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Analysis of chosen indicators of environmental quality in river Utrata in relation to possible impact of „Góra Żbikowska" landfill

Magdalena MATULA[1], Małgorzata WOJTKOWSKA[1]

[1] *Warsaw University of Technology, The Faculty of Building Services, Hydro and Environmental Engineering, Nowowiejska street 20, 00-653 Warsaw, tel.: +48 500-744-454, e-mail: Magdalena.Matula@onet.pl*

Abstract

The paper presents the results of study on influence of „Góra Żbikowska" landfill on surface water and bottom sediments of part of the Utrata river. This landfill pile is located in south-west part of Warsaw agglomeration. The results were considered in relation to the influence of old landfills on water environment. The tested parameters were: concentrations of metals in bottom sediments (8 sites) and physio-chemical parameters of water (2 sites) pointing to significant pollution of both mentioned components of water environment. The bottom sediments collected from the site located nearby „Góra Żbikowska" landfill (site number 7) contained the highest concentrations of heavy metals. In this site particularly high concentration of copper was found, furthermore this concentration exceeded the third class of bottom sediments purity (in accordance with geochemical criteria) [11].The metals in bottom sediments presumably come from the period when the landfill was not sufficiently isolated, but further extended analyses are needed to prove this statement, as well as confirm the necessity of the landfill closure and efforts for reclamation of the whole area surrounding the pile, including part of river.

Keywords: heavy metals, municipal waste landfill, water pollution, surface waters, bottom sediments

Streszczenie

Analiza wybranych wskaźników jakości środowiska wodnego rzeki Utraty w kontekście potencjalnego oddziaływania składowiska odpadów „Góra Żbikowska"

Praca dotyczy wpływu czynnego składowisku odpadów innych niż niebezpieczne i obojętne „Góra Żbikowska" na wody oraz osady denne odcinka rzeki Utraty. Składowisko położone jest w południowo-zachodniej części aglomeracji warszawskiej. Wyniki badań były rozpatrywane pod kątem oddziaływania składowisk odpadów na środowisko wodne. Zbadane parametry, tj. stężenia metali w osadach dennych (8 stanowisk) oraz parametry fizykochemiczne wody powierzchniowej pobranej z dwóch punktów położonych w niedalekim sąsiedztwie składowiska, wskazują na znaczne zanieczyszczenie obu badanych komponentów środowiska wodnego. Największe stężenia metali stwierdzono w osadach dennych pobranych ze stanowiska nr 7. Szczególnie wysokie stężenia dotyczyły miedzi, przekraczały one bowiem (zgodnie z kryteriami geochemicznymi) III klasę czystości [11]. Opisane wyniki mogą posłużyć za podstawę do przeprowadzenia szerszych i aktualniejszych badań oddziaływania omawianego składowiska odpadów na jakość wód i osadów dennych rzeki Utraty. Powtórzenie badań na zaproponowanych w pracy stanowiskach, może pozwolić na potwierdzenie konieczności zamknięcia składowiska i rekultywacji terenu lub wykazać, że metale ciężkie w osadach dennych pochodzą głównie z okresu, w którym składowisko nie było dostatecznie zabezpieczone.

Słowa kluczowe: metale ciężkie, składowanie odpadów, zanieczyszczenie wód, wody powierzchniowe, osady denne

1. Introduction

The waste management is one of the issues with broad and very demanding subject range. This issue means: collecting, transporting, recycling, recovering and disposal of wastes, including the control of those actions and areas where the wastes are disposed. The issuing of permits is also a vital part of waste management [1].

It should be also noted that the legislation concerning wastes has become one of the widest and the most complex part of the environmental law in international and European Union regulations as well as in internal legislation of many counties in the world [2].

Apart from the issues mentioned above, particular attention to the impact of waste on the environment should be paid, especially in regard of the disposal of municipal waste, which in accordance with Polish Act on Waste [3] are defined as wastes generated by household, except of end of live vehicles, as well as wastes which do not contain hazardous waste from other waste generators, which due to their nature or composition are similar to the wastes generated in households. Disposal of these wastes, due to their heterogeneous nature and inadequate preservation in operational or closed landfills, is a vital issue in terms of environmental protection and sustainable development.

Because of its origin, biological characteristic and chemical composition, the municipal waste can pose a threat to lives or health of humans and the whole environment. One of the biggest threat is caused by waste containing heavy metals. Those threats can appear in all stages of waste management, i.e. collection, transport, recycling, and especially during its landfilling [14].

