Chapter 17

The Use of Waste Sludge: Benefits to the Regenerative Economy in Bulgaria

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Abstract This chapter's target is to accentuate on the benefits for the social-economic development, resulting from the wastewater governance. The wastewater treatment is the process of extraction of extra-resources, namely: residual biogas, used for heat and electricity; sand used in the construction; sludge and purified water, discharged into hydro-basins. Simultaneously, attention should be paid of the environmental challenges in relation to the circular economy. The sludge use should become a national policy with a direct governmental engagement, having in view that wastewater treatment plants and wastewater safety are strategic guidelines. Statistical information was used by Eurostat and the Ministry of Agriculture and Food and Forestry (MAFF)'s Agristatistics Department (2020). A brief literature review of publications on the topic is made at the outset. Thereafter, more light is placed on the regulatory framework in the EU and Bulgaria. The analysis continues with the situation so far, based on existing statistics on the quantities of sludge received and its utilization in agriculture in the European countries and in Bulgaria. Dependence and sludge effect on grain yield are determined on the basis of regression analysis.

Keywords Sustainable · Regenerative economy · Waste sludge · Agriculture

17.1 Introduction

In today's society, there are often controversies related to finding environmentally and economically balanced policies. The controversy is the result of the desire of policymakers to combine the goals of *economic growth* with those of *sustainable development, environmental protection, circular and regenerative economy* (United Nations, 2012, 2015, 2019; FAO & IFAD, 2019; European Commission, 2020). In order to achieve regenerative sustainability, it is necessary to ensure regenerative relationships that allow socio-economic and environmental systems to evolve

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continuously. In recent years, the concept of sustainable development has received a significant international response, being one of the two topics of the 2012 United Nations Conference on Sustainable Development (United Nations, 2012). Governments have agreed to outline the green economy as an important tool for sustainability and to stimulate economic growth, employment, reducing poverty, and maintain balance in the planet's ecosystems.

This chapter's target is to accentuate the benefits for the social-economic development, resulting from wastewater governance. Wastewater treatment is the process of extraction of extra-resources, namely: residual biogas, used for heating and electricity; sand used in construction; sludge and purified water, discharged into hydro-basins. Simultaneously, attention should be paid to the environmental challenges in relation to the circular economy. Statistical information was used by Eurostat (2020) and the MAFF's Agrostistics Department. A brief literature review of publications on the topic is made at the outset. Thereafter, more light is placed on the regulatory frameworks in the EU and Bulgaria. The analysis continues with the situation so far, based on existing statistics on the quantities of sludge received and its utilization in agriculture in the European countries and in Bulgaria. Dependence and sludge effect on grain yield are determined on the basis of regression analysis. Collecting information related to sewage sludge from treatment plants is a difficult and time-consuming process. The main problem is the identified discrepancies in the data provided by different sources. There is clearly an insufficient amount of information collected on sludge and their application in agriculture.

According to the Sustainable Development Goals (United Nations, 2015), agriculture is targeting policies related to environmental protection and conservation of natural resources. In this regard, sustainable agriculture requires politicians, experts, and practitioners to review the traditional agricultural practices known to date. They should balance both the increase in the economic viability of farms, on the one hand, and the enhancement of their social responsibility, on the other (FAO & IFAD, 2019). There are a number of systems for sustainability in agriculture: bio-economy, eco-economy, green economy, shared economy, circular economy, recovery/regenerative economy, etc. results (Bashev, 2016; Hetemäki et al., 2017; Brown et al., 2018; Kopeva, Sterev, & Sabeva, 2018; Kalmykova, Sadagopan, & Rosado, 2018; OECD, 2019).

The concept of a "circular economy is based on the view that prosperity" in agriculture does not mean only increasing the consumption of natural resources, but rather keeping ecosystems in balance with nature (European Commission, 2018; Mensah & Ricart Casadevall, 2019).

Regenerative agriculture is defined as a system of principles and practices leading to increased biodiversity, enrichment of soils, and improvement of ecosystem services. At the same time, yields, climate resilience, and community vitality are increasing (Walthall et al., 2012; FAO, 2016, Elevitch, Mazaroli, & Ragone, 2018).

