PROLONGED IMPACT OF CLOSED MUNICIPAL SOLID WASTE LANDFILLS ON GROUNDWATER

LÅNGTIDSEFFEKTER PÅ GRUNDVATTEN AV STÄNGDA DEPONIER





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Abstract

The article analyzes the observations of the impact of preserved landfills on the hydrosphere (ground-, surface water, and filtrate) of adjacent territories in the countries of Northern Europe and the Russian Federation. The behaviour of more than 80 components over a long time was analyzed. Graphs of changes in the most representative of them are given in the article. Landfills impact the environment both during operation and after their closure, as long as substances are subject to dissolution, chemical transformation, or decomposition. It is shown that even 20 years after the closure of the landfills, intensive contamination of groundwater continues. The main conclusion is that it is necessary to move from waste disposal at landfills to their deep processing and use in the national economy. Of course, this has been a well-known fact for a long time, but unfortunately, in Russia, burial at landfills is still ongoing, and even new landfills are being created.

Sammanfattning

I artikeln analyseras effekterna av stängda deponier på hydrosfären (grund- och ytvatten och filtrat) omkring dem i norra Europa och Ryska federationen. Fler än 80 parametrar observerades under lång tid. Diagram över förändringar i de mest representativa av dem ges i artikeln. Deponier har en inverkan på miljön både under drift och efter stängning, så länge det finns ämnen som är föremål för upplösning, kemiska reaktioner eller nedbrytning. Det påvisades att även 20 år efter att deponierna stängts fortsätter en intensiv förorening av grundvattnet. Den huvudsakliga slutsatsen är att det är nödvändigt att frångå deponering av avfall och övergå till djup bearbetning och återanvändning i den nationella ekonomin. Naturligtvis har detta varit ett välkänt faktum under lång tid, men i Ryssland pågår tyvärr fortfarande deponering på deponier och till och med nya deponier skapas.

Keywords: landfills of solid household waste, underground water, environmental pollution.

Background

The relevance of handling household garbage, the description of existing landfills, the legal component of the issue are described in our works (Dzhamalov, 2019, Dzhamalov, 2021, Zlobina, 2021). The problems of Russian landfills were also covered in the Swedish media (Lauren, 2019a; 2019b). In Russia, the problem is more urgent than ever: new landfills are being created instead of a complete transition to waste recycling. The impact of landfills on the environment, particularly groundwater, occurs not only during their operation but also for a long time after their closure, which, in our opinion, is not sufficiently covered in the literature. The present article presents data confirming this statement on the examples of measurements at closed landfills in Sweden, Finland, and Russia.

Emissions from a decommissioned landfill are mainly represented by landfill gas and filtrate. Their number depends on what kind of waste was placed at the landfill during operation, how long it functioned, and how long it was mothballed. Organic substances, for example, are active for about 35 years, ammonium nitrogen for more than 50 years, heavy metals and chlorides for up to hundreds of years.

To analyze the aftereffect of the landfill, the Scandinavian countries were selected as the closest to the Russian north in terms of climatic and natural-geological conditions. In Sweden and Finland, less than 1% of the total waste is sent to landfills. This 1 % includes, in particular, ash from the combustion of biofuels, some industrial waste, asbestos, ceramics, and some types of metals. Only recycled garbage is allowed to be taken to the landfill.

By the second half of the 2010s, 30 billion tons of waste were accumulated in the Russian Federation. There are about 15 thousand only authorized waste disposal facilities on the country's territory, covering an area of approximately 4 million hectares. Every year, about 70 million tons of mixed

