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Heavy Metal Contamination of Oued El Harrache Surface Water (Algiers- Algeria)

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ABSTRACT

Marine pollution resulting from the presence of heavy metals at high concentrations is a serious threat to marine fauna, flora and the human health. Thus, the present study was conducted to quantify the concentrations of these dangerous pollutants and make the Algerian public aware of the intensity and of these toxic elements contaminating the water surface of Oued El Harrache (Algiers- Algeria). Several physicochemical and heavy metal parameters were addressed to examine the impact of trace elements concentations on selected sites along the river under study. Results showed that, this wadi which exists in the North of Algeria and which is used by many farmers for irrigation is highly polluted and loaded with extremely high concentrations of heavy metals, mainly from effluents and discharges of industrial and anthropic activities, which are very harmful to our health and to the environment in general. All these undesirable effects damage the balance of all ecosystems and affect sustainable development, and this requires cooperation between industrial companies and different state domains such as agriculture and environment to solve this serious problem; and it remains the remediation of water is the best way to fight against this phenomenon that degrades our life and our environment.

INTRODUCTION

Water is a vital and limited socio-economic resource. It is subject to increasing demand for domestic and industrial purposes, which threatens the sustainability of surface and groundwater and has implications for agriculture, forestry, industry and drinking water supplies. It is essential that water resources are managed strategically and sustainably **(Ashref-Dar, 2020)**. Therefore, environmental degradation and the lack of safe water are major obstacles to sustainable development **(WHO, 2017; Samai et *al.*, 2022).**

Water covers 70% of the planet, divided into 98% salt water and 2% fresh water. It is the vital element for all living beings, but only 0.02% is usable by humans **(Paquerot, 2005)**. The aquatic ecosystem is subject to the interaction of the three compartments of the biosphere, and with the pollution that has covered the entire globe, water has become the reservoir of different types of pollutants from different sources **(Aarab, 2004).**

The acceleration of industrialization and development of the countries with the increase of the demand of heavy metals, which are considered as major pollutants compared to a great number of other toxic pollutants, cause a high anthropic emission of these contaminants in the biosphere **(Zeggai, 2020)**. Heavy metals are natural constituents in rocks and mineral deposits. Thus, these elements are normally present at low levels (trace levels; less than 0.1%) in soils, sediments, surface waters and living organisms **(Alloway & Ayres, 1997; Callender, 2003)**. These low concentrations of heavy metals constitute the geochemical background of a certain environment. To assess the impact of a heavy metal in the environment, presence alone is not sufficient. This impact is potential if the given metal is found at levels of abnormally high concentrations, compared to the geochemical background **(Alloway & Ayres, 1997)**. Therefore, knowledge on the geochemical background is essential to determine heavy metal contamination caused by mining activity **(Runnels et *al.*, 1992)**.

Once heavy metals have been released into the environment, either by natural (e.g. weathering) or anthropogenic (e.g. mining) processes from their source, they can be transported by wind via aerosols or by water via water, suspended solids or river bottom sediments; their concentrations are an important parameter to characterize the impact, however it is very important to know the availability of their concentrations in the environment to terrestrial and aquatic organisms **(Ayres, 1997; Salvarredy Aranguren, 2008)**. Trace metal pollution in the water body is a serious problem, threatening not only the aquatic ecosystem but also human health **(Cheng et *al.*, 2002)**. Trace metal toxicity affects several vital body systems and damage their function. The main organs affected by heavy metal toxicity are the neurological system **(Akins, 1992)**, the renal system as well as the hepatic and gastric systems; once one of these organs is affected, the effects become irreversible. Even these trace metals are toxic to living organisms, their excessive exposures can lead to adverse effects, even at low concentrations **(Attar, 2014)**. They are considered as environmental pollutants. They have a direct impact on the environment due to their toxicity and accumulation in trophic chains **(Veschambre, 2006).**

The main objective of the study was to characterize and quantify the trace metal elements (TMEs) in Oued El Harrache, wilaya of Algiers (North of Algeria), which is the main watercourse of the wilaya of Algeria that is highly polluted, presenting all the warning signs of an ecological disaster. This site receives all kinds of waste, and the water of the opaque Wadi is impure, which unfortunately ends its natural path on a beach in the town of Bordj El Kifene (Algeria).

MATERIALS AND METHODS

1. The study area

The Oued El-Harrach watershed, which belongs to the large Algerian coastal watershed extends over about 50km from the North to the South and 30km from the East to the West, covering an area of about 1250km^2. This area is divided into three (03) parts belonging to the Blidéen Atlas (600 km^2), the other to the Mitidja plain (550 km^2) and the third to the Sahel slope (100 km^2). It extends mainly on the wilayas of Algeria and Blida, and in the South it borders wilaya of Medea and in the northeast a small part of the wilaya of Boumerdes. The source of Oued El Harrach goes back to the town of Hammam Melouane on the northern slopes of the Atlas Blideen through the confluence of two wadis, Oued El Mekka and Oued Lakhra. It then flows from the South to the North for about 67km through the Mitidja plain before joining the bay of Algeria. Before ending up in the Mediterranean Sea, Oued El Harrach receives the waters of five main tributaries: Oued Djemma, Oued Terrou, Oued El Kerma, Oued Smar and Oued Ouchaiah (Fig. 1) **(Madani, 2017)**.

