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# ENVIRONMENTAL IMPACT ASSESSMENT OF THE OBSOLETE PESTICIDE DUMPS LOCATED IN THE BELARUSIAN PART OF THE ZAPADNAYA DVINA RIVER BASIN

## OCENA ODDZIAŁYWANIA NA ŚRODOWISKO WYSYPISK PRZESTARZAŁYCH PESTYCYDÓW, POŁOŻONYCH W CZĘŚCI BIAŁORUSKIEJ DORZECZA RZEKI ZAPADNAYA DVINA

***Abstract*:** The article presents an assessment of the environmental impact of obsolete pesticide dumps located in the Belarusian part of the Western Dvina river basin (Postavy, Gorodok and Verkhnedvinsk pesticide dumps). The study focuses on identifying the migration of persistent organic pollutants (POPs) from pesticide dumps to groundwater and soil, as well as assessing the potential risk of transboundary transport of pollutants by the waters of the Western Dvina River.

***Key words*:** obsolete pesticides, persistent organic pollutants, migration of pollutants, environmental assessment, environmental risks
***Słowa kluczowe***: przestarzałe pestycydy, trwałe zanieczyszczenia organiczne, migracja zanieczyszczeń, ocena środowiskowa, zagrożenia środowiskowe

## Introduction

Dumps of obsolete pesticides pose a potential threat to the environment and humans as sources of toxic substances. The presence of pesticides in the environment is dangerous because of their resistance to degradation and their ability to migrate over long distances and accumulate in the tissues of living organisms. Even non-toxic doses of some persistent organic pollutants (POPs) can lead to the development of diseases of the human immune and reproductive systems due to their bioaccumulative properties and mobility in food chains.

In the 1970s and 1980s, about 8000 metric tons of pesticides to be disposed of was accumulated on the territory of the Republic of Belarus as a result of improper planning in agriculture [1]. This group includes both banned for use and expired pesticides. It was decided to dispose of obsolete pesticides in underground storages, which in most cases are pits (trenches) with impervious screens made of compacted clay at the bottom. When a pit or a trench was filled up with pesticides, it was covered by earth (buried). The most toxic substances were placed in concrete bunkers.

There is historical data on the presence of POPs-containing pesticides in the Verkhnedvinsk pesticide dump. There is no such data for the Gorodok and Postavy pesticide dumps.

Burying of pesticides was regulated by a temporary instruction [6]. According to the instruction, pesticide dumps should have impervious screens of compacted clay with a thickness of at least 1 m on the walls and at the bottom of the pit/trenches in which obsolete pesticides are placed. After filling the pit/trench it is covered with plastic wrap, then a layer of clay and a layer of soil.

For almost all pesticide dumps of obsolete pesticides there is no documentation related to their construction. Therefore, it is not possible to assess their compliance with environmental safety requirements.

In 1971–1988 in the Republic of Belarus, a total of seven pesticide dumps of obsolete pesticides were built: Brest, Slonim, Dribin, Petrikov, Verkhnedvinsk, Gorodok and Postavy. To date, obsolete pesticides have been completely removed from the Slonim and Brest pesticide dumps. At the Petrikov pesticide dump, work is still underway. Verkhnedvinsk, Gorodok and Postavy pesticide dumps are located in the basin of the Western Dvina River in the Vitebsk region of the Republic of Belarus. The first pesticide dump for obsolete pesticides was Postavy, which began to fill up in 1971. The Gorodok and Verkhnedvinsk dumps were built in 1973 and 1982, respectively.

In total, about 1000 metric tons of obsolete pesticides were buried in three pesticide dumps: in Postavskoe – 102 metric tons, in Gorodokskoye – 411 metric tons and in Verkhnedvinskoye – 455 metric tons. Surface runoff and groundwater from these three pesticide dumps ultimately end up in the Zapadnaya Dvina River. And pesticides, in the event of their migration from burials, may end up in the surface waters of neighboring states, namely Russia, Lithuania and Latvia.

The three storages of obsolete pesticides under consideration are located at the borders of the Republic of Belarus with neighboring countries. Thus, the Verkhnedvinsk pesticide dump is located at the borders of the Republic of Belarus with Latvia and Russia. The minimum distance to the border with Latvia is 7 km, with Russia – 28 km. Gorodok storage is located 10 km from the border with Russia, 10 km, Postavy storage – 20 km from the border with Lithuania (Figure 1).

