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IMPACT OF TECHNICAL LANDFILL BOUGUERGUER ON WATER RESOURCES AND THE ENVIRONMENT (NORTH-EAST ALGERIA)

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Abstract: While landfilling remains the most economically viable and commonly employed method of waste disposal, it poses potential risks of environmental degradation, including foul odor emission, biogas production, and the generation of leachates carrying a significant pollution load. Leachates, upon infiltrating the subsoil, contribute to a profound degradation of groundwater. This study focuses on assessing the impact of leachates from the public landfill of Bouguerguer (wilaya of Guelma) on groundwater and surface water. Two sampling campaigns were conducted, with the first involving 5 samples and the second comprising 8 samples, both carried out in 2018. Analytical results reveal that water sourced from wells, springs, and downstream surface water from the technical landfill Bouguerguer is heavily contaminated with organic matter and metallic trace elements (Cr^{+6}, Pb^{+}, Fe^{+3}, and Ni). Levels of organic matter (BOD5: 50 mg/l - 10 mg/l, dissolved oxygen: 0.5-9 mg/l) are notably elevated in surface and groundwater, respectively. Additionally, concentrations of trace metal elements (Cr^{+6}: 0.075-2.45 mg/l, Pb+: 0.03-1.16 mg/l, Fe^{+3}: 0.006-7.07 mg/l, Ni^{+}: 0.29-25 mg/l) significantly surpass the standards set by the World Health Organization (WHO). Consequently, these findings substantiate our hypothesis that degraded groundwater and surface water contribute significantly to the prevalence of diseases in Guelma Wilaya. This study emphasizes the urgent need for local authorities to implement preventive measures to mitigate pollution and to rehabilitate the landfill in accordance with international standards.

Keywords: Landfill, Leachate, Groundwater, Surface water, Heavy metals

1. INTRODUCTION

Good water resource management requires that water quality not be compromised by significant degradation of its chemical or biological properties (Berkani et al., 2023; Aina, 2006). A decline in water quality can affect both human and ecosystem health (Gachet, 2005; Djemaci, 2012).

In conjunction with economic expansion, enhanced lifestyles, and increased consumerism, cities worldwide will persistently confront a formidable solid waste management (SWM) challenge (Shitaw et al., 2022). This is anticipated to intensify with the global population projected to reach 8 billion by 2025 and 9.3 billion by 2050, with approximately 70% residing in urban areas (Ismaila et al., 2022).

Nevertheless, leachate from landfills significantly impacts both groundwater and surface waters. Leachate migration induces changes in the geological characteristics of the soil. The decomposition of substances and the action of microbes determine the physical, chemical, and biological properties of the deposited material (Yaashikaa et al., 2022; Mvula et al., 2023). A United States Environmental Protection Agency (USEPA) survey revealed that approximately 75% of landfills in the United States contaminate groundwater (USEPA, 2004). Similar cases have been identified worldwide, particularly in European countries, Australia, and China (Lei Shi et al., 2021). In China, the volume of landfill leachate often surpasses the design capacity, leading to elevated water levels within the landfill body and subsequent infiltration of leachate into the surrounding areas, causing landfill instability, in India, Exposition of the cancerous substances present in the liquids that cause cancer, which signifies that it may increase the risk of developing certain types of cancer (Rakhi et al., 2021).

The awareness of solid urban waste in Algeria only materialized in 2001 with the enactment of Law 01-19 on waste management and the establishment of the National Program for the Integrated Management of Household and Similar Waste whose impact on the environment is very direct (Attoui, 2014), known as PROGDEME in French. PROGDEME aims to eradicate illegal landfills while fostering recycling and selective sorting activities (Medjahed & Brahamia, 2019).

Despite the efforts made in the creation of waste storage centers, the Technical landfill Bouguerguer (W. Guelma), which is largely in line with this approach, functions very poorly; the heaps of unsorted waste and the overexploited locker are still sources of pollution aggravated because of their concentration: production of leachate poorly drained and untreated, production of unrecovered biogas, etc.

The major concern generated by The Technical landfill Bouguerguer is that of leachate, a liquid that comes from the percolation of water through the waste stored in landfills, taking on both mineral and organic substances, it can mix with surface water as well as with groundwater and therefore constitute a polluting element both quantitatively and qualitatively, (Frigon et al., 1992).

Indeed, the infiltration and diffusion of these pollutants towards the water table or their flow by the hydrographic network towards the plain of Boumahra can lead to an insidious degradation of groundwater and surface water (Cheniti et al., 2021).

The main interest of this study is to determine the impact of leachate generated by the technical landfill of BOUGUERGUER on the quality of surface and underground waters of the plain of BOUMAHRA, intended for the supply of drinking water, and the irrigation of the neighbouring cultivated lands.

2.METHODOLOGY

2.1. Study area

The study area occupies the center of the wilaya of Guelma it crosses the communes of Heliopolis, Belkhir, Djeballah Khemissi and Boumahra, (Figure 1). The Seybouse is the main wadi that digs the plain of the study area, the latter offers slopes generally little accentuated, more gentle for the slopes exposed to the south. Its bottom is flat and has a low longitudinal and transverse slope. Towards the north the reliefs that immediately overhang the plain are characterized by medium slopes.

