ENVIRONMENTAL RISK FROM WASTE DISPOSAL FACILITIES LOCATED IN THE BELARUSIAN PART OF THE ZAPADNAYA DVINA RIVER BASIN

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Abstract

Municipal solid waste and obsolete pesticides landfills are significant potential source of environmental pollution due to concentration of toxic substances and biochemical reactions going on within the stockpile of waste after its deposition. The territory under consideration is the Vitebsk region of the Republic of Belarus which is almost completely situated within the borders of Western Dvina river Basin. Active municipal solid waste landfills were built during last 50 years and significantly differ in their ability to prevent pollution. More than a half of the municipal solid waste landfills have reached the limits of their capacity and need to be closed and replaced by the new ones. Obsolete pesticides landfills should be eradicated to implement the provisions of the Stockholm Convention on Persistent Organic Pollutants.

Key words: *waste, landfill, ground water, pollution, Vitebsk region*

INTRODUCTION

Economic activity involves production, distribution, and consumption of goods. One of the side effects of such activity is waste generation. Currently in the Republic of Belarus no more than 10% of the total volume of municipal solid waste (MSW) is processed, and about 90% is disposed of in landfills [1]. MSW generation increased from 291 kg per person in 2005 to 451 kg per person in 2015 [2]. It can be suggested that landfilling will continue to be the main method of MSW disposal in the nearest future in the Republic of Belarus. In addition, the Republic of Belarus inherited seven landfills of obsolete pesticides (OP) which represents Persistent Organic Pollutants built in the 1970-1980s. Three OP landfills with at least 1,000 tons of pesticides and 26 MSW landfills, which receive over 2 million cubic meters of MSW annually, are located within the Vitebsk region which is almost entirely within the borders of the Belarusian part of Western Dvina River Basin (WDB) (Fig. 1).

Landfills in the WDB do not always prevent contamination of groundwater and surface waters with produced leachate. There were recorded cases when concentrations of toxic chemicals in the groundwater exceeded permitted hygienic level both at MSW and OP landfills. Pollution of the environment and drinking water supplies in particular can cause adverse health effects. Such risk is significantly higher at the landfills located on the poorly protected aquifers and groundwater level close to the surface. In addition, during flood periods, pollutants from landfills with river runoff can potentially reach Western Dvina River and the Baltic Sea. Therefore, all this is of particular concern because of the potential transboundary impact of the buried waste on the state of the environment of the EU neighboring countries.

RESEARCH METHODOLOGY

The impact of MSW and OP landfills on the environment was assessed using traditional methods of environmental studies. The study included preparatory stage, field work and data analysis. The preparatory stage included: collection of the available screening data on groundwater, surface water, soil; the volume of landfilled MSW and OP; geological and hydrogeological conditions of the area (aquifer properties); existing isolation from the rain and meltwater to prevent leachate production, the state of engineering systems for collecting and withdrawing the leachate.