After the construction of graves in 1971–1988. no environmental studies have been carried out at the sites of obsolete pesticides. For the first time, the survey of the Verkhnedvinsk, Gorodoksk, and Postavy pesticide dumps was carried out by the Central Research Institute for the Integrated Use of Water Resources (Minsk, Belarus) in 1999–2000 when samples of groundwater were taken from wells in the nearest rural settlements, as well as samples of surface water, soil and vegetation. Since 2003, Belarusian Research Center Ecology (Minsk, Belarus) has also been conducting environmental surveys at the pesticide dumps of obsolete pesticides.

The Republic of Belarus, as a party to the Stockholm Convention on Persistent Organic Pollutants, has adopted a National Plan for the implementation of obligations under this convention for the period up to 2028. Within the framework of this plan, it is planned to eliminate all existing pesticide dumps of obsolete pesticides [*National plan*… 2006; *Report on the frontal*… 2021]. Currently, plans are being developed to eliminate the Postavy and Gorodok pesticide dumps of obsolete pesticides.

This article provides an assessment of the migration of POPs from pesticide dumps of obsolete pesticides in the Belarusian part of the Western Dvina River Basin and their impact on the environment, primarily on groundwater. In addition, proposals are given to reduce this impact.


Fig. 1. Location of the three obsolete pesticides pesticide dumps in the Belarusian part of the Western Dvina river basin
Ryc. 1. Lokalizacja trzech mogilników przestarzałych pestycydów w białoruskiej części dorzecza Zachodniej Dźwiny
Surce: compiled by the authors.
Źródło: opracowane przez autorów.

## Materials and methods

This article is based on archival data and data from our own research conducted in 2005–2021 [*Assessment*… 2007; Kuzmin, Dziamidou, Babko 2017; *Temporary*… 1971; *The identify*… 2010; Sazonova, Kuzmin, Babko 2011]. The assessment of the state of the environment at the pesticide dumps of obsolete pesticides was carried out in three stages: the preparatory stage, the field stage, and the stage of laboratory research and analysis of the results.

The preparatory stage included the analysis of archival data on the amount and types of buried pesticides, as well as on the design of pesticide dumps. Much attention was also paid to the analysis of hydrogeological conditions and assessment of the protection of groundwater from pollution. This was necessary for planning field work based on the storage conditions of obsolete pesticides at each pesticide dump.

During the field work, the zones of influence of pesticide dumps of obsolete pesticides were examined and the condition of surface and ground waters, soils, and plants was assessed. At this stage, samples of surface water and groundwater, as well as soils were taken to determine the content of pollutants in them. The samples were studied using equipment and methods certified in the Republic of Belarus.

## Geology and environment at the pesticide dumps

The site of the **Verkhnedvinsk** obsolete pesticide dump is surrounded by forest. It is located 500 from Turia River, which is a tributary of the Saryanka River, which in turn flows into the Western Dvina River.

The upper layer of the geological section at the site of the storage of obsolete pesticides is represented by varved clays. In some places they are covered with a layer of clay sands up to 1.5 m thick. The layer of varved clay has a thickness of at least 15–20 m, which was revealed by exploration wells drilled during the survey of the site [Kuzmin, Savastenko 2011].

Due to the occurrence of clay on the surface, there is no groundwater at the site. In shallow clayey sands, a perched water is formed. Perched water does not have a significant effect on the storage conditions of unsuitable pesticides. Infiltration of atmospheric precipitation into the underlying aquifers through the storage is unlikely due to the significant thickness of the clay layer. However, it cannot be ruled out that pesticides would enter nearby streams with perched water and then eventually end up in the Zapadnaya Dvina River.

There is no any data on the design of the trenches/pits in which pesticides are stored.

**Gorodoksk** pesticide dump for obsolete pesticides is located in a wooded, swampy area. A swamp adjoins the storage area for obsolete pesticides from the east. As a result, access is only possible from three sides. There are relatively few settlements in this area. The nearest one is located 3.5 km from the pesticide dump.

In the area where the repository of obsolete pesticides is located, the first aquifer from the surface is confined to fluvioglacial sands fluvioglacial sands with a thickness of about 7 m. Below there are sandy loams and loams of the Poozersky glaciation. The groundwater level is at depths from 1.5 to 3 m from the surface.

According to the ecological passport of the obsolete pesticide´s storage, drawn up in 1990, it consists of four trenches 10 m long, 2 m wide and 2 m deep. The walls, bottom and ceiling of the trenches are made of compacted clay 1 meter thick. To store the most toxic pesticides, a bunker made of monolithic reinforced concrete with a wall thickness of 300 mm was built in the southeastern part of the pesticide dump.

