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Scientific-organizational and normative-legal aspects of recovery of sediments of communal sewage (on an instance of European experience)

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The purpose. To show scientific-organizational and normative-legal aspects of recovery of sediments of communal sewage (SCS) in Ukraine and the European Union. **Methods.** Analysis, synthesis, generalization. **Results**. Volumes of formation and recover of SCS in countries of the European Union are brought. Normative-legal basis of application of SCS in farming agriculture in Ukraine and the European Union are described. Scientific-organizational aspects of application of SCS as fertilizers in countries of the European Union are analyzed. Modern approaches to methods of processing SCS for their further application as organomineral fertilizer are shown. **Conclusions**. At present it is of utmost necessity implementation of effective and ecologically safety method of recovering those volumes of SCS which were formed and have been collected in Ukraine for many years. World experience testifies to the following: under condition of observance of scientifically-proved organizational and normative-legal requirements, the most rational method of recovering SCS is their application as fertilizer in the recycled form. That will ensure entering organic matter and nutrients in soil and recovering these wastes.

Key words*: sediments of communal sewage, legal basis, normative baseline, European experience.*

Introduction. Waste management is one of the priorities to be resolved in Ukraine. As part of the Strategy of environmental policy an increasing in 1.5 times the amount of recycling and use of wastes as secondary raw materials till 2020 has declared.

European integration processes in Ukraine put serious tasks because the EU approach to waste management is based on three principles: waste reduction, recycling and reuse, improving waste disposal technologies and monitoring. The issue of sewage sludge (SS) disposal is very urgent all over the world, because the biological method of waste water purification had taken a leading place among the technologies at the beginning of the last century. As defined by DSTU 7369: 2013 "sewage sludge is a mixture of solid particles with organic and mineral substances which are a sediments after primary purification of waste water by settling (raw sludge), and microorganisms involved in a biological purification of waste water and outputs from process (excessive active sludge). For now, Ukraine has accumulated a significant amount of SS, which creates environmental and social tension at the surrounding areas to waste water treatment plants.

Results and discussion. Countries choose ways of SS utilization depending on the regional geo-ecological characteristics (Table 1). SS use as a fertilizer in agriculture, green building, for biological reclamation of disturbed areas, landscaping, etc. [0].

1. Sewage sludge production and utilization in different countries [0]

Country or Region	Sludge production, million tons dry solids per year	Sludge utilization rate, %	Main sludge applications
Australia	0,4	80	Land application, energy recovery
South Africa	1,0	80	Land application
India	-	80	Land application
Japan	2,2	74	Energy recovery, construction productions
United States	17,8	55	Land application
Republic of Korea	1,9	6	Land application, construction productions
European Union	9,0	40	Land application

In Ukraine SS processing with the use of components has used almost never, that is why all volume of produced SS (about 40 million tons per year) is stored. Meanwhile, there is a trend of decline of SS storage in landfills in countries of European Community (Table 2) and an applicable regulations impose on the owners of treatment facilities an commitments of integral solution of SS problem. For example, there is complete abandonment of SS storage is declared in Germany, only storage of SS with organic matter content less than 5% is allowed.

2. Production and use of sewage sludge in Europe (median values of data for 2005 to 2014)

Country	Production ktDS/y	Per capita production gDS/cap d	Disposal ktDS/y	Disposal ktDS/y		
				Agricuture + Compost	Landfill	Other
Germany	2,0	65,6	1,9	0,9	0,001	1,0
Spain	1,2	68,7	1,1	0,9	0,2	0
France	1,0	41,4	1,0	0,9	0,04	0,02
Poland	0,5	38,3	0,5	0,1	0,1	0,3
Austria	0,3	84,6	0,3	0,12	0,02	0,15
Sweden	0,2	61,2	0,2	0,1	0,07	0,7
Finland	0,15		0,15	0,14	0,03	0,001
Greece	0,13	33,0	0,13	0	0,08	0,05
Lithuania	0,05	37,1	0,02	0,02	0	0
Bulgaria	0,04	15,5	0,03	0,01	0,01	0,001

Approximate cost of different methods of SS disposal in European Union, taking into account the cost of dewatering and transport, for 2015 varies from 125 to 375 EUR per ton (Table 3).