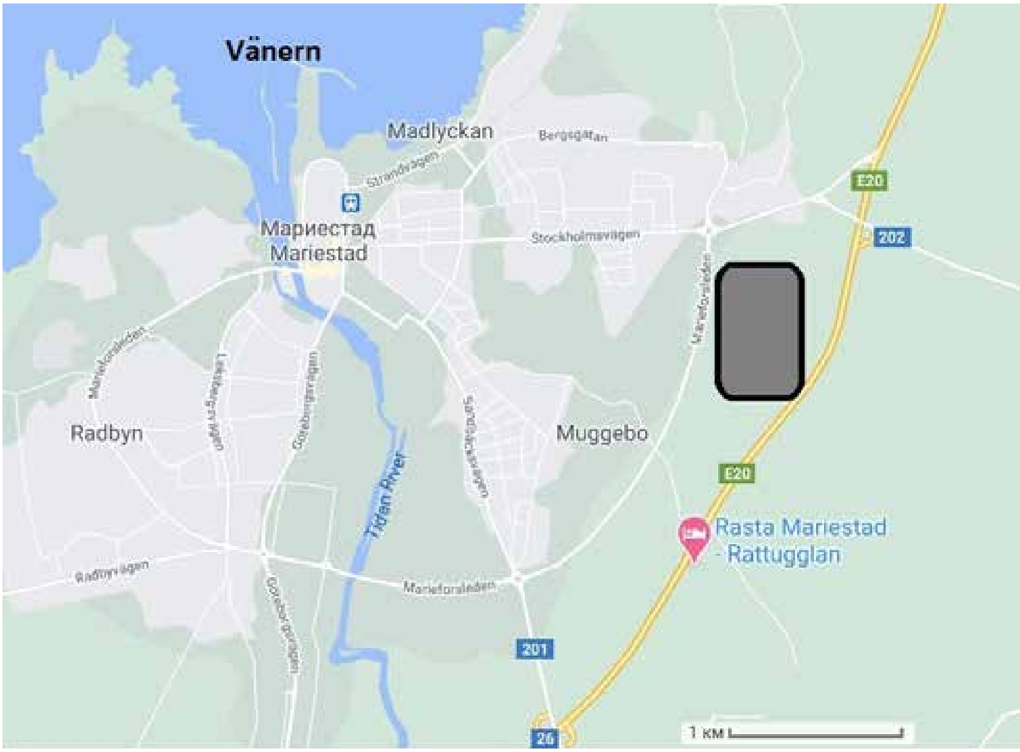

Figure 1. *The location of the Bångahagen landfill relative to the city of Mariestad and Lake Vänern.*

Figure 2. *The plan of the Bångahagen landfill.*

solid municipal waste is generated in Russia, and only 5-7 % is recycled; the rest is buried.

In this article, we wanted to show that the negative impact of landfills is manifested not only while they are functioning, but also for many decades after their closure. Therefore, from the point of view of environmental protection, the disposal of waste in landfills is a dead-end approach to their disposal.

Observations at landfills

Sweden

The closed landfill Bångahagen is located near the town of Mariestad on the shore of Sweden's largest lake Vänern. The administration of the Bångahagen landfill has kindly provided information about the facility and, most importantly, the results of observations of the composition of the ground, surface water and filtrate.

The Bångahagen landfill with an area of 25 ha, is located 3 km east of the centre of Mariestad. Urban development begins 500 m to the north of the landfill. The beginning of the operation of the landfill dates back to the 1920s. It is used for the disposal of non-hazardous waste, but there is a site with the burial of ash from an oil fire on the territory of the landfill, and it is classified as a site with hazardous waste. Since the landfill does not comply with the new rules for sealing the bed, the reception of household waste stopped in 1989, and the landfill itself was closed in the same year.

The landfill is located on a relatively flat area at an altitude of 75 meters above sea level. The direction of the groundwater flow is indeterminate due to the flat terrain. The groundwater level is close to the earth's surface at a depth of 0.1-1 m, which indicates that the territory is flooded. The average

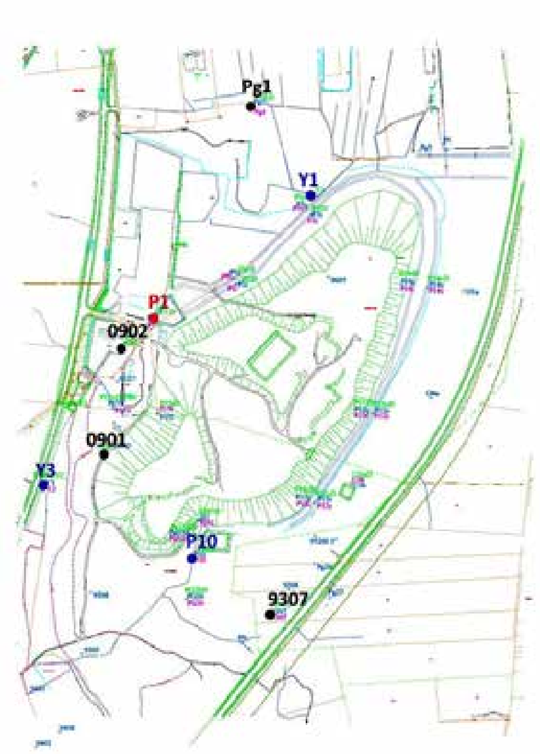

Figure 3. *Location of sampling control points at the Bångahagen landfill. Groundwater – points Pg1, 0901, 0902, 9307. Surface water – Y1, Y3, P10. Filtrate - P1.*

amount of precipitation is about 500 mm per year.