Fig. 2. Verkhnedvinsk pesticide dump.
Rys. 2. Mogilnik w pobliżu miasta Wierchniedwińska
Source: c. 2006, photo by A. Babko.
Źródło: ok. 2006 r., fot. A. Babko.

The site of the **Postavy** obsolete pesticide dump is surrounded by forest. It is situated 7 km to the south from the city of Postavy.

Postavy pesticide dump is located on the watershed of the Zapadnaya Dvina and Viliya river basins. The closest river to the repository is the Myadelka River. It flows out of Lake Myadel, 8 km south of the burial site, and flows south of Postavy into the Bireta River, which is a tributary of the Desna River.

In the area where the repository of obsolete pesticides is located, the first aquifer from the surface is confined to fluvioglacial sands with a thickness of about 18 m. Below there are sandy loams and loams of the Poozersky glaciation. The groundwater level is at depths from 13 to 15 m from the surface.

Fig. 3. Gorodok pesticide dump
Ryc. 3. Mogilnik w pobliżu miasta Gorodok
Source: c. 2007, photo by A. Babko.
Źródło: ok. 2007 r., fot. A. Babko.

Geomagnetic studies carried out in the summer of 2021 suggest the presence of reinforced concrete slabs at the base of the trenches in which pesticides are stored. Two areas of positive magnetic anomalies were detected. They are representing the main body of the storage in the center of the site and a much smaller site possibly connected with buried metal details (like metal containers or construction waste).


Fig. 4. Postavy pesticide dump
Rys. 4. Mogilnik w pobliżu miasta Postawy
Source: c. 2007, photo by A. Babko.
Źródło: ok. 2007 r., fot. A. Babko.

## Results and its discussion

Despite the fact that environmental monitoring at pesticide dumps is mandatory in the Republic of Belarus, there is no continuous series of observational data for them. Available water and soil sampling data used in the article are noted in the Table 1.

Table 1.

Data on water and soil samples used in the article

Tabela 1.

Wykorzystane w artykule dane dotyczące próbek wody i gleby

| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Verkhnedvinsk pesticide dump | | | | | | | | | | | | | | | | | | | |
| Water | + | + | + | + | | + | + | + | | | | | | | + | + | + | | |
| Soil | | | | | | | | | | | | | | | | | | | |
| Gorodok pesticide dump | | | | | | | | | | | | | | | | | | | |
| Water | | | + | + | + | | + | + | | | + | | | | + | + | + | | |
| Soil | | | | | | | | | | | + | | | | | | | | + |
| Postavy pesticide dump | | | | | | | | | | | | | | | | | | | |
| Water | | | | | + | | + | + | | | | | | | + | + | + | | |
| Soil | | | | | | | | | | | | | | | | | | | + |

Source: compiled by the authors based on [*Unpublished protocols*... ].
Źródło: opracowane przez autorów na podstawie [*Unpublished protocols*... ].

## Contamination of groundwater and surface water

Water near **Verkhnedvinsk** pesticide dump is monitored the analysis of perched water samples from an observation well, as well as samples of surface water from nearby streams and from the Turya River. All detected concentrations of pesticides were below MPC.

The presence of pesticides in perched water samples was found in 2003, 2005 and 2006 when the presence of HCH and DDT isomers were detected. In 2007–2020, no pesticides were found in the samples of perched water.

In the waters of streams pesticides were identified in 2003, 2005, 2006 and 2009. HCH and DDT isomers were detected, as well as aldrin. As for samples from Turya

river, the only case when traces of HCH was detected in 2006 does not have any credible explanation and is likely an error of sample collection or analysis.

Table 2.

Detected pesticides concentrations in ground and surface water at Verkhnedvinsk pesticide dump*

Tabela 2.