3. The cost of different methods of sewage sludge utilization

Methods of utilization	Cost, EUR/т dry matter
Land application, wet SS (4% of dry matter)	200-375
Land application, mechanically dewatered SS (25% of dry matter)	125-175
Land reclamation, mechanically dewatered SS (25% of dry matter)	175-275
Incineration, mechanically dewatered SS (25% of dry matter)	175-325
Co-incineration in cement plant, dry OCB (90% of dry matter)	125-325

Agricultural utilization of SS performs an important environmental function, returning nutrients to the natural cycle. As a result of long-term researches carried out in a different countries both the positive impact of SS on fertility and productivity of soil was established and the negative - in the form of biological pollution and heavy metals contamination, salinity, etc.

The soil fertility protection during SS application in legislation of Ukraine regulated by the Law of Ukraine "On Land Protection", the Order of State Committee for Construction, Architecture and Housing policies Ukraine on February 19, 2002 № 37, which established The Rules of wastewater acceptance to enterprises

in municipal and departmental sewage system of Ukraine and the Order of Ministry of health of Ukraine "On approval of the state sanitary rules of planning and building of settlements".

According to Article 39 of the Law of Ukraine "On Land Protection" soil application of SS can be carried out after permission of executive authority on ecology and natural resources and agreement with the executive authority on agricultural policy and public health.

Application of SS is not allowed on lands of the nature reserve and other environmental, health and recreational purposes, the water fund lands and other areas subject to special protection, on lands used for cattle breeding, cultivation of vegetables and fruits, as well as on lands in which the content of any toxic substances exceed the maximum permissible concentration. Importation into Ukraine of SS is prohibited.

According to the Order of State Committee for Construction, Architecture and Housing Policy of Ukraine on February 19, 2002 № 37 ECOTAX for placement of sediments and sludge produced in sewage treatment plants, to specially equipped facilities of water utility, is not charged in case of evidence of long-term plan of measures for SS recycling or disposal, which agreed with the territorial bodies of Ukraine Ministry of Ecology.

If it is impossible to use SS as fertilizer due to it unsuitability for use in agriculture (high content of heavy metals, toxic substances, etc.) and it needs to placement in special landfills, estimated cost of these works (including fees for environmental pollution) is distributed among Enterprises those responsible for pollution of sediment and silt by toxic substances.

In European Union the use of SS in agriculture is regulated by Directive 86/278 / EC [8]. Thus, Article 1 defines the purpose of regulation and streamlining of use of sewage sludge in agriculture, which should be done in a way that excluded the harmful effects on soil, vegetation, animals and people and at the same time stimulates the rational use of it. Article 2 of the Directive defines the term "sludge" and "recycled sludge".

The term "sludge" means a final deposit from sewage treatment plants which processes domestic or urban waste waters and a deposit from other sewage treatment plants which processes liquid discharges, similar in composition to household wastewater; final sediment from sewage treatment plants that do not belong to the category of objects mentioned above.

The term "processed (purified) sludge" means a deposit, which was subjected to biological, chemical or heat treatment (purification), long-term storage or any other recycling process, which provides a significant reduction of it ability to fermentation and damaging to health.

Moreover, this sludge can be used in agriculture in case Member State finds it acceptable not to cause harm to human health and the environment, special provisions governing it use are developed.

It should be noted that EU the use of SS in agriculture so to say "no needly" has never considered, only if it is usefull for increasing soil productivity, and only on areas which require additional fertilization and in necessary doses. SS application for fruit and vegetable crops, pastures and territories near water bodies is prohibited.

Determination of SS doses, and a possibility of it application have to do with environmental and agrochemical point of view, it is necessary for each type of soil, crops, and needs to be based on the chemical composition of SS.

The chemical composition of SS depends on specificity of industry and household utilities, cleaning methods, a season, etc. The results of practical research on sludge from treatment plants, which treats wastewater from various sources (household, industrial enterprises, hospitals) in different countries shows considerable range of fluctuations of trace and basic elements.