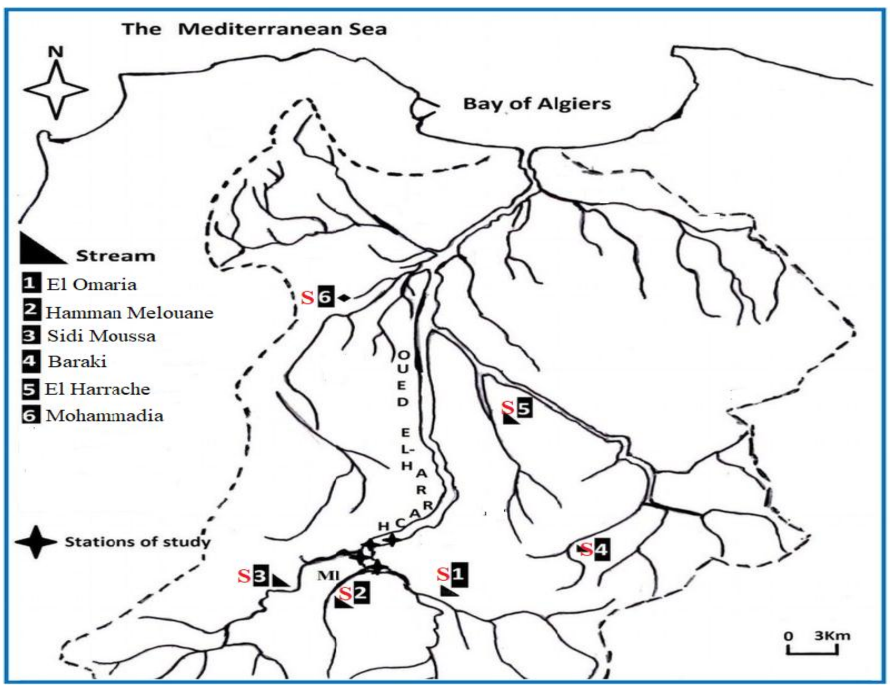

Fig. 1. Presentation of the study area

2. Sample collection

Water samples were collected from the surface waters of Oued El Harrache at depths varying between 15 & 20cm. Sampling was achieved twice, and hence it was divided into two groups: the first was in January 2022 and the second in June 2022, with two stations for each sampling from the upstream, the center and the downstream, respectively.

For upstream: Site 1 (S1): El Omaria, willaya of Medea.

Site 2 (S2): Hamman Melouane, wilaya of Blida.

For the center: Site 3 (S3): Sidi Moussa, willaya of Algiers.
Site 4 (S4): Baraki, willaya of Algiers.
For the downstream: The site 5 (S5): El Harrache, willaya of Algiers.
Site 6 (S6): Mohammadia, willaya of Algiers.

Very clean bottles were used for sampling. They were rinsed three times with the water to keep the characteristics of water for analysis. They were then filled with water (surface water 15 to 20cm deep) until the overflow to avoid any possible chemical reaction. Finally after capping, each bottle was carefully labeled and numbered with the date, the coordinates and the sampling number. Then, they were kept at 4°C during transport to the laboratory and were analyzed within 24 hours.
The following parameters were carried out:
Table (1) shows the parameters measured in the laboratory.

Table 1. Parameters measured in the laboratory **(Guibaud & Gauthier, 2003)**

Parameter	Method of measurement
pH	pH- meter type PHYWE.
Conductivity (EC)	Conductivity meter type W.T.W 1330 with measuring cell type LR 325/01 with thermal compensation.
Suspended matter (SS).	Vacuum filtration.
Chemical oxygen demand (COD).	using a colorimetric analyzer
Concentration of biodegradable organic matter (BOD_5).	Biochemical oxygen demand for 5 days (DBO_5) (Par Oxymétrie)
Nitrates (NO^-_3), nitrites (NO^-_2), ammonia nitrogen (NH^+_4).	Spectrophotometry
Chloride concentration (Cl^-).	Volumetry.
Determination of heavy metals: lead (Pb), zinc (Zn), copper (Cu), iron (Fe), cadmium (Cd).	Atomic absorption spectrometry.

3. Statistical analysis

All results were analyzed using the statistical software XLSTAT, version 7.5.2.