Stężenia pestycydów w wodach gruntowych i powierzchniowych na mogilniku w pobliżu miasta Wierchniedwińska*

| | 2003 | 2005 | 2006 | 2009 |
|---|---|---|---|---|
| Ground water | ΣHCH: $5.9*10^{-5}$ mg/dm$^3$ | ΣDDT: $4.5*10^{-5}$ mg/dm$^3$ | ΣHCH: $3.7*10^{-5}$ mg/dm$^3$ | No pesticides detected |
| Surface water | ΣHCH: $7.4*10^{-5}$ mg/dm$^3$ ΣDDT: $1.5*10^{-5}$ mg/dm$^3$ Aldrin: $3.1*10^{-5}$ mg/dm$^3$ | ΣDDT: $2.9*10^{-6}$ mg/dm$^3$ | ΣHCH: $9.0*10^{-7}$ mg/dm$^3$ | ΣHCH: $1.3*10^{-5}$ mg/dm$^3$ |

* ΣHCH and ΣDDT are the sum of the concentrations of all HCH isomers and DDT, DDD, and DDE respectively. The maximum concentration was selected among samples of each type (groundwater, surface water).

Source: [*Unpublished protocols*...].
Źródło: [*Unpublished protocols*... ].

The most difficult situation is developing at the **Gorodok** pesticide dump. Migration of pesticides into the groundwater and surface waters was detected since the very beginning of regular monitoring.

In a groundwater sample from observation well No. 3, taken in August 2009, the total content of HCH isomers reached 0.117 mg/dm3 (5.85 MPC). In a repeated sample from the same observation well, taken in October 2009, the total content of HCH isomers was 0.128 mg/dm3 (6.4 MPC). Reported values for 2017–2019 are so high that they do not fit into the scheme of previous measurements. They need to be verified by subsequent measurements.

Table 3.

Detected pesticides concentrations in ground and surface water at Gorodok pesticide dump

Tabela 3.

Stężenia pestycydów w wodach gruntowych i powierzchniowych na mogilniku w pobliżu miasta Gorodok

| | 2005 | 2006 | 2007 | 2009 | 2010 |
|---|---|---|---|---|---|
| Ground water | Observation wells were build in 2006 | ΣHCH: 0.0027 mg/dm$^3$ | ΣHCH: 0.012 mg/dm$^3$ | ΣHCH: 0.117 mg/dm$^3$ | ΣHCH: 0.048 mg/dm$^3$ |
| Surface water | ΣHCH: 4.2*10$^{-6}$ mg/dm$^3$ | ΣHCH: 6.5*10$^{-4}$ mg/dm$^3$ Heptachlor: 7.5*10$^{-6}$ mg/dm$^3$ Endosulphate: 1.9*10$^{-5}$ mg/dm$^3$ | Pesticides were not detected | Pesticides were not detected | ΣHCH: 0.021 mg/dm$^3$ |

| | 2013 | 2017 | 2018 | 2019 |
|---|---|---|---|---|
| Ground water | ΣHCH: 0.0152 mg/dm$^3$ | ΣHCH: 1.6 mg/dm$^3$ | ΣHCH: 4.78 mg/dm$^3$ | ΣHCH: 10.2 mg/dm$^3$ |
| Surface water | ΣHCH: 5.6*10$^{-5}$ mg/dm$^3$ | No samples | No samples | No samples |

Source: [*Unpublished protocols*...].
Źródło: [*Unpublished protocols*... ].

Groundwater near **Postavy** pesticide dump is monitored using four observation wells. Samples of surface water were also taken from Myadelka River, Dolzha lake, Glodovo lake, Zadevskoe lake but only to determine the content of inorganic substances. All detected concentrations of pesticides were below MPC.

Groundwater sampling revealed that HCH and DDD compounds as well as heptachlor were present in groundwater (Table 3). Pesticide concentrations in the most polluted observation well No. 3 were as low as 0.01 MPC. However, data for 2017–2019 indicates that their concentrations have risen sharply. As with the reported values for Gorodok pesticide dump for the same period, they are extremely high and need to be verified by subsequent measurements.

In our opinion, **soil contamination** with pesticides near pesticide dumps is mainly due to the migration of pesticides with surface runoff. This was evidenced by the results of soil studies at Gorodok pesticide dump, when three layers of soil were tested for pesticides. In most on the 16 sampling sites, the highest concentrations of pesticides were found in the surface layer, decreasing with the depth. However, in some cases, the concentrations were maximum under the surface layer of the soil. This can be explained by the fact that pesticides spilled out of the container during the filling of the storage.

Table 4.

Concentration of pesticides in ground and surface waters
of the Postavy pesticide dump (no surface water samples were taken)

Tabela 4.

