization of sludge from WTPs; the requirements for producers and users of sludge for utilization in agriculture; the permit regime for the use of sludge from the WTPs; and methods for sampling and testing sediments and soils, etc. The production and utilization of sludge in agriculture is supervised by REWI and BAFS, which issue permits (licenses) and control the “production” and quality of sludge for agricultural utilization and the use of agricultural sludge. Similarly, there are strict regulations and safety standards for transportation of sludge and safety standards for farm produce for human and animal consumption.

There have been huge public, community and business investments for improving wastewaters management in the last twenty years. Furthermore, increased costs of WTPs for efficient wastewater management and sludge utilization have been easily covered by the price to final water users and/or public programs (tax payers). In addition, there has been a strong government, public, NGOs and community pressure on WTPs as producers of waste to take actions, improve management and join the cycle economy. Besides, some WTPs (Sofia), transportation (Burgas) and other companies see sludge trade and delivery as a new prospective business opportunities having long-term strategies for the expansion links with other chain agents.

A major problem identified related to institutional environment is the high costs for different agents for AUWMC for study, introduction and compliance with the formal rules and standards. That is particular important factor for smaller-scale

WTPs and businesses associated with the agricultural sludge utilization having insufficient capability (stuff, finance, expertise, etc.) to apply laws and standards. Particularly important factors identified are the enormous direct (paperwork) and transaction costs, and slow issuance of new permits by government authorities along with the high costs of soil sampling.

It is well known that formal institutions in Bulgarian do not work always well (Bachev & Ivanov, 2021). Moreover, the one-time licensing of main agents in AUWMC, development of “personal relations” and the infrequent (often on received signals) control contribute to low enforcement of rules and standards. For instance, there are reported many cases for provision to farmers from WTPs, transportation, and importing into farmlands incompletely treated sludge and higher than the allowed rates of sludge per area, applying on unauthorized plots, and/or not according to allowed manner (with simultaneous burial), etc.

Regular sludge users in Bulgarian have been few large, highly specialized (in grain) and innovative farming enterprises with strong incentives for and capability to innovate, use external consultants, reduce costs, take and bear risks, experiments new methods etc. All of them report significant production and economic benefits from replacing expensive N, P and K mineral fertilizers (purchase, application, interest payment, etc.) with sludge, deep plowing, irrigation (e.g. corn), and increase in the quality and quantity of yield over a longer-period of time – 5 years (Bachev & Ivanov, 2021). In addition, the use of sludge produces more green mass for silage and hay, larger cobs and ears, and improves the quality of the harvest leading to more effective (easy, more profitable) sales. Potential for future agricultural utilization of sludge in the country is enormous having in mind reported positive effects and small number of farms utilizing most of the generated sludge – e.g. in different years only seven farmers in Sofia region recycle between 37.9% - 61% of the entire generated sludge in the country (from WTP in Sofia).

The specific business model of Sofia’s WTP include covering the personnel and other costs for obtaining permits for using farmers, providing free of charge sludge and transportation to the user-farm, and machine and operator for sludge covering into farmlands. At the same time, during the delivery and spreading the soil is compacted, and the aeration disturbed, hindering plants development and reducing yield in the first years after sludge application. Besides, the import of sludge requires better organization and management of production since there is a short technological period after the harvest for sludge delivery, spreading and plowing.

Furthermore, upon delivery an unpleasant odor spreads causing dissatisfaction from neighboring farms, businesses and residents forcing interruption of the process for several days.

The slow process of obtaining new permits for sludge application led to a long (10 years) period to rotate all areas of using farms. Very few non-using farmers are familiar with the multifaceted socio-economic and environmental effects of agricultural sludge utilization. Major factor restricting experimentation with or transition to sludge utilization is the release of the specific odor and negative public opinion, and concerns (uncertainty) about the possible long-term impacts on soils quality, protection of natural biodiversity, and health of workers, animals, consumers and guests (tourists, etc.) (Bachev & Ivanov, 2021). In certain cases, there is strong resistance against sludge use by land owners leasing lands to interested farms. Some farmers indicate larger marketing costs for selling informally “branded” and “special” farm product with sludge input. Currently there is no market in the sludge utilization chain and “personal” rather than market relations between small number of actors dominate. That is associated with developing of investment (asset) dependencies between partners, power relations, interlinking transactions, gray and illegal practices and corruption (Bachev & Ivanov, 2021). Furthermore, many farmers believe that if the sludge is sold as a commodity (a fertilizer), this would limit agricultural use since there is no specialized (but rather general fertilizer) market for it, while its supply is monopolistic for the region.

Up to date the CAP instruments and public funds have not been financially supported the utilization of sludge by agricultural producers and related agents such as transport companies, intermediaries, collective organizations, etc. in AUWMC. The important agro-ecosystem service “waste utilization” has not been socially recognized and financially supported and that is among major reasons for the slow progress of WTPs sludge use in Bulgarian farms (Bachev & Ivanov, 2021). Another reason contributing to this process have been on going debates and associated uncertainties of the EU Green Deal implementation and CAP reforms.

Another critical factor deterring agricultural (and overall) utilization of sludge is availability of up-to-date and reliable information on the diverse agronomic, environmental, health, socio-economic etc. effects and risks associated with sludge utilization. In mass media there have been few general and contradictory publications on agricultural utilization of sludge mostly sponsored by interested parties such as WTPs and environmental protection groups. There are no comprehensive

independent assessments on de-facto socio-economic and other effects on farms and related agents. Few existing scientific publications have been based on laboratory tests and experimental trials in “ideal” (rather than real life) conditions - optimal farming techniques, correct fertilization rates, good management, etc. Furthermore, research tests are usually made with adequately treated sludge, while in practice the sludge delivered and imported is not treated or partially treated, with higher than allowed humidity, incorrectly imported, etc. Therefore, many farmers indicate they “do not trust the local research institutes” on this matter.

Another challenge is that there is no appropriate training and advisory service on agricultural sludge utilization. Some farmers conduct own experiments, find own solutions and/or seek and exchange information and training from private consultants, WTP experts, scientific workers, and other countries. However, most sludge-using farmers have been reluctant to share experiences due to lack of time, reluctance for publicity, secrecy about yields and profits from competitors and authority, fear of increased interests for limited resource “sludge”, etc.

Conclusions

There has been a fundamental modernization of the wastewaters management system in Bulgaria during the EU pre-accession and membership periods. Transition toward sustainable management of the wastewaters have been associated with modern disposal of generated sludge from WTPs in the country and increasing agricultural utilization. Agricultural Utilization Wastewaters Management Chain emerged and gradually extended along with augmentation of the amount of produced sludge and share effectively used in agriculture. That has been results of improved formal regulations and standards and incentives for the major actors in the chain (WTPs and farmers) to produce, transport, utilize and trade sludge and sludge based commodities. Nevertheless, the potential for inclusion of agriculture in WTPs sludge utilization has not been entirely used and policy target in the area effectively reached. That has been a consequence of numerous economic, behavioral and social factors critical among them being the significant transition and compliance costs of sludge transformation from waste into good, lack of adequate public information, training, and support, environmental and health risks associated with agricultural sludge utilization, opposition of landowners, businesses, eco-groups and residents, and uncertainty of directions for CAP reformation and policies development.

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