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THE USE OF SEWAGE SLUDGE IN AGRICULTURE: A SWOT ANALYSIS

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Key words: *sewage sludge, SWOT analysis, fertilizer use, environmental risk*

INTRODUCTION

The use of sludge as a fertilizer or soil improver as a method of exploiting the nutritional compounds is one of the practices agreed in the context of sustainable development. This practice is carried out in a highly organized and regulated system among partners: the sludge producer, the user, the environment agency and the local decision makers (Figure 1) (U. EPA, 1999; Europene, 1986; I. Leonard, M. Dumitru, N. Vranceanu, D. M. Motelica, & V. Tanasa, 2007b; Ministerul Mediului şi Gospodăririi Apelor (M.M.G.A), 2004; Raducanu, Nedeff, Barsan, Chitimus, & Mosnegutu, 2013).

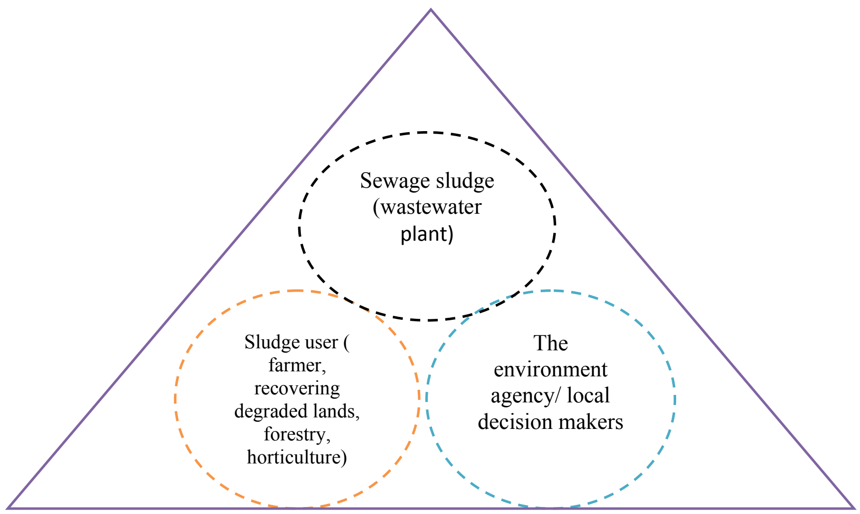

Figure 1. General scheme of the factors involved in using sewage sludge

Given the heterogeneity and complexity of the sludge, the acceptance of such practices of disposal/ recovery depends on many internal and external factors, among which we can mention (Pintea, 2012; Stoicescu, 2011):

- ✓ Legislative factors (related policy issues) at regional, national, international level;
- ✓ Sociological factors: the public perception of the acceptance of the product, the risk to human health;
- ✓ Administrative - geographic factors: land topography, environmental impact, sludge logistics and transportation.

The valorisation of this particular type of waste (biosolids) in agriculture is preceded by a complex physical-chemical analysis of sludge quality, on which the user is issued a certificate endorsed by the competent bodies (PERSENVIR, 2010; Stoicescu, 2011; Zafar, Javed, Ali, Anwar, & Khattak, 2012). The user (land manager) is also obliged to know the agrochemical characteristics of the soil to be fertilized with sewage sludge, to determine the appropriate dose of biosolids / area (Paian & Goian, 2006).

The main normative act governing the European sludge usage in agriculture is the Council Directive 86/278/EEC on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture and it refers to: land topography and slope, soil texture and permeability, groundwater depth and protection of water supply sources of settlements, edaphic volume, soil pH and cation exchange capacity, heavy metal laden sludge and soil, and heavy metals limit values which may be introduced into the soil annually and recommendations on plant culture. These legal issues are customized in each country (Direcția, 2012; Pescod, 1992; Singh R. P. & M., 2008).

Council Directive 86/278/EEC was implemented in Romania by OM 49/2004 for the approval of technical norms on environmental and in particular soil protection, when sewage sludge is used in agriculture. This order was amended in October 2004 by the Order 334/2004, under which the use of sludge is prohibited on the following types of land used for: grazing; growing shrubs; culture of vegetables; fruit trees cultures 10 months before harvest and during harvest (Consiliul, 1991; Consilul, 1986; EPA, 1999; Ministerul, 2004; Paian & Goian, 2006).