From a geological point of view, the study area is part of the geological set of the North East Algerian tell. It is constituted by sedimentary grounds in the whole are of age Cretaceous, Oligocene, Mio-Pliocene and Quaternary, these alluviums are permeable constituted of the groundwaters of terraces which have a hydrogeological interest, these aquifers are fed by

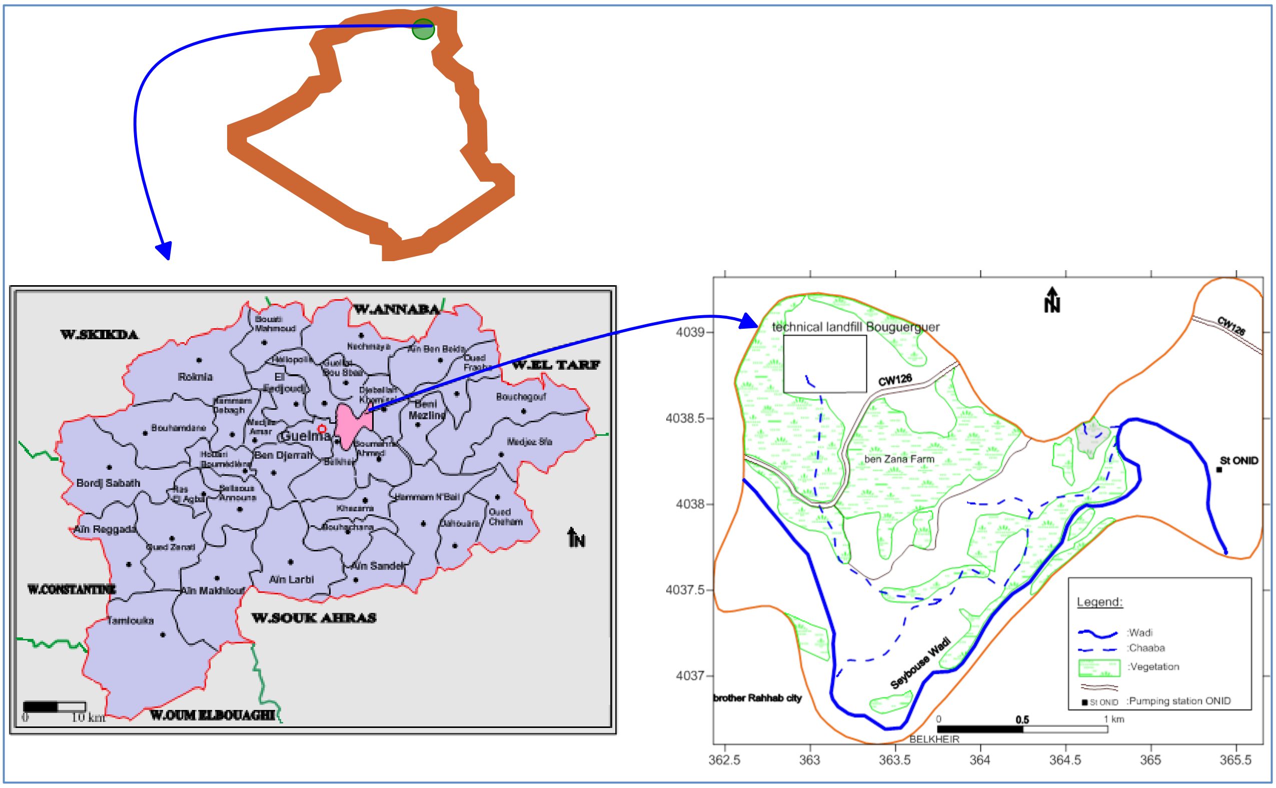

Figure 1. Geographical location of the study area

the waters of infiltrations of the rains and the side contributions of the catchment area of the Seybouse Wadi.

The study area is subject to a Mediterranean climate, rainy and cold in winter and hot and dry in summer. The average annual precipitation for a 30-year observation period ranges from (612.89 -589.5 mm) with an annual temperature of about 18.26°C.

According to the geophysical and hydrogeological study on the Technical landfill Bouguerguer, the clayey-silt alluvium constitutes in the studied perimeter an aquifer (perched) with an interstice porosity of low importance. The flow of this water seems to be in the direction of the Chaaba which constitutes a channel serving as a drain towards which converge, both surface water and groundwater. These waters feed the alluvial aquifers of the plain of Guelma located below.

2.2 Presentation of the BOUGUERGUEUR technical landfill Center

Through continuous and recurring field inspections, both inside and outside the landfill, several management violations and deficiencies in the necessary equipment have been observed. These shortcomings not only jeopardize the proper and effective waste management but also pose a threat to the environment and water resources in close proximity, the preservation of which is paramount.

According to the report prepared by the AQUASOL-CONSULT study office, the surface of the Technical landfill Bouguerguer is made up of permeable clay-silt alluvial deposits and constitutes an aquifer whose flow is from east to west.