2. Characteristics of „Góra Żbikowska" landfill

„Góra Żbikowska" landfill in Pruszków Gąsin (Masovian Voivodeship, Poland), a landfill for non-hazardous and inert waste, was established in 1965 [4]. According to the Polish Act on Waste [3] municipal, non-hazardous and inert or solid wastes which meet the criteria set out in mentioned Act can be landfilling in those kind of object.

The whole area of the landfill is 14,5 ha [16]. The geological research conducted in 1992 proved that the poorly permeable layers - clays occurred at a level of 6 - 8 m below ground level [17].

Fig. 2.1. The „Góra Żbikowska" landfill pile (coordinates: 52.1783, 20.7755). (source: own elaboration based on: https://www.google.pl/maps/ and http://umpruszkow.bip.org.pl/)

In accordance to the information that can be found in the website of the Mazovia Voivodeship Environmental Protection Inspector [16] the landfill was not isolated until the 2007. Before the 2007 the landfill also did not have any installation to the rainwater and leachate capture. Today the landfill is insulated and sealed moreover it is equipped with a septic tank, therefore the amount of the leachate penetrating into the ground is potentially limited.

The landfill is divided into two parts: A (sectors S1-S17 and S21-S24) and B (sectors S18-S20) [4] (Fig. 2.1). The sector A is being unexploited since the 2010 and sector B is still working. The most recent information indicates that the landfill "Żbikowska Góra" in 2016 received 6818,16 Mg of selectively collected municipal wastes and on this date met all of the requirements [16].

The sector A were reclaimed (Fig. 2.1 and 2.2) and plans [17] provide also the complete reclamation of sector B. In the past it was planned to reclaim entire landfill into sport and recreation area with outdoor fitness equipment within a park. In fact, for the past 14 years the landfill has been partly under reclamation. That process includes usage of primer from the ground clay with a thickness of 2 m (geologic barrier) to seal the migration of contaminations into the ground. However, at the beginning of its operation the landfill was not properly protected and insulated [6]. In according to the reclamentation process a few piezometers were placed in order to measuring the pollutants in groundwater.

The area which is located to the east of „Góra Żbikowska" landfill, across the Utrata river, has industrial character and is used for the storage of construction aggregate. The area to the north of the landfill is undeveloped (Fig. 2.1). The average flow rate in Utrata in 2004 in Żbików (the stream gauge profile calculated into a point near the site no. 8 - see Fig. 3.1) river was 0,818 m^3/s [18].

Fig. 2.2. The „Góra Żbikowska" landfill pile and Utrata river - the street view nearby the sampling site WP2 (see Fig. 3.1). (source: https://www.google.pl/maps/)

3. Materials and methods

The research concerned bottom sediments and surface water from the Utrata river, located to the north of the „Góra Żbikowska" landfill (Fig. 2.1 and Fig. 3.1). The river Utrata is 78,2 km long and its source is located on the north slope of Wysoczyzna Rawska, with estuary in Sochaczew. The river Utrata is a right tributary of the river Bzura [7]. The location of sites from where the bottom sediments and water samples were taken is shown in Fig. 3.1.

The surface water samples from the Utrata river were collected in May and August from two sampling sites. The sites were located - upstream (WP1) and downstream (WP2) in relation to the landfill (Fig. 3.1). The samples were collected to the polyethylene bottles, filled completely to the top to exclude air. Then the samples were transported immediately to the laboratory where such physicochemical parameters as oxygen indicators (DO, BOD_5, COD) and chosen mineral salts were tested.

Fig. 3.1. The sampling sites. (source: own elaboration based on: https://www.google.pl/maps/)

The bottom sediments were collected in October from the surface layer from 0 to 5 cm. The bottom sediments were dried in room temperature to achieve the constant mass (about 14 days). Then air-dried samples were mineralized using wet method, with a water solution of concentrated nitric acid and hydrochloric acid (3 HNO_3 65% :1 $HClO_4$ 60%) in temperature about 180 ^oC. Afterwards, samples were analyzed using atomic absorption spectrometry with flame atomization (F-AAS) towards the content of metals: zinc, copper, lead, nickel and cadmium.