The public acceptance of the use of sludge as a fertilizer in agriculture is equally necessary. This is the subject of many pros and cons debates which take place at present. (Baumgarten & Spiegel, 2004; Christofoletti, Francisco, & Fontanetti, 2012; Elsäber, 2011; Zafar et al., 2012).

The main purpose of this paper is the making of a SWOT analysis (Cojocariu, Lazar, Nedeff, & Lazar, 2014) on the use of sludge for agricultural purposes in the European Union countries.

MATERIALS AND METHODS

This study was conducted from the perspective of our assessment after the study of relevant scientific literature, since September 2013 to March 2014.

Thus, there were summarized and analysed the data identified in public statistics and scientific publications about the quantities of sludge generated in recent years in the European Union. At the same time emphasis was laid on aspects that relate to the use, processing and application in agriculture, forestry or restoration of degraded land.

Given the complexity and diversity of the problems which can be identified in all the factors involved in sludge recovery (producers, users, government agencies) at a national and regional level, such a SWOT analysis is useful and necessary before using sludge as fertilizer or soil improver. Next the main points of this SWOT analysis (Figure 2) will be presented, analysed and interpreted.

RESULTS AND DISCUSSIONS

The sludge resulting from wastewater treatment are mixtures of water and clay particles, pollutants, different types of cations and anions held by the organic or inorganic colloidal fraction. (Arthurson, 2008; Singh R. P. & M., 2008; Stoicescu, 2011)

The amount of sludge currently generated by sewage treatment plants is an environmental aspect which varies according to: the density of the population connected to sewerage, industrial and rain water intake and last but not least, the technology applied in the process of wastewater treatment (primary or secondary treatment) and the operational yields.

The origin of the wastewater, the technological treatment step where sludge is formed and separated, the chemical composition, the degree of technical processing reached in the treatment process are some of the fundamental characteristics that require a particular approach to the problem of sewage sludge (Ditoiu, 2010; Elsäber, 2011; Mironescu, Oprean, & Mironescu, 2008; Richard, 2001; Samolada M.C. & A.A, 2014).

The amount of sludge produced at the European Union level in 2010 has a total value of 11.564 (ktds/year) (Figure 2). Some of this total amount of sludge variably produced from state to state is used in agriculture. In comparison to other countries, it can be seen that the recovery of sludge in agriculture is not common practice in Romania. There are multiple causes, from the lack of technology to poor public awareness.

As the 2020 estimates show in Figure 3, sewage sludge will be used in a proportion of only 20% in the Romanian agriculture (Samolada M.C and Zabaniotou A.A., 2014).

As it can be seen from Figure 2 and Figure 3 the percentage of sludge produced in EU countries and used in agriculture will increase in 2020 by 2%, from 42% in 2010 to 44% in 2020.

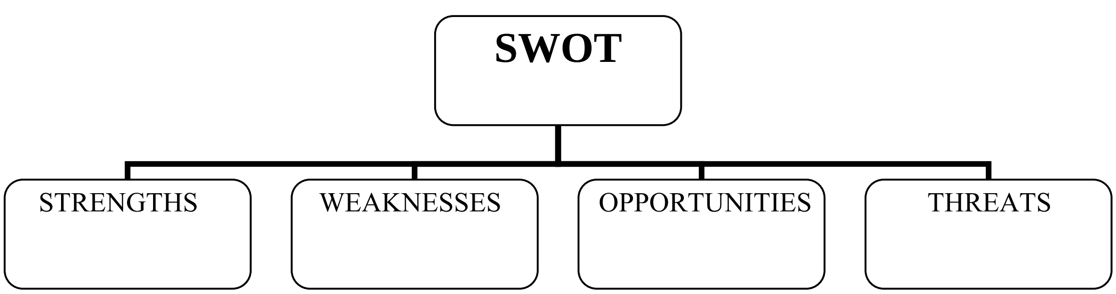

Figure 2. SWOT diagram

In 2010, in the European Union countries sludge is mainly used in agriculture in Luxemburg (90%), Ireland and Hungary (75%), Spain (65%) and France (60%). This ratio is mainly the same in 2020.
Total national production of sludge is estimated to increase by about 3.2 times in 2020 (Figure 3). This is due to the implementation of the norms according to which by 2018 every community with at least 2,000 residents should be serviced by a treatment plant (Paian & Goian, 2006; Samolada M.C. & A.A, 2014).