The filtrate from the landfill was collected in ditches that surround almost the entire perimeter of the landfill, except for some parts where the landfill is protected by clay or sealed mounds. The collected filtrate is diverted through a system of ditches to a storage pond located northwest of the landfill. Water from the pond is pumped to the treatment facilities of Mariestad.

A system of horizontal drains on most of the landfill intercepts the flow of surface and underground water. An external ditch diverts the collected water into the Tidan River, about 3 km southwest of the landfill. Tidan eventually runs into Vänern.

Groundwater

Twice a year, groundwater samples are taken from points Pg1, 9307, 0901 and 0902 and filtrate at point P1 (Fig. 3). At the same time, the depth of the groundwater level and its electrical conductivity are measured.

For the analysis, a series of observations of electrical conductivity, ammonium nitrogen and chlorides concentrations in groundwater and filtrate was selected. The same elements for comparison are also considered in the materials analysis for the Iiliarvi landfill in Finland. Heavy metals are found in small quantities, and their content in groundwater varies slightly over time.

Similar diagrams for the same indicators are also available for filtrate and surface water. For the convenience of analyzing the dynamics of changes in these indicators, the data on these three elements in the filtrate and the amount of precipitation are summarized in one graph (Fig. 7).

As can be seen from the diagrams, the content of chlorides in the filtrate (Fig. 7) and groundwater (Fig. 5) is the highest among other chemical elements. We will analyze the relationship between the content of chlorides in the filtrate and groundwater both in space and in time.

The minimum content of chlorides in groundwater is observed at point 9307, south of the landfill. To the north (point Pg1), the concentration is higher and slightly depends on the season. This

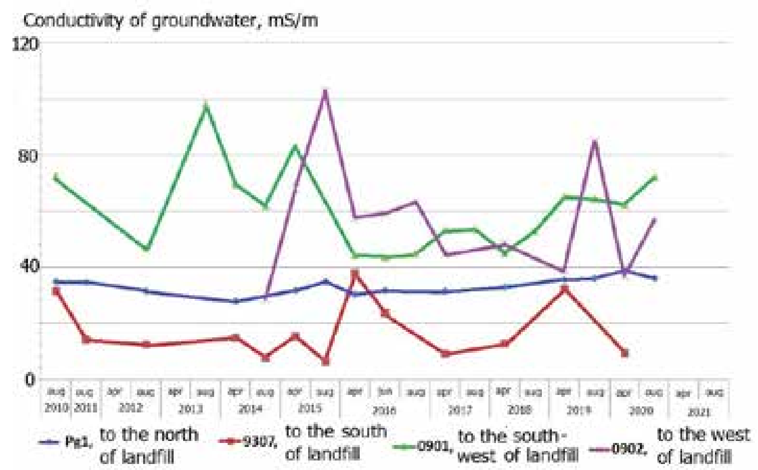

Figure 4. *Dynamics of changes in the electrical conductivity of groundwater.*

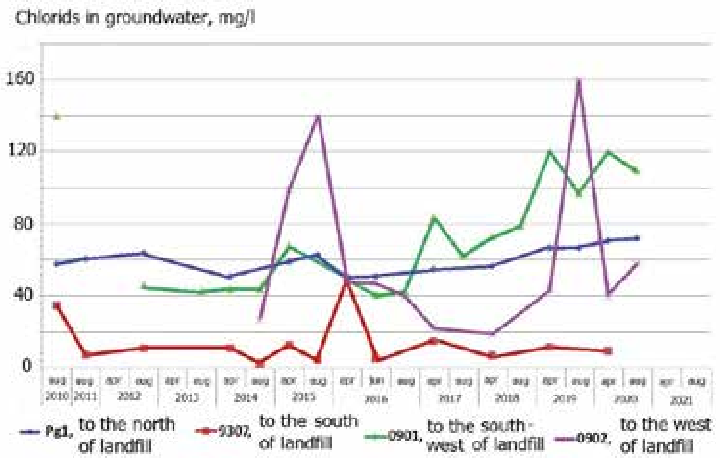

Figure 5. *Dynamics of changes in the concentration of chlorides in groundwater.*