The goal of regenerative agriculture is to improve soil quality, preserve biodiversity in farmlands and, at the same time, produce profitable agricultural products (Rodale, 1983). The regenerative systems in agriculture provide more efficient "ecosystem services and profitability for farmers" than the intensive production

model. To achieve this, the management model in farms should be rethought through the application of “individual regenerative practices within the current production model” (LaCanne & Lundgren, 2018).

In this regard, the utilization of sludge in agriculture is one of the options in support of strategies for the regenerative economy. The management of sewage sludge from the sewage treatment plants is undoubtedly one of the most sensitive and unresolved issues facing society not only in Bulgaria but also in the world (Di Fraia, Damian Figaj, Massarotti, & Vanoli, 2018; European Commission, 2006; Linderholm, Tillman, & Mattsson, 2012; Yapıcıoğlu & Demir, 2017; Zaharinov, 2011). At the same time, there is increasing interest among the scientific community on the socio-economic and environmental impact of this activity.

The wastewater recycling is a basic component of the circular economy. The wastewater treatment uses the extraction of extra-resources. After a three-step water purification remain the aforementioned biogas, sand, sludge, and purified water. Practically, the biogas could be used for heating and electricity, the sand – in building construction, the purified water – in hydro-basins. With regards to sludge utilization, there are several options related to the improvement of agricultural and non-agricultural soils. The sludge could be used also in forestry, recovery of disturbed terrains, e.g., mines, eroded areas, for fuel, and construction technologies.

In recent years, there has been an increasing need for a sustainable strategy for the management of this waste product. There is a great concern about limiting traditional recycling options, such as direct use in agriculture and others. At this stage, managing these processes requires complex solutions involving all stakeholders, not just treatment plants and sludge users. The utilization of sludge in agriculture should not be considered as the only opportunity to utilize the entire amount of sludge generated by treatment plants (Rada, 2017; Trzcinski, 2018; Turlej & Banaś, 2018; Usman et al., 2012).

17.2 Material and Method

The analysis is complemented by summarized information based on technological studies carried out, expert opinions and regulatory framework. The current situation has been taken into account using data from Eurostat (2020) on the amount of sediment formed in treatment plants in the European Union and Bulgaria. The development also uses statistical information from MAFF, Agrostistics Department. On the basis of the regression analysis, the effect of the sludge on the grain yield and the benefits for the regenerative economy in Bulgaria is sought.

In order to assess the effect on the regenerative economy of the cereals production and the utilized sludge in agriculture in Bulgaria, a regression model is tested. In this case, it is assumed that the mean yield is the dependent variable - y , and the independent (factor) variable is the sediment - x , i.e., it will be checked whether the average yield of the cereals changes under the influence of the sludge. The purpose of using regression analysis is to describe the function of the relationship between x

and y using the function of correlation analysis and to determine the strength of this relationship.

The level of dependence between the average yield and the sludge will be verified by a linear function:

$$C = a + b.E + \varepsilon \quad (17.1)$$

Where:

y – dependent variable equal to the average yield of the cereals crops;

x – an independent variable indicating the amount of sludge recovered;

a – free member;

b – coefficient indicating the change of the dependent variable (y) when changing the independent variable (x) by 1;

ε – random component.

17.3 Regulatory Framework

Directive 86/278 / EU “Environmental Protection Directive” is about the utilization of sewage sludge in agriculture, which is forbidden due to the lack of compliance with the specific requirements. However, the sewage sludge is not dangerous, if suitably used and managed, moreover, after meeting certain requirements, it would not be risky or its usage could even bring benefits. EU has a precise regulation on these issues, stating that sewage sludge is excluded from the category of hazardous waste: Directive 91/156/EU “Waste Base Directive”; Directive 94/3/EU; Directive 2000/60/EU on the landfill; Directive 2000/60/EU, describing the Community action framework, related to the water policy.

Bulgaria joined the EU as a Member State in 2007. Applying the requirements of European legislation in the field of environmental protection, and in particular waste management, Bulgaria also regulates the use of sewage sludge on agricultural soils in its territory.