The increase of the total amount of sludge means that stakeholders should identify optimal solutions for the sludge management. Table 1 shows the SWOT analysis on the use of sewage sludge at EU level. The use in agriculture, forestry or for restoring degraded lands is not a widely applied practice in Europe but it is studied in research projects and extensively debated in scientific publications (Ditoiu, 2010; Gheorghe, Lucaciu, Paun, Stoica, & Stanescu, 2013; Mironescu et al., 2008; Oros, 2012; Paian & Goian, 2006; PERSENVIR, 2010; Pintea, 2012; Stoicescu, 2011).

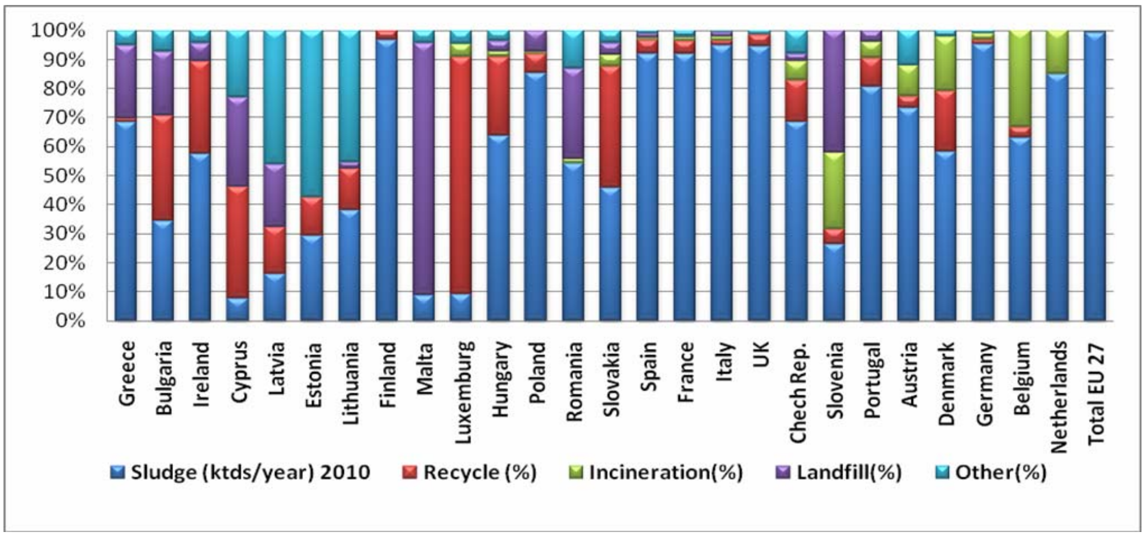

Figure 3. Amount of sludge produced in the European Union in 2010
(made by Samolada M.C and Zabaniotou A.A., 2014)

