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Implementation of the Green Deal in the management of nutrients – phosphorus recovery potential from sewage sludge

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ABSTRACT

This paper presents an analysis of a phosphorus (P) recovery potential from waste generated in one of the mono-incineration plants of municipal sewage sludge (SS) located in Poland. The amount of sewage sludge ash (SSA) generated in the analyzed plant varied from 35.0 Mg in 2019 to 419.0 Mg in 2016, which affects the amount of P potentially recoverable from this waste. The P content in the analyzed SSA was equal to 9.5%, while the P-bioavailability reached 48.3%. The P recovery potential was equal to 31.8 Mg in 2016, which means that from 323.2 Mg of SSA generated, it was possible to recover 31.8 Mg of P. In 2018, the P recovery potential reached 22.1 Mg and it was systematically decreasing to 3.5 Mg in 2020, as a consequence of a reduction in the amount of SS sent for incineration, and thus a reduction in the amount of SSA produced in the installation. Nutrient-rich waste, as SS and SSA should be directed to treatment processes to recover nutrients, which can be further use in the production of mineral fertilizers. The European Commission strongly recommends this solution as a scope of the 'Farm to Fork' strategy which is an integral part of the European Green Deal. Moreover, P recovery from waste for fertilization purposes is also one of the main goals of the Integrated Nutrient Management Action Plan, which is the strategic tool to support a circular economy implementation in water and fertilizer sectors in Europe.

Keywords: Green Deal; Circular economy; Nutrients; Phosphorus (P); Bioavailability

1. Introduction

Nowadays, the management of mineral raw materials is an important issue in development policy in all countries of the world [1,2]. On the European level, the importance of sustainable management of raw materials has been underlined for many years [3] in the official documents of the European Commission (EC), as the development strategies of the European Union (EU) – the Europe 2020 Strategy for smart, sustainable and inclusive growth [4] and the newest strategy – the European Green Deal (EGD) [5]. The EGD aims to convert the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy that is climate-neutral and where economic growth is decoupled from resource use [5]. At present, all member states are more or less dependent on the supply of many resources from external sources, and their dependence tends to rise with the technological advancement of the analyzed economy [6]. To ensure the security of resources is particularly important for the critical raw materials (CRMs) [7–9], deficiency of which may disrupt the proper functioning of the economies of many European countries [10].

One of the most important CRMs are phosphorus (P) raw materials [11] which affect the ability to provide a sufficient amount of food for humans [12]. Due to the high risk associated with deliveries and high economic importance, phosphate rock is included in the list of CRMs since 2014, and white phosphorus from 2017 [7–9]. Currently, there is lack of a mineral deposits of phosphate rock in Europe [13], therefore the European countries need to cover the demand

Presented at the 1st International Conference Strategies toward Green Deal Implementation - Water and Raw Materials (ICGreenDeal2020), 14–16 December 2020, held online by the Mineral and Energy Economy Research Institute, Polish Academy of Sciences for P raw materials through import from countries of varying stability, both economic and political. At the same time, P has its "dark" side [14] as it is one of the main factors for the eutrophication of water reservoirs [15] which is an undesirable phenomenon [16], for example in the Baltic Sea basin. This means that, on the one hand, P is one of the most important raw material for the European economy, and on the other hand, it is lost through improper management as a consequence of insufficiently treated municipal sewage directed to natural receivers and excessively fertilized soils with phosphorus fertilizers [17].

In order to improve P flows in the economy, the EC pointed out that more sustainable nutrient management is an important task for the implementation of the European Green Deal Strategy [5]. As one of the proposed initiatives, a development of national strategic plans for agriculture that will fully reflect the ambition of the EGD was announced. Moreover, one of the European strategies for the Green Deal is the 'Farm to Fork' strategy [18] which is aimed at the reduction of pollution from excess nutrients. To strengthen the implementation of these activities, the EC also indicated that, as part of new circular economy (CE) Package, the Integrated Nutrient Management Plan [19] that includes actions to ensure more sustainable application of nutrients and stimulation of markets for recovered nutrients will be proposed. There is also plan to review the directives on wastewater treatment and sewage sludge and to make the assessment of natural means of nutrient removal and recovery (e.g., by algae). The improved nutrient management aims also to improve water quality and reduce emissions which are important aspects of the Green Deal implementation.