Municipal sewage sludge is characterized by a high content of organic matter (75%) [2]. It can be source of phosphorus and nitrogen for soil, but most of potassium in located in the liquid phase of sludge and can leach during storage on about 50 - 80%. Fluctuations of the contents of nutrients in SS according to the literature, if for nitrogen — 0.8 - 6%, phosphorus — 0.6 - 5.6%, potassium — 0.1 - 0.5% [2].

The presence in SS a significant part of domestic sludge causes potential presence of pathogenic microorganisms. The sanitary and bacteriological standardization of SS carried out on the presence of E. coli bacteria, pathogenic and viable helminth eggs [3].

Many researchers emphasize that the most serious problem associated with the use of SS in agriculture is the possibility of accumulation of heavy metals in soil and plants. Meanwhile, the defining characteristic is not a presence of an element but its concentration, because depending on a concentration of an element

can be regarded as a trace element or heavy metal [4]. Taking into account the fact that a soil may be not complete source of microelements for plants, its content in fertilizers is considered as a positive factor.

However, taking into account these risks, the use of SS in agriculture requires an introduction of a clear system of monitoring of accumulation of heavy metals in soil and products. Standards on heavy metals content in SS (in mg/kg dry matter), for agricultural purposes in different countries is given in Table 4.

4. Limits for heavy metals in sewage sludge in different countries

Countries			**Cd**	**Co**	**Cr^{+3}**	**Cu**	**Mn**	**Ni**	**Pb**	**Zn**	**Hg**	**Sr**
Ukraine	Class	1[1]	3-5	5-20	100-400	100-300	250-750	50-75	100-200	300-1000	2-5	50-70
		2[2]	5-15	20-50	400-600	300-700	750-1500	75-150	400-600	1000-2000	5-10	75-100
		3[3]	16-30	50-100	600-750	700-1500	1500-2000	150-200	600-750	2000-2500	10-15	100-300
		4[4]	30-40	100-150	750-2000	1500-2500	2000-3000	200-400	750-1200	2500-4000	15-20	300-500
		5[5]	30-40	150-200	2000-4000	2500-4000	2500-4000	400-600	1200-1500	4000-7000	20-30	400-500
Directive ECN№86/278			20-40	-	-	1000-1750	-	300-400	750-1200	250-4000	16-25	-
Russian Federation[i]			15-30	-	500-1000	750-1500	-	200-400	250-500	1750-3500	7,5-15	-
Poland			20	-	2000	1000	-	300	750	2500	16	-
USA			50	-	500	750	-	150	500	1500	-	-
France			15	-	1000	1000	-	300	900	3000	10	-
Germany			10	-	900	800	-	200	900	2500	8	-
Netherlands			1	-	75	75	-	30	100	300	1	-
Sweden			2	-	100	600	-	50	100	800	3	-

Notes:

1. Application (or compost production) in doses appropriate standard fertilizers.

2. Applying of 3-4 t / ha per year or not more than 10 tonnes / ha every three years.

3. Applying of 5-6 t / ha of dry matter one time every 5 years with the obligatory monitoring heavy metals accumulation in a soil.

4. Agricultural utilization is prohibited without processing, SS can be used only as a component for production of compost.

5. Agricultural utilization is prohibited, SS can be used for fertilization of decorative plants, in green woodland sector (or land reclamation).

6. Depending on a crop.

The Working Document for SS [12] also normalizes content of organic pollutants and dioxins in SS agricultural purposes (Table 5).

5. Limit values for organic pollutants and dioxins in SS for agricultural purposes

Pollutant	**Contents, mg/kg dry matter**
AOX	500
LAS	2600
DEHP	100
NPE	50
PAH	6
PCB	0,8
PCDD/F	100

Furthermore, according to Working Document [12], sewage sludge must pass appropriate certification (Table. 6).

6. Requirements for sewage sludge

Sewage sludge production, t DS/y	The minimum number of tests per year				
	Agronomical indexes	Heavy metals	Organic pollutants	Dioxins	Microorganisms
<250	2	2	-	-	2
250-1000	4	4	1	-	4
1000-2500	8	4	2	-	8
2500-4000	12	8	4	1	12
>4000	12	12	6	1	12

It is noted that certification may be delayed for 1-2 years in the case of systematic compliance of SS to requirements. As well as chemical composition of SS must be taken into account a topography, slope and soil characteristics. Eligibility criterias for soil application of include grain size, water permeability, erosion, a depth of the groundwater, soil pH and heavy metals content [1, 7]. Applying of SS in acidic soils and soils with very low or too large permeability is excluded.

