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DISTRIBUTION OF HEAVY METALS FROM TAILINGS PONDS AND LANDFILLS INTO UNDERGROUND AND SURFACE WATERS

Bojana Živković [1], Jelena Đokić [1]*

[1] *University of Priština in Kosovska Mitrovica, Faculty of Technical Sciences, Serbia*

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Abstract

Heavy metals contaminate underground and surface waters from illegally constructed industrial and municipal landfills. Numerous papers on the subject contain undeniable evidence, and they have determined heavy metal migration into nature by measuring concentrations in underground and surface waters near tailings ponds and landfills. Heavy metal measured values exceed the WHO limit quota. The characteristics of heavy metals and their negative impact on the environment and people's health have prompted a large number of investigations into this global problem. This paper provides an overview of the literature on the subject, with the goal of emphasizing the anthropogenic influence of heavy metal pollution as a critical issue, particularly in developing countries.

Keywords: landfills; heavy metals; waters; pollution; monitoring

Introduction

Protection against the harmful effects of heavy metals, which largely end up in nature due to negligent disposal of tailings, municipal and industrial waste, is an essential component of environmental protection. Due to their extremely harmful influence, it is necessary to control the anthropogenic influence on the continuous increase in the presence of heavy metals in the environment.

Some heavy metals are essential bioelements that are found in trace amounts or at extremely low concentrations. Increased concentrations of the mentioned metals, on the other hand, are toxic to all forms of nature because they do not decompose, but rather accumulate and cause permanent degradation of nature [1].

Numerous studies on the subject have helped to shape public perception of heavy metal toxicity. *Ninkov et al.* [2] conducted research that found heavy metals in Banat agricultural, grassland, and vineyard soils, as well as lake sediments.

[*] Corresponding author: Bojana Živković, *bojanaz1981@gmail.com*

Arsenic (As), copper (Cu), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), nickel (Ni), zinc (Zn), and other heavy metals bioaccumulate and pile up in body tissues via the food chain. Pb, Cd, Hg, and As were discovered in the organs and muscles of certain Danube fish species [3], and high concentrations of mercury were discovered in the bodies of marine fish [4]. *Parvin and Tarek* [5] investigated the presence of Pb, Cd, Ni, Mn, and other heavy metals in edible plants and rice grains near a municipal landfill.

Surface water is found on the earth's surface, and heavy metals enter it either directly through wastewater contamination or through deposits of soil washed waste rich in atmospheric precipitation.

Groundwater is found beneath the soil's surface, and heavy metals migrate into it from contaminated soil via cracks, submersion of surface or atmospheric water through different soil layers, and so on. Heavy metal pollution spreads with the movement of water and aquifer dispersion. Heavy metal salts are highly toxic, bind to enzymes, and can travel long distances. Excessive heavy metal concentrations in water are determined by the amount of precipitation, the proximity of the source, and the activity of the biological system. Following a review of the literature, the focus of this paper is on the problem of heavy metal distribution from tailings and industrial and communal landfills into underground and surface waters. Numerous studies on the subject point to a massive problem that must be addressed on a global scale as soon as possible. The European Water Framework Directive (2000/60/EC; European Commission 2000), the WHO, the Waste Framework Directive, the Landfill Directive, the IPPC European Waste Catalogue, and the United Nations Sustainable Development Agenda (SDG) are frequently cited by experts as guidelines for problem prevention and a road map for problem resolution. The Agenda for Sustainable Development 2030 is the best example, as it presents 17 sustainable development goals, with goal number 6 (Clean Water and Sanitation) referring to water and sanitation, subgoal 6.3 referring to water quality improvement, wastewater treatment and reuse, and subgoal 6.6 referring to the protection and restoration of water management ecosystems, including forests, mountains, rivers, lakes, and floodplains. Goal number 11, Sustainable Cities and Communities, emphasizes the importance of responsible municipal waste management, among other things. Goal number 12 of the 2030 Agenda for Sustainable Development (Responsible Consumption and Production) includes responsible consumption and production, and sub-goals 12.2 and 12.4 refer to sustainable management and efficient use of natural resources, respectively.