The main document regulating the environment-friendly sound management and introducing the requirements of the Sludge Directive at a national level is the Regulation on the order and “manner of utilization of sludge from wastewater treatment through its use in agriculture” (Adopted by Decree No 339 of 14.12.2004., SG No. 112 of 23 December 2004). In 2011, the Regulation was amended and a number of amendments were made and the provisions of 2004 were amended in SG from 29/08.04.2011.

The review of the legislation shows that a very small part of the national legislative framework relates to the use of sludge for purposes other than agriculture (e.g., use for forestry or restoration of disturbed terrains). The incineration or disposal of sludge is also examined in the by-laws governing the incineration or landfill of waste. The by-laws on the implementation of the WMA, concerning indirectly the management of sludge in Bulgaria, are: “Regulation No. 4 on the Conditions and

Requirements for the Construction and Operation of Incineration Plants and Co-incineration Plants” (promulgated SG, issue 36 of 2013); “Ordinance No. 6 on the Conditions and Requirements for the Construction and Operation of Landfills and Other Facilities and Installations for the Recovery and Neutralization of Waste (Issued by the Minister of Environment and Water”, prom. SG 80/13/2013, (effective from 13.09.2013); “Ordinance No. 26 of October 2, 1996 for the reclamation of disturbed terrains, improvement of poorly productive lands, removal and utilization of the humus layer” (promulgated SG, issue 89 of 22.10.1996, amended and supplemented - issue 30 of 2002).

The Regulation No 6 of 2013 (State Gazette (SG), 2013) regulates the requirements of the European Waste Landfill Directive (EC, 1999). It prohibits the disposal of liquid raw sludge and implies an increasing need to create opportunities for the treatment and utilization of sewage sludge resulting from the requirement to phase out biodegradable waste destined for landfill by 2020.

The main subject of these recent amendments to the provisions of the Regulation is the changes related to the adoption of stricter limits for heavy metal concentrations. Other changes include the introduction of new precautions for the control of organic compounds, as well as the bacteriological and parasitological requirements that treated sludge must meet.

17.4 Results

The responsibility for the recovery of the sludge is a matter of national law. The trend of burning sludge for generating electricity and heat is increasing in major cities in Europe. In smaller settlements, the sludge is still plowed into agricultural land, but after its treatment to avoid risks to human health and soil and water protection.

According to the Report of Executive Environment Agency in Bulgaria (2017), the recycling and recovery of sewage sludge should reach 65% by the end of 2020. At the same time, their energy recovery should reach 35% by the end of 2020.

In 2017, Ireland ranks first among European countries with nearly 80% of recovered sludge in agriculture, followed by Latvia with 48% (see Fig. 17.1). Although France is a leader in the generation of sewage sludge, its arable land is enriched by over 25% of the amount received. However, with the emphasis on sediment generation per inhabitant, Albania ranks first with 34 kg. dry sludge per capita and 3 kg/person utilized in agriculture for 2017. Hungary is next with 27 kg. dry sludge per capita total sediment and 2.8 kg. per person utilized in agriculture. In Bulgaria the distribution is 9 kg. total per person, of which 3 kg. are dry sludge in agriculture. Romania, as a neighboring country, has 1 kg of sludge per capita, related to 14 kg. total amount of sediment per inhabitant.

For the period 2006–2017, in the treatment plants in Bulgaria, there is an almost 80% increase in the generated sludge, which has changed from 38 thousand tons of dry substance to 68.6 t at the end of the period (see Fig. 17.2). At the same time, its

Fig. 17.1 Sewage sludge utilization and disposal from urban wastewater (in dry substance (d.s.) in some European countries, thousand tonnes (2017). (Source: Eurostat (2020), Sewage sludge production and disposal)

Fig. 17.2 Sewage sludge utilization and disposal from urban wastewater, in Bulgaria, dry substance (d.s.), thousand tonnes (2006–2017). (Source: Eurostat (2020) – Sewage sludge production and disposal)

utilization in agriculture is 33% on average. The highest amount of utilized sludge in agriculture is reported in 2015 – nearly 53%, followed by 2009 and 2016, respectively, by 42% and 40%. According to Eurostat (2020), the smallest quantity imported in 2007 was only 16%. For the period 2006–2017, the share of sludge deposition decreased three times, from 11.9 thousand tons of dry substance in 2006, it was limited to 3.8 tons in 2017. By 2020, the disposal of the sludge is required to be discontinued. After 2011, in Bulgaria, the alternative to the recycling of the sludge is its composting with bio-waste. The resulting high quality organic manure (compost) is of high quality and safe for the health of the population and the

environment. This process has a high degree of hygiene, stabilization, drying, addition of organic substances, and reduction of unpleasant odor. The existing composting systems optimize oxygen delivery through digital control, which accelerates the decomposition of organic components. Compost could be used effectively to combat eroded terrains (Figs. 17.3 and 17.4).