The most promising solution in the field of phosphorus management – which could keep its amount in the economy and reduce its impact on eutrophication – is P removal and recovery from municipal wastewater and products of its subsequent treatment as sewage sludge (SS) and sewage sludge ash (SSA). Due to a significant increase in the amount of SS directed to thermal treatment in Poland in the last years [20], an interesting source of recovered P is waste generated after mono-incineration [21,22]. It showed the highest recovery efficiency (comparing to wastewater and sewage sludge), up to 97%. Therefore, the main objective of the current paper is to assess P recovery potential from waste generated in one of the mono-incinerations plants located in Poland. The scope of the research includes the inventory of SS directed to the thermal processing and waste generated in this plant, an evaluation of the P recovery potential from waste and a discussion on the further possibilities of P recovery from waste in the context of the Green Deal implementation.

2. Materials and methods

The research was divided into three steps. In the first step, an inventory of material flow and characteristics of the mono-incineration plant is presented. The second step includes the identification of the chemical composition of waste generated in the mono-incineration plant. The third step presents P bioavailability and P recovery potential of waste generated in the facility and discussion. The specific methods used during the study are described below.

2.1. Material flow and facility characteristic

In the first step of the research, a survey method was used to collect all needed information on the amount of waste processed in the selected wastewater treatment plant (WWTP) equipped with SS incinerator. The questionnaire included questions about the amount of waste (SS and SSA) generated in 2010–2018 at the WWTP as well as the methods of waste treatment. The operator of the WWTP has been also asked to provide the detailed characteristic of the mono-incineration plant of the sewage sludge. The developed and distributed questionnaire was anonymous. In the current study, no personal data was collected and asked information was obtained in the line with the General Data Protection Regulation. Supplementary information on the characteristic of the facility was taken from the available literature using the desk research method. It included the review of the publications available in scientific platforms as Elsevier ScienceDirect, Elsevier Scopus, Google Scholar, Multidisciplinary Digital Publishing Institute (MDPI) and Polish databases as BazTech and Polish Scientific Bibliography. An important source of data was also the official reports published by the analyzed WWTP.

2.2. Chemical composition of SSA

In the second step of the research, the operator of the mono-incineration plant was asked to share the samples of SSA in the period of time October 2019 – June 2020. Approximately, 0.5 kg of sample was collected from the facility and directed to the chemical characterization. The representative samples were taken by the operator, according to the recommendations provided by the lab technicians. The samples of SSA were then transported in the dedicated plastic containers to the laboratory for further analysis. The samples of SSA were analyzed for selected elements (three replicates), including primary macronutrients: phosphorus (P) and potassium (K), secondary macronutrients: calcium (Ca), magnesium (Mg), sodium (Na) and sulfur (S), and other main elements: aluminum (Al) and silicon (Si). The following micronutrients have been also analyzed: cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), zinc (Zn), and other elements: chromium (Cr) cadmium (Cd), lead (Pb), nickel (Ni), arsenic (As), tin (Sn) and mercury (Hg).

The analysis of the above elements have been conducted according to the overall accepted norms, as PN-EN 13657:2006, PN-EN ISO 11885:2009. The elements in SSA were determined with the use of inductively coupled plasma optical emission spectroscopy (ICP-OES), flame atomic absorption spectrometry (FAAS) and specifically for trace elements, inductively coupled plasma mass spectrometry (ICP-MS). Mercury (Hg) has been determined with the use of the following norms – PN-EN 13657:2006, PN-EN ISO 12846:2012+Ap1:2016-07E, PB/I/11/C:10.04.2017, through the Cold Vapour Atomic Absorption Spectrometry (CVAAS) method.

2.3. P bioavailability and P recovery potential

In this step of the research, P bioavailability in SSA, according to the norm PN-R-04023:1996, was analyzed.

The spectrophotometric method was used to determine the availability of P by plants. With the use of the obtained results of P bioavailability, the theoretical P recovery potential from waste was calculated. The average value of P concentration in the analyzed waste and its amount generated in the mono-incineration plant were used in the estimation. The used method was described in [23,24].