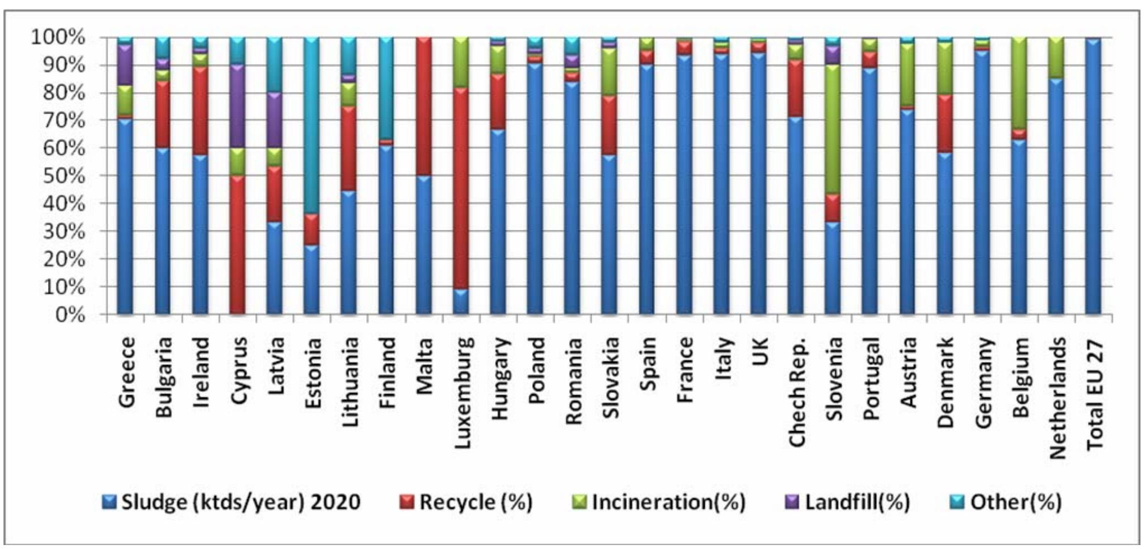

Figure 4. Amount of sludge estimated for 2020 in EU countries
(made by Samolada M.C and Zabaniotou A.A., 2014)

Table 1. SWOT analysis on the use of sewage sludge in agriculture at EU level

Strengths	• Recovery of sludge items with fertilizer value ; • Replacements of chemical fertilizers, respectively lower fertilization costs; • Increase of agricultural crops productivity; • Improvement of soil characteristics: bulk density, porosity, increasing water retention.
Weaknesses	• Lack of infrastructure necessary to process the sludge which is to be used in agriculture; • Long transport distances to the agricultural land • Potential beneficiaries' low awareness; • Increased toxicity potential of the sludge due to the diversity of pollutants found in domestic wastewater (toxic organic compounds, polychlorinated biphenyls (PCBs, polycyclic aromatic hydrocarbons PAHs).
Opportunities	• Solutions for the sustainable use of the valuable sludge compounds; • Creating new jobs; • Improving biochemical processes in the soil, including humification processes; • Improving soil structure and permeability for the water which facilitates farming means savings for the farmer; • Restoration of degraded lands.
Threats	• Effect on the ecosystem durability and sustainability; • Changes of scenery (visual discomfort), releasing odours; • The danger of polluting surface waters; • The danger of transferring pollutants to the level of plants, animals and the whole trophic chain.

STRENGTHS

Sewage sludge has a fertilizing value insofar as its chemical composition reflects it. The macronutrients concentration varies within wide limits depending on local conditions. Lixandru (2005) stated that "a typical sludge" has the following concentrations of nutritive elements: 3.2% nitrogen, 1.4% phosphorus, 0.23% potassium, 2.7% calcium, 0.4% magnesium (Lixandru, 2005).

Manara and Zabaniotou (2012) (Figure 5) provide a differential analysis according to the methods of treating sludge (Manara P. & A.A, 2012; Samolada M.C. & A.A, 2014).

The condition of accepting the use of sludge on agricultural land depends on the processing degree, its stabilization and sanitizing it. The recommendations of the various abilities bodies (Direcția, 2012; Olusegun B. Samuel, Fidelia I. Osuala, & Peter G.C Odeigah, 2010; Paian & Goian, 2006; Singh R. P. & M., 2008) state the following aspects:

a. spreading and incorporation sludge on agricultural land (with a slope of 0-16%) during the growing season takes place when the soil work is done;
b. for the proper degradation of sludge, this must be incorporated by deep plowing and disking;
c. spreading sludge in winter is allowed only on well-drained land, where the slope does not exceed 6%;
d. for the flooded land, sludge spreading and incorporating is compulsory to be done in the same day;
e. sludge distribution plan is calculated each year by the dates of planting and harvesting crop, soil agro-chemical data and the required dose for the crop.

