Impact of landfill sites on superficial water quality: case of the controlled landfill of Zerizer (NE Algeria)

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Abstract: In the present study, the characteristics of physico-chemical parameters of surface water at Zerizer city in Algeria, around the landfill site was investigated to evaluate the effect of landfill leachate migration on surface water. To highlight this objective, the sampling points were collected at different distances from the landfill site, located along the watercourse during two periods (high and low water) at the year 2019. The collected water samples were subjected to physicochemical analysis (Ph, CE, TDS, OD, BOD5, COD, NO₃, NO₂, NH₄) and heavy metals (Fe, Pb, Mn, Zn, Cr, Cu), according to internationally accepted procedures and standard methods. The results of this study were compared with Algeria standards and World Health Organization guidelines. The results obtained from the physicochemical analysis revealed that water samples are characterized by high concentration of EC (7470 µS/cm), TDS (3280 mg/l), BOD5 (53.4mg/l), COD (250.7 mg/l), NO₃ (147 mg/l), Pb (0.581 mg/l), Mn (3.1 mg/l), Cr (0.57 mg/l) and Fe (3.3 mg/l) was obtained at the sampling point near to the landfill site (Z1). This concentration of measured and analyzed parameters decreases with increasing distance from the landfill. Furthermore, the values have exceeded the specified standards which indicated that the water quality has been significantly affected by leachate percolation. So, there is an urgent need to adopt certain measures at the landfill site for the protection of environmental quality around Zirezer landfill site.

1. Introduction

One of the problems we are constantly facing is Environmental management problem (Bowen et al., 2021; Ikram et al., 2019), especially regarding waste management. During the last decade, the amount of solid waste has increased dramatically due to rapid population growth combined with uncontrolled urbanization. Landfilling of municipal solid waste (MSW) is very common method for disposal of waste around the world. (Butt et al., 2014) and one of the cheapest methods (Özkan et al., 2019). However, there are many health and environmental issues that are presented by this method. Landfill leachate is one of the major environment impacts in communities all over the world (Alemayehu et al., 2019), due to high amounts of inorganic ions, organic compounds and heavy metals and ammonia, which are generated as a result of percolating excess rainwater through the waste layers of a landfill (Wijekoon et al., 2022). This problem is even more serious in developing countries as long as Leachate can migrate to areas near landfills, particularly to waste courses and groundwater (Danthurebandara et al., 2012; Salami et al., 2013; Baghanam et al., 2020; Parvin, Tareq, 2021). In this context, the aim of this work is to study the impact of the Zirezer landfill leachate on surface (in Algeria).

Municipal solid waste of Zirezer landfill site originates as the solid wastes of a municipality collected from five cities in El Taref province namely: Zerizer, Ben M'hidi,

Asfour, Besbes and Echatt, in which the people 152 605 inhabitants (The General Census of Population and Housing, 2021) and the ordinary waste of private companies such as Cojaal, Cara, Nair. Recently, the amount of collected waste exceeds the capacity of the landfill liner, which is about 13 522 m³, with a saturation rate of 350%. It becomes overexploited and as a result, waste is discharged near close to her in the absence of a second liner. Concurrently, the leachate ponds become over-saturated, which favors their overflow without treatment into the Bounamoussa wadi located downstream from the landfill site. In this regard, the presence of a single liner, landfill site location (in agricultural land and near the surface water), are an important factors of leachate migration into the urban and an agricultural area of Zerizer city located downstream from the landfill site. which constitute a real problem of human safety. In this study, spatiotemporal variation of surface water, near a landfill site of Zerizer city was investigated. For this purpose, the analyses of heavy metals and physicochemical parameters were performed during two monitoring campaigns at 2019 (high and low water period).

2. Materials and Methods

2.1. Study area

The study was conducted at the landfill site located in Zerizer city, which is located in the North-East of Algeria and in the South-West part of the territory of El-Tarf province (Figure 1). The geographical coordinates are 36°42'28.8"N and 7°53'37.7"E.

The landfill site was excavated in the Numidian clay-sandstone complex, the downstream part of which is in contact with the Bounamoussa plain. It is part of the geological ensemble of the Tellian Atlas, where two main formations are distinguished: The tertiary formations, mainly sedimentary to the south and west, on which the landfill site is based and quaternary formations, mainly agricultural alluvial formations downstream of the landfill site (Villa, 1980; Joleaud, 1936). The study area is characterized by a humid climate. The rainfall is generally more important, exceeding 800 mm/year and an average temperature of about 18°C. Study area and interpolation maps had been drawn by ArcGIS software (10.5) (Figure 1).

Figure 1. Location of the study area

2.2. Water sample collection

Two samples were taken the first in January 2019 (the period of high water) and the second in June 2019 (the period of low water). The sampling points Z1, Z2, and Z3 situated 100 m, 500 m and 1.7 km away, respectively, from the landfill (Figure 1, Table 1). The samples were collected according to the method described by Rodier (Rodier et al., 2009), then they were immediately transferred to the laboratory for the analysis. Water temperature, electrical conductivity, pH, dissolved oxygen and total dissolve solids were measured in situ, whereas other parameters were measured in the laboratory.

Table 1. Description of samples sites.

Sample collected sites	Description of sample collection sites
Z1	The leachate discharge is very important (100 m from landfill site)
Z2	The wadi crossing the agricultural land (500 m from landfill site)
Z3	The wadi crossing the agglomerations (1.7 km from landfill site)

2.3. Physicochemical analysis

At each sampling, temperature (T), electrical conductivity (EC), total dissolve solids (TDS), pH and dissolve oxygen (DO) were measured in situ using a WTW multi-parameter (P3 PH/LFSET multiline), pH meter (waterproof) and an Oximeter (WTW) with a probe (Cellox 325) (for recording the dissolved oxygen).

The physicochemical analysis (Chemical Oxygen Demand (COD), Biochemical oxygen demand (BOD), nitrate (NO_3), ammoniacal nitrogen (NH_4) and heavy metals: lead (Pb), copper (Cu), zinc (Zn), iron (Fe), Manganese (Mn), and Chromium (Cr), were estimated by Spectrophotometry methods (Cuprizone, Dithizone and Triazine).

3. Results

The results obtained were compared with Algeria standards and World Health Organization guideline (the Algerian one according to JO 19 June 2011 N° 34 and WHO surface water standards, 2006). Spatiotemporal variations of physico-chemical water quality parameters in dry and wet seasons are given in table 2 and figures 2, 3, 4, 5 (Z1, Z2, Z3 present the samples collected during high water period whereas, Z'1, Z'2 and Z'3 present the samples collected during low water period in 2019).

3.1. Assessment of spatiotemporal variations of water quality parameters (in situ).

The results of measures in situ of the physico-chemical parameters show a significant qualitative degradation of water bordering wadi located downstream of the discharge.

3.1.1. The temperature

The temperature of surface water may varies depending on the climate and atmospheric conditions (Chen et al., 2019). In this study, the temperature values measured ranged from 10.9 to 12.8°C in wet seasons, however in dry seasons we found 23°C for all sampling points (Figure 2). Obviously, this Results are related to the seasonal changes.

3.1.2. The hydrogen potential (pH)

The pH value of water is a measure of acidity or alkalinity (Mouchara., 2009). PH values of surface water were 6.6, 7.3 and 7.9 in sampling points Z1, Z2 and Z3 respectively, during the high water. At the same sampling points pH values were 6, 6 and 7.4 during the low. The higher values of pH were recorded in the winter season as compared to summer. The maximum pH noticed in the high water was 7.9 at third sampling point (Z3) and the minimum pH recorded was 6 at first sampling point Z1 during the low water. The pH of surface water in Z3 showed a very slightly alkaline tendency during two seasons. However, in Z1 showed a slightly acidic (6-6.6). This acidification of waters, particularly at Z1 may explain by the discharge of leachate from the landfill. These pH values may serve to promote the release of metal complexes from sediments and may pose a risk to the growth and development of aquatic life (Xiao et al., 2019; Subin, Husna., 2013). In this study, the pH ranges from 6 to 7.9 conform with Algerian (6,5-9) and WHO standards (6,5-8.5) (Figure 2).

3.1.3. The electrical conductivity (EC)

The measurement of electrical conductivity provides an assessment of mineralization of the water (Makhoukh., 2011; Rodier., 1984) and also to see salinity of water. The EC in the sampling points ranged from 1920 to 7470 $\mu\text{S}/\text{cm}$ in the dry season and from 1004 to 2400 $\mu\text{S}/\text{cm}$ in the wet season. The highest values of EC; 2400 $\mu\text{S}/\text{cm}$ and 7470 $\mu\text{S}/\text{cm}$ are reached at Z1 during the two periods in January and June, respectively, and then gradually decrease away from the landfill to 1986 $\mu\text{S}/\text{cm}$ and 5890 $\mu\text{S}/\text{cm}$ at Z2 (in the winter and summer seasons) and decline to 1004 $\mu\text{S}/\text{cm}$ and 1920 $\mu\text{S}/\text{cm}$ at the third point Z3 (Figure 2). This variation is more pronounced during the summer, due to the high evaporation and to the low water levels, thus supporting the predominance of the leachates which is charged in organic substances and the dissolution of certain mineral substances of rocks. In the winter season, there is a decrease in conductivity, which could be explained by the effect of dilution of water wadi during of heavy rainfall. On the other hand, spatial fluctuations are consistent with those reported by (Hicham et al., 2018; Zaafour, 2012). Due to the risks that landfill leachates may pose especially at Z1 is significant due to its proximity to the landfill. In this case, the value has exceeded the specified standards (WHO standard for surface water (1000 $\mu\text{S}/\text{cm}$) and the Algerian standard (2800 $\mu\text{S}/\text{cm}$) which indicates low water quality.

3.1.4. Total Dissolved Salts (TDS)

TDS values ranged from 1151 mg/l to 1438 mg/l at sampling points Z3 and Z1 respectively during the wet season. On the other hand, during the dry season, we recorded levels fluctuating between 608 mg/l (Z3) and 3280 mg/l (Z1). The high concentrations were noted during the dry period at Z1 and the minimum at Z3 (Fig 2). This evolution coincides with that of electrical conductivity. This strong mineralization decreases when we move away from the landfill site, this mineralization can be explained by the presence of dissolved ions and discharges into the wadi (Singh, Hussian., 2016; Mishra, Saksena., 1991) and also by the excessive use of fertilizers in Zerizer city.

3.1.5. Dissolved oxygen (DO)

Dissolved oxygen is an important measure for assessing water quality (Naubi et al., 2016; Mouchara., 2009), self-purification and Pollution of a watercourse (Makhoukh., 2011). Dissolved oxygen (DO) measurements indicated the absence of O_2 at all samples in both periods, with the exception, in January 5.73 mg/l was recorded at Z3 which is the furthest point (1.7 km) from the landfill site (Figure 2). This result can be explained by the activity aquatic organisms present in the water; the processes of oxidation and

decomposition of organic matter that is a favorable environment for fermentation and the release of odors. (Makhokh et al., 2011). Moreover, compounds accumulate have strong odors and present phytotoxicity (Subin, Husna, 2013), which explains thus strong foul smells and the dark color of the water. In this case, water is not suitable for any use and its use constitutes a real health risk.

Figure 2. Spatiotemporal evolution of parameters measured in situ concentrations: (a) temperature; (b) the hydrogen potential (pH); (c) the electrical conductivity (EC); (d) Total Dissolved Salts (TDS); (e) Dissolved oxygen OD.

3.2. Spatiotemporal variations of nutrients in water quality (NH_4 , NO_2 and NO_3)

The Ammonium NH_4 concentration change results showed a decreasing spatial change during the wet season where the high concentration was recorded at Z1 - 0.61mg/l and then begins to decrease to 0.55 mg/l in (Z2) to 0.48 mg/l in Z3. On the other hand, we have marked the opposite during the summer, it is a growing variation of the contents of NH_4 ranging from 0.47 mg/l to Z1, then it begins to increase to reach 0.52 mg/l to Z2 and 0.61 mg/l to Z3 level (Figure 3), in which the wadi crosses agricultural lands (Z2) and agglomerations (Z3), this is explained by the intensive use of pesticides

and the domestic discharges from agglomerations. Moreover, the majority of the concentrations obtained exceed the standard set by the WHO (0.5 mg/l).

The Nitrite NO_2 values in the sampled water range from 0.54 mg/l to 0.75 mg/l during the wet season and 0.16 mg/l to 0.31 mg/l during the dry season (Figure 3). However, the set remains below the WHO standard (1 mg/l). These low levels are explained by the easy oxidation of nitrite ion to nitrate. Thus, nitrate NO_3 is the final stage of nitrogen oxidation and represents the form of nitrogen with the highest degree of oxidation present in water (Boubryem, Derradji, 2018; Rodier et al., 1996).

The Nitrate NO_3 values range from 42.05 mg/l to 147 mg/l, values that far exceed WHO standards and those of Algeria (50 mg/l) (Figure 3). This seasonal change in nitrites and nitrates (NO_2 and NO_3) could be explained by the excessive use of fertilizers (Benabdellouahad, 2006; Neal et al., 2000), on the one hand and leaching of agricultural land during heavy rains (Hicham et al., 2018; Khattabi, 2002) as well as excessive leachate discharges from the Zirezer inter-municipal landfill.

Figure 3. Spatiotemporal evolution of the organic elements concentrations: (a) Ammonium NH_4 (mg/l); (b) Nitrite NO_2 (mg/l); (c) nitrate NO_3 (mg/l).

3.3. Spatiotemporal variations of Chemical and biological oxygen demand (COD and BOD5) in water quality

The value of Chemical oxygen demand (COD) fluctuated from 40 mg/l (Z3) to 119 mg/l (Z2) in winter and from 123.5 mg/l (Z3) to 250.7 mg/l (Z1) in summer. However, the value of biological oxygen demand (BOD5) ranges from 3.6 (Z1) to 6.8 (Z3) in winter and 53.4 (Z1) to 39.4 mg/l (Z3) in summer (Figure 4). The low concentration in winter are mainly due to the dilution phenomenon by heavy rainfall. However, the high concentrations in summer could be explained by the direct release of raw leachate with high organic and nutrient content into the wadi (Su et al., 2021), largely exceed the guideline value which is 30 mg/l. In addition, the COD/BOD5 ratio represents the index of estimation of the biodegradability of the organic matter of an effluent in which to indicate

the degree of pollution and also to propose a suitable method of treatment (Belghyti et al., 2009). The following limitations are generally encountered: COD/BOD5 < 2: the effluent is readily biodegradable and has low toxicity; COD/BOD5 between 2 and 3: biodegradable effluent; COD/BOD5 > 3 the effluent is not biodegradable (Dhimni et al., 2015). The values of this ratio obtained are between 3.85 and 3.13 in the summer period and between 5.88 and 27.5 in the winter period, which attests to water heavily charged with organic matter difficult to eliminate (Table 2).

Table 2. Results of COD/BOD5 ratio values (Biodegradability criteria)

	Z1	Z2	Z3
high water	27,5	24,79	5,88
low water	3,85	3,71	3,13

(a)

(b)

Figure 4. Spatiotemporal evolution of COD et BOD5 concentrations: (a) BOD5(mg/l); (b) COD (mg/l).

3.4. Spatiotemporal variations of the heavy metals

The examination of the results of the concentrations of heavy metals clearly indicated a high contamination of the superficial waters by iron and manganese, where high concentrations of these metals were recorded at point Z1 and becomes progressively lower when moving away from the landfill site to the point Z3, which represents the lowest concentrations of these metals, this contamination caused by the direct contact of the superficial water with the leachate (Z1). We noted a contamination of the quality of the superficial water by the two metals compared to those recorded in 2012. The variations of Iron and Manganese (Figure 5: B, D) showed high concentrations of these elements largely exceed the Algerian standards admissible for superficial waters during the period of high waters (January), the concentrations were higher than 1mg/l for the two elements, we can explain this contamination by the agricultural activity (pesticides and insecticides) and the leaching during the intense rainfall. The low concentrations of these elements were marked during the low waters period and don't exceed the Algerian standards for superficial waters.

While the lead concentrations (Figure 5: A) represent values higher than the Algerian standards of the surface waters during the two measurement periods or the highest concentration is recorded at Z1 of the order of 0.581mg/l and 0.356 mg/l respectively for the month of June and January, on the other hand the lowest concentration is noted at the level of Z1 of the order of 0.325mg/l for the month of June and 0.162mg/l for the month of January.

Zinc and copper concentrations (Figure 5: C, F) showed values under the standards. The maximum of concentrations were recorded 1.061 mg/l and 1.54 mg/l respectively,

during the dry period, while low values were recorded during the winter. These fluctuations may explain by leachate due to the decrease in the flow of watercourse in the dry period. On the other hand, the variations in Chromium concentrations (Figure 5: E) indicated that the values superior to the admissible norms of the superficial waters. The high concentrations were marked during the wet period in Z1 0.51 mg/l, this concentration is diminished progressively moving away from the landfill to reach 0.26 mg/l in the point Z3, this contamination linked to the washing of the soil charged in metallic substance after the migration of these toxic metals to the bottom of the water course partially clogged by the fine materials (clays and silts) during the dry period (Zenati et al., 2013).

Figure 5. Evolution of the heavy metals concentrations: (A) lead concentrations Pb (mg/l); (B) Manganese Mg (mg/l); (C) Zinc Zn (mg/l); (D) Iron Fe (mg/l); (E) Chromium Cr (mg/l); (F) Copper Cu (mg/l).

4. Discussion

In this section, we will discuss the main findings of the research. This paper was the subject of assessment of spatiotemporal variations of physicochemical water quality parameters of the Bounamoussa wadi located downstream from the landfill site. The results of our analysis showed:

First, temporal evolution was similar, where the high concentration (EC, TDS, BOD5 COD, PB, Zn and Cu) was recorded during low water. However, their low concentration

was marked during the high-water period. The water quality was influenced by seasonal changes the concentrations high in summer can be explained by due to lack of rainfall and high evaporation that provides cumulating in sediments of water wadi. While the low concentration in winter can be explained by dilution by rainwater's.

High concentrations of NH_4 , NO_2 and NO_3 in winter do the excessive use of fertilizers in Zerizer city (agricultural land).

Secondly, spatial evolution was similar during two monitoring campaigns. Which, the majority of the highest concentrations are obtained at the sampling point closest to the landfill site (Z1), then, they gradually decrease away from the landfill, which clarifies that the leachate is the potential source of surface water contamination. The water quality was influenced by the leachate resulting from landfill site.

Our physico-chemical study shows that surface waters in the vicinity of the landfill are characterized by: acidic (Z1; $\text{pH} < 6$) to alkaline (Z3; $\text{pH} > 7$) water, highly mineralized and saline due to the high values of electrical conductivity and total of dissolved salts TDS, an environment poor in dissolved oxygen; high concentrations of BOD, COD and NH_4 , NO_2 and NO_3 indicated the extent of organic pollution in the surface water; concentrations of Iron, Manganese and lead have revealed levels that largely exceed the standards (WHO and Algerian), indicators of water pollution.

5. Conclusions

The chemical analysis results show a significant qualitative degradation of surface water, where the majority of the analyses (EC, TDS, NH_4^+ , NO_3 , COD and BOD5, Pb, Mn, Fe and Cr) have revealed levels that largely exceed the standards (WHO and Algerian), especially in Z1 and Z2 given their proximity to the landfill site that generated significant quantities of leachate without any pre-treatment. Nevertheless, this contamination tends to be reduced at Z3 which is located away from the landfill site (1.7 km). Comparatively, the pollution status of water is high at Z3. Therefore, the Zierzer landfill is considered as a main source of pollution in the study area.

Recommendations

Necessary steps should be taken by the authority to prevent further contamination from leachate. The following recommendations can be suggested for an effective protection of the water:

- It is therefore essential to stop the use of these waters, control the quality of the waters and follow their evolution.

- It is necessary to establish a barrier on the water of the wadi to prevent its use (either for irrigation or for feeding livestock) as a short-term precaution.

- create one or two landfill liner and deep leachate retention ponds to retain the leachate during the floods in the wet period that do not have an indirect contact with the hydrographic networks.

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