3. Results

3.1. Material flow and facility characteristic

The mono-incineration plant (Thermal Sludge Conversion Installation) is located near one of the Polish cities in Warmian-Masurian Voivodeship (north-eastern part of Poland). The mono-incineration plant was launched in 2010 as one of the elements of the Water and Sewage Management Project, financed by the EU funds. The total capacity of these plants is equal to 3.200 Mg d.w. of SS per year. The SS directed to the combustion process comes from mechanical and biological municipal WWTP, launched in 1983 and systematically modernized. The activated sludge method is used for wastewater treatment, with the chemical support of PIX (iron-based coagulant). The installation for thermal processing of sludge was designed to completely burn dry SS with a low moisture content of up to 20% of sludge volume. The process of SS treatment includes two steps – drying and incineration. In the first place, the SS is dried in specially dedicated dryers and then converted into granules and directed to the furnace. The incineration line consists of three sections: combustion, waste gas treatment and heat recovery. The main elements include retention tank with capacity ensuring a minimum of 3 d of SS accumulated storage, SS water evaporation line (drying), cyclotron for removing process gases, a unit for thermal sludge conversion (furnace) with devices auxiliary (e.g., heat exchanger, reagent dispensers, controlling devices, waste gas treatment system and bagging device) and waste storage site. A stoker-fired furnace is used for combustion. The heat generated is used to dry another portion of the SS, which saves natural gas costs [25,26].

The amount of SS generated in the WWTP and the amount of SS directed to the process of thermal treatment are presented in Table 1. Since 2013, the amount of SS generated at the WWTP has remained at a similar level, about 20,000.0 Mg. In 2018, the amount of SS generated was equal to 21,031.0 Mg, of which 21% was sent to the incineration process. The rest of the sludge was landfilled. In 2019–2020, as a result of operational downtime, the number of SS sent for combustion has significantly decreased, to 701.0 Mg in 2020. The reduction of the mass flow of SS after the incineration was in the range of 92%–96% in 2011–2020, which allowed to solve the problem of managing this waste.

According to the catalog of waste, the final combustion products generated in the analyzed mono-incineration plant are:

- bottom slag and ash [19 01 12],
- wastes not otherwise specified [19 01 99],
- solid wastes from gas treatment [19 01 07*]
- fly ash other than those mentioned in 19 01 13 [19 01 14].

The amount of this waste generated in the mono-incineration plant in 2010–2018 is presented in Fig. 1. The bottom slag and ash which could be indicated as the SSA was changing non-linearly in the years 2010–2018. In the first years of operation of the mono-incineration plant, large amounts of SSA were also produced from large amounts of SS sent to combustion. However, as a result of a decrease in the amount of SS burned in 2013–2015, there is a clear decrease in the amount of SSA generated. In 2016, the amount of SSA reached 323.2 Mg, and since then the amount of SSA generated in this facility has been systematically decreasing, to 29.254 Mg in 2020.

3.2. Chemical composition of SSA

The results of the chemical composition of the SSA are presented in Fig. 2 and Table 2. The content of primary and secondary macronutrients is provided in Fig. 2. The highest content of macronutrients was recorded for calcium (127.0 g/kg d.w.) and phosphorus (93.05 g/kg d.w.). There is also promising content of other nutrients as potassium (8.06 g/kg d.w.), magnesium (22.01 g/kg d.w.), sodium (3.48 g/kg d.w.) and sulfur (3.41 g/kg d.w.). Other elements present in SSA were aluminum (>1.0 g/kg d.w.) and silicon (0.408 g/kg d.w.).

The analyzed SSA contains also micronutrients, as cobalt (10.0 mg/kg d.w.), copper (0.972 g/kg d.w.), iron (>15.0 g/kg d.w.), manganese (>0.50 g/kg d.w.), molybdenum (<0.4 mg/kg d.w.) and zinc (2.25 g/kg d.w.). The high content of aluminum (>1.00 g/kg d.w.) and iron negatively affects the bioavailability of P for plants (because they form P-bonded forms), while the high content of silicon negatively affects the possibility of P recovery in the process of thermochemical transformation.