Additionally, chosen physicochemical indicators were tested in supernatant from site 7 (Fig. 3.1), collected from bottom sediment. Although these tests were not originally planned, the results are interesting and it was decided to combine them into the analysis. From other samples the amount of supernatant water was insufficient, thus the tests could not be performed.

4. Results

The results of the analysis of physicochemical parameters of the surface water collected from sites WP1 and WP2 [6] are shown in table 4.1. The results of analysis of pH and conductivity conducted in March as a part of monitoring of the landfill were also added to mentioned table (No. 4.1) [4].

They indicate that the river Utrata is contaminated. These parameters, according to regulations on the classification of surface water bodies and environmental quality standards for priority substances (hereinafter “the regulation”) [8], exceed the concentrations characteristic for second class of quality, in respect of COD, BOD indicators and the content of sulfide in both sites (WP1 and WP2) and for both concerned dates.

The content of chloride and calcium ions in water collected in the second quarter of 2011 also exceeds the values which characterize the water of second-class quality [8]. Only content of magnesium ions are higher in the second then in the third quarter.

The average concentration of water quality indicators characterizing the nutrients status is higher in site WP2, which is located below in relation to the river course, then in site WP1. The average concentrations are also significantly higher in third then in second quarter. The differences between other parameters measured in WP1 and WP2 are mostly irrelevant, except the concentration of sulfates, which is almost 75% higher in WP2 and basicity which is 3,5 times lower in WP2.

In according to the regulation [8], the concentration of dissolved oxygen, magnesium ions in third quarter, calcium ions and orthophosphate in second quarter and nitrite nitrogen in site WP1 are within the ranges which characterize the water of second-class quality. However, the physicochemical parameters are mostly within the ranges beyond the values characteristic for water of second quality class [8].

Table 4.1. The physicochemical parameters of the surface water collected during 2011 from sampling sites WP1 and WP2 and the parameters of supernatant

Indicator [unit]	Sampling time*	Sampling site		Supernatant from bottom sediment (site No. 7)	The border values for physicochemical elements (supporting biological elements)**	
		WP-1	WP-2		I class of water quality	II class of water quality
DO [mg O_2/dm^3]	M	9.2	9	-	≥ 7.5	≥ 6.8
	A	12.2	12.2			
COD [mg O_2/dm^3]	M	92	90	-	≤ 25	≤ 30
	A	100	97			
BOD_5 [mg O_2/dm^3]	M	5.2	4.6	-	≤ 3.0	≤ 4.5
	A	5.2	4.6			
chloride [mg Cl^- /dm^3]	M	32.5	32.5	75	≤ 26.0	≤ 33.7
	A	54.5	60.5			
magnesium [mg Mg^{2+}/dm^3]	M	56.16	49.44	-	≤ 18.4	≤ 22.0
	A	16.8	16.32			
calcium [mg Ca^{2+}/dm^3]	M	25.6	22.4	-	≤ 81.0	≤ 81.7
	A	103.2	103.2			
sulfates [mg SO_4^{2-}/dm^3]	M	95	85	-	≤ 42.0	≤ 57.0
	A	97	162			
orthophosphates [mg/dm^3 PO_4^{3-}]	M	0.08	0.09	-	≤ 0.065	≤ 0.101
	A	0.9	0.65			
ammonium nitrogen [mg N-NH_4/dm^3]	M	0.45	0.63	-	≤ 0.25	≤ 0.738
	A	0.7	1.02			
nitrite nitrogen [mg N-NO^{3-}/dm^3]	M	2.2	2.5	-	≤ 2.2	≤ 3.4
	A	1	1.3			
basicity [expressed as mg$CaCO_3/dm^3$]	A	640	180	310	≤ 232.3	≤ 242.2
pH	-	7.33	7.34	6.21	7-7.9	7-7.9
conductivity [μS/cm]	-	720	676	875	≤ 549	≤ 620

* May (M), August (A), other term (-)
**according to the Regulation of the Minister of the Environment of 21 July 2016, Item 1187

The supernatant was collected from site 7, located downstream (in relation to the direction of the river flow) the „Góra Żbikowska" landfill, and sample was decanted off the sediment. It should be emphasized that the composition of the supernatant is closely related to solid phase, due the continuous exchange processes between water and bottom sediment. The dynamics of these exchanges is based on feedbacks. The exchange processes can be divided into two main groups, in terms of the direction, i.e. passage of organic and mineral components or gases into water environment, and from water environment into sediment [9].