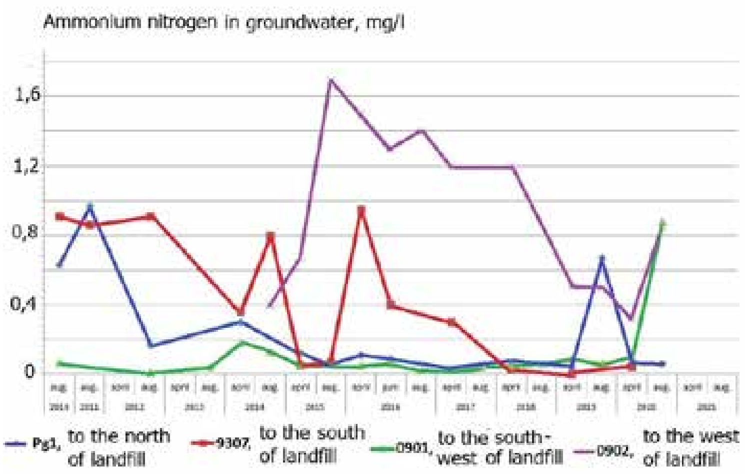

Figure 6. *Dynamics of changes in the concentration of ammonium nitrogen in groundwater.*

is explained by the direction of groundwater discharge from the landfill – the height difference between the landfill and the lake is about 30 m, the discharge of groundwater occurs in the northwest direction towards the lake. At points 0901 and 0902, the concentrations are maximum; these points are geographically located closest to filtrate intake.

Ammonium nitrogen is a biogenic element, and its content in water is subject to significant seasonal fluctuations: it decreases in spring, increases in summer due to increased bacterial decomposition of organic substances. This is illustrated in Fig. 6, the peaks of nitrogen concentration occur in August, the lows – in April.

The electrical conductivity depends on the concentration of dissolved elements and the water temperature. The threshold value of electrical conductivity for this landfill is assumed to be 80 ms/m. The graph in Fig. 7 shows that this threshold in the filtrate is constantly exceeded. In groundwater (Fig. 4), the value of the electrical conductivity threshold is exceeded only at two sampling points and only twice in the history of observations. These points are located near the filtrate sampling site.

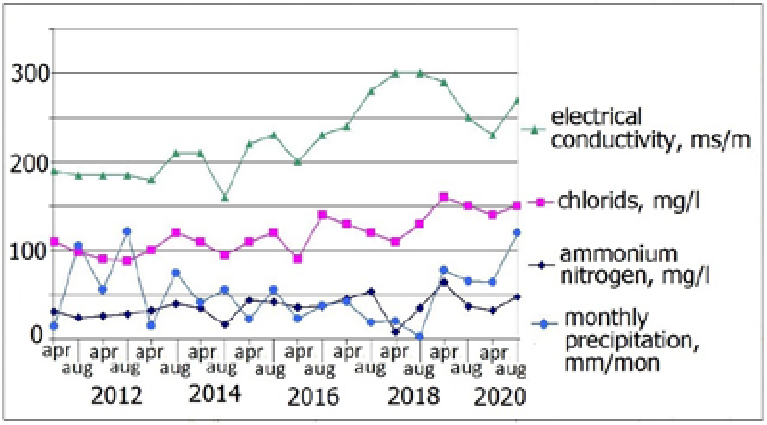

Figure 7. *Electrical conductivity, concentrations of ammonium nitrogen and chlorides in the filtrate at point P1 and the value of monthly precipitation.*

Figure 8. *The location of the Iilijarvi landfill relative to the city of Naantali.*