RESULTS

1. The hydrogen potential (pH)

The pH measures the concentration of H^+ ions in water. It reflects the balance between acid and base on a scale of 0 to 14. The value 7 corresponds to neutrality. The area between 0 and 7 constitutes an acidic environment and between 7 and 14, the environment is basic. The pH gives information on the origin of the water. For example, surface waters have a pH between 7 and 8 **(Rodier et *al.*, 2009)**. The values obtained reveal that the pH is clearly acidic in all the sampled sites, whose values are between 5.78 and 6.37 (for the month of January) and between 5.61 and 6.09 (the month of June) (Fig. 2).

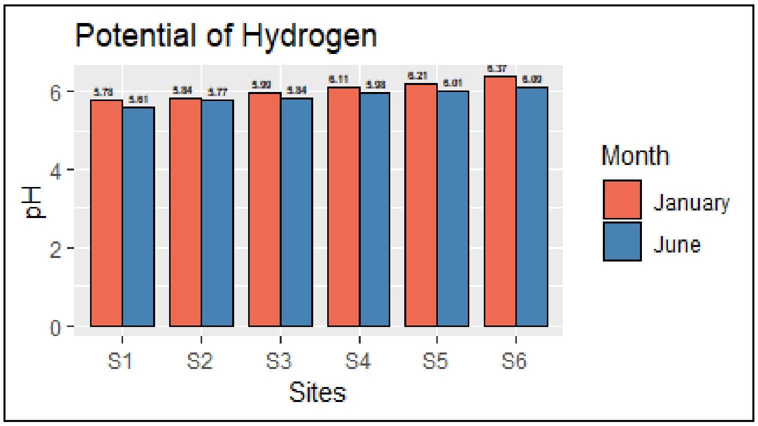

Fig. 2. Spatio-temporal variation of the pH

2. Electrical conductivity (EC)

It provides information on the ability of water to conduct electric current. A device called a conductivity meter is used. The conductivity measurement provides information on the content of dissolved matter in water in the form of electrically charged ions. The temperature of the water influences the conductivity, which is greater than the higher temperature **(Aubert, 1978)**. The measurement of the conductivity allows to appreciate the quantity of salts dissolved in water, giving an idea on the total mineralization of a water. The values of electrical conductivity in Oued El Harrache vary from 2190µs/cm to 3177µs/cm for January and between 2284 µs/cm & 3299 during June (Fig. 3).

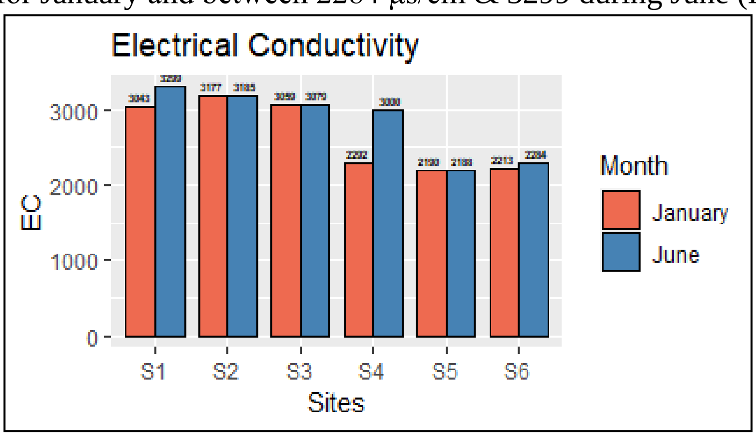

Fig. 3. Evolution spatio-temporel of EC

3. Suspended solids (SS)

Suspended solids include all mineral or organic materials that do not solubilize in water. It includes clays, sands, silts, small organic and mineral matter in addition to plankton and other microorganisms in water. The amount of suspended solids varies with the season, flow regime, sedimentation, erosion and other factors. This material affects water transparency and decreases light penetration and consequently photosynthesis

(Mouaz & Bentchich, 2017). The SS contents found are in the range of 34.45mg/l and 40.66mg/l and 36.79mg/l and 45.43mg/l, respectively, for the two sampling groups. They are well above the WHO standard of 30mg/ l (Fig. 4).