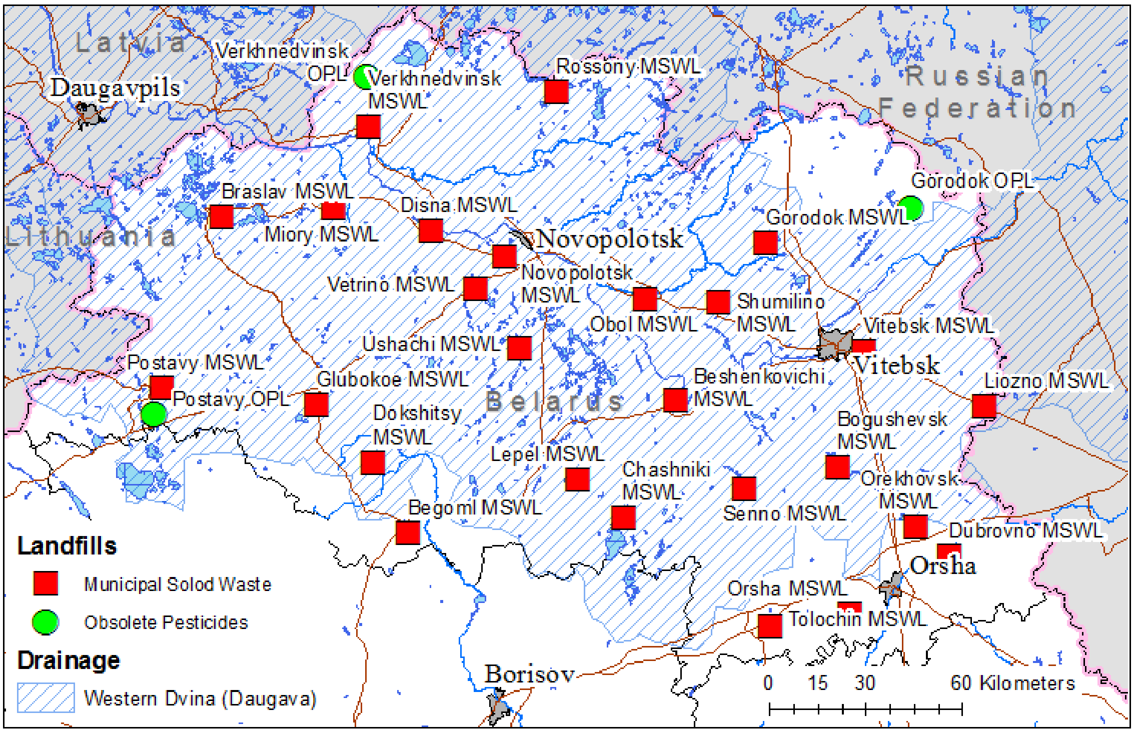

Figure 1. Municipal solid waste (MSWL) and obsolete pesticides (OPL) landfills

The fieldwork included sampling of surface and groundwater at the landfills as well as soil and bottom sediments of water bodies in the landfills proximity. Landfills were also inspected to verify their compliance with the national regulatory requirements of the Republic of Belarus and the implementation of measures aimed at prevention of environmental pollution.

Analytical study included chemical analysis of collected samples of surface and ground water, soil as well as analysis of data collected during the previous field researches by the authors in 2004-2016, data collected within the framework of the National Environmental Monitoring System in the Republic of Belarus, some of which are presented in the Annual reviews [3].

An expert assessment of environmental risks associated with landfills was carried out. Environmental risks were understood as the likelihood of negative changes in the environment and the long-term adverse effects of these changes arising from pollution.

Assessment of groundwater pollution from the landfills included a comparison of the concentration of pollutants in the monitoring wells up and down the regional groundwater flow relative to the landfill site, as well as national hygienic requirements for drinking water. Along with the assessment of environmental risks, measures were proposed to minimize their negative impact on the environment and public health.

Pollution Load Index (PLI) for eight pollutants (Ammonia nitrogen, Nitrate nitrogen, Iron, Copper, Salinity, Oil products, Surfactants, Zinc) was calculated to measure actual level of groundwater pollution by the landfills in Vitebsk region. PLI was calculated according to [4] for each MSW landfill as follows:

$$CF = \frac{C_{pollutant}}{C_{background\ value}};\ PLI = \sqrt[n]{CF_1 \times CF_2 \times \ldots \times CF_n}$$

Where $C_{pollutant}$ – is the concentration of a pollutant in the most contaminated observation well, $C_{background\ value}$ – concentration of the same pollutant in the uncontaminated well up the local stream of groundwater.