Due to dependencies which exists between level of insolation and physical and chemical properties of soils and epidemiological risk which is associated with agricultural utilization of SS, V. Khilchevsky divided a main types of soils into 3 groups. The first is sod-podzolic soils (high and very high risk of pollution), the second — gray podzolic and brown soils (medium degree of risk), the third - chernozems (minimal risk) [1].

Nevertheless, the direct applying of SS in a soil can be a significant environmental risk, that is why in the world the more rational is to use recycled waste in order to minimization of a volume and ensuring hygiene standards of a final product [9]. According to the Working Document safe application of SS in agricultural practice is possible only after advanced processing [12]. Conventional processing is permitted in some cases (Table 7).

7. Requirements for sewage sludge processing depending on it application

Application	Conventional processing
Pastures	Allowed, deep applying and no grazing for 6 weeks
Feed crops	Allowed, no harvest within 6 months after SS applying
Fields	Allowed, deep applying
Vegetables and fruits	Not allowed, no harvesting for 12 months after SS applying
Fruits and vegetables consumed raw	Not allowed, no harvesting for 30 months after SS applying
Gardens	Allowed, deep applying without people access for 10 months

Conventional treatments means thermophilic, aerobic or anaerobic stabilisation at a temperature of at least 55°C with a mean retention period of 20 days; conditioning with lime ensuring a homogenous mixture of lime and sludge (keep a pH of at least 12 for 24 hours) and mesophilic anaerobic digestion at a temperature of 35°C with a mean retention period of 15 days.

Advanced treatments consist of thermal drying ensuring that the temperature of the sludge particles is higher than 80°C with a reduction of water content to less than 10%; thermophilic aerobic stabilisation at a temperature of at least 55°C for 20 hours as a batch; thermal treatment of liquid sludge for a minimum of 30 minutes at 70°C followed by mesophilic anaerobic digestion at a temperature of 35°C with a mean retention period of 12 days; conditioning with lime reaching a pH of 12 or more and maintaining a temperature of at least 55°C for 2 hours.

The global problem of waste accumulation determines a great interest in developing biotechnological processes of organic waste recycling, which will ensure an effective organization of effective and environmentally friendly technologies. In the literature, observed that one of the most perspective ways of processing of SS is composting [5]. According to the literature data, this method allows to get organic fertilizer for a short period of time with a high content of nutrients in available for plants form. In addition, composting provides stabilization and sanitary disinfection and improves the consumer qualities of SS. There is an evidence that composting microorganisms reduces mobility of heavy metals and concentration of environmentally hazardous organic compounds. Many authors have noted that organic matter of mature

composts has particular value to potential humus formation in a soil because there are resistant to decomposition of high molecular weight humic substances in composts [7].

Biotermical process is recognized as the most effective in the case of composting of raw SS [10]. This method is used both separately and in combination with anaerobic digestion in mesophilic conditions. For composting mechanically dehydrated or dried sludge SS different technologies are used: in piles and trenches, fermenters, etc. [5]. When choosing composting technology must take into account a costs of implementation and the level of complexity of a technology. Several studies observed that the most cost-effective technology of SS - is composting in tunnel and rolls [7].

Conclusion

Presently understanding of urgent necessity of introduction of effective and environmentally friendly methods of utilization of that volume of sewage sludge produced and accumulated for many years in Ukraine is extremely important. World experience shows that the most rational method of sewage sludge utilization is to use as fertilizer, preferably in processed form that will provide income of organic matter and nutritive element to soil and recycling of wastes, in case of accordance to regulatory requirements regarding a composition of SS, characteristics of a territory and crops.

Numerous researchers in different countries proved a need to implement SS processing to ensure sanitary standards and improve quality of a final product. Significant perspectives of implementation of processing technologies of SS is also due to a low cost, constantly renewable large base and high fertilizing potential of SS. Rational scientifically grounded processing and application of SS in agriculture contributes to solving a several problems: entering of organic matter and nutrition elements to a soil and waste utilization.

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