-The first trap of capacity 90.000m^3 has reached saturation and there is risk of collapse of the dikes The leachate extraction wells are cracked due to the load of waste and machinery (Figure 2a).

-The Technical landfill Bouguerguer treats approximately 140 t/d of solid waste destined for landfill to minimize the amount of waste landfilled it is preferable to focus on a policy of sorting, recycling (Figure 2 b and c).

-Indeed, the presence of a well at a distance of (10 - 15m) from the first trap testifies to the existence of a shallow groundwater layer likely to be contaminated by leachate infiltration loaded with various pollutants (Figure 2 d).

-All Technical landfill Bouguerguer of household waste produces biogas, it is necessary to capture it in order to recover it, unfortunately the Technical landfill is devoid of this type of management (Figure 2e).

-The Technical landfill Bouguerguer was equipped with a leachate treatment plant which operates either by membrane system or by reverse osmosis the problem of leachate overflow in the Chaaba towards the Seybouse Wadi will be eradicated. In addition, the water recovered after treatment will be used for cleaning machinery, trucks, hangars, (Figure 2i and 2f).

-Constituted by three lagoons the first of approximately (30m x15m) connected with the other two lagoons of dimension (15m x15m each) by plastic pipes.

-The lagoon geo-membrane that has been used to protect the soil from leachate contamination is inflated and torn in the environment and may be vulnerable to leachate infiltration pollution (Figure 2g).

-The flexible leachate pipes are drilled in places, leaving toxic leachate on the ground (Figure 2h).

3. MATERIAL AND METHODS

To better understand the problems of leachate discharge into the natural environment and to be able to detect a possible pollution, we proceeded to a control of the liquid discharge produced by the Technical landfill Bouguerguer, of the underground waters of the plain and those of the Seybouse Wadi. We carried out many sampling campaigns. Sampling was conducted at a weekly time step throughout the year 2018, specifically in March and April. The targets included: leachate tank, wells, and surface waters downstream of the landfillthe Temperature (T), pH, and electrical conductivity (EC) were measured in situ using a WWT 82 362 multi-parameter instrument. The geographical coordinates were obtained using a GPS Status. The network of sampling points is presented in Figure 3. The water samples were kept at 4°C in a cooler during transport to the laboratory.

The samples were taken for the determination of organic pollution (BOD_5, O_2) and Total Chromium. Total Iron with 5 samples using (HACH 8080 method) and ASTM methods, and 8 samples were used to highlight the presence of metal contamination (Cr^{+6}, Pb^+, Ni, and Fe^{+3}), using spectrophotometry method DIN EN SO7393G42. Triazine, Dimethylglyoxime, dithizon.

4. RESULTS AND DISCUSSIONS

The chemical results of the groundwater samples were compared by the standards of potability of the WHO 2017, on the other hand those of leachate were estimated compared to the Algerian standards of the discharges, so the samples sampled at the level of Chaaba and Seybouse Wadi are evaluated by those of the standards of surface water.

Figure 2. Photos taken in the BOUGUERGUEUR technical landfill center.

4.1. Physicochemical parameters for the two campaigns (March -April 2018)

4.1.1. Temperature

The water temperature is an important parameter because it allows to determine the use of the water for the comfort of the users. It also allows to correct the analysis parameters whose values are linked to the temperature (conductivity in particular). Moreover, by highlighting the contrasts of the water temperature on a medium, it is possible to obtain indications on the origin and the flow of the water.

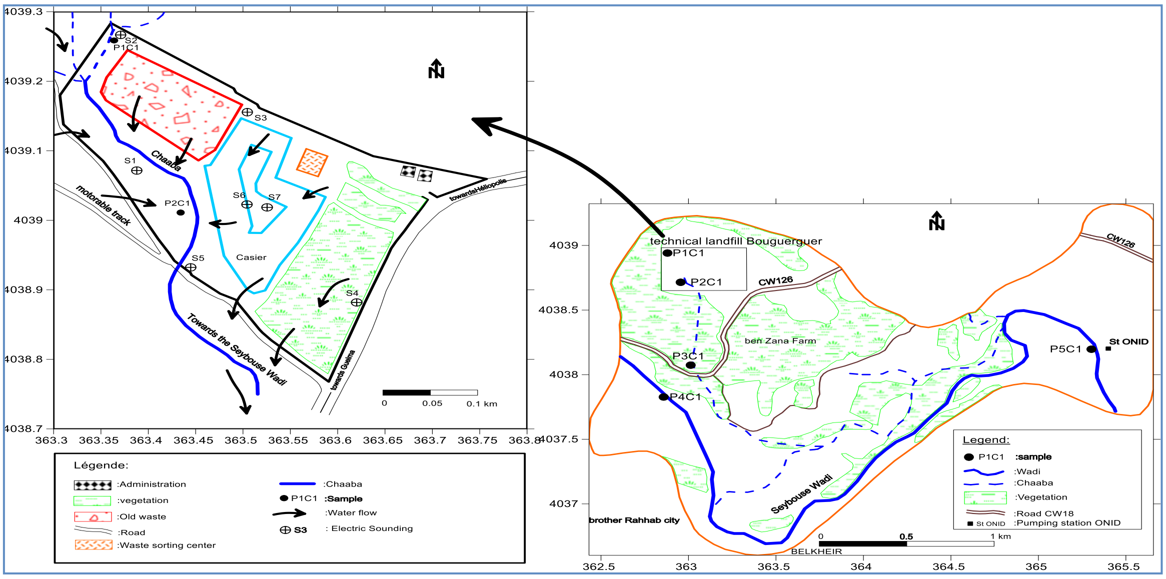

Figure 3. Water withdrawal inventory map for the Campaign (March 2018)

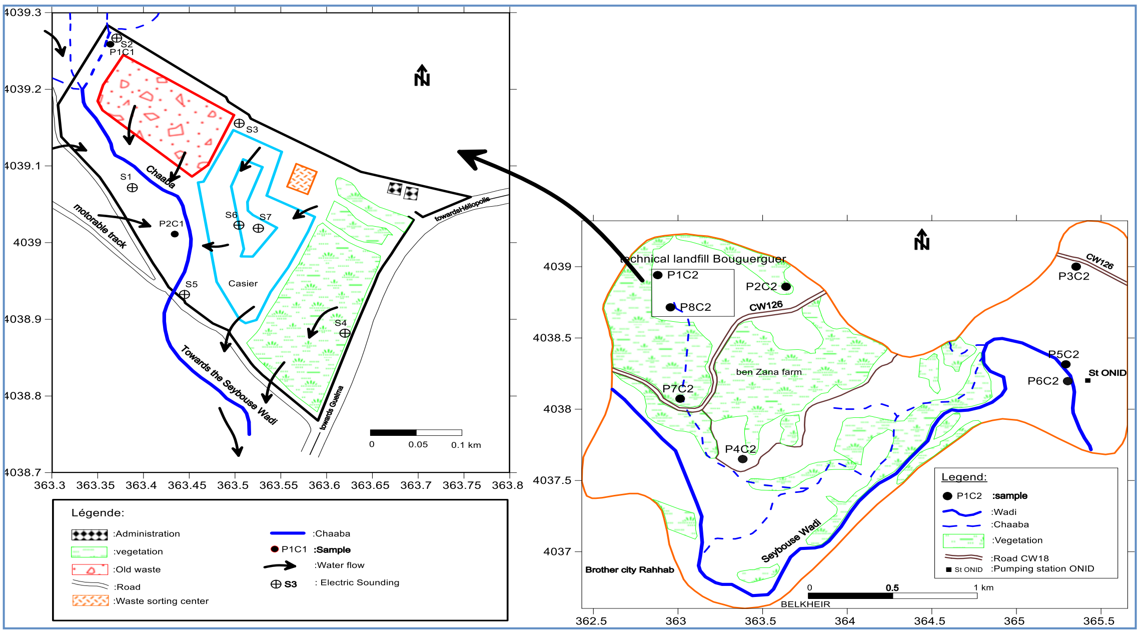

Figure 4. Water withdrawal inventory map for the Campaign (April 2018)

According to the figure (Figure 5A), the temperature of water for the first campaign varies between 16.1° C and 16.3°C while the values of water temperatures for the second campaign oscillate between 20.8°C recorded at the level of P1C2 (well in the landfill), and 19°C marked at the level of well P2C2 which is outside the Technical landfill Bouguerguer

4.1.2. Hydrogen potential (pH)

The pH is a parameter that determines the acidity or alkalinity of water, it measures the acidity of water and the concentration of H+ ions. Alkalinity measures all the substances that can react with hydrogen ions, in particular, carbonate and bicarbonate ions. The pH of drinking water varies between 6.5-9 (WHO 2017):

From the histograms of Hydrogen Potential below we note:

- for the first campaign (March 2018) the samples oscillate between 7.46- 8.87, the highest values are recorded at the level of Chaaba P3C1 and the leachate basin P2C1 with values respectively around 8.87 and 8.80 (Figure 5B).

- The second campaign (April 2018) the samples vary between 7.36 and 8.51 the high concentrations are located at the level of Chaaba P7C2 and the leachate basin P8C2 of the leachate basin with values respectively of the order of 8.51 and 8.07. The high levels indicate that these waters are loaded by mineral and organic substance (Serge et al., 2020).

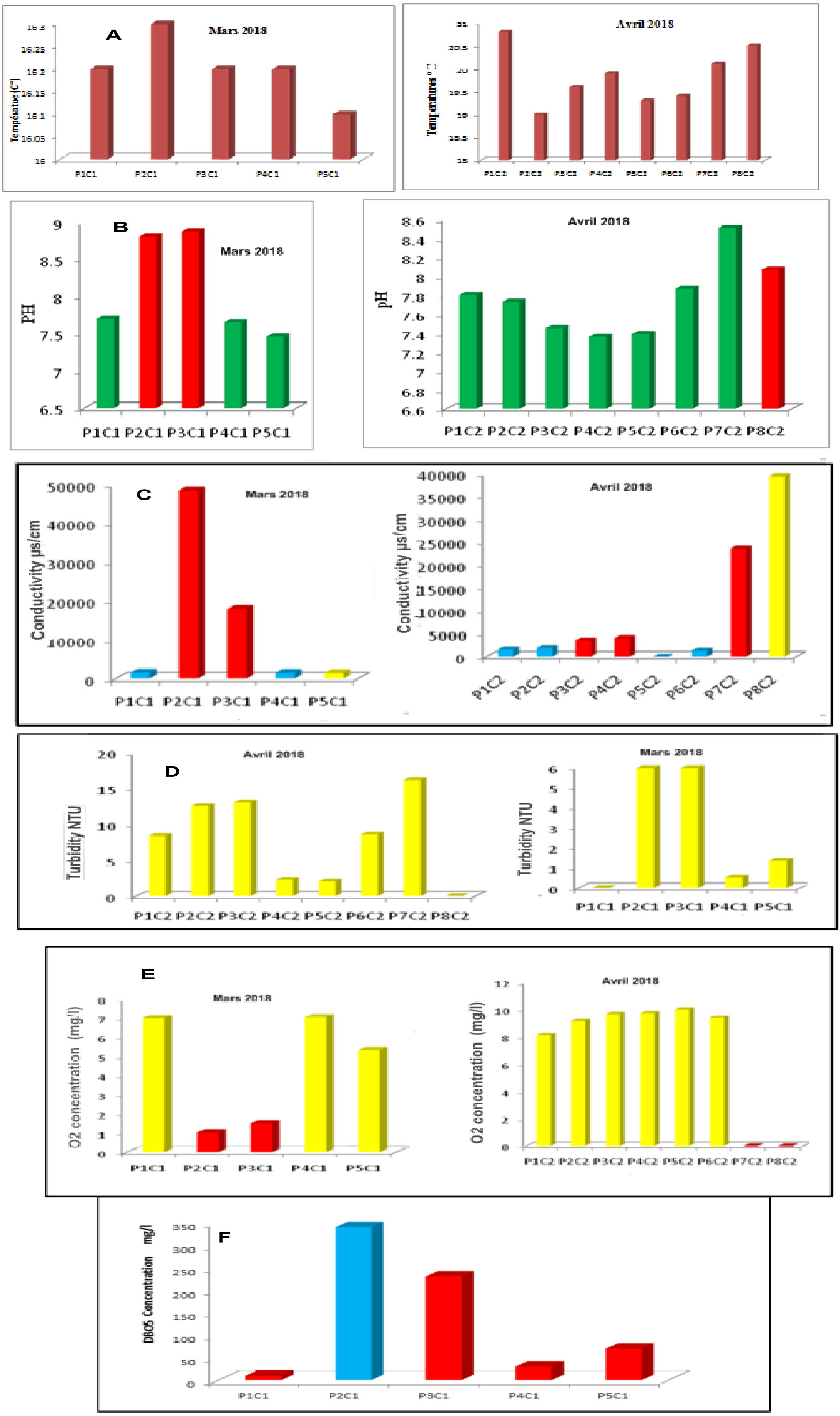

Figure 5. Physicochemical and organic parameters for the two campaigns (March –April 2018).

4.1.3. The Electrical Conductivity EC

The electrical conductivity is a linear function of the dissolved ions, it represents the total mineralization of the water (Makhoukh et al., 2011; Rodier, 1984). According to the histograms below we notice:

- In the first campaign (March 2018) we note a maximum content of 48500 µs/cm recorded at the level of Leachate basin P2C1 and a minimum of 1461 µs/cm recorded at the level of Seybouse Wadi near ONID P5C1 (Figure 5C).

- In the second campaign (April 2018) we note a maximum value of 39400 µs/cm recorded at the level of the leachate basin P8C2 against a minimum content of 2.11 µs/cm is recorded at the level of ONID P5C2. The high values of conductivity at the level of the leachate basin show an important mineralization, due to the presence of heavy metals and other toxic elements, these resultants are consistent with those reported by (Hicham et al., 2018; Zaafour et al., 2012).

4.1.4. Turbidity

From the histograms quoted below we notice:

- For the two companions, the highest values of turbidity are recorded at the level of the leachate basin P2C1 with a threshold of 5.97 NTU and Chaaba P3C1 with 5.97 NTU translating a strong mineral load (Figure 5D).

4.1.5. Dissolved oxygen

This is the O2 content for which the water is 100% saturated. On the other hand, the presence of oxygen in water results from diffusion from the air at the surface and especially from the photosynthetic activity of aquatic plants, including phytoplankton algae (Mouchara, 2009).

From the graphs below we notice:

- The first campaign (March 2018) concentrations of dissolved O_2 oscillate between 7.05- 1.01mg/l, the highest contents are recorded at the level of the sampling of Seybouse Wadi P4C1: 7.05 mg /l on the other hand the low content is marked at the level of the leachate basin of the landfillP1C1: 1.01mg /l (Figure 5E).

- For the second campaign (April 2018) the dissolved O_2 contents in drinking water vary between 8.16 and 10.01 mg/l with an average value of 9.35mg /l the highest concentrations are recorded at the level of the source ONID P5C2, on the other hand the lowest content is observed at the level of P1C2 (Figure 4E).

- For surface water samples, dissolved O2 concentrations range from 0.03 mg/l recorded at the level of ChaabaP7C2 and 9.44mg/l near ONID P6C2. We also note very low concentrations of dissolved oxygen at the level of the leachate basin P8C2 with a content of about 0.03 mg/l (Figure 4.E), These low values are due to the absence of oxygen in the leachate which results from an anaerobic process.

4.1.6. Biological Oxygen Demand (BOD_5)

The BOD_5 or Biological Oxygen Demand over 5 days, represents the quantity of oxygen necessary to the micro-organisms to oxidize (degrade) all the organic matter of a water sample maintained at 20°C, in the dark, during 5 days.

According to the histogram below, BOD_5 contents vary between 10 and 340mg/l. The maximum is recorded at the level of the leachate basin P2C1 with a value of 340mg/l lower than the Algerian standards of rejection (500 mg/l). The low value is recorded at the level of the well of ladfill P1C1 with 10mg/l, it largely exceeds the WHO 2017 standard for drinking water (BOD_5 < 5mg /l) (Figure 5F).

This vulnerability of wells can be explained by their low depth (Mezouari et al., 2011) and by the lack of protection measures (proximity of the leachate basin). At the level of surface waters, the values of BOD5 vary between 30mg/l and 70mg/l. The latter is largely exceeding the standard of surface waters (7mg/l) recorded at the level of sampling of Chaaba, we explain these high concentrations during this period by the direct discharge of raw leachate, rich in organic matter and nutrients (Makhoukh et al., 2011), into the river waters. This is accompanied by a decrease in flow and flow velocity, leading to a significant increase in organic load due to the intensive activity of microorganisms (Makhoukh, 2011). This activity, which consumes oxygen, is responsible for the self-purification of the water (Ghebbache et al., 2021). These results match those obtained by (Ghebbache et al., 2021).

4.2. Classification of heavy metals for the first campaign (March 2018)

4.2.1. Total Chromium:

Chromium as one of the toxic heavy metals it presents a risk of pollution of groundwater and surface water. According to the histogram below, it can be seen that it is at the level of the Chaaba that we record the highest value of total chromium including 1.32mg/l P3C1. This value highly exceeds the Algerian standard >0.1mg/l due to direct contact of leachate with Chaaba water (P2C2: 1.35mg/l), unlike other samples (P1C1, P4C1, P5C1) of surface water whose total chromium contents are acceptable and below the standards (WHO 2017 standard 0, 1mg/l) (Figure 6A).

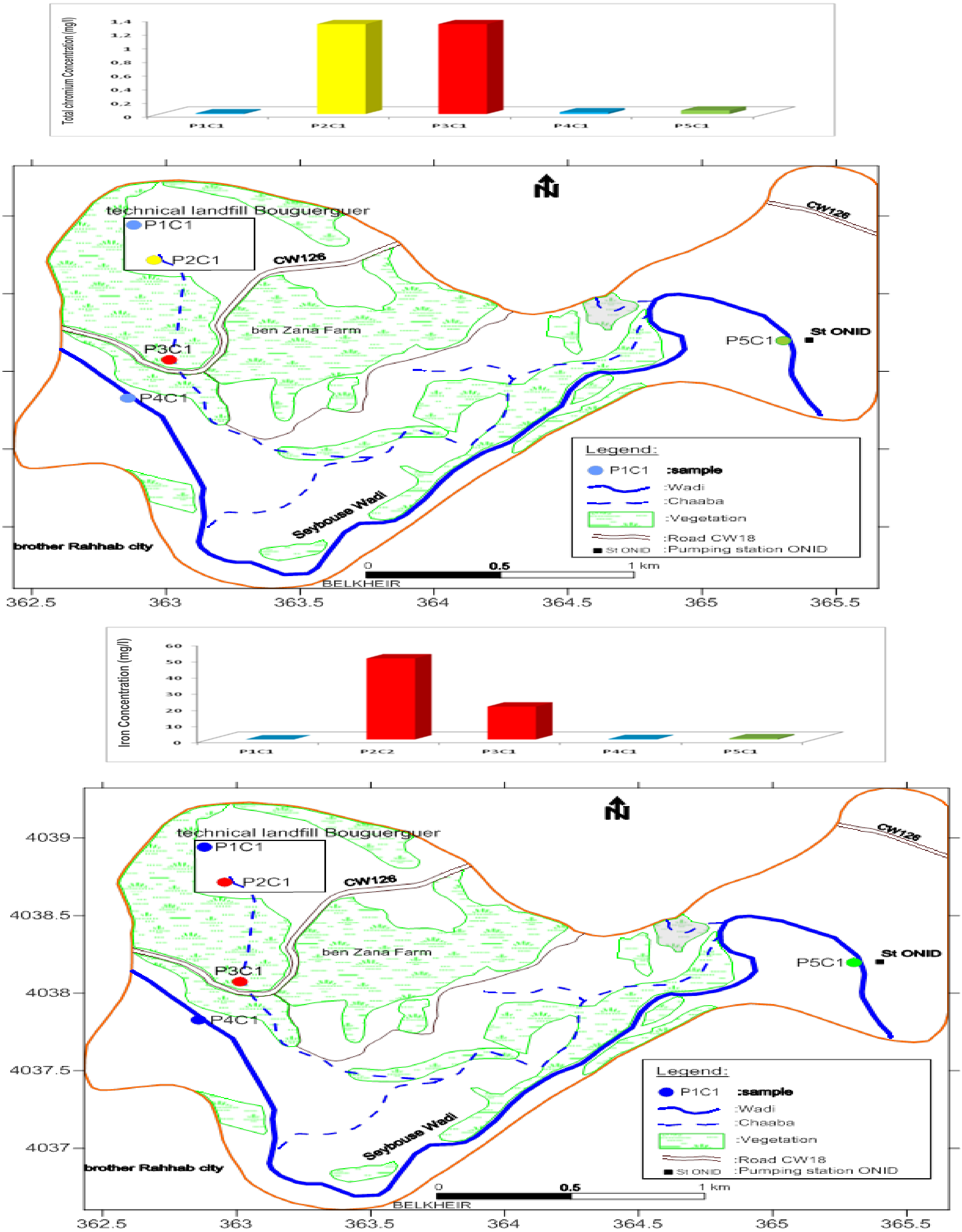

Figure 6. Variation of total chromium and total iron levels in sampled water points (March campaign)

4.2.2. Total Iron

In the surface waters of the study area, the concentrations of iron fluctuate between 0.24 mg/l and 20.3 mg/l with an average of 7.07mg/l All the water points have levels that exceed the Algerian standard (1mg/l). However, the sampling of the Chaaba P3C1 presents too high contents (>1mg/l), These strong contents are explained especially by contaminations coming from leachates (50mg/l) which discharges directly in the Seybouse Wadi has starting from the Chaaba, on the other hand one notes weak concentrations in total Iron recorded in the waters of well P1C1 with a value of 0.006 mg/l this content remains inferior to the Algerian standards of the groundwater 0.3 mg/l, (Figure 6B).

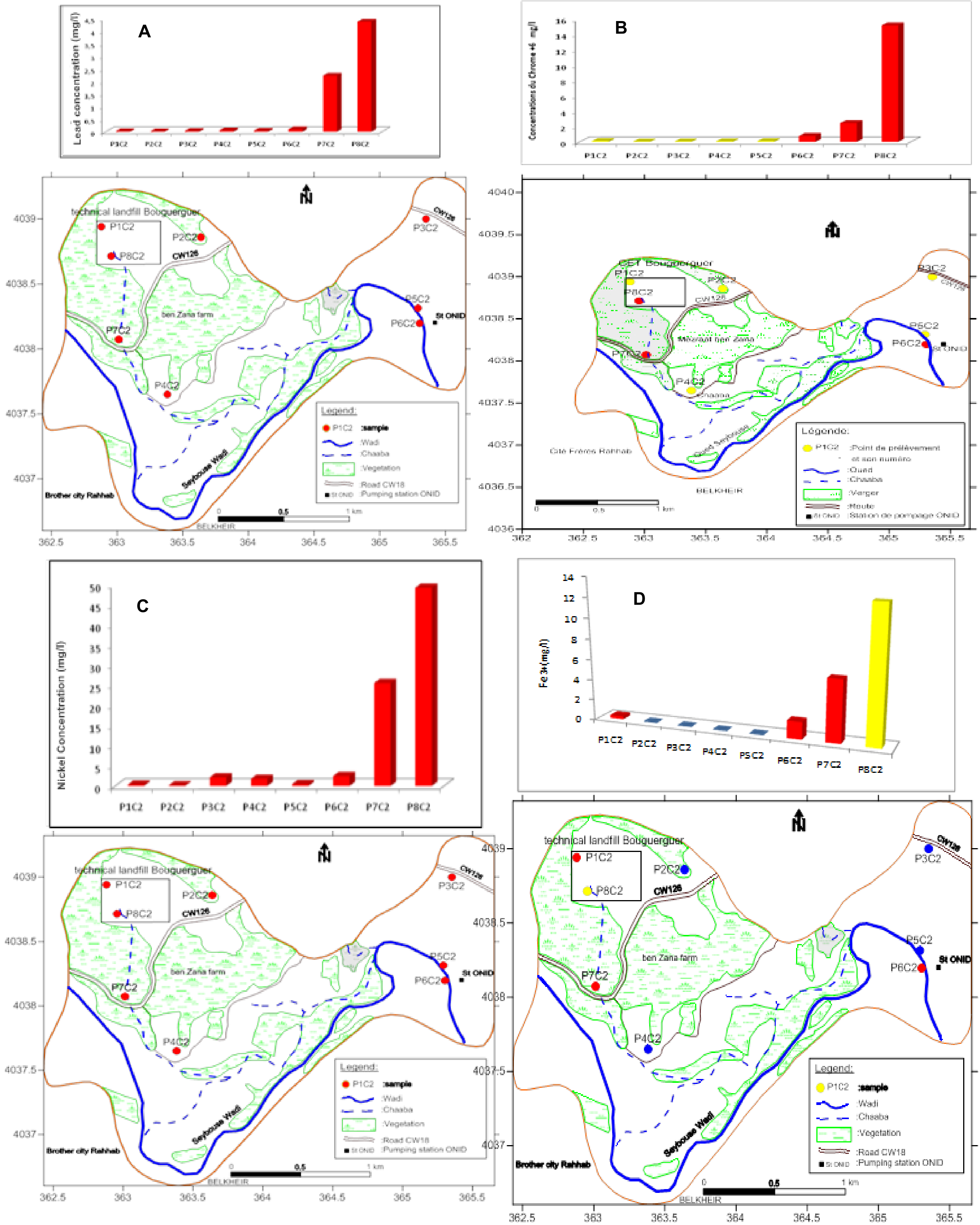

Figure 7. Variation of Heavy metal concentration in sampled water points (April campaign)

4.3. Classification of heavy metals for the second campaign (April)

4.3.1 Lead

Lead as a dangerous heavy metal, presents a risk of pollution of groundwater (surface and deep). The histogram below shows that in the groundwater of the study area, lead concentrations vary between 0.017 mg/l and 0.059mg/l with an average of 0.03mg/l (Figure 7A). All the water points have levels that exceed the Algerian standard and that of the WHO (0.01mg/l). Concerning the surface waters, the lead contents are between 0.098 mg/l and 2.235mg/l where we note the highest value at the level of sampling of Chaaba, the presence of this toxic element (lead) in the leachate (4.38mg/l) attests the degree of dangerousness of the waste that the landfill receives (Lagier, 2000) The findings align with the results reported by (Ghebbache et al., 2021). Also, the discharge of leachate in the Chaaba which crosses the CET contributes amply to the contamination of surface and underground waters of the region as well as the surrounding environment (Zair et al.,2021).

4.3.2. Chromium (Cr^{+6})

The figure below shows that the highest levels of Chromium recorded in the leachate basin P8C2 (4.35 mg/l) which largely exceed the Algerian standards of discharge (0.1 mg/l). All the groundwater points have levels that exceed the standard of potability (<0.001mg/l) with concentrations varying between 0.06mg/l and 0.11mg/l with an average of 0.08mg/l (Figure 7B). Surface waters record relatively higher concentrations of Chromium than groundwater and exceed the standard of surface waters (2µg/l) The results are consistent with the outcomes presented by (Hafsi et al., 2024), especially the sampling of Chaaba P7C2 (2.45mg/l).

4.3.3. Nikel (Ni)

We notice according to the histogram below that the highest content in Nikel is recorded at the level of the leachate basin P8C2 with a value of 49.3 mg/l on the other hand the lowest content is observed at the level of the well landfill P1C2 with a value of 0.29mg/l (Figure 7C). However, the concentrations in Nikel recorded at the levels of the 08 samplings remain above the norms WHO fixed has < 0.002 mg/l for the surface waters and 0.07 mg/l for the drinking water (Majour et al., 2022). In addition, the P8C2 samples of the leachate basin show very high concentrations exceeding by far the Algerian standards of discharge 2 mg/l. The high values of Nikel at the level of leachate proves once again that the waste at the level of the CET contain toxic elements which are directly poured into the Chaaba which adheres to the pollution of groundwater and surface water.

4.3.4. $Iron^{+3}$

We note according to the figure below for this toxic element that the iron contents in groundwater are below the standards of potability only in the well P1C2 (is inside the landfill) that we note a value that exceeds the standard 0.28mg/l >0. 2mg/l (Figure 7D), concerning the sampling of surface waters, the concentration of iron varies between 1.68 recorded at the level of sampling ONID and 6 mg/l noted at the level of Chaaba. The findings align with the results reported by (Hafsi et al., 2024). These strong contents are explained especially by a contamination due to the flows of water charged by polluting substances coming from leachate.

5. CONCLUSION

The effectiveness of landfills depends on careful management and treatment of their by-products to prevent negative environmental impacts.

The analytical results of this study confirmed the negative impact of the BOUGURGUER landfill on the surface and groundwater pollution in the study area. However, the excessively high values of certain elements, particularly heavy metals (Cr^{+6}, Pb+, Fe^{+3}, and Ni), indicate this degradation. Furthermore, the elevated concentrations of these elements can lead to serious health issues for the neighbouring human population on one hand and adversely affect ecosystems on the other hand. It becomes imperative to preserve the environment by adopting appropriate waste disposal practices, strictly adhering to government policies and regulations.

This adherence should be coupled with effective waste separation and a robust leachate treatment system. Furthermore, considering the relocation of landfill sites becomes relevant. Local authorities are urged to take all preventive measures to mitigate this pollution and rehabilitate the landfill in accordance with international standards.

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