The coefficient of determination R^2 shows what percentage of change in score is due to the factor. In this case, 3.6% of the increase in the average yield of the cereals can be considered to be due to the use of the sludge. The equation describes this relationship insufficiently. There are obviously other factors not included in the analysis. The correlation coefficient R (see Table 17.1) shows a weak relationship between the average yield and the sludge (0.189), i.e., it would not be appropriate to state that in this case the sludge affects the average yield of the crops, but rather the relationship is too weak. The value of Sig. F = 0.599 is greater than 0.05, therefore the linear model is not appropriate (see Table 17.2).

However, the results could be interpreted as follows: The free member a - 3025.5 indicates what the average yield (kg/ha) of the cereal crops would be if no sludge was used in the cultivated land (Fig. 17.5). The coefficient b - 2.8272 shows the change of the dependent variable y at the change of the independent variable x by 1 unit. Increasing x (in this case the sludge) by 1 kg of d.s./ha will increase the average grain yield by 2.83 kg/ha.

The regression equation is as follows:

$$C = 2,8272E + 3,025.5 \quad (17.2)$$

or Average yield = 3025.5 + 28,272 sludge.

Fig. 17.3 Dynamics of arable land (ha), cereal crops and utilized sludge of dry substance (d.s.), tonnes in Bulgaria (2008–2017). (Source: Eurostat (2020) – Sewage sludge production and disposal; MAFF, Agrostatistics)

Fig. 17.4 Percentage share of utilized sludge dry substance (kg) on the gross production of cereal crops in Bulgaria (2008–2017). (Source: Eurostat (2020) – Sewage sludge production and disposal; MAFF, Agrostatistics and own calculations)

Table 17.1 Model summary

Regression Statistics	
Multiple R	0,189,747
R Square	0,036004
Adjusted R Square	−0,0845
Standard Error	349,6538
Observations	10

Table 17.2 ANOVA^a

ANOVA	df	SS	MS	F	Significance F
Regression	1	36,529,3	36,529,3	0,298,789,128	0,599,552,484
Residual	8	978,062,4	122,257,8		
Total	9	1,014,592			

^aDependent Variable: RankRents

Fig. 17.5 Correlogram of the relationship between average yield and sludge deposited. Trend model

17.5 Discussions

The various aspects and effects of sewage sludge recovery have been investigated in the scientific literature worldwide.

In a report from RPA, Milieu Ltd. and WRc for the European Commission, DG Environment (2008), an analysis is presented of the socio-economic and environmental aspects of the impacts of sediment. It is emphasized that not all impacts can be assessed at this stage. An assessment has been made of human health, the effects of emissions into the air, including bioenergy production. Palme, Lundin, Tillman, and Molander (2005) present “sustainable development indicators” for sewage sludge utilization and “wastewater treatment systems”. The results of the assessment of lifecycle risk economic indicators and uncertainty are used as inputs to classify the technical capabilities of sludge processing, using multi-criteria analysis. The results obtained reflect the economic, environmental, technical, and social aspects of the sustainable development of the sludge treatment system.

Özerol and Günther (2005) summarize that poor sludge “planning and management” can lead not only to “high health and environmental risks” but also to undesirable economic and social outcomes, nationally and globally. Singhirunnusorn, Sahachaisaeree, and Stenstrom (2011) focus on socio-economic factors as determining factors for the utilization of sewage sludge from sewage treatment plants. Singhirunnusorn et al., (2011) propose “an analytical approach for locally appropriate technology that integrates socio-economic parameters as a part of the decision-making process”.