Underground and surface water polluters with heavy metals

Tailings ponds, illegal industrial landfills, and dumps are major sources of heavy metal pollution in underground and surface water. Zinc, lead, arsenic, cadmium, chromium, mercury, and copper are the most common heavy metals found in the environment as a result of the aforementioned polluters. Given their toxicity, the mobility of the aforementioned metals is a major issue, and a solution entails the rehabilitation of landfills and legal waste disposal, as well as monitoring, which allows inspection of the state of a specific and potentially contaminated area [6]. The heavy metal limit values set by the EU and other countries' laws signal dangers and obligate us to actively combat water pollution. Primary activities should focus on raising public awareness about the toxicity of heavy metals to the environment and their impact on human health. Correct disposal and responsible waste management are critical to resolving the issue, as is immediate damage repair.

Tailings ponds

Inadequate treatment and disposal of heavy metal containing waste contribute to pollution of the environment. Investigation results for areas surrounding tailings ponds frequently show heavy metal contamination of surface and underground waters. Serbia has complied with EU waste legislation, but the situation on the ground is not in accordance with regulations. Large mines do not have designated waste disposal landfills or waste water treatment plants. As a result, waste water from plants and drainage water flushing tailings ponds flow untreated into surface watercourses, permeate the soil to reach underground waters, and travel long distances.

Copper ore mine in Bor is an example of a heavy metals polluter of underground and surface waters. The flotation tailings pond water and the plant's waste water flow into the Borska and the Kriveljska rivers; hence, the heavy metals from these rivers migrate to the Timok and the Danube. An inspection of the water in the Borska and the Kriveljska rivers has revealed an increased amount of copper (Cu 0.376 mg/dm^3-168.140 mg/dm^3), as well as other heavy metals like Zn (0.170 mg/dm^3-13.040 mg/dm^3), Cd (0.008 mg/dm^3-0.035 mg/dm^3), and Fe (0.20 mg/dm^3-455.40 mg/dm^3), whose concentrations were significantly higher than the limit values [7-8]. The level of pollution of the inspected rivers has been so much alarming that their waters could not be categorised. The fact that the upstream water of the Kriveljska river, before receiving the flotation water, belongs to the I and II categories, according to the level of pollution and use (Limit values of the elements are given in the Official Gazette of the Socialist Republic of Serbia no. 31/82), qualifies the flotation as a polluter [9]. *Milentijević et al.* [10] have pointed out in their paper the increased values of heavy metals (Cu, Zn, Fe, Cd and Pb) in the Ibar river, close to the flotation landfill of the municipality of Leposavic. Leachates of the four studied deposits contain high concentrations of heavy metals (Crnac: Cu 0.06 mg/l, Fe 13.8 mg/l, Pb 0.99 mg/l, Cd 0.0036 mg/l, and Zn 1.4 mg/l; Zuta Prlina: Cu 0.01 mg/l, Pb 0.03 mg/l, Fe 10.4 mg/l, Cd 0.044 mg/l, and Zn 10 mg/l; Belo Brdo and Koporic: Cu 0.03 mg/l, Fe 3.1 mg/l, Pb 0.03 mg/l, Cd 0.003 mg/l, and Zn 0.11 mg/l, and 0.69 mg/l for Belo Brdo), and flow directly into the tributaries of the Ibar. This has led to the measured values of heavy metals in the Ibar River, taken from three locations, exceeding the limits defined by the EU Directive 2000/60, and to designating the landfill as the main polluter. Mine tailings endanger not only underground and surface water in Serbia, but also in larger, more developed countries. An inspection of underground and surface water was carried out in China's Dexing mine district, which has the largest open pit and tailings pit. The Dexing and Lean rivers and their tributaries cut through the mine area, some of which flow through the tailings of copper, zinc, lead, and gold mines. Heavy metal concentrations were determined in 114 samples of surface water collected from the rivers and their tributaries, as well as 27 samples of underground water collected from wells. The main pollutants of surface and underground water were identified as Cd, Cu, Zn, and Pb, which is consistent with previous research on the subject. The values of the examined metals were higher near the industrial landfill, which confirms their migration [11]. The pollution of rivers with heavy metals from tailings can also be seen in the Kazretul and Mashaver rivers in Georgia, which are close to a mine tailings pond. *Avkopashvili et al.* [12] used 20 water samples from the rivers to determine heavy metal concentrations. The study was conducted because the rivers had been used as natural reservoirs for industrial and mine pit water. The industrial water was mostly drained into the Kazretul, and high concentrations, in relation to WHO of Pb (20.0 ml/l; WHO-0.065), Cu (1855.3 mg/l; WHO-0.017), Zn (2581.9 mg/l; WHO-0.20), Fe (1723.6 mg/l; WHO-0.50), Ni (69.0 mg/l; WHO-1.40), Cd (4.5 mg/l; WHO-0.01) and Co (85.5 mg/l; WHO-0.05), were detected in the Mashaver and Kazretula rivers, which proves the negative impact of the tailings pond whose drainage water flows into this river. The river Bone in Indonesia is contaminated by trade gold mines located in its vicinity. By examining its water, the authors have obtained results which reveal extremely high amounts of heavy metals present in the river the concentrations being: As 66-82500 mg/l, Hg 17-2080 mg/l, and Pb 11-1670 mg/l. The shown levels have exceeded the WHO limit values for drinking water by 1000-10000 times, which qualifies the Bone river as inadequate for drinking or cooking purposes, although the local population uses it for that purpose [13].

Industrial landfills

The issue of industrial waste disposal has been debated on a global scale, and the framework of the debate includes future solution proposals as well as possibilities for rehabilitation of current heavy metal water pollutions. According to some studies, heavy metal concentrations are tens, if not hundreds, of times higher than the limit values.

This section discusses industrial waste as a source of heavy metal pollution in water through examples of legitimate (active and closed) landfills, including waste containing heavy metals discharged into natural recipients via industrial plants.

Underground and surface waters near the Lapes industrial landfill in Kaunas, Lithuania, have been inspected for heavy metals. The samples were collected from the Marile stream, a nearby spring, and four boreholes. Each sample was found to contain heavy metals using the photometric method. All samples had Fe concentrations that were 200 times higher than the limit values. Chromium, lead, and nickel were also found in high concentrations, some of which were nearly 39 times higher than Lithuania's limit values. The authors discovered that the concentrations were higher in samples collected closer to the landfill, while concentrations were lower in samples collected further away [14]. A heavy metals survey was carried out in order to assess soil and groundwater contamination in the industrial city of Sialkot, Pakistan. The landfills where the research was conducted were made of waste from factories that processed leather and manufactured surgical instruments. The following metals had the highest concentrations in this sequence: Cu, Mn, Cr, Pb, and Hg. Average values of metals in water (Cr 0.001 mg/l; Mn 0.019 mg/l; Cu 0.033 mg/l; Cd 0.002 mg/l; Hg 0.006 mg/l; Pb 0.034 mg/l) did not exceed WHO limits (Cr 0.05 mg/l; Mn 0.2 mg/l; Cu 2 mg/l, Cd 0.005 mg/l; Hg 0.006 mg/l; Pb 0.05 mg/l), while elevated concentrations of some metals were found in the soil. Samples collected closer to the landfill contained higher amounts of metals, while the same values decreased with greater distance [15]. In 2019, investigations into the presence of heavy metals in underground and surface waters were conducted in the city of Jima, south-western Ethiopia, which has several industrial waste landfills. Twenty samples were examined using atomic absorbent spectrophotometry. The results showed that the Cd and Pb concentrations exceeded the EU, WHO, and USEPA maximum limit values [16].

Water quality conservation has long been a source of concern in south-western Nigeria. Heavy metals that enter local water matrices are major polluters. According to *Akinnifesa et al.* [17], *Akiniemi et al.* discussed the direct contamination of a river with heavy metals near an industrial plant in Ibadan, Oyo State. Although the measured concentrations of heavy metals did not exceed WHO limits (Cu 0.035 mg/l; Cr 0.026 mg/l; Ni 0.036 mg/l; Cd 0.026 mg/l; Zn 0.075 mg/l; Pb 0.032 mg/l), the authors presented their claim about the alleged pollution of the river by heavy metals originating from the factory.

Poland has also investigated the effects of industrial landfills on surface water in order to obtain a clearer picture and a true state of distribution of heavy metals from landfills. During a two year period in 2017 and 2018, the water of the river Bzure was sampled within a 120 kilometer radius. Every year, one sample was collected from 17 different sites at various times of the year. The study discovered seasonal and precipitation related variations in heavy metal concentrations. Zn concentrations were highest in January, February, and April; Ni and Pb were highest in December and April; and Cd was highest in December, January, February, and August. The increases were mostly minor, and all of them were below the quota at the start of 2019. Nickel was the only metal studied that demonstrated the ability of distant migrations, as evidenced by its detection nearly 70 kilometers away from the landfill [18].

The general public is unaware of the pervasive environmental contamination caused by heavy metals from industrial landfills. As a necessary contribution to problem solving, research intensification and investment are required, which would aid in determining the degree of heavy metal contamination of underground and surface water, the degrading characteristics of heavy metals with regard to human health, and the problem of pollution remediation. Any analysis of this topic is critical, especially because it would emphasize prevention as the foundation of a complex environmental protection process while also emphasizing the importance of other segments. Even after the activity, industrial landfills pose a potential risk to underground and surface water, so the effect of landfills must be monitored for decades after closure. *Janas and Zawadzka* [19] investigated heavy metal pollution in underground water near a decommissioned industrial landfill in the vicinity of Zgierz. They compared the obtained results to previous ones and concluded that the analyzed parameters have recently increased significantly. Copper, lead, and chromium concentrations, in particular, were found to be tens of times higher when compared to the time period when the landfill was active. The authors have highlighted the possibility of a leakage of the landfill's seeping water at the joins of the geosynthetic base based on the results of the heavy metals.

Municipal landfills

A municipal landfill must be built and organized in accordance with legal regulations, or it will pollute the environment. The first step in the systematic construction of a landfill is the proper selection of its location, which is now made easier by a plethora of modern methods used for location selection, such as AHP, Promethee, GIS, and so on [20]. Noncompliance with legal regulations when locating landfills causes them to become unsanitary and unhygienic. Furthermore, people do not follow waste collection regulations, so they dispose of various metallic objects and electronic waste at dumpsites, which are the primary causes of underground and surface water pollution with heavy metals from municipal landfills. This section of the paper discusses the impact of illegal municipal landfills on heavy metal contamination of water. Although some of the landfills have been closed, their contribution to the spread of heavy metals into underground and surface waters is unavoidable.

Dervievi et al. [21] conducted an inspection of surface and underground waters at the Grabovac site in the municipality of Zvecan in order to assess underground water pollution with heavy metals from municipal waste and to propose steps for removal and reduction of current contamination. Samples were taken in April 2013, September 2013, and February 2014. Inductively coupled plasma-optical emission spectrometry was used for the analysis (ICP-OES Optima 2100 DV). Heavy metal concentrations were found in high concentrations near an illegal landfill and in a well in Grabovac (Fe 10095 mg/l; Ni 0.529 mg/l; Cd 0.19 mg/l), prompting a prompt response.

The majority of developing countries face the issue of solid waste disposal. We contribute to the migration of heavy metals, which are frequently found in municipal waste, into the environment by disposing of objects at dumpsites without selection. Disorganized landfills are frequently found near cities, amplifying their negative impact. The Republic of Ghana is also dealing with this issue and is looking for a suitable solution. Underground waters near Oti, an illegal municipal waste landfill in Kumasa, have been analyzed to determine the concentrations of heavy metals that migrate from the landfill as well as the landfill's harmful influence on water. The obtained results have shown that the levels of Fe (10.885-25,.612), Zn (1.722-6.022), Pb (1.516-3.574), Cd (0.492-1.083), Cr (0.701-1.918) and Cu (1.731-1.984) exceeded the EPA sanctioned limits (0.03 mg/l; 3.0 mg/l; 0.01 mg/l; 0.003 mg/l; 1.0 mg/l; 0.05 mg/l). The analyses show that seeping water from the Oti landfill is percolating [22]. *Amano et al.* [23] also looked into the groundwater and surface water impacts of the unsanitary Oti Municipal Landfill, which provides drinking water to residents of Kumasi City, Ghana. Numerous inspections were conducted within a 1.34 kilometer radius of the landfill, including analyses of the presence and concentration of heavy metals in underground and surface water. Then, 12 samples were collected from boreholes and streams, and 6 samples were collected from hand dug wells. Heavy metal concentrations were analyzed by atomic absorption spectrophotometry, and the results showed a high level of toxic and carcinogenic Cd in all samples (0.0122 mg/l - 0.01090 mg/l), compared with WHO limits (0.003 mg/l), while lead, copper, and manganese were below detection limits. Further away from the landfill, cadmium values decreased, directly marking the Oti landfill as a polluter. Amin Bazar, Matuail, Mogla Bazar, and Rowfabad are four municipal waste landfills in Bangladesh that dispose of waste from three of the country's six major cities, contaminating underground and surface water with heavy metals. The analysis performed by *Parvin and Tareq* [5] confirms that certain heavy metal concentrations exceed WHO and Bangladesh-sanctioned limit values. The study field surrounding Ampar Tenang, a legal landfill, was used to determine the concentrations of heavy metals in surface and groundwater. Surface water samples were taken from the Labu River, while groundwater analysis was performed using samples taken from dedicated wells. Manganese, chromium, copper, zinc, lead, cadmium, nickel, and cobalt levels were measured in the Labu River. The results showed high concentrations of Zn, Pb and Cr, while other parameters varied. Iron, lead, copper, nickel and cadmium had increased concentrations as follows: Fe in all wells, Cu and Pb in five of them, while Ni and Cd values increased in three wells. The hypothesis of the origin of heavy metals in the landfill is justified, even if it is closed, because the authors claim that there are no natural sources of the investigated metals near the locations where the samples were collected [24].

As one of the most densely populated countries, India generates a large amount of municipal waste, which is frequently disposed of in unsanitary landfills and contaminates nearby waters. There are three active landfills in Erode: Vendipalajam, Semur, and Vairapalajami, and an inspection of underground waters revealed high iron concentrations. *Nagarajan et al.* [25] investigated the concentrations of heavy metals in underground waters to determine the potential penetration of landfill seeping water into the environment. The samples were collected from 43 assigned wells with depths ranging from 1 m to 15 m, and the analysis was performed using atomic absorbent spectrometry. In comparison to the WHO limits, the results showed significantly higher concentrations of Fe, while Pb, Cr, Cu, and Ni were detected in concentrations within the allowed limits. The analysis also revealed that the concentrations of heavy metals decreased with increasing distance and depth, indicating that the aforementioned landfills are unquestionably sources of these metals. According to the authors, the high iron values are due to large amounts of metals discovered in landfills. Calcutta, an Indian city, disposes of the majority of its municipal waste at the Dhapi unsanitary landfill, which spans 24.71 ha. The landfill is uncontrolled and a direct hazard to the environment, with active and closed off parts. *De et al.* [26] investigated the landfill's seeping water, which contaminates the area's underground and surface water. High levels of lead and mercury have been discovered in both parts of the landfill. Cr and Zn concentrations were high in the active part of the landfill, but median in the closed off part. Iron levels in the landfill were found to be in the range of 0.80-11.25 mg/l in the active area and 1.32-9.37 mg/l in the closed off area.

Nigeria has many problems with pollution of underground and surface waters, so the country is constantly concerned about water quality conservation. Many authors have investigated heavy metal pollution in water caused by municipal landfills, and all have found alarming results. Uio, an unsanitary landfill in Nigeria, is a regional source of heavy metal pollution in surface water. According to some findings, all surface water samples had higher concentrations of heavy metals, implying that the landfill had a negative impact. Fe and Pb levels in surface water samples exceeded the permitted limits, while the other detected metals (Cr, Zn, As, Fe, and Cd) were within the permitted limits [27]. *Olagunju et al.* [28] quantified and assessed the risk of heavy metals from the Avotana landfill in Nigeria reaching underground waters. Pb levels in underground water samples collected from wells and boreholes exceeded WHO limits in all examined samples, while Cd concentrations were higher only in the radius of 1-150 m. Except for Zn, the values of all analyzed metals were proportional to their proximity to the landfill. The contamination index indicated moderate contamination and focuses on the landfill's necessary sanitary rehabilitation. Several sites in the western Nigerian state of Ondo have been investigated for the presence of heavy metals in underground and surface waters. The authors chose a stream for a surface water investigation because it is unfortunately used as a landfill by the local population. The waste in the stream contains a variety of objects, including metallic and electronic waste, as evidenced by the analysis, which revealed high concentrations of lead, copper, nickel, zinc, and cadmium. The authors were particularly concerned about the locals' use of the stream water for other purposes, as well as the location of the watercourse itself. Underground waters were studied in wells with and without rings. The wells without rings were much more polluted, even 50% of them had high levels of lead, compared with WHO norms. Ni (0.887 mg/l) and Cd (0.969 mg/l) had alarming values in almost 100% of the analyzed samples from both the stream and ringless wells [29]. *Enitan et al.* [30] have identified heavy metal levels in the Nigerian river Ndawuse, which is located in close proximity to the Mpape illegitimate landfill in Abuja. The concentration of Cr in the river was 0.098 ml/l, which exceeds WHO limits; the average concentration of Fe was 1.203 mg/l, which also exceeds the limits; and the concentrations of Cu, Zn, and Pb were also higher than the norms.

The proximity of residential areas to municipal landfills poses a significant health risk to residents. There is a nonsanitary landfill of heterogeneous solid waste in the city of Bulawaj, Zimbabwe, located in the immediate vicinity of a residential area, so it is critical to become aware of a potential underground water pollution with heavy metals, the same water used by residents of Bulawaj. The underground waters contaminated by boreholes near the landfill contained high concentrations of lead and cadmium, far exceeding WHO limits, demonstrating that the landfill is the primary source of pollution [31]. Every day, 22.5 tonnes of municipal waste from the Solan district are disposed of at the Salogra landfill. A massive amount of waste is disposed of in a 3 hectare area, necessitating inspections of the landfill's potential environmental contamination. *Sharma and Ganguly* [32] investigated the landfill's seeping waters, as well as the underground and surface waters surrounding the landfill. All of the samples tested positive for Pb, with underground water containing 0.027 mg/l and surface water containing 0.024 mg/l. The analysis also revealed the presence of zinc and chromium, but their concentrations did not exceed the permitted limits. *Naminata et al.* [33] presented findings from an investigation conducted in 2013 and 2014. The investigation included the analysis of samples from the landfill's leachate, groundwater, and surface water, as well as the surroundings of the unsanitary landfill Akouedo in the district of Abidjan, Ivory Coast. The analysis showed the presence of heavy metals (Cr, Cu, Zn, Pb and Ni) in surface waters in concentrations: Cr 0.05 mg/l, Cu 0.01 mg/l, Ni 0.01 mg/l, Pb 0.02 mg/l, in the rainy season, while the equivalent values for the dry interval are: Cr 0.19 mg/l, Cu 0.05 mg/l, Ni 0.04 mg/l, Pb 0.17 mg/l, which does not exceed the limit values of ANESs (Agreement on National Environmental Standards of Laos). Zn not detected. Groundwater was sampled and analyzed from wells near the landfill. Lead had values much higher than WHO limits (Pb 0.01 mg/l) in all groundwater (for the dry season, Pb 0.06 mg/l at the landfill, 0.04 mg/l outside the landfill; for the rainy season, the lead value is 0.05 mg/l), especially in groundwater outside the landfill, in the dry season the level of lead is worrisome. Cr also shows high values when compared with WHO quota, which sets the limit value at 0.05 mg/l. The measured concentration of chromium in the rainy period at the landfill is 0.06 mg/l, while the value for the dry interval is 0.04 mg/l inside the landfill, and the measured concentration outside of it is 0.06 mg/l. Although the impact of pollution on surface water has not been observed, the levels of Cr and Pb in groundwater represent a serious threat to the environment [34].

This paper has emphasized that economically weaker countries are more likely to face the problem of heavy metal pollution from landfills; however, countries with high standards are not excluded, and Norway is a good example. The illegal Ravdelen solid waste landfill in Norway is a source of heavy metal contamination in the environment. According to a study conducted by *Abiriga et al.* [35], there is underground water pollution with heavy metals from the closed landfill, but it is much milder than when the landfill was active. Nonetheless, the analysis revealed high concentrations of zinc, lead, and, in rare cases, copper, while cadmium, chromium, and mercury had concentrations higher than benchmark values only in some of the samples, but they did not exceed Norway's drinking water standards. Nickel levels were below detection.

Good practice

Numerous studies have found heavy metals in the waters surrounding industrial and municipal landfills as a result of seeping water that leaks from the landfill's mass. Heavy metals pose a significant risk to people's health and the environment, so hazardous situations must be avoided through the systematic construction of new landfills or the rehabilitation of existing ones. *Podlasek et al.* [36] came to some interesting conclusions after inspecting two landfills, Radiowo in Poland and Zdounky in the Czech Republic, and they emphasize the importance of technical management of landfills, proper shutdowns, and monitoring. The goal of their investigations was to determine the level of contamination with heavy metals based on the presence of heavy metals in underground waters near landfills, from which they would determine the effects of landfill rehabilitation and legitimate technical management. Long-term inspections have revealed that the Zdounky landfill does not pollute underground waters or have landfill leakage, whereas analysis results for the Polish Radiowo landfill have revealed a decrease in pollution levels, which is directly related to the sanitary works performed at the landfill. As a result, these two landfills may be regarded as good practice examples. The Czech Republic landfill Tepanovica is another example of good management, as evidenced by monitoring results for surface and underground waters surrounding the landfill from 2002 to 2010. Five control sites were used to collect underground and surface water samples. The metals studied, mercury, zinc, lead, chromium, and cadmium had legally permissible concentrations and had no negative impact on underground and surface waters [37]. A proper management of landfills includes building systems, such as soil-water protection system, vertical barriers, drainage system, etc. In practice, the mentioned systems have given positive results concerning reducing concentrations of heavy metals in underground and surface waters near landfills in the short term [38]. Upgrading the existing plants with seeping water purification systems is very important. That is particularly necessary for unregulated landfills, whose results show high concentrations of heavy metals in seeping water, but not in the underground and surface waters surrounding landfills, like the case of the Piyungan landfill [39].

Aside from sanitary works at landfills, which are used to prevent water contamination, methods to reduce existing pollution must be implemented. *Odom et al.* [40] demonstrated positive ways of influencing heavy metal pollution in the environment through their research. The authors demonstrated environmental contamination with heavy metals in a radius of 15 m (from the disposal hotspot to the interior of the inactive cell) and in leachate from a dugout 4 m away from the landfill cells in the Dompoase landfill area in Ghana by inspecting the soil and water. The authors' main goal was to show that using low-valent CaO could result in heavy metal stabilisation in various samples as well as pollution reduction. Their investigation revealed a decrease in metal concentrations that took 21 days to occur, confirming positive effects on contaminated areas.

Monitoring surface and underground waters near landfills is an essential component of environmental conservation because it allows for the tracking of pollution levels over time, the planning of damage recovery, and the control of contamination. If we truly want to conserve water, we should assess and track the contamination of underground and surface waters surrounding landfills, even if they are legitimate and sanitary landfills.

Conclusion

Every country's capital resource is groundwater and surface water. This eliminates carelessness and forces us to take a more conscientious and responsible approach to their preservation. Water can become contaminated with a variety of extremely harmful pollutants, such as heavy metals. Following a review of the literature, this paper concluded that tailings, industrial and communal landfills are the primary polluters of underground and surface water with heavy metals, with the most common heavy metals being Fe, Cu, Pb, Ni, Cr, and Cd. The paper has analyzed both legitimate and illegitimate landfills, one of which is active, and the other passive. A review of the research found that heavy metal concentrations were significantly lower in areas around closed landfills than in active landfills. Dhapi, an unsanitary landfill in India, had an LPI for heavy metals (Leachate pollution index) of 34.02 for the active part, and 31.80 for the closed part. The closed and illegal Ravdelen landfill in Norway had significantly lower heavy metal concentrations after closure than during its active phase, when it was 21 years old. Some landfills are the only waste disposal sites for large and densely populated cities, and they are managed by local governments. Despite being listed as legitimate, they have no protective surface or leachate processing facilities, they are heavy metal polluters and illegitimate to boot.

Water pollution is viewed as a global issue, particularly in transition countries, poor countries (Ghana, Nigeria), and populous countries like India. There is a solution, but it necessitates significant financial resources, which is both a problem and a guideline for prioritizing conservation of the most important resource.

For already existing landfills, some of solutions for the analyzed problem would be:

- improving the design of the landfill and upgrading the leachate treatment system, as in the case of the Radiowo landfill in Poland and the Piyungan landfill in Indonesia;
- supervision and monitoring of landfills during operation and after closure, which would point to potential harmful effects of landfills on the environment;
- maintenance, which should comprise maintenance of storm water system, maintenance of drainage system for leachate, and maintenance of the plant for the processing of leachate;
- decontamination of soil of heavy metals, for example, by stabilizing low-valent CaO, which proved to be very effective in the case of the Dompoase landfill in Ghana.
- landfills to be built should provide protection of underground and surface water from heavy metal pollution, exclusively with implementation of a construction plan in accordance with regulations and monitoring. Correct location selection, installation of an impermeable geosynthetic base, construction of a system for collecting and removing stormwater, a drainage system for leachate, a leachate purification system, etc., are a basis for a responsible approach with regard to underground and surface water protection from excessive concentrations of heavy metals.

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