The SSA also contains elements that are undesirable in materials that could be used in the production of fertilizers (Table 2). Legally required limits, for four elements for which the limits of the content in mineral fertilizers are

Table 1
Mass flow of sewage sludges and waste after incineration in 2011–2020

Specification	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	Amount [Mg]									
SS generated in WWTP	38,241	14,901	19,823	20,371	19,605	21,065	17,515	21,031	22,523	17,193
SS directed to incineration	5,025	5,076	1,837	2,045	2,773	5,113	4,214	4,491	958	701
Waste after incineration	394	417	153	171	185	419	329	290	35	37

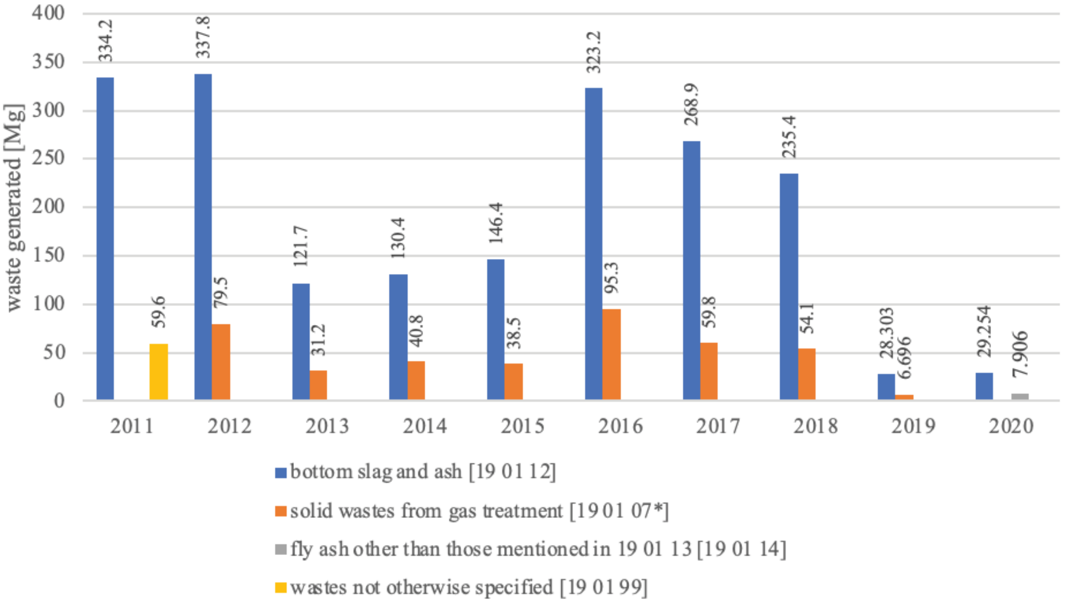

Fig. 1. Mass flow of wastes generated in mono-incineration plant.

Table 2
Chemical composition of SSA

Element	Maximum levels		
	SSA sample	Polish fertilizer regulation [27]	EU fertilizer regulation [28] mineral fertilizer
	mg/kg dry matter of sample		
Pb	47.5	140	120
As	<5.0	50	40
Cd	<0.05	50	60 mg/kg of P_2O_5[a]
Hg	<0.05	2.0	1.0
Ni	65.6	ns.	100
Cu	972	ns.	ns.
Zn	2250	ns.	ns.
Cr	97.0	ns.	ns.
Mn	>500	ns.	ns.
Sn	<5.00	ns.	ns.
Co	10.0	ns.	ns.
Fe	>15,000	ns.	ns.
Mo	<0.4	ns.	ns.
Al	>1,000	ns.	ns.
Si	408	ns.	ns.

ns. – not standardized;

[a] in case the total phosphorus content in the inorganic macronutrient fertilizer is equal to or greater than 5% calculated as phosphorus pentoxide (P_2O_5) ('phosphoric fertilizer')

used in Poland, were not exceeded [27]. Content of lead was equal to 47.5 mg/kg d.w., arsenic <5.0 mg/kg d.w., cadmium <0.05 mg/kg d.w. and mercury <0.05 mg/kg d.w. In the European regulation, the limit value is also indicated for nickel, which was not exceeded [28]. The content of nickel was 65.6 mg/kg d.w.

3.3. P bioavailability and P recovery potential of SSA

The samples of SSA were also examined to identify P bioavailability, which is the indicator presenting the efficiency of P uptake by plants [29]. The obtained results show that the P bioavailability of analyzed SSA was equal to 48.3%. This means that the P contained in SSA it is chemically bound [30] and therefore is not completely available for plants (desired value in 100%) [31]. It is recommended to use selected P recovery methods (chemical or thermochemical) in order to increase P bioavailability of SSA to plants [32].