Table 1. Characteristics of municipal solid waste landfills of Vitebsk region

	Name (according to the nearest town, city)	Area occupied by waste, ha	Annual volume of MSW, 1000 tons	Active since	Environmental protection facilities	Max GWL*, m	PLI*
1.	Begoml MSWL*	1,5	2	1991	-	10	1,15
2.	Beshenkovichi MSWL	2,5	3	1997	Clay liner, earth embankment	3	2,34
3.	Bogushevsk MSWL	1,0	1	1974	-	1	DNA*
4.	Braslav MSWL	1,5	3	1994	-	20	1,00
5.	Chashniki MSWL	6,5	11	1995	Clay liner, earth embankment	2	1,13
6.	Disna MSWL	1,5	1	1992	Earth embankment	1	DNA
7.	Dokshitsy MSWL	1,5	9	1995	Earth embankment, drain	10	1,20
8.	Dubrovno MSWL	3,5	11	1993	Earth embankment, drain	12	2,20
9.	Glubokoe MSWL	3,0	10	1979	-	2	1,11
10.	Gorodok MSWL	4,5	4	1975	-	10	1,35
11.	Lepel MSWL	2,5	10	1981	Earth embankment, drain	3	2,49
12.	Liozno MSWL	3,0	18	1988	Earth embankment	1	1,08
13.	Miory MSWL	2,5	6	1991	-	5	1,08
14.	Novopolotsk MSWL	6,5	80	1989	Bituminous geomembrane, earth embankment, drain	1	8,11
15.	Obol MSWL	1,0	<1	1997	Drain	2	1,14
16.	Orekhovsk MSWL	1,5	2	>2003	-	10	1,17
17.	Orsha MSWL	8,0	100	1981	-	40	1,27
18.	Postavy MSWL	4,0	5	1977	Earth embankment, drain	3	3,48
19.	Rossony MSWL	1,0	3	1994	-	2	1,08
20.	Senno MSWL	2,5	4	1972	-	15	1,26
21.	Shumilino MSWL	2,0	<1	1967	-	5	1,01
22.	Tolochin MSWL	1,5	2	2002	Clay liner, earth embankment	18	1,02
23.	Ushachi MSWL	1,5	3	1998	-	5	1,18
24.	Verkhnedvinsk MSWL	2,5	5	1975	Earth embankment, drain	2	1,18
25.	Vetrino MSWL	1,0	15	1974	-	10	1,34
26.	Vitebsk MSWL	2,5	264	1975	Earth embankment	1	1,46

*MSWL – Municipal Solid Waste Landfill, GWL – ground water level, PLI – Pollution Load Index, DNA – Data not available

HISTORICAL ASPECT

Originally in the territory of the USSR, waste was stored without any technology. The first improved landfills appeared in the late 1960s in Rostov-on-Don, Russia. They differed from the usual landfills of that time in that how records were kept for the received solid municipal waste, that the waste was leveled, consolidated and layered with soil. However, no measures to protect groundwater from leachate contamination has been undertaken [5].

Almost half of currently operating MSW landfills in the Republic of Belarus were built without any prior planning. These are primarily MSW landfills, which were opened prior to the adoption of the Sanitary Regulations for design and management of MSW landfills of 1983. This document was developed on the basis of advanced experience in the USSR and became an important milestone in improving the regulation of waste management. It was replaced in the Republic of Belarus only in 2006 by the new Sanitary Regulations.

Despite the fact that the Sanitary Rules of 1983 recommended to design MSW landfills on the territories composed of clays or heavy loam and where groundwater is at a depth of more than 2 meters, a number of MSW landfills in the Republic of Belarus were built on sites with unfavorable geological conditions even after 1983. In these cases, the choice of the location of the proposed MSW landfill site was obviously carried out without proper preliminary study of the territory.

More than half of the MSW landfills in Belarus were built in quarries, which was previously considered one of the most effective ways of their reclamation. However, the bottom of quarries in most cases is composed of sands and sandy loams that do not protect groundwater from pollution.

FINDINGS

Waste composition. Waste is heterogeneous in composition, hazard classes, physical and chemical properties. Under the influence of elements of nature and interaction with each other, waste in landfills undergo complex changes. MSW in the Republic of Belarus has the following typical composition (Fig. 2).