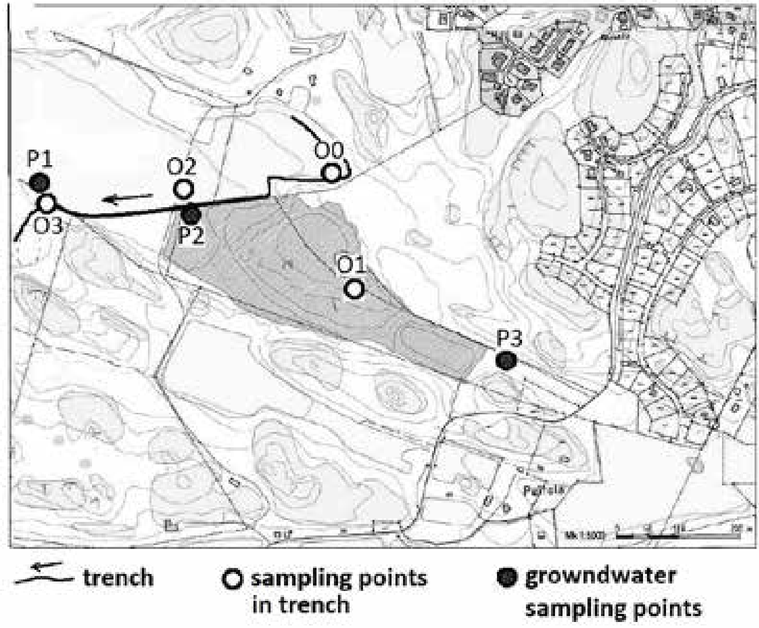

Figure 9. *Plan of the Iiliyarvi landfill and sampling points for surface and underground water.*

Finland

The data on the closed Iilijarvi landfill in Finland are taken from the thesis of Saila Porthen (Porthen, 2018), who in her research used the official report from Southwest Finland Water and Environmental Research Ltd (Reports, 2018). Naantali is a town in Southwestern Finland, 15 km west of Turku, on the Baltic Sea coast. The Iiliyarvi landfill is located 2.5 km southwest of the town of Naantali.

The company Southwest Finland Water and Environmental Research Ltd has been regularly monitoring the Iiliyarvi landfill's territory, surface and ground waters since 2004. The landfill was operated from 1965 to 1995. The location of the water sampling points is shown in Figure 9.

Surface water samples were taken from three points. The observation point O0 is located in a trench outside the landfill and does not receive water from it. Point O1 is located in the middle part of the landfill. The O2 point is located on the northern border of the landfill. The O3 observation point is located in a trench at the edge of the field.

Results of monitoring of water in trenches for 2004–2017

Based on the monitoring results at the Iiliyarvi landfill, diagrams of changes in several parameters in surface and ground waters were constructed: electrical conductivity, ammonium nitrogen, total nitrogen, total phosphorus, chlorides, sulfates.

The electrical conductivity (milliSimens/meter) is related to the amount of salts dissolved in water. An increased value of electric drive indicates significant mineralization. Wastewater and fertilizers also increase the amount of salts in the solution. The value of electrical conductivity in drainage waters above the landfill (point O0) is less than all other measurement points where surface water is more polluted.

Nitrogen enters water bodies with sewage, flood and rainwater. The nitrogen content depends on the time of year. During the growing season, nitrogen reserves are depleted due to absorption by plants. In winter the use of nitrogen in vegetation is low, which leads to the fact that nitrogen concentrations in the water remain high, which is confirmed by the results of observations.

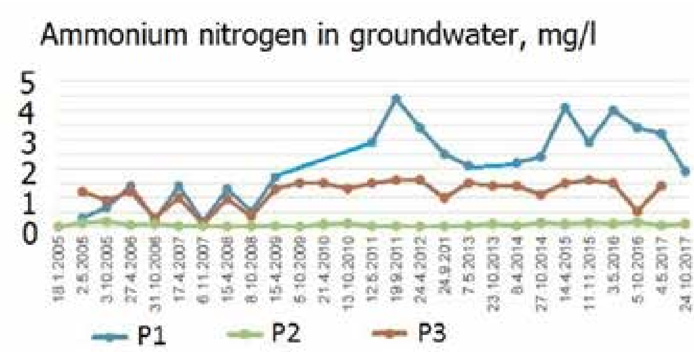

Figure 10. *The concentration of ammonium nitrogen in groundwater samples (Reports, 2018).*