The P recovery potential from analyzed SSA was estimated for the individual year, and it is presented in Fig. 3. The P recovery potential was equal to 31.8 Mg in 2012. This means that from 323.2 Mg of generated SSA this year, it was possible to recover 31.8 Mg of P. In 2018, the P recovery potential reached 22.1 Mg and systematically decreases to 3.5 Mg in 2020. In previous years, no actions in the field of P recovery on commercial-scale were taken, and this possibility was irretrievably lost because the SSA was stored, mainly with other waste, and the mixed waste can not be used for fertilization purposes.

4. Discussion

In 2014 [33], the EC has indicated the circular economy as the economic model of the EU with strong emphasis on the waste management as one of the key elements of CE implementation [19]. Many improvements have been made since then in the field of sustainable waste management [34], including wastewater [35,36] and sewage sludge [37]. Currently, the CE is indicated as one of the main blocks of the European Green Deal - new agenda for sustainable growth [19]. Therefore, a circular management of nutrient-rich waste is in line with the assumptions of the Green Deal. The results of the current study confirm that the waste generated in the mono-incineration plants of the municipal SS have good fertilizing properties due to the high content of nutrients, as calcium (12.7%), phosphorus (9.3%) or magnesium (2.2%). The previous research showed that the content of Ca in SSA from mono-incineration plants in Poland were: 7.5% [24] and 7.8% [38] in Cracow, 9.8% from Szczecin and Gdansk, 10.5% from Lodz, 11.5% from Gdynia, 14.0% from Kielce [24]. The high content of Ca in analysed SSA could be caused by sludge stabilization with lime. The content of P in the SSA from mono-incineration plants in Poland was studied in the previous works. The following content of P was reported: 6.8%–7.8% in samples from Cracow; 9.9% - 10.8% from Szczecin; 8.7% - 11.4% from Lodz, 11.3%–12.2% from Gdynia; 8.3%–11.2% from Kielce, 12.7% from Gdansk, 9.8% from Warsaw, 9.4% from Olsztyn [24,38,39]. Despite the encouraging content of P raw materials in SSA, the usage of raw SSA on the earth surface as the fertilizer is not possible in Poland due to the Regulation [40] does not mention this waste as acceptable for fertilization purposes without prior treatment. Directing this waste for fertilization purposes would help to accelerate the transformation process towards the CE, and thus contribute to the achievement of EGD objectives. The SSA can be directed to the further processing as chemical and thermochemical treatment [11], and thanks to that it can be used as a substitute in mineral fertilizers [41]. It is a very promising solution that can reduce the need for import of P raw materials in Poland [42]. Therefore, it is strongly recommended to direct the SSA for further treatment processes.

In order to assess the possibility of P recovery from wastewater and products of its subsequent treatment (including sewage sludge and sewage sludge ash), it is necessary to provide the amount of SS directed to the thermal treatment, as well as the P content in the waste generated after this process [25]. This study showed that the amount of SS directed to mono-incineration and thus, the SSA generated in 2011–2020 have changed in very large ranges. In 2016, the highest amount of SS was combusted (5113 Mg) and highest amount of SSA was produced (323.2 Mg). Since 2016, the SSA amount has systematically decreased, to 37.2 Mg in 2020. It should be underlined that the thermal conversion of the municipal SS allowed for the significant reduction of the mass flow of SS (92–96%). However, from the perspective of the CE, the incineration of waste is a debatable solution. The EC underlines in the waste directive [43] that the Member States shall take measures to ensure that waste that are separately collected for preparing for reuse and recycling, instead of incineration. The thermal conversion of waste is only recommended when it shows the best environmental outcome (based on the Article 4). In the case of Polish mono-incineration plants, more and more facilities selectively store the SSA [11], so that in the future it can be used for the P recovery. It should also be emphasized here that only the SSA from mono-incineration plants can be directed to P recovery in the process of chemical or thermochemical treatment and production of fertilizers. On the other hand, the SSA that is non-selectively stored, is not suitable for P recovery in the installations developed so far due to the presence of other pollutants and the form of mixed waste itself. Moreover, the EC requires the implementation of the EU waste management hierarchy [43], where the waste incineration (with energy