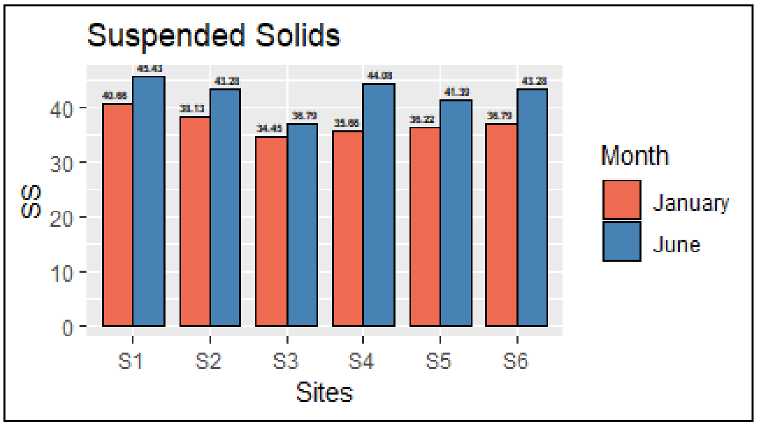

Fig. 4. Spatio-temporal evolution of the SS

4. Chemical oxygen demand (COD)

It is the measure of the quantity of necessary oxygen, which corresponds to the quantity of oxidizable matters by the oxygen in an effluent. It represents most of the organic compounds (detergents, faeces). It is measured by the consumption of oxygen by a solution of potassium dichromate in sulfuric medium in the presence of silver sulfate and mercury sulfate II (complexing chlorides), maintained hot for 2 hours (**Mekhalif, 2009)**. For COD contents, the values obtained fluctuate between 43.99mg/l and 45.66mg/ l for the first group and 49.51mg/ l and 66.77mg/ l for the second. All these values are well above the standard value (40mg/ l) (Fig. 5).

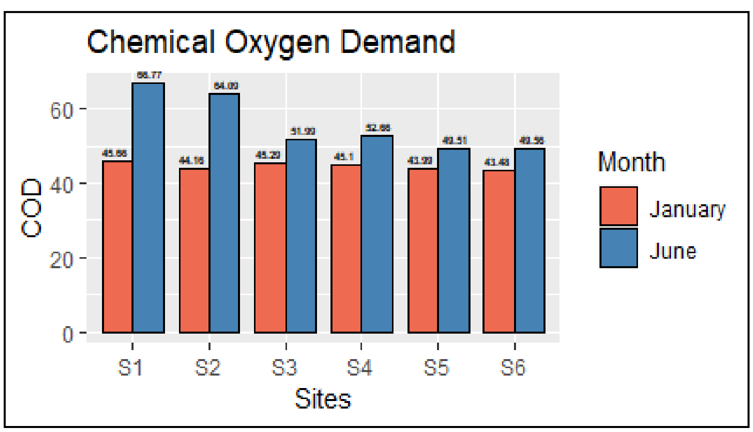

Fig. 5. Evolution spatio-temporel of COD

5. Nitrates (NO^-_3)

Nitrates come from the complete oxidation of organic nitrogen. They are present in the soil, surface water and groundwater. They result from the natural decomposition by microorganisms of nitrogenous organic matter, such as vegetable proteins, animal proteins and animal excrement. The ammonium ion formed is oxidized to nitrates. The presence of nitrates in the environment is a natural consequence of the nitrogen cycle **(Demdoum, 2010; Derrahal, 2019)**. The results show that Oued Bousselam is exteremly loaded with nitrates, whose recorded values are between 50.98 and 52.02mg/ l (Fig. 6), and these values exceed the normal level (50mg/ l).

6. Biochemical oxygen demand (BOD_5)

It characterizes the oxygen consumption (mg/L) of the purifying bacteria, i.e. the quantity of oxygen necessary for the living micro-organisms to ensure the oxidation and stability of the organic matter present in the wastewater. The measurement conditions are incubated at 20°C in the dark. The duration of the whole process is three weeks (BOD21), but this duration is very long. It thus presents the concentration of biodegradable materials. By convention, the value of BOD obtained is five days of incubation and that is the noted BOD_5 **(Gaid, 1984; Sadik, 2017)**. According to the results obtained, the values of BOD_5 measured vary between 31.12mg/ l and 39.14mg/ l for January and 36.16mg/ l & 59.84mg/ l for June; These results do not meet the standard value required by the WHO, which is 25mg/ l (Fig. 6).

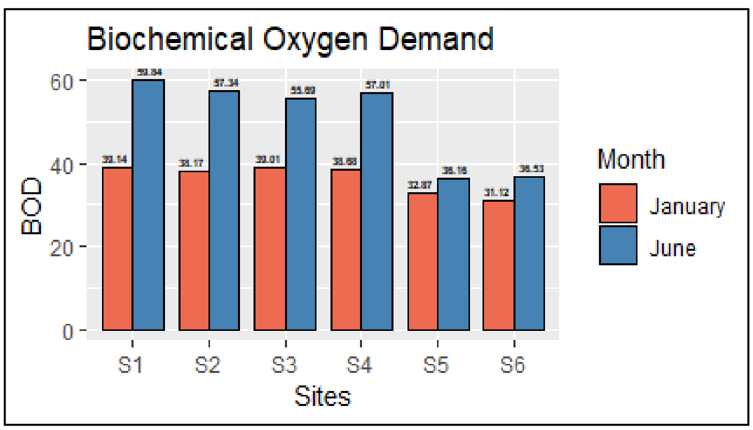

Fig. 6. Spatio-temporal evolution of the BOD_5

7. Nitrate (NO^-_3)

Nitrate constitutes the final oxidation stage of nitrogen and represents the form of nitrogen, with the highest degree of water being between 1 and 10mg/ l; its contents in untreated wastewater are low (**UNEP/MAP/MEDPOL, 2004; Samai et *al.*, 2022)**. Nitrate measurements showed values ranging from 51.01 to 66.1mg/ l during January and from 52.87mg/l to 77.35mg/l in June (Fig. 7), which are well above the standard (44 mg/l).