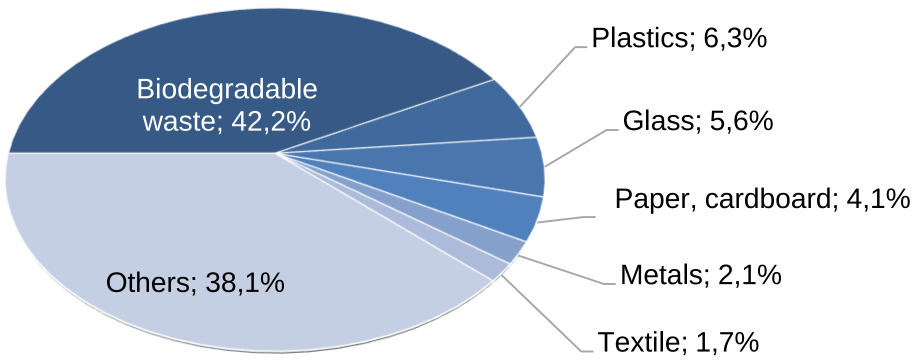

Figure 2. Composition of the Municipal Solid Waste in the Republic of Belarus [6]

Composition of obsolete pesticides formally known only for the Verkhnedvinsk OPL. Information about the other two OPLs in Vitebsk region is absent (presumably lost). Among the identified pesticides at Verkhnedvinsk OPL, those classified as persistent organic pollutants constitute approximately 8% by weight – DDT (7.1 tons), Heptachlor (0.14 tons) and partially HCH (15.3 tons).

MSW landfills. Groundwater is the most affected medium by the pollution, in particular with nitrogen compounds, oil products, heavy metals. The maximum concentration of oil products was recorded at the level of 11 times more than the national Maximum Permissible Concentration (MPC), ammonium nitrogen – 87 times MPC, nitrate nitrogen – 35 times MPC, lead – 17 times MPC, copper – 12 times MPC. According to our data for the period 2005-2016, groundwater pollution from the landfills was significant.

Calculated PLI value is maximum for the Novopolotsk MSW landfill (Fig. 3). The reason for this is a combination of one or several factors, among them: a) possible breach of the geomembrane tightness, b) unfavorable engineering and geological conditions, as well as the c) infiltration of leachate directly into the ditch, because the earthen shaft, which is supposed to prevent spreading of the leachate beyond the landfill, almost completely covered with waste.

PLI value exceed 2.0 at three other MSW landfills from 24 for which data are available: Postavy, Dubrovno, Beshenkovichi and Lepel MSWLs. We did not manage to find any factor (group of factors) common for all these MSW landfills with high PLI. Neither size nor presence of geomenbrane (clay liner) or any other characteristics allow to predict the level of pollution by a landfill. This suggests that the performance of a landfill as a facility isolating waste and its products of decomposition from the environment depends on a group of factors including the quality of construction works.