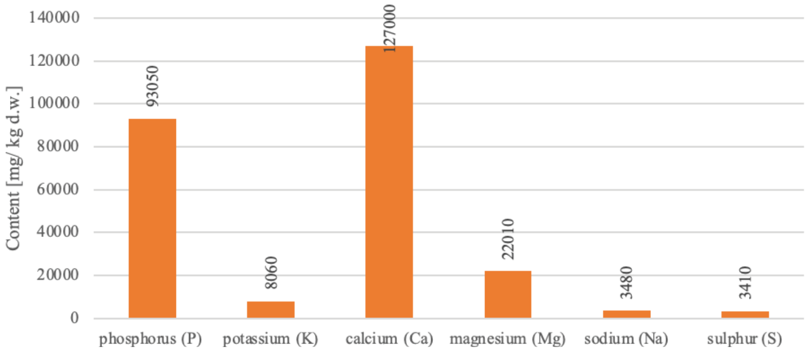

Fig. 2. Content of macronutrients in SSA.

recovery) is a solution that is indicated just before the last option - safe disposal. For these reasons, many environmental organizations (as eg. European Environmental Bureau) are against the incineration of waste. The problem concerns mainly the municipal solid waste, but such recommendations are also indicated for the SS [20]. In facilities where the thermal conversion method of SS has been implemented, usually the combustion installations have been financed by domestic and European financial sources [26]. Currently, most of them are in operation, therefore measures should be taken to the best sustainable use of produced waste, which is P-rich. The detailed analysis on the amount of P-rich waste generated on national levels [20,44] can also help in planning activities to reduce nutrients losses in the whole EU. In addition, it can be used to estimate the economic efficiency of investments in the field of the P recovery (investment and operating costs, return on sales of recovered P) and the selection of the investment location (taking into account the costs and time of transport logistics).

The SSA from the analysed plant is landfilled, and therefore the value of the P recovery potential is not utilized. The results of current study showed that the P recovery potential varies greatly depending on the amount of waste generated annually and it could reach 30.4 Mg (data from 2016). The previous research showed that the P recovery potential from all 11 mono-incineration plants in Poland reached 1,613.8 Mg in 2018, of which 33.9% was bioavailable [24]. The P recovery potential from SSA generated in the mono-incineration plant in Warsaw (where 37.8% of total ashes generated in country are produced) reached 991.3 Mg, while in Cracow 336.9 Mg (P bioavailability 43.5%), in Lodz 434.7 Mg (P bioavailability 35.9%), in Gdansk 417.6 Mg (P bioavailability 45.7%), in Gdynia 189.0 Mg (P bioavailability 26%), in Szczecin 154.4 Mg (P bioavailability 32.3%) and in Kielce 80.8 Mg (P bioavailability 19.7%). The P recovery potential depends on the distribution of this element in SSA and the size of the plant [23]. Detailed information on the P recovery potential from various waste groups, including the SSA, is crucial for the further planning and implementation of investments in the recovery of this CRM from waste. Moreover, the knowledge on the P content in waste generated and the P bioavailability are important for the estimation of nutrient flows, which are indicated in the "Farm to Fork" strategy [18], integrated part of the EGD [5]. The EC underlines that it will act to reduce nutrient losses by at least 50%, without deterioration in soil fertility, assumed to entail a reduction in fertilisers use at least 20% by 2030. This will be achieved by the systematic implementation and enforcement the relevant laws on environment and climate. The identification of nutrient load reductions on the national levels, which are required to achieve these goals will be conducted by individual European countries. Moreover, the application of balanced fertilization and sustainable nutrient management – with strong focus on nitrogen and phosphorus (which should be better managed throughout their whole lifecycle) is also indicated in the 'Farm to Fork' strategy [18]. It should be also underlined that next to municipal SS and SSA [45], other waste streams (as biomass ash [46,47], phosphogypsum [48], industrial sewage sludge [49]) have also potential to nutrients recovery. The important tool to increase the sustainability of the livestock sector and to solve the problem of nutrient pollution at source is the Integrated Nutrient Management Plan which is proposed by the EC. Currently, the content of this document is discussed on the international level, for example, by the European Sustainable Phosphorus Platform (ESPP), which is networking platform for companies and stakeholders to address the phosphorus challenges. The ESPP already prepared the official document (intended for discussion and comment) aimed to provide input to the EC on possible objectives, content and mechanisms for such the Integrated Nutrient Management Action Plan [50]. The important part of this document is related to the integrated nutrient management and climate change policies. More targeted fertilizer nutrient management can contribute to a higher efficiency of nutrient and thus contribute to reducing greenhouse gas (GHG) emissions, especially N_2O emissions. Based on proposed recommendations, the Integrated Nutrient Management Action Plan should:

- "address nutrients across all existing areas of EU policy (environment, water, air, industrial emissions, waste legislation, circular economy, agriculture, food and diet,

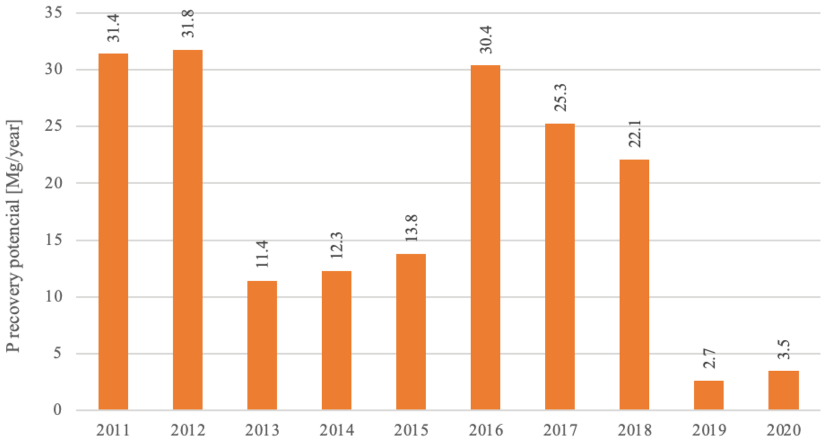

Fig. 3. P recovery potential from SSA in 2010–2018.

animal feed, fertilizers, raw materials, climate change and others),
- cover all nutrients: nitrogen, phosphorus, other nutrients and micro-nutrients and soil organic carbon,
- integrate existing policies and implementation structures (e.g., water basin management organizations, agricultural funding and rural development and others) in order to be realistically implemented by companies and by local/regional territories" [50].

An important aspect of the P recovery from waste and production of the fertilizers is placing such producers on the market. In 2019, the EC presented the new regulation of fertilizers and fertilization [28]. There is also strong need to increase the usage of recycled or organic materials for fertilizing purposes. It is extremely important in the way to the CE model at the European level. Further promotion and increased use of recycled nutrients could accelerate the transformation towards the CE. The more resource-efficient general use of nutrients can be achieved, next to the reduction of the EU's dependency on nutrients from countries, as Russia and Morocco. The further recommendations, official documents and legal commitments are underway in the field of nutrients management. They focus on more sustainable and circular management of waste streams rich in nutrients, (including P-rich SS and SSA). It can also be expected in the coming years to strengthen the implementation of the Green Deal strategies, as "Farm to Fork" strategy or "Biodiversity" strategy because for these purposes the financial resources are provided from the Just Transition Mechanism, which amounts to EUR 150 billion in the perspective 2021–2027.

5. Conclusions

The new EU strategy for economic growth – the European Green Deal - introduces significant changes in the field of nutrients management at the national and European levels. The proposed Integrated Nutrient Management Action Plan, which is a part of the new CE Action Plan draws attention to the need to identify nutrients loads by individual Member States and this also applies to the phosphorus loads, which is a critical resource. It is also important to analyse the amount of P in waste generated in individual economies and sectors. Due to SS is one of the most important P carrier, it is important to identify the P content in SS and in waste products from its processing, such as SSA. The research confirmed that the P content in SSA from mono-incineration is high (up to 9.4%) therefore it should be directed to further economic purposes as fertilizer production instead of landfilling. It could support the sustainable management of waste in municipal facilities and thus contribute to the implementation of the Green Deal objectives and its strategies as the "Farm to Fork' strategy which promotes the sustainable and circular management of nutrient-rich waste. Further efforts and detailed inventory of P-rich waste and its flows in individual economies is planned.

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