Stężenia pestycydów w wodach gruntowych i powierzchniowych
na mogilniku w pobliżu miasta Postawy (nie pobrano próbek wód powierzchniowych)

| | 2007 | 2009 | 2010 | 2017 |
|---|---|---|---|---|
| Ground water | ΣDDT: $5.9*10^{-5}$ mg/dm$^3$<br>Heptachlor: $1.4*10^{-5}$ mg/dm$^3$ | ΣHCH: $4.0*10^{-5}$ mg/dm$^3$<br>Heptachlor: $3.7*10^{-5}$ mg/dm$^3$ | ΣHCH: $1.4*10^{-5}$ mg/dm$^3$<br>ΣDDT: $8.9*10^{-4}$ mg/dm$^3$ | ΣDDT: 0.18 mg/dm$^3$ |

| | 2018 | 2019 |
|---|---|---|
| Ground water | ΣDDT: 0.044 mg/dm$^3$ | ΣDDT: 0.18 mg/dm$^3$ |

Source: [*Unpublished protocols*...].
Źródło: [*Unpublished protocols*... ].

According to a 2013 soil survey of the Gorodok pesticide dump, pesticide concentrations were below the detection limit in most of the 16 soil samples collected, and only two samples showed insignificant concentrations of pesticides.Concentrations exceeding the MPC were observed at one point, where the DDT concentration reached 0.173 mg/kg (1.59 MPC) (Table 5).

According to the latest soil survey of the Postavy pesticide dump, the maximum concentrations of HCH and DDT are 20–60 times higher than in Gorodok pesticide dump (Table 5). The location of the most polluted sampling sites generally corresponds to the location of positive magnetic anomalies (the central part and the northeast corner). Such a situation could occur, for example, when pesticides were spilled and mixed with sand while covering pesticide-filled pits/trench during construction work.

Table 5.

Detected pesticides concentrations in soil at Gorodok and Postavy pesticide dumps

Tabela 5.

Wykryte stężenia pestycydów w glebie w mogilnikach w pobliżu miast Gorodok i Postawy

| | 2013 | 2021 |
|---|---|---|
| Gorodok | ΣHCH: 0.0184 mg/kg ΣDDT: 0.173 mg/kg | No data |
| Postavy | No samples | ΣHCH: 0.393 mg/kg ΣDDT: 11.39 mg/kg |

* ΣHCH and ΣDDT are the sum of the concentrations of all HCH isomers and DDT, DDD, and DDE respectively. The maximum concentration was selected.

Source: [*Unpublished protocols*...].
Źródło: [*Unpublished protocols*... ].

## Conclusion

Studies conducted by both the authors of this article and other organizations on the three considered pesticide dumps for obsolete pesticides located within the Belarusian part of the Zapadnya Dvina river basin have established that all pesticide dumps for obsolete pesticides affect the soil, surface water and groundwater. This also applies to atmospheric air. Although measurements of the concentration of pesticides in the air have not been carried out, their presence is often determined by the characteristic smell in the vicinity of pesticide dumps.

Research confirms the migration of pesticides and their decay products from pesticide dumps into groundwater. At the Gorodok and Postavy pesticide dumps, migration to surface waters was also revealed.

Concentrations of pesticides in groundwater at the sites of these pesticide dumps in most cases ranged from 1*10-6 to 1*10-5 mg/dm3. But in 2009 the total content of HCH isomers at the Gorodok pesticide dump reached 6.4 MPC. And the data reported for Gorodok and Postavy pesticide dumps for 2017–2019 reveals that pesticides concentrations spiked. However, this data needs to be verified by subsequent measurements.

Studies also confirm the presence of pesticides in the surface soil layer of pesticide dumps. This is typical for areas located down the slope. Pesticide concentrations vary from insignificant values close to the detection limit to values many times higher

than the established standards. The maximum concentration was recorded for DDT at the Postavy pesticide dumps and amounted to 42.8 MPC. The types of pesticides found in soil are the same as those found in groundwater and surface water.

The three pesticide dumps under consideration can be ranked according to the risk of pollution from the highest to the lowest as follows: Gorodok, Postavy, Verkhnedvinsk. The typical rate of transfer of pollutants from pesticide dumps by groundwater is up to several tens of meters per year and is relatively low. In addition, pesticide dumps are located at a distance from populated areas. Therefore, contamination of drinking groundwater with pesticides is not expected in the foreseeable future. At the same time, if surface water is polluted as a result of flat runoff by atmospheric precipitation, pesticides can enter the Zapadnaya Dvina river basin.

The practical experience of the authors of the article indicates that the only effective way to eliminate the risk of environmental pollution and the negative impact on public health from obsolete pesticide dumps is the recovery of pesticides and their disposal.

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