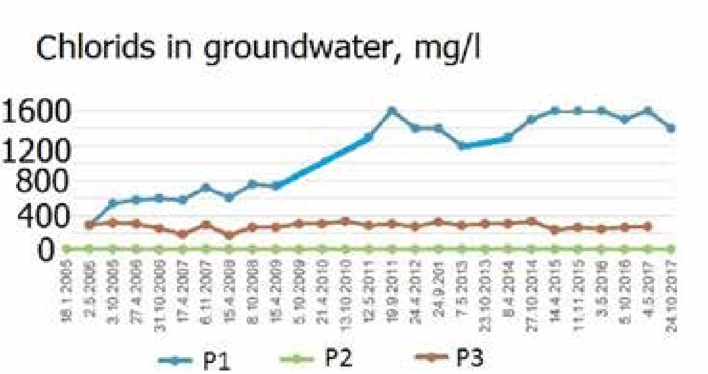

Figure 11. *Concentration of chlorides in groundwater samples (Reports, 2018).*

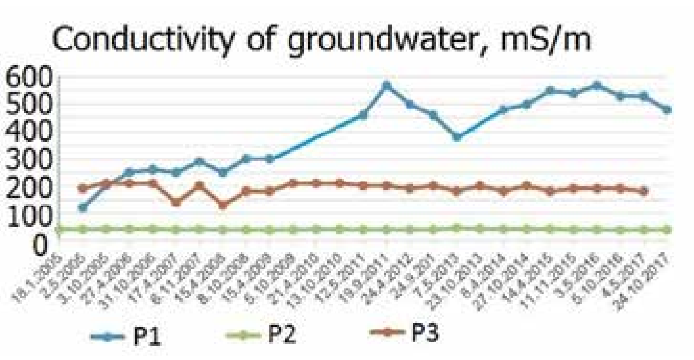

Figure 12. *Electrical conductivity in groundwater samples (Reports, 2018).*

The phosphorus content is an essential indicator in the assessment of water eutrophication. Phosphorus concentrations in surface waters vary from season to season; in winter they are lower than in summer. Since 2012, increased phosphorus content has been observed in the observation points O0, O2, O3 compared to the trench at the landfill (point O1). This is due to the removal of fertilizer fields. The water at the landfill (point O1) is slightly polluted; in the trenches where the field's runoff was observed, the water is heavily polluted.

Results of groundwater monitoring for 2004-2017

Groundwater analyses data from wells P1, P2, P3 was obtained from (Porthen, 2018). The concentration of ammonium nitrogen and chlorides in groundwater samples everywhere, except for the well outside the landfill (P1), exceeds the norms.

The limit value of the electrical conductivity of water for domestic needs in Finland is 250 mS/m, which is exceeded in the well P2, located in the upper part of the landfill.

When comparing the results, changes in precipitation and temperature should be taken into account. In rainy periods, the runoff is correspondingly more significant than in dry periods, which affects the electrical conductivity when diluting the solution.

Russia

The dump of household and industrial waste "Dubna-1" (Dubna Pravoberezhnaya) is located in the interfluve of the Volga, Dubna and Sestra rivers (Fig. 13). Its area is 4.2 ha. The volume of waste accumulated at the landfill is approximately 368 thousand tons. It was closed in 2016. Currently, work has begun on its discontinuation.

Groundwater lies at shallow depths (0.5-2 m). The landfill is an embankment surrounded by two drainage ditches for the removal of filtrate. Geochemical monitoring of drainage and groundwater was carried out from 2005 to 2014.

The content of macro-and microelements in the drainage waters of the landfill varied according to

Figure 13. *The location of the Dubna-1 landfill relative to the Volga, Dubna and Sestra rivers.*

the seasons of the year. The concentration of Cl-ions in drainage waters varied from 47 to 194 mg/l and did not exceed the MPC (MPC 300 mg/l). In groundwater, the content of Cl-ion varied from 27 to 95 mg/l (as of 2014). The maximum concentrations were observed during the summer low water period.

The influence of the landfill was manifested in the transformation of the hydrochemical type of groundwater, from the HCO3-Na type to the SO4-Na and Cl-Na types. The pH values decreased from 7.2 to 4.2. The weak groundwater protection led to a constant deterioration of their quality due to increased concentrations of several macro-components (SO4, Cl-, Na, etc.).

In two wells located near the landfill, the mineralization of groundwater exceeded 1.5 g/l. At the same time, the concentrations of trace elements in the composition of groundwater did not exceed the MPC. In the drainage waters, the concentrations of Zn, Cu, Pb, Ni and Cd were many times higher than at a distance of 2 km from the landfill.

The impact of landfills on groundwater pollution

Observations of changes in groundwater quality under the influence of landfills have established that the maximum impact of landfills on groundwater occurs in the first 4-7 years after the appearance of landfill masses. Excess concentrations were found for all macro- and micro-components in groundwater and at other landfills.

Conclusions

Monitoring of closed landfills shows that their impact on the hydrosphere of adjacent territories occurs not only during operation but also after a considerable time after the termination of their operation. Furthermore, this is despite the fact that in the Scandinavian countries, less than one per cent of waste, which cannot be disposed of in any other way, is buried in landfills. It is worth noting that in the Scandinavian countries, the rule on continuing observations at landfills after their closure is strictly observed.

The main conclusion can be only one, and very briefly formulated: landfills have no place on earth, The earth in the broad sense, and not only Russia. From burial at landfills, it is necessary to move to deep processing in the national economy.

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