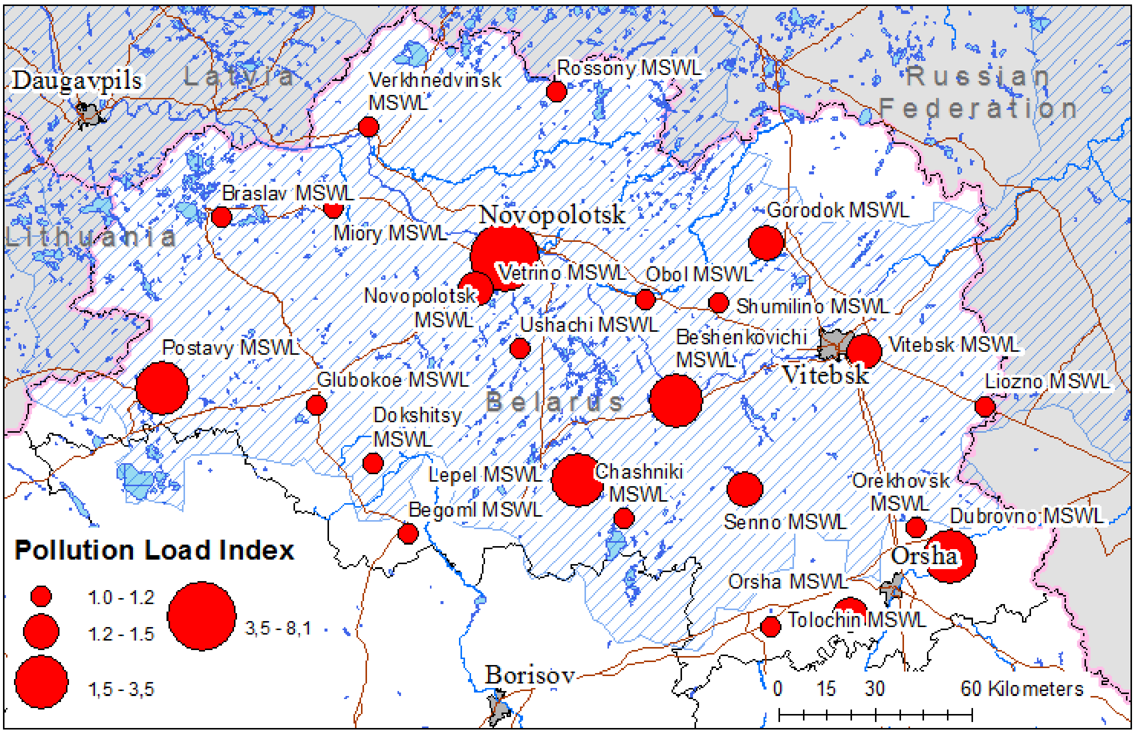

Figure 3. Pollution Load Index of MSW landfills

To investigate the groupings of factors influencing the magnitude and the pattern of groundwater pollution, we conducted a factor analysis of all available data on chemical pollution of groundwater and properties of MSWLs. Rotated Component Matrix for factor analysis is presented in Table 2. The number of components was limited to four after a series of test runs of factor analysis.

Table 2. Groupings of factors influencing groundwater pollution the MSW landfills*

	Component			
	1	2	3	4
Salinity of Groundwater	.916			
Concentration of Iron	.861			
Concentration of Sulfates	.824			
Concentration of Chlorides	.650			-.336
Concentration of Nitrate Nitrogen	.600			
Level of Aquifer Protection from Pollution	-.600		-.396	
pH of Groundwater	.554			
Concentration of Ammonia Nitrogen	.551		-.326	
Concentration of Chromium	.516			
Concentration of Oil Products	.410			
Concentration of Phenols		.956		
Concentration of Zinc		.912		
Annual Volume of Waste		.879		.365
Concentration of Surfactants	.413	.670		
Concentration of Lead		-.363		
Presence of a Construction Plan			.784	
Year of Construction			.766	
Land Cover of the Adjacent Territory			.712	
Particle Size of Local Sediments			-.629	
Presence of a Liner (Geomembrane)			.547	-.396
Total Accumulated Volume of Waste				.830
Maximum Groundwater Level	-.345			.728
Area Occupied by Waste	.457			.656
Layer of Accumulated Waste Thickness		.520		.569
Concentration of Phosphorous (total)			-.352	.462
Concentration of Copper				-.374

*Extraction Method: Principal Component Analysis. Rotation Method: Quartimax with Kaiser Normalization. Loads less than .300 are hidden.

Extracted components can be explained by grouping of landfill properties and chemical pollution as the following:

- Factor 1: Landfills with {the low level of aquifer protection, high groundwater level, large area occupied by waste}, are usually cause groundwater to have higher {salinity, pH value as well as measured concentrations of pollutants (iron, sulfates, chlorides, nitrate nitrogen, ammonia nitrogen, chromium, surfactants and oil products)}.

- Factor 2: Landfills with {big annual volumes of waste and thick layer of accumulated waste} are more likely to cause {higher concentrations of phenols, surfactants and zinc}.
- Factor 3: Newer landfills {are constructed according to a plan}, usually have either geomembrane or clay liner, situated in forested areas, and smaller particle sizes (clay, loam)}.
- Factor 4: Landfills with {big annual volumes of waste and thick layer of accumulated waste} are more often {have deeper ground water levels, do not have liners}.

Concentration of lead and copper received relatively low factor loadings in our analysis and this metal were not included in the explanatory part. Their concentration did not demonstrated correlation with other factors.

Results of the data analysis indicate that the impact of pollution on groundwater depends on the geology of the landfill site, as it was shown in previous work [7, 8].

OP landfills. Groundwater, surface water and soil screening at OP landfills revealed emission of pesticides into the environment. Pesticides have been detected in soil, surface and groundwater. Chemical studies of the content of pesticides in the air in the Republic of Belarus have not yet been carried out [9].

Groundwater experienced the greatest level of contamination with pesticides, especially the first from the earth's surface aquifer. Concentrations of HCH and DDT in groundwater at Postavy and Verkhnedvinsk OP landfills do not exceed the MPC. On average, for HCH (the most common pesticide in areas affected by pesticides disposal) they range from 0.002 MPC to 0.014 MPC. Therefore, situation at most of the OP landfills is currently stable and sampling reveal only slow migration of pesticides into the environment.

Concentrations of pesticides in the groundwater usually 2-3 orders of magnitude lower than the MPC. In most cases, concentrations varied from $1*10^{-6}$ to $1*10^{-5}$ mg/L. For the first time, the maximum permissible concentration of pesticides was established at the Gorodok OP landfill in 2009. The total content of the HCH isomers reached 0.117 mg/L, which corresponded to 5.9 MPC. In 2010, at the Gorodok OP landfill, pesticides were detected in 3 monitoring wells except for a well located outside the site.

In particular, the following cases of migration of pesticides into the groundwater were found:

- Concentration of DDT in the samples from monitoring well # 3 at the Gorodok OP landfill reached 6.4 MPC which is the maximum concentration of any pesticide ever detected in the Republic of Belarus;
- HCH, DDT, Aldrin, Heptachlor, Dieldrin, Endrin were found in the samples from monitoring well # 1, Verkhnedvinsk OP landfill; HCH was found at the point of confluence of two streams at a distance of 0.1 km from the landfill;
- HCH, DDT, Heptachlor were detected in the samples of groundwater at the Postavy OP landfill.

CONCLUSION

The results of our research and experience in the operation of existing MSW landfills say that the latter are the source of groundwater pollution. Nearly half of them were built prior to the introduction of Sanitary regulations for landfills in 1983 and do not have any facilities for environmental protection. The construction of landfills on weakly permeable soils with a minimum waterproof layer is much cheaper than construction of landfills on easily permeable soils and the construction of a more advanced insulating layer to ensure the same level of safety for groundwater. Ignoring this fact and recommendations of the Sanitary regulations, a significant number of landfills in the Republic of

Belarus were built at the site of the unused sand quarries with an unprotected aquifer. These considerations are especially topical for the territory of Vitebsk region, within which 80% of landfills have almost exhausted their resource capacity [7] and in the coming years it will be necessary to find new sites for storing waste.

OP landfills by their negative influence on the environment can be ranked as follows starting with the worst case: Gorodok – Postavy – Verhnedvinsk. The first aquifer from the surface is the main source of water supply in rural settlements and in case of erosion of packaging of pesticides migration of toxic substances into the groundwater can intensify, which can lead to the most unfavorable consequences. Measures implemented by managing organizations of landfills do not address needs of protecting ecosystems.

Based on the results of the research, we believe that the eradication of pesticide burials, which was mentioned in the National Plan of Implementation of the commitments undertaken by the Republic of Belarus to implement the provisions of the Stockholm Convention on Persistent Organic Pollutants in 2011-2015 and until 2028.

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