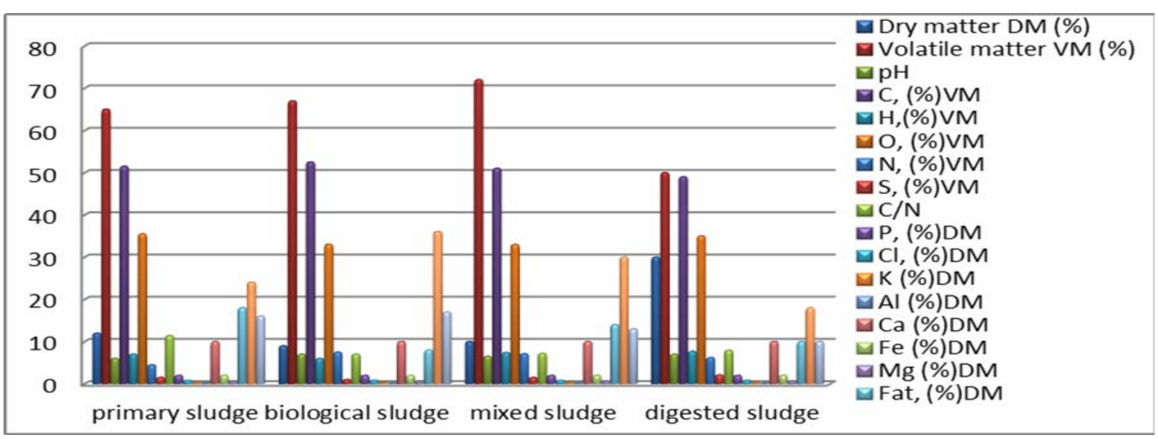

Figure 5. Typical characteristics of sludge originating from various treatment methods Manara and Zabaniotou (2012) (made by Samolada M.C and Zabanitou AA, 2014)

The calculation formula for the amount of sludge that can be used on agricultural land for 30 years is calculated in relation to the concentration of each heavy metal (I. Leonard, M. Dumitru, N. Vranceanu, D. Motelica, M.,, & V. Tanasa, 2007a) as follows:

$$\mathbf{Dn_{30} = (0.8\ C_{max\ soil} / C_{sludge}) * K} \quad (1.1)$$

where:

$\mathbf{D_{n30}}$ is the amount of sludge applicable as dry substance in 30 years in t / ha;

$\mathbf{C_{max\ soil}}$ is the allowed metal concentration in the soil in mg / kg of dry matter;

$\mathbf{C_{sludge}}$ is the existing metal concentration in the soil in mg / kg of dry matter;

K is a factor that indicates the amount of existing soil in the fertile horizon of 1ha farmland area (K=3000). This formula can help the calculation of sludge doses which can be applied as dry matter in 30 years in t/ha.

The monitoring of the used sludge quantity must be done extremely carefully throughout the sludge application. It will be taken into account the type of crop rotation and soil characteristics to avoid the risk of pollutants bioaccumulation.

Sludge fertilization positively influences certain agro-physical soil characteristics. The bulk density of the soil decreases with the accumulation of organic matter, increases the total porosity of the soil, increases the structural stability of soil aggregates, particularly by applying lime-treated sludge (Leonard et al., 2007a).

The bulk density (DA) of the soil is a very important parameter in the agrotechnical characterization of a soil, being comparable to soil texture from a pedological point of view or to chemical characteristics in terms of soil agrochemistry. (Hoban, 2008; Leonard et al., 2007a).

WEAKNESSES

The concentration of heavy metals (cadmium, nickel, zinc, lead, copper, chromium, mercury) limits the use of sludge in agriculture. This is regulated by the European Council Directive 86/278/1988 and at the national level by Order 344/2004.

After our analysis of the sludge generated by the treatment plant Bacau, Romania (Table 3) we notice the restrictiveness of Order 344/2004 on the content of heavy metals compared to the maximum allowed by the Directive 86/278/1988.

The sludge generated by the treatment plant of the city of Bacau (2013) (Table 2) shows values within limits of national and international legal norms and it can be processed for the use in agriculture.

The components specified by the Council of the European Commission in the list of toxic organic pollutants in a total of 332 substances, grouped into four levels of toxicity (Baumgarten & Spiegel, 2004; OECD, 2001) restrict the use of sludge very much.

The amount of accumulated sludge which can be applied in time is calculated according to the limits of pollutants concentration, including toxic organic substances, using the following formula (Metcalf & Eddy, 1991):

$$\mathbf{Rm = Lm / (Cm) (2000)} \quad (1.2)$$

where:

Rm= maximum amount of sludge which can be applied during the land use, expressed in tonnes of dry matter per acre (one acre=0.4047ha)

Lm= the maximum amount of pollutant which can be applied during the land use according to norms, expressed in pounds per acre (one pound= 453.59g)

Cm= percentage of pollutant contained in sludge, expressed in decimals (e.g. a content of 50ppm Cd in sludge =0.000050

2000 = pound /tonne of dry matter from the sludge (2000 pounds = 907 kg)

A major impediment in using sewage sludge in agriculture, forestry, restoration of degraded lands is the lack of technology required to ensure proper stabilization and sanitization of the sludge (composting premises, performant plants) (Akram J., Nafise N., & F., 2011; Christofoletti et al., 2012; Czechowski & Marcinkowski, 2006; D'Imporzano, Garuti, Negri, & Adani, 2014).

Tabel 2. Content of heavy metals in sewage sludge produced at Bacau, Romania treatment plant in 2013 (internal documents)

Sludge origin	Cadmium (ppm)	Copper (ppm)	Nickel (ppm)	Lead (ppm)	Zinc (ppm)	Chromium (ppm)	Cobalt (ppm)
Treatment plant at Bacau	9.8	182	86.5	10.5	1170	459	4,6
LMA (CE)	10	1000	300	750	2500	1000	-
LMA(Ro)	10	500	100	300	2000	500	50

LMA (CE) = the maximum allowed by Directive 86/278/1988;
LMA (RO)= the maximum allowed by Order 344/2004.

Sludge transportation by special equipment is another difficulty in valuing it, as this requires extra costs.

When using the sludge, it is recommended to protect water sources, by maintaining a minimum distance of 1500 m from the water abstraction points, 100 m from rivers, and the area of protection from public roads is 100 m and 500 m from the settlements (Direcția, 2012; Kelessidis A. & StasinakisA.S., 2012).

OPPORTUNITIES

The use of sewage sludge in agriculture is a multidisciplinary activity involving many partners from different fields. This way of recovering sludge meets the sustainable development criteria (Berkesy C., Berkesy L., Gavriloaie C., & M., 2009; Winker M., Vinnerås B., Muskolus A., Arnold U., & Clemens J., 2009). This favours the emergence of a sludge recovery market and requires continuous monitoring. Monitoring is done in order to prevent the damage of soil functions, the quality of the environment and human life. An agro-chemical and microbiological mapping of the soil, a physical-chemical and biological analysis of the groundwater will be done after the first year of applying the sludge, which is considered a reference year (Lixandru, 2005).

The free disposal of sludge for its use in agriculture, as well as ensuring its spreading cost in countries with a developed economy is a good opportunity to save resources (Pescod, 1992; Singh R. P. & M., 2008). The use of sludge in the recovery of degraded land (waste dumps, phosphogypsum, and oil polluted land) provides a fast restoration of their fertility through organic matter intake (Samolada M.C. & A.A, 2014; Singh R. P. & M., 2008).

THREATS

The use of sludge in agriculture exposes the indigenous microbiota of the soil, the plants and animals of that habitat and indirectly humans to pollutants.

Pathogens (bacteria, fungi, viruses, protozoa and eggs of parasitic worms) have a high risk of translocation in the trophic chain. The main bacteria which can be found in the sewage sludge are: *Salmonella, Shinella* and *Campylobacter*. Among protozoa, *Entamoeba histolytica, Giardia lambia, Balantidium coli* produce severe forms of diarrhea, and the intestinal parasites *Ascaris sp, Taenia sagitata, Trichuris trichiura* can survive in the sewage sludge for a while. Their concentration in the sewage sludge can be considered a major risk to human health (McKinley, Parzen, & Guzmán, 2012; Nordin A., Nyberg K., & B., 2009; Tedesco & Laughinghouse, 2012; Truhaut, 1977).

Pathogens limits sludge must fit into (Allievi, Colombi, Calcaterra, & Ferrari, 1994; Arthurson, 2008; Singh R. P. & M., 2008): *Coliformi fecali* - $1,5x10^6$/g sludge dry matter; *Streptococci fecali* - $1,5x10^5$/g sludge dry matter; *Salmonella sp*- absent in 0,5g sludge dry matter; Geohelminths eggs identified as viable eggs in 100g of sludge.

It is recommended that the use of the soils where sludge was applied should be carried out 18 months after its application, in order to prevent health risks. In this respect, sludge stabilization and sanitization is a prerequisite in the case of its use in agriculture. Processes that significantly reduce pathogens are: aerobic and anaerobic digestion, composting, lime stabilization and irradiation, and the processes which can reduce pathogens in time are those of inter-specific and intra-specific nature from the sludge biota (Arthurson, 2008; Sylwan, 2010; Thaddeus K. Graczyk et al., 2008; Wani S. A, Chand S, & T., 2013; Winker M. et al., 2009; Wolfe, 1992).

For example, in the case of cadmium, the zootoxic level is 1mg/kg in the plant, and the phytotoxic level starts at 8 mg / kg. Therefore, it is very important to calculate the amount of sludge which can be applied, depending on the pollutant concentration limits in sludge (Molnár & Feigl, 2013; Oros, 2012; Tedesco & Laughinghouse, 2012).

Among the heavy metals in sludge with a high level of toxicity we can mention the following in the order of decreasing toxicity: zinc, copper, nickel. For this reason the national agricultural service in England recommends users take into account the equivalent of zinc - (EZ in ppm = 1Zn+2Cu+8Ni) which should not be over 5-10% of the cation exchange capacity of the soil which was not fertilized with sludge (Baumgarten & Spiegel, 2004; Leonard et al., 2007a; Pintea, 2012).

CONCLUSIONS

This study presents the components of the SWOT analysis (strengths / weaknesses / opportunities / threats) on the use of sewage sludge in agriculture, which are listed, described and compared. The whole SWOT analysis which was undertaken in this context leads to some certainties. Thus it is revealed a vast interdisciplinary field, with real relevance for the present, but especially for the future of communities. Theoretical conclusions can and should, in their later development, become the basis of a sustainable agriculture.

The use of sewage sludge in agriculture is one of the methods of releasing them, but also a form of valuing their content of organic matter and nutrients in full agreement with the principles of sustainable development. The method of agricultural use of sewage sludge is of interest not just for farmers, but also for the producers of sewage sludge (managers of wastewater treatment plants), transporters (in charge with the spreading technique and incorporation of sewage sludge into the soil) and final beneficiaries (consumers of food products). The application of inadequate doses of sludge results in their transfer to plants, thus exceeding the zootoxic level, without the plants showing obvious symptoms.

After this SWOT analysis and considering the current legislation on the use of sludge in agriculture, it is recommended that all the general and particular aspects mentioned above should be taken into consideration.

* This article was presented to IJAS International Multidisciplinary Conference Malta 2014 by poster. I thank the organizers of that conference for the occasion and the participants for comments on the poster presentation.

ABSTRACT

The use of sewage sludge in agriculture is an efficient method from the economic point of view and is also sustainable from an ecologic perspective. However, intense debates on this topic occur nowadays because of the possible damage on population, flora and fauna. The aim of this paper is to highlight the use context of sewage sludge in agriculture reported to European Union countries. As main strong points, we identified certain beneficial impact on the biological, physical and chemical characteristics of soil, due to soil nutrients that are taken from the organic components of the waste. The economic costs are also reduced by replacing chemical fertilizers. But, low levels of investment and the limited capacity of the local authorities contributes to the use of the sewage sludge in agriculture on a reduced scale. The existing legislation that facilitates the development of viable markets for the processed sewage sludge is an opportunity. The risk of accumulation of pollutants in soil (heavy metals, organic pollutants, and pathogens) and their bioaccumulation in various trophic levels is obviously a reality. According to the results of the Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis a detailed matrix based on row data was realized. From the literature review, we noted an increased number of risks presented especially in recent years. Based on the conducted studies we suggest that all responsible factors should pay an increased attention to the use of sludge in agriculture.

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