Another group of authors (Maktabifard, Zaborowska, & Makinia, 2018; Smol, Adam, & Preisner, 2020; Zaharinov, 2011) draw attention to wastewater treatment plants, which “can be an important part of the circular economy for sustainability, thanks to the integration of energy production and resource recovery during clean water production”. This “can be done through the production of biogas and the recovery of energy” (Neczaj & Grosser, 2018).

At this stage, in Bulgaria, with few exceptions (Kopeva et al., 2018; Kopeva & Sabeva, 2018), there are no scientific publications related to the regenerative economy and the assessment of the socio-economic impact of sludge in general. The focus is on policies that prioritize environmental values. At the same time, the regenerative economy is in line with the recovery of invested resources. They are an invaluable asset and contribute to people’s well-being.

The regenerative system is associated with continuous self-renewal. It is a process that contributes to building relationships and is constantly supporting the development of socio-economic and environmental systems. In regenerative sustainability, synergies are created that continuously regenerate natural capital. In practice, this means more permanent crops, limitation of synthetic fertilizers, and diversification in crop rotation, animal husbandry systems, and the creation of functional natural areas. Integrating policies aimed at innovative management of agricultural practices, integrating the principles of biodynamics (Beluhova-Uzunova

& Atanasov, 2017) into the potential for restoring soil fertility, producing sustainable and healthy foods, and holistic governance to counteract biodiversity loss.

The publications available on the topic of sewage sludge include studies of individual elements in the technological process, in the management of technologies and the assessment of the environmentally friendly and efficient use of the sludge. In Bulgaria (Tsolova & Marinova, 2005; Baykov, Zaharinov, & Kaleva, 2013; Popova et al., 2017) have extensive research experience. The benefits of sludge for agriculture as a fertilizer and improver of the soil structure has been proved by numerous publications (e.g., Zaharinov (2011) states that sediments from “humification products” do not cause “serious” damage to the ecosystem). It is claimed that the use of sludge in agriculture is a cost-effective and environmentally friendly method. Sludges from wastewater treatment are known to contain organic and inorganic nutrients that can replace both mineral fertilizers and manure. Sludge naturally acts as a soil improver and promotes soil fertility. However, some European countries have introduced some sludge utilization organizations on agricultural land. So far, however, there is no serious indication that further restrictions will be taken in this area. It is useful to know that the presence of sediment in the soil further enhances its ability to retain water, permeability, and porosity that are indicative of good functional status (Chew et al., 2019; European Commission, 2001; Milieu Ltd, WRC, & RPA, 2008; Monteiro Faria, Célio de Figueiredo, Rodrigues Coser, Teixeira Vale, & Gehrke Schneider, 2017; Tsoleva & Marinova, 2005; Zaharinov, 2011).

In this regard, the public should be aware that the treatment, disposal, and utilization of sludge in agriculture are carried out in accordance with the legal framework.

17.6 Conclusion

The utilization of sludge in agricultural lands is strictly regulated in the legislative system in Bulgaria and this process is strictly regulated in the Ordinance on the order and method of utilization of sludge obtained as a result of sewage treatment in WWTP. According to statistics, the impact of sludge on gross production is on average 2.5%. In this case, this is considered to be additional added value and, in practice, benefits in support of the regenerative economy. The correlation coefficient R shows a weak relationship between the average yield and the sludge (0.189), i.e., it would not be appropriate to state that in this case the sludge affects the average yield of the crops, but rather the relationship is too weak. It should be known that other factors, such as sowing material, geographical location, soil types, rainfall, humidity, agrotechnical activities, etc. influence the gross production.

When assessing the effects of sewage sludge from wastewater treatment on the regenerative economy, it should be known that soil, water, and climate are unified. In order to make a comprehensive assessment, the positive and/or negative impacts of all environmental factors should be included.

The analysis shows that there is a need for planning policies concerning the utilization of sludge in Bulgaria. This also raises the need for additional investment to find applications in the context of regenerative and bio-economy. Although sludge recovery is a global challenge, finding the right solution is often in the regional dimension.

Therefore, the utilization of sewage sludge in terms of a sustainable model of consumption and production will increasingly be on the agenda, which is a challenge for the regenerative economy. It could be affirmed, taking in consideration that wastewater treatment and wastewater safety are strategic directions for the future of society, that the sludge utilization should be considered as a national policy with the commitment of the government.

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