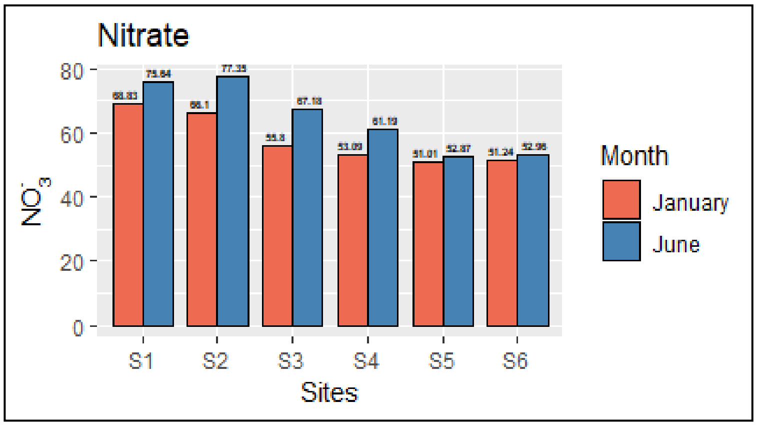

Fig. 7. Spatio-temporal evolution of the NO^-_3

8. Nitrites (NO^-_2)

Nitrites result from incomplete oxidation of organic nitrogen or reduction to nitrates. The main causes of pollution are the use of fertilizers, the manufacture of explosives, chemical and food industries. The nitrate content of water is usually higher than the nitrite content. High nitrite concentration indicates bacteriological pollution due to ammonia oxidation **(Ayad, 2017)**. Fig. (8) shows that the nitrate levels obtained from Oued El Harrache exceed the standard (0.1mg/ l); It recorded values ranging from 0.58 to 0.99mg/ l in January and between 0.64 and 1.16mg/ l in the month of June.

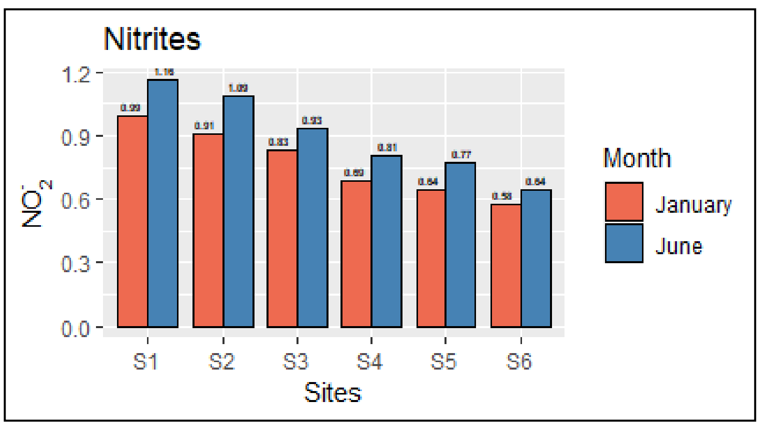

Fig. 8. Spatio-temporal evolution of the NO^-_2

9. Ammonium (NH^+_4)

Ammonium (NH^+_4) is the most toxic form of nitrogen. Its presence in water is linked to urban and industrial discharges or the reduction of nitrogen forms (nitrates and nitrites) under reduced conditions **(Debieche, 2002)**. The presence of ammonium ion (Fig. 9) in natural waters is an indication of pollution caused by domestic discharges on the one hand and by the reduction of nitrates on the other. In general, the average levels recorded are higher than the standard set by the OMS (0.1 mg/l). Its recorded levels range between 0.15 and 0.2mg/ l for January; while for June, ammonium levels range between 0.19 and 0.30mg/ l.