The characteristic of the supernatant from site 7 is slightly acidic (pH 6.21), and according to polish regulations [8] exceeds the value of pH characteristic of water of second-class quality. Other parameters under scrutiny i.e.: the electrolytic conductivity (875 μS), basicity (310 mg $CaCO_3/dm^3$) and the amount of chloride (75 mg Cl^-/dm^3) also exceed the values which characterize water of second class quality in relation to the regulation [8]. Thus, it can be concluded that the poor quality of surface water is associated with the impact of the landfill on the aquatic environment of the Utrata river.

The measured concentrations of metals in bottom sediments divided into particular sampling points were shown in figure 4.1. The boundaries concentrations of metals in accordance to geochemical criteria [11] were plotted on figure 4.1 as lines. The black straight line symbolizes class I of contamination, orange dotted line and red dashed line, respectively, class II and class III.

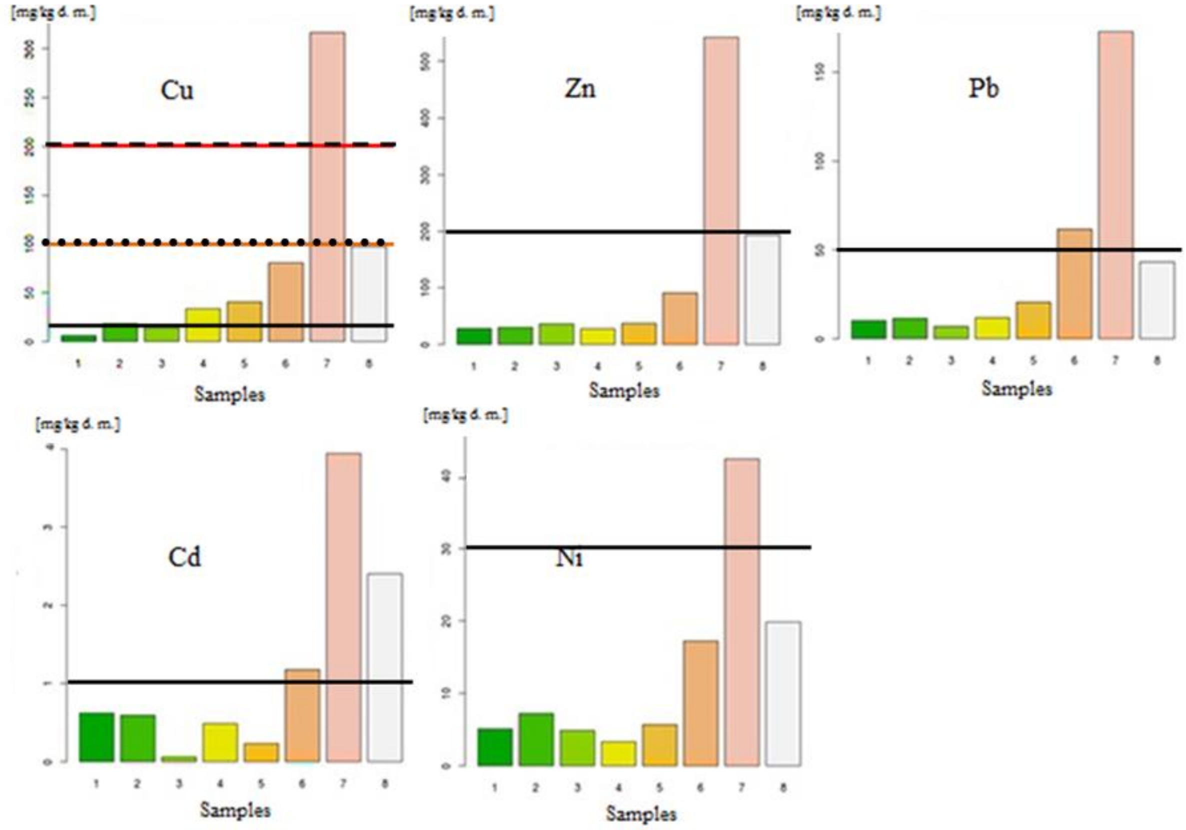

Fig. 4.1. The content of particular metals in bottom sediments, divided into locations sites (the horizontal lines indicate limit values provided for geochemical criteria - details in the text)

The research of metal content in bottom sediments prove that the most loaded are sediments collected from sites: 6, 7 and 8. The lowest concentrations concerned all metals in few first sites. The growing tendency of most of metal's concentration (except of Cd) from site 4 to 7 with significant decrease in site 8 can be seen. It can be noticed that concentrations of nickel, cadmium and lead in particular sites show similar trends. The concentrations of cadmium, lead and copper, are lowest in site 3. The highest concentrations of all metals in bottom sediments occur in site 7. Also, taking into account the river flow, which affects underground flow, it can be concluded that the leachate from the „Góra Żbikowska" landfill reach the Utrata river near site 7. The pollutions, especially metals, have a tendency to accumulate in bottom sediment, hence the level of their concentration can prove the anthropogenic impact in the past [10].

According to the classification of sediments based on geochemical criteria [11], only the sediments collected from sites 1, 2 and 3 can be classified as first class of quality. The rest of sediments were characterized by even 20-fold higher content of metals, which classified them in the second class and the sediment from site 7 even in the third class of quality.

5. Conclusions

The results of research concerning both surface water and bottom sediments indicate a significant pollution and anthropogenic impact on the quality of water and soil environment of Utrata river. The pollutions indexes which are present in investigated samples come from the river basin and their source can be, most likely, the effluent from the „Góra Żbikowska" landfill. The differences in the concentration of tested indicators (especially nutrients), between sampling sites and significant excess of the concentration in relation to the geochemical background, indicate that. Not all of the indicators differ significantly between WP1 and WP2 sites what indicates poor water condition in Utrata river as the effect of anthropogenic impact on its basin. The significant difference between basicity could be the effect of a random error (single measurement) or prove the buffer properties of water (or bottom sediments) in combination with a large inflow of acidifying factors.

It should be noted that the processes affecting the release of metals from bottom sediments are strongly dependent on the physicochemical parameters of water [12]. These processes include: precipitation, sorption and desorption. They determine the balance between forms of metals located in bottom sediment and those which are present in water. The most important indicators are: oxygen concentration, pH changes and the content of organic matter [9]. Metals are easily adsorbed (especially in physical processes) and turn into dissolved forms in water. It is obviously associated with their bioavailability and harmfulness to the environment. Therefore the research of metal's concentrations in bottom sediment should be linked with changes in water quality [9]. Considering the differences between the results of tested parameters from second and third quarter of 2011, it should be noted that the physicochemical parameters of water change over time, therefore the significant amounts of metals could be released into water course.

The metals whose concentrations were under consideration have toxic properties. According to literature the most toxic to the water environment is mercury and then copper, which high concentrations appreciably inhibit the growth of plants [13] or e.g. fish reproduction processes. This is vital due the high concentrations of copper in tested sediments. The consequence of accumulation of significant amounts of metal is the extinction of species which are sensitive to environmental pollution [15]. This phenomenon results, *inter alia*, in: loss of biodiversity and expansion of populations of species which are pollution-tolerant then displacement of species originally inhabiting a given area [10].

A significant part of landfill is unexploited and under reclamentation process thus the acidification stage in this part, when the metals were highly leached, should have ended long ago. Considering all of the insulations and protection elements on functioning part of landfill the leachate at present are potentially trapped and disposed. Therefore it can be presumed that the metals in bottom sediments are temporarily immobilized and come from the time when landfill was not properly insulated.

The high concentrations of metals in sampling site No. 7 could be also caused by low average flow rate in Utrata river in considered part. The dissolved forms of metals which could reach the river in leachate from landfill were capable to undergo precipitation reactions or sorption and then deposited in bottom sediments.

The subject research showed that the „Góra Żbikowska" landfill, not properly protected and sealed in the past, could adversely affect the quality of the water and soil environment of Utrata river. Actually, the landfill has been insulated and sealed, therefore the amount of the leachate penetrating into the ground was potentially limited. However, it can't be clearly stated whether the parameters that were investigated in water and the content of metals in sediments are related to the current functioning of the landfill. It should be noted that the quality of water and soil environment of Utrata river indicate the need for reclamation of the whole landfill area and reduction of anthropogenic impact on the whole basin.

The „Góra Żbikowska" landfill has not been closed or additionally secured yet, therefore the possibility of further negative environmental impact of landfill on the Utrata river cannot be ruled out. The results revealed that there is a need to continue studies on conditions of surface water as well as bottom sediments in Utrata river.

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