Polish Journal of Environmental Studies Vol. 13, No. 2 (2004), 237-244

Letter to Editor

Risk Analysis of Sewage Sludge - Poland and EU Comparative Approach

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Received: 5 May, 2003
Accepted 19 August, 2003

Abstract

This paper presents a comprehensive and systematic approach to sewage sludge management in both Polish and European Union (EU) legislative systems. It starts with risk, which can be caused by sewage sludge mismanagement. Also, technical aspects and boundaries of utilization and recycling routes are presented. A comparison of national and EU legislation is also presented. The next part is devoted to sewage sludge production, distribution and utilization in Poland. Finally, the influence of sewage sludge treatment and utilization on health and environmental risk in Poland are presented.

Keywords: sewage sludge, environmental risk, health risk, recycling, utilization

Risk Exposure Caused by Sewage Sludge. Utilization and Recycling Routes [1]

Growing interest in sewage sludge management has been accelerated by public interest in the agricultural use of sludge. Since 1995 protection against Genetically Modified Organisms (GMO), dioxins, and Bovine Spongiform Encephalopathy (BSE) have attracted public attention to the issue of food production safety with a focus on minimizing human exposure to such risks.

Sludge is a by-product of the water treatment process. Three main categories of sludge can be distinguished:
- sludge originating from the treatment of urban waste water, consisting of domestic waste water or in a mixture with industrial waste water and run-off rain water,
- sludge originating from the treatment of industrial waste water,
- sludge from drinking water treatment.

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Sludge is composed of by-products collected at different stages of the wastewater treatment process. It contains compounds of agricultural value (including organic matter, nitrogen, phosphorus and potassium, and to a lesser extent calcium, sulphur, magnesium), and pollutants, which usually include heavy metals, organic pollutants and pathogens. Characteristics of sludge depend on the original pollution load on the treated water, and also on the technical parameters of the waste water and sludge treatment process. Sludge is usually treated, before disposal or recycling, in order to reduce its water content, its fermentation propensity or the presence of pathogens. Several different treatment processes can be employed at the processing stage i.e. thickening, dewatering, stabilisation, disinfection, and thermal drying. After treatment, sludge can be recycled or disposed of using the following approaches: recycling for agriculture (landspreading), incineration, landfilling, silviculture, land reclamation, wet oxidation, pyrolysis and gasification.

Landspreading

Sludge or sludge-derived material can be used as a replacement for conventional fertilizers in agriculture. During the composting process vegetable co-products are added to sludge, which change it into a stable organic matter. Landspreading, however, involves transfer of pollutants from the sludge to the soil, and then into the air and water. This may introduce contamination into the food chain.

Incineration

Incineration is a combustion process that may be performed in different ways. Mono-incineration technique when sludge is incinerated in dedicated plants, incineration of sewage sludge with other wastes or co-incineration when sludge is used as a fuel in energy or material production. Pyrolisis and oxidation are also techniques worth mentioning. Sludge incineration generates emissions of greenhouse gases, particles, acid gases, heavy metals, volatile organic compounds into the air. Similarly, soil can be contaminated with ashes and flue gas treatment residues, water can be contaminated with products from the flue gas wet treatment process. Emission levels and harmfulness depend on the incineration process used and on sludge characteristics. The energy required for the sludge drying process is usually lower then the energy produced in the combustion process of the sludge. The incineration process may additionally produce noise, dust, odour and visual pollution.

Landfilling

Sludge can be landfilled as mono-deposit when only sludge is disposed and as a mixed-deposit when sludge is disposed of with municipal waste. Mixed-deposits are more commonly observed. Landfilling requires the use of additional materials when leachate is treated on-site. Landfilling operations generate greenhouse gases such as carbon dioxide and methane, the amount of which can be reduced in the case of bio-gas collection and combustion. Soil and water in the neighbourhood of the dumpsite could be contaminated by ions, heavy metals, organic compounds and micro-organisms present in leachate. Other environmental impacts generated by the landfills are noise, dust, odours, land use, disturbance of vegetation and landscape.

Forestry and Silviculture

Forestry refers to amenity forests and mature forest exploitation. On the contrary, silviculture refers rather to intensive forest production. Sludge in these areas can increase tree growth and provide nutrients to the soil. Excessive use of sludge may lead to degradation of the upper layer of the soil and the humus, as well as nitrogen leaching by groundwater. Use of sludge in mature forest, when no additional nutrients are required, may interfere with the natural biotopes. Health endangerment in consequence of spreading heavy metals across forestry and silvicultre is lower than across agriculture because of the small percentage of forest product in the human diet.

Land Reclamation and Vegetation

Sewage sludge may be used to restore derelict land or protect soil from erosion through soil provision and increased vegetable covering. At industrial sites topsoil is often absent or damaged. Soil can be deficient in nutrients and organic matter, as well as intoxicated or have adverse pH levels. All the factors described create a hostile environment for the development of vegetation. Instead of using inorganic fertilizers or imported topsoil, organic wastes like sewage sludge can be used. The use of sludge in agriculture is presumed to be less dangerous then in food production.

Developing Technologies

Several new technology alternatives considering combustion are under development or have been already introduced onto the market. These technologies include wet oxidation, pyrolisis and the gasification process. Among others it is worth mentioning RCP 200 (MIRO) method of metals recovery from sewage sludge. Especially interesting is the method of dewatering and biodegradation of chemical industry originated sludge [2], by employing crops. Other technologies, which may be a combination of the processes described above, are often found.

Comparative Survey of EU and Polish Legal Regulations [3]

The European Commission Directives regulating sludge materials are translated into national legislations by Member states and accession countries. The most relevant Directives for sludge management are:

- Council Directive 86/278/EEC on protection of the environment refers, in particular, to the soil when sewage sludge is used in agriculture. Minimum quality standards for the soil and sludge, and also monitoring requirements are specified in that Directive. It also contains limits for heavy metals concentration in sewage sludge as well as in soil when sewage is used on land, and the maximum annual heavy metals load through the application of sewage sludge.
- The Waste Framework Directive (91/156/EEC amending 75/442/EEC on waste) defines the waste management hierarchy, according to which preferences are given to prevention from waste followed by waste reduction, re-use, recycling, energy recovery. Principles of the use and disposal of waste, waste management plans, approval procedures, and monitoring, are also mentioned in this Directive. Also “waste” definition, a list of different types of waste, is provided by Commission Decision 2001/118/EEC.

Table 1. Limit of heavy metals value in sludge [mg/kg DM] (shaded cells represent limit values below those required in Directive 86/278/EEC) [3].

	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As	Mo	Co
Directive 86/278/EEC	20-40	-	1,000-1,750	16-25	300-400	750-1,200	2,500-4,000	-	-	-
Austria	2a	50a	300a	2a	25a	100a	1,500a			10a
	10b	500b	500b	10b	100b	400b	2,000b			
	10c	500c	500c	10c	100c	500c	2,000c			
	4d	300d	500d	4d	100d	150d	1,800d			
	10e	500e	500e	10e	100e	500e	2,000e	20e	20e	100e
	0.7-2.5f	7-300f	70-300f	0.4-2f	25-80f	145-150f	200-1,800f			
Belgium (Flanders)	6	250	375f	5	100	300	900f	150	-	-
Belgium (Walloon)	10	500	600	10	100	500	2,000		-	-
Denmark										
- dry matter basis	0.8	100	1,000	0.8	30	120g	4,000	25 h		
- total phosphorus basis	100			200	2,500	10,000g			-	-
Finland	3	300	600	2	100	150	1,500	-	-	-
	1.5i			1 l		1.00 l				
France	20j	1,000	1,000	10	200	800	3,000	-	-	-
Germany	10	900	800	8	200	900	2,500	-	-	-
Greece	20-40	500	1,000-1,750	16-25	300-400	750-1,200	2,500-4,000	-	-	-
Ireland	20	-	1,000	16	300	750	2,500	-	-	-
Italy	20	-	1,000	10	300	750	2,500	-	-	-
Luxembourg	20-40	1,000-1,750	1,000-1,750	16-25	300-400	750-1,200	2,500-4,000	-	-	-
Netherlands	1.25	75	75	0.75	30	100	300	-	-	-
Portugal	20	1,000	1,000	16	300	750	2,500	-	-	-
Spain										
- soil pH < 7	20	1,000	1,000	16	300	750	2,500	-	-	-
- soil pH > 7	40	1,750	1,750	25	400	1,200	4,000	-	-	-
Sweden	2	100	600	2.5	50	100	800	-	-	-
UK	-	-	-	-	-	-	-	-	-	-
Accession countries										
Estonia	15	1,200	800	16	400	900	2,900	-	-	-
Latvia	20	2,000	1,000	16	300	750	2,500	-	-	-
Poland	10	500	800	5	100	500	2,500	-	-	-

a - Lower Austria (grade II)
b - Upper Austria
c - Burgenland
d - Vorarlberg
e - Steiermark
f - Carinthia

f - These values are reduced to 125 (Cu) and 300 (Zn) from 31/12/2007
g - For private gardening lead value is reduced to 60 mg/kg DM or 5,000 mg/kg P
h - For private gardening
i - Target limit values for 1998
j - 15 mg/kg DM from January1, 2001 and 10 mg/kg DM from January1, 2004

Table 2. Estimated reduction of total nitrogen and potassium discharges [thousands tons / %] [4].

Country	N-reduction		P-reduction	
	thousands tons /year	%	thousands tons /year	%
Cyprus	n.a.	n.a.	n.a.	n.a.
Czech Republic	9.4	33%	2.4	42%
Estonia	2.8	57%	0.15	37%
Hungary	19.3	53%	3.7	57%
Latvia	3.9	63%	0.7	68%
Lithuania	5.5	49%	1.1	54%
Malta	0.4	49%	0.1	56%
Poland	83.2	67%	12.4	71%
Slovakia	6.4	41%	1.4	47%
Slovenia	2.2	37%	0.4	38%

- The Council Directive of 21 May 1991 concerning urban wastewater treatment (91/227/EEC) known also as The Urban Wastewater Treatment Directive, protects the environment from the adverse effects of wastewater discharge. The Directive sets minimum sewage treatment standards to be achieved by the end of 2005.
- The Council Directive 91/679/EEC of 12 December 1991, concerning prevention of water from pollution caused by nitrates from agricultural sources, is known as the nitrates Directive.

The Sewage sludge problem is regulated in the followings Polish acts:

- The Waste Act of 27 April 2001 (Ustawa o odpadach), which denotes sewage sludge as a waste and allows for application of waste regulations to the sewage sludge.
- Introduction to the Environmental Protection Act, Waste Act, and amendments in some Acts of 27 July 2001 (Wprowadzenie ustawy - Prawo ochrony środowiska, ustawy o odpadach oraz zmiana niektórych ustaw), which regulate sewage sludge utilization routes.
- Environmental fine imposed by Ordinance of the Cabinet of 9 October 2001 (Rozporządzenie Rady Ministrów w sprawie opłat za korzystanie ze środowiska), which specifies fees for dumping sewage sludge into the environment from different sources.
- Waste landfilling fees imposed by Ordinance of the Cabinet of 22 December 2002 (Rozporządzenie Rady Ministrów w sprawie opłat za składowanie odpadów) determines fees for landfilling waste, including sewage sludge with different contents and/or origins.

Comparison of heavy metal limits between Polish regulations and EU Directive 86/278/EEC reveals that for six out of the seven elements, the Polish norm is more restricted than the European standard norm. According to Polish regulations the maximum amount of cadmium which can be found in milligrams per kilogram of dry matter (DM), is 10 compared with 20-40 mg/kg DM. Similarly, Polish regulations set the maximum amount of chromium in sludge at 500 mg/kg of DM, whereas the EU does not specify any limit at all. The directive described above limits the maximum amount of copper within the range between 1,000-1,750 mg/kg of DM, whereas in Poland the maximum value cannot be higher than 800 mg/kg of DM. According to the EU, limits for mercury are between 16 and 25 mg/kg DM, while in Poland they cannot be higher than 5 mg/kg of DM. Nickel contents in sewage sludge dry matter cannot be higher than 300-400 mg/kg in the UE, while in Poland it can not be higher than 100 mg/kg DM. It should be also mentioned that lead limit, according to EU regulations of 750-1,200 mg/kg DM, is significantly higher than the Polish limit of 500 mg/kg DM. Zinc limit in Poland is equal to the lower limit of EU regulation, which is 2,500-4,000 mg/kg DM.

It is estimated that only as an effect of introduction of Urban Wastewater Directive (91/227/EEC) in candidate countries should it bring significant reduction of total nitrogen and potassium discharges. Anticipated amounts of N and P total reduction are shown in Table 2. The most significant reduction in nitrogen discharges is to be reached in Poland (67%), Latvia (63%) and Estonia (57%). The biggest reduction in potassium reduction is to be reached in Poland (71%), Latvia (68%) and Hungary (57%).

Production, Utilization and Distribution of Sewage Sludge in Poland

In 1997, sewage sludge production in Poland was 1,395 thousands tons of dry matter (DM). That makes Poland a significant contributor to European producers of sewage sludge. Germany produces approximately 4 times more sewage sludge than Poland, which makes it the biggest European producer. Italy is second with 3,400 thousands tons of DM. The fifth European producer, with 1,000 thousands tons of DM, is Great Britain. The major

Table 3. Sewage sludge production in European countries (thousands tons of dry matter) [5].

Country	Year (Last available)	Sewage sludge production (thousands of tons)	Citizens (millions)	Sewage sludge production (kilos/per capita)
Austria	1996/1997	309	8	41
Belgium	1995	88	10	9
Denmark	1997	162	5	31
France	1995	900	57	16
Germany	1993	4,921	81	61
Greece	1997	59	10	6
Ireland	1995	29	4	8
Italy	1991	3,400	57	60
Luxembourg	1997	8	0,4	20
Netherlands	1996	600	15	40
Poland	1997	1,397	38	37
Portugal	1994	8	10	1
Spain	1994	404	39	10
Sweden	1994	230	9	26
Great Britain	1996	1,000	58	17

producers with an output greater than 500 thousands tons of DM are presented in Fig 1. A better way of comparison is production per capita shown in Table 3. In that category leading countries are: Germany with 61 kg/capita, Italy with 60 kg/capita and Austria with 41 kg/capita. Other significant producers are the Netherlands (40 kg/capita), Poland (37 kg/capita) and Sweden with 26 kg/capita.

Data concerning sewage sludge in Poland are fragmentary, making it impossible to show the full picture in the matter. However, a few tendencies can be observed from Table 4, including that total production of municipal sewage sludge rose from 340,040 tons of DM in 1998 to 397,216 tons of DM in 2001. In the same time municipal sewage sludge landfilled and stored in areas of sewage treatment plants dropped from 1,156,955 to 728,897 tons of DM. The amount of landfilled municipal sewage sludge first dropped from 191,606 to 151,618 tons of DM in the years 1998-2000, and rose in 2001 to 198,630 tons of DM. Industrial usage, described in the category of sewage sludge, first rose from 19,815 to 28,274 tons of DM (1998-2000), and then fell to 24,220 tons of DM in 2001. Drop in incineration of municipal sewage sludge was observed between 1998 and 2001. The tendency reversed in 2001, and 6,937 tons of DM has been incinerated. From 2000-2001 the amount of composted sewage sludge rose from 25,528 to 27,591 tons of DM. Usage in agriculture fell from 50,628 to 49,302 tons of DM. Other usage dropped from 97,867 to 90,536 tons of DM. According to the Polish Ministry of the Environment, the total amount of produced sewage sludge is estimated to double in 2015.

Table 5 shows distribution of industrial sewage sludge in Poland. Production of industrial sewage sludge dropped from 942,251 in 1998 to 649,625 tons of DM in 2001. At the same time industrial sewage sludge landfilled and stored in areas of sewage treatment plants dropped from 22,657,919 to 10,931,854 tons of DM. Similarly, a drop in landfilled sewage sludge was also noticed. Between 1998 and 2001 it decreased from 511,425 to 276,740 tons of DM. Industrial usage dropped from 196,245 in 1998 to 115,503 tons of DM in 2001. The amount of incinerated industrial sewage sludge rose from 26,992 to 39,637 tons of DM between the years 1998-2001. 2,213 tons of DM were composted and 113,261 tons were used in agriculture in 2001.

Table 6 depicts total (industrial and municipal) sewage sludge distribution in Poland during 1997-2001. Between 1998-2001 sludge production in Poland dropped from 1,282,291 to 1,046,841 tons of DM. At the same

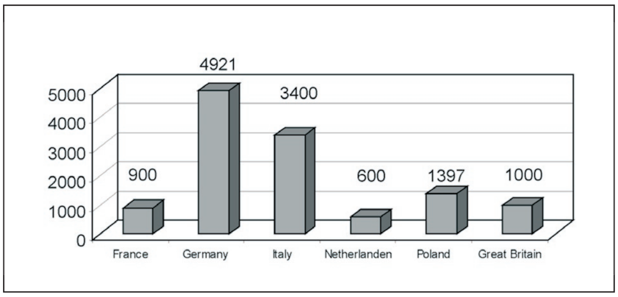

Fig 1. Sewage sludge production in selected European countries [5].

Table 4. Municipal sewage sludge distribution in Poland (tons of dry matter, DM) [6].

Year	Total	Utilized	Economically utilized	Neutralized	Landfilled	Industrial usage	Non-industrial usage	Incinerated	Composted	Agriculture usage	Other usage	Landfilled and stored	Usage of previously landfilled and stored sewage sludge
1997	3,359,842	903,189	204,441	272,406	2,184,248							1,229,363*	
1998	340,040				191,606	19,815	114,230	14,389				1,156,955*	
1999	354,400				204,432	21,273	123,807	4,888				1,191,782*	97,016
2000	359,819				151,618	28,274		5,904	25,528	50,628	97,867	675,011	105,906
2001	397,216				198,630	24,220		6,937	27,591	49,302	90,536	728,897	56,802

*Except "Landfilled and stored" field, data in *marked row in tons of wet matter

Table 5. Industrial sewage sludge distribution in Poland (tons of dry matter, DM) [6].

Year	Total	Economically utilized	Neutralized	Landfilled	Industrial usage	Non-industrial usage	Incinerated	Composted	Agriculture usage	Landfilled and stored
1997	3,259,322	1,353,640	135,580	1,770,102					249,660	22,780,024*
1998	942,251			511,425	196,245	207,589	26,992			22,657,919*
1999	1,014,054			617,398	164,820	204,782	27,054			18,358,739*
2000	703,258			322,905	126,630		28,196	2,532	161,630	13,978,705
2001	649,625			276,740	115,503		39,637	2,213	113,261	10,931,854

*Except "Landfilled and stored" field, data in *marked row in tons of wet matter

Table 6. Total sewage sludge distribution in Poland (tons of dry matter, DM) [6].

Year	Total	Utilized	Economically utilized	Neutralized	Landfilled	Industrial usage	Non-industrial usage	Incinerated	Composted	Agriculture usage	Other Usage	Landfilled and stored	Usage of previously landfilled and stored sewage sludge
1997	6,619,164	903,189	1,558,081	407,986	3,954,350					249,660		24,009,387*	
1998	1,282,291				703,031	216,060	321,819	41,381				23,814,874*	
1999	1,368,454				821,830	186,093	328,589	31,942				19,550,521*	97,016
2000	1,063,077				474,523	154,904		34,100	28,060	212,258	97,867	14,653,716	105,906
2001	1,046,841				475,370	139,723		46,574	29,804	162,563	90,536	11,660,751	56,802

*Except "Landfilled and stored" field, data in *marked row in tons of wet matter

time, sewage sludge landfilled and stored in the area of sewage treatment plants dropped from 23,814,874 to 11,660,751 tons of DM. The amount of landfilled sewage sludge dropped from 703,031 in 1998 to 475,370 tons DM in 2001. Similarly, industrial usage decreased from 216,060 to 139,723 tons of DM. A rise in incineration was observed from 41,381 in 1998 to 46,574 tons of DM in 2001. On the other hand, 29,804 tons DM of sewage sludge was composted and 162,563 tons of DM was used in agriculture in 2001. 90,536 tons of DM of sewage sludge were treated using methods not mentioned above.

Health and Environmental Risk Reduction in Poland Due to Sewage Sludge Treatment and Safe Utilisation

Poland, after accession to the European Community, will be obliged to meet criteria specified in EC legal requirements within 8-13 years. For example, in member states since 2005 sewage sludge with organic matter cannot be landfilled. Polish sewage sludge regulations met current EU requirements, and would meet 6 of 8 heavy metals limits, listed in prognosis introduced by a new directive by 2015 [7]. With strict legal regulations more important is to improve procedures, and practices in order to ensure safe and effective utilization and distribution routes of sewage sludge. The main, goals especially concerning municipal sewage sludge outlined by Polish Ministry of Environment, are [8]:

- increase in efforts of to gain better control of sewage sludge utilization and distribution, in order to minimise health and environmental risks,
- increase in the amount of treated sewage sludge,
- maximize of use of sewage sludge bio-genes substances, with special attention to chemical and health safety.

As mentioned previously, the amount of municipal sewage sludge produced will be doubled by 2015. So it is extremely important to develop strategies to limit the amount of landfilled sewage sludge. The Ministry of the Environment predicts that sewage sludge will be more often used in land reclamation and vegetation within the program of reclamation of post-industrial areas. Due to high potential health and environmental risks generated by sewage sludge, it will be mainly landfilled. Based on this estimation, the amount of landfilled municipal sewage sludge will rise from 42.12% to 45% in 2010 and finally will reach 39% in 2015. Proportion of incineration treatment of sewage sludge should rise from 1.6% in 2001, through 5% in 2010 to 8% in 2015. That planning, however, is limited by new investments in incineration plants.

Composting is a preferable method of sewage sludge utilization. Unfortunately, it may be treated more like an intermediate stage in sewage sludge utilization. That is caused by serious doubts about sanitary and health qualities of composting product, although treated in that way sewage sludge could be mixed with soil and/or different wastes. Treated in that way sewage sludge could be used in the process of building municipal parks and green areas. Prepared sewage sludge could be used in land reclamation and landfilled areas reclamation. It is estimated that 20% of municipal sewage sludge could be composted; however, this requires building sufficient amount of composting plants.

Another preferable route of utilization of sewage sludge will be landspreading. The introduction of more effective and safer regulations will limit the increase of landspreaded sewage sludge. In 2015 about 26% of sewage sludge will be neutralized in this way. Sewage sludge usage as fertilizers will reach 46%, including composted sludge.

Summary and Investment Opportunities

Only a limited part of total sewage sludge production of Poland is subject to treatment. Not many sewage treatment plants in Poland have introduced methods of sewage sludge utilization. That will change because of the possibility to gain co-founding of such projects from The National Fund for Environmental Protection and Water Management. That fact, with legislative pressure, should accelerate processes of treatment and utilization of sewage sludge in Poland. Due to health risks highlighted by Genetically Modified Organisms (GMO), dioxins, and Bovine Spongiform Encephalopathy (BSE) issues, attention will be given to safe use of sewage sludge.

European experience with sewage sludge treatment could be applied for developing incineration and composting plants. A stable policy on helping such activities in Poland, supported by European and Polish funding, should have significant impact of the amount on safely treated and used sewage sludge.

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