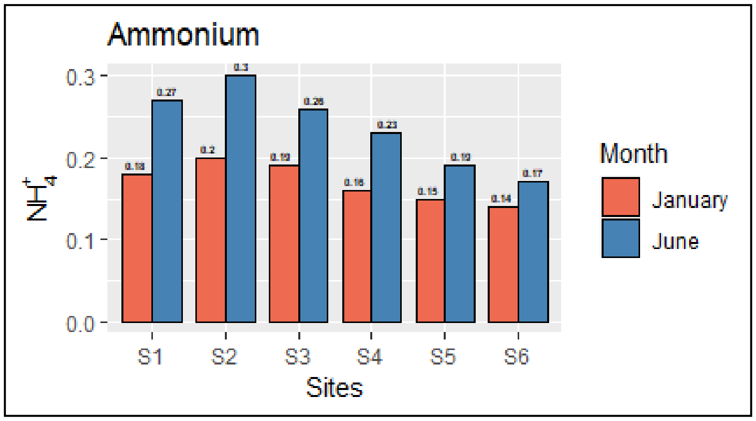

Fig. 9 : Spatio-temporal evolution of the NH^+_4

10. Chlorides (Cl^-)

Chlorides are important inorganic anions found in varying concentrations in natural waters, usually as sodium (NaCl) and potassium (KCl) salts. They are often used as an index of pollution. They have an influence on the aquatic fauna and flora as well as on the growth of plants **(Aboulay et *al.*, 2013; Chibane & Djennad 2019)**. The concentrations of chloride ions in the waters of this wadi are between 218 and 428mg/ l (Group 1) and between 368mg/l and 512mg/l (Group 2) (Fig. 10).

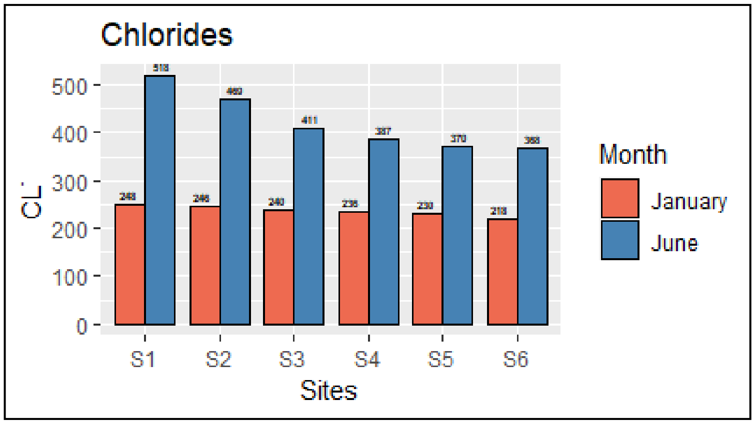

Fig. 10. Spatio-temporal evolution of the Cl^-

11. Lead (Pb)

Lead is a toxic element with very high toxicity, even at trace concentrations, with no known beneficial effects. The results for this element show excessive values for both years (January and June) for all stations, which are 100 times higher than the OMS standard (0.01mg/l). For the first sampling group, the values are between 0.99 and 1.09mg/ l; while for the 2^{nd} one, the values vary between 1 and 1.22mg/ l (Fig. 11).

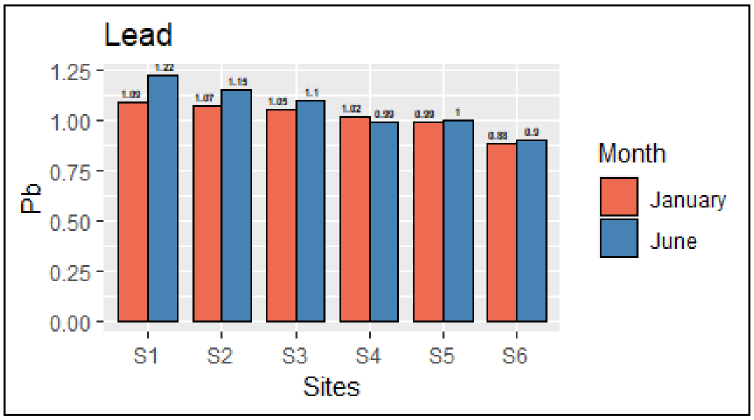

Fig. 11. Evolution spatio-temporel of Pb

12. Zinc (Zn)

Zinc is one of the most abundant trace elements in the human body. It is of fundamental importance for many molecules, cellular, metabolic and immunological processes, including antioxidant responses. Zinc deficiency has been associated with a large number of deficiencies in the body. Being an essential metal for the human body, the presence of this metal in drinking water does not cause a problem. The histogram in Fig. (12) shows that zinc concentrations range from 2.44 to 3.01mg/ l for all sites sampled in January; and from 2.99 to 3.79mg/l for the June sampling. These values exceed OMS standards (2mg/l) **(Hadjou Smir, 2020)**.

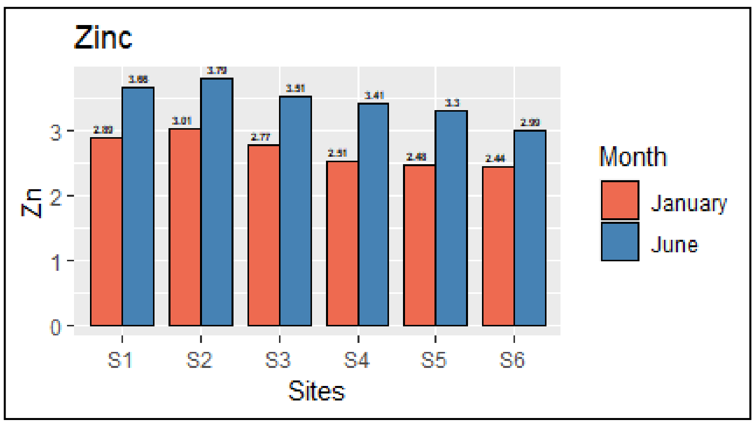

Fig. 12. Spatial and temporal evolution of the Zn

13. Copper (Cu)

This trace element is also considered one of the most important metals in the body. It plays fundamental roles in several biological processes among them are: the ability to accept easily and give electrons, which explains its important role in enzymatic reactions, such as oxidation-reduction and the elimination of free radicals from the body involved in cellular metabolism, as well as in the formation of red blood cells In case of deficiency of copper occurs, neutropenia, cardiac disorders, osteoporosis and anemia. The results obtained show that this metal is present at all the sites sampled with high levels that oscillate between 2.75 and 2.99mg/ l (for the month of January) and between 2.81 and 3.32mg/ l (for the month of June) (Fig. 13).

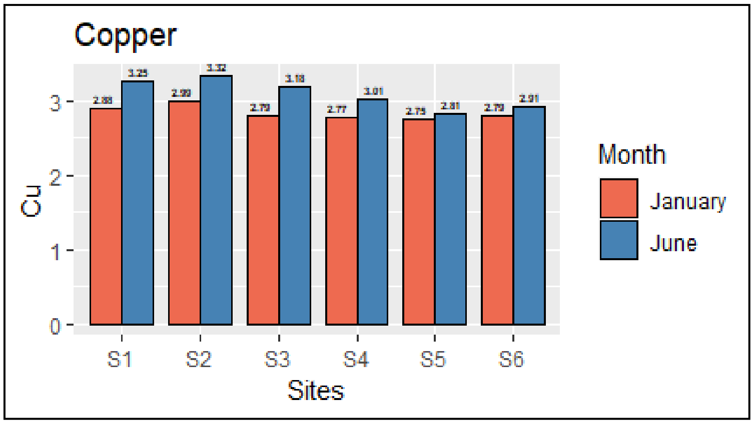

Fig.13. Spatio-temporal evolution of Cu

14. The iron (Fe)

Iron is one of the most important and abundant metals in human cells, and its importance cannot be neglected, given its multiple functions in the body. Iron is a component of hemoglobin and functions as an oxygen carrier in the blood and muscles. This metal is involved in the synthesis of hormones, as well as certain proteins and connective tissue, affecting the development, growth and normal functioning of cells. Regarding iron, our results recorded high levels of this element. They vary between (0.59 and 0.82m/l) and (0.72 and 0.98mg/l), respectively, for the two sampling groups (Fig. 14). These levels are 3 times higher than the maximum tolerated standard of the OMS (0.2mg/ l).

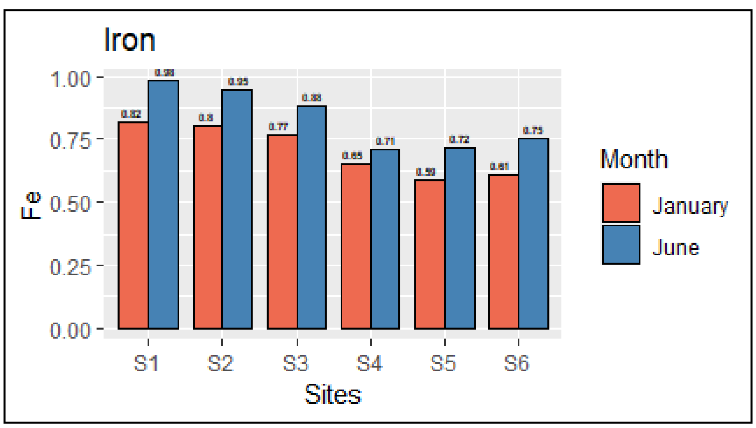

Fig.14. Spatio-temporal evolution of Fe

15.Cadmium (Cd)

This metal whose importance in the body has not yet been found suggests that this metal is non-essential. The results obtained show that the presence of cadmium (Fig.15) at all stations exceeds the standard set by the WHO (0.003mg/ l), with levels varying between 0.009 and 0.015mg/l (for the month of January) and between 0.010 and 0.023 mg/l (for the month of June).

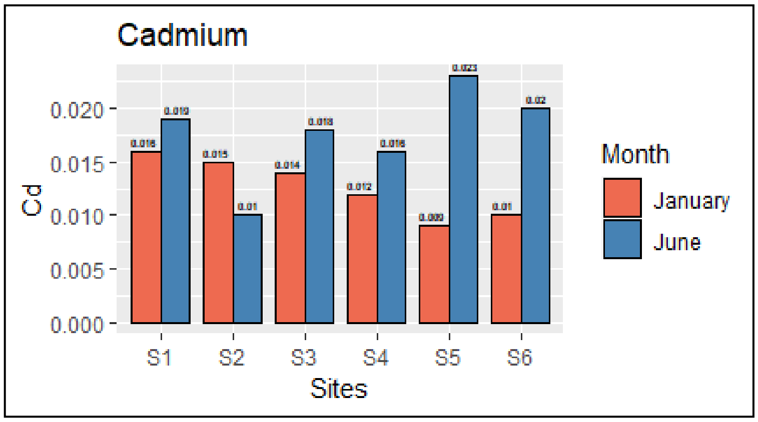

Fig. 15. Spatial and temporal evolution of the Cd

DISCUSSION

The pH Value recorded in the current study is due to the effect of acidic discharges from the agglomeration and municipalities crossed by Oued El Harrache. Thus, an industrial and domestic pollutions were detected in the waters of this watercourse originated from an acid origin (**Rodier et *al.*, 2009).**

The values of electrical conductivity show that this Wadi is highly mineralized. These high values of conductivity reflect a continuous supply of mineral salts all along the river, especially in the month of June **(Aubert, 1978).**

The increase of SS is very remarkable in June, this is due to industrial, urban and even agricultural discharges that are thrown directly into this wadi **(Rodier et *al.*, 2009)**.

The eesults of COD could be essentially linked to the high load of organic matter in domestic wastewater and the effluents of industrial units discharged all along this wadi **(Mekhalif, 2009)**.

In general, the peak of BOD_5 values was recorded in the month of June due to the important discharge of domestic wastewater by each municipality as well as to the effluents of industrial establishments **(Sadik, 2017).**

The increase in nitrates is related to the large volume of wastewater and discharges by some industries along the Wadi, especially in June **(Aubert, 1978)**.

For nitrites (NO^-_2): in the month of June, they reach the maximum, and this increase is caused by the effect of the oxidation of the ammonium form **(Ayad, 2017)**.

For Oued El Harrache, the concentrations of ammonium (NH^+_4) are very variable and high. Ammonium is a good indicator of urban effluent pollution in watercourses **(Debieche, 2002)**.

The chloride ion (Cl^-) levels recorded in Oued El Harrache are very high; This increase is linked to the discharges of anthropic and industrial activities released directly into the Oued El Harrache (Algiers- Algeria) **(Aboulay et *al.*, 2013)**.

The intoxication by this metal is manifested by anemia, which is one of its main symptoms and nephrotoxicity as well. It causes disorders of the neurological system causing an encephalopathy; the digestive disorder is also present **(Attar, 2020).**

The high level of zinc in the water can lead to intoxication, which is the cause of smelter's fever, as well as other symptoms, such as respiratory and gastrointestinal disorders in addition to anemia **(Attar, 2020).**

The values of Cu are very high compared to the maximum concentration set by the OMS for the element of copper (2mg/l). The intoxication by this metal is determined by headaches and gastrointestinal problems. Different types of cancer can be caused by excessive exposure to copper **(Attar, 2020).**

For iron (Fe), an excess of this metal in the blood causes a multitude of problems in the human organism, mainly the formation of free radicals which is the cause of degenerative diseases such as cancer, heart attack, hepatic fibrosis as well as oxidative stress **(Attar, 2020).**

For cadmium (Cd), the contamination by this element is caused by the industrial discharges all along this wadi. The toxicity of cadmium is mainly manifested by anemia, digestive disorders, as well as a renal attack which subsequently leads to a bone disorder. A decrease of the pulmonary function can take place **(Attar, 2020)**.

4.1. Statistical treatment of physicochemical data on the waters of Oued El Harrache

Statistical treatment of physicochemical data on Oued El Harrache waters

Method of data processing.

PCA is a data analysis tool that allows to explain the structure of correlations using linear combinations of the original data. The objective of PCA is to present, in a graphical form, the maximum amount of information contained in a data table, based on the principle of double projection on the factorial axes. pH, conductivity, moisture, organic matter, calcium carbonates, particle size and porosity.

07 variables were treated by PCA, followed up at 20 stations.

The principal component analysis (PCA) was performed on a data matrix composed of 20 rows representing the sampling stations surveyed and 07 columns representing the physicochemical variables measured.

The goal of the analysis was to obtain a small number of linear combinations of the 20 variables that represent most of the variability in the data.

a. Correlation matrix

1- For the high water period.

The correlation matrix gives the significant links between the different variables necessary to study the variables necessary for the study of the parameters used. These links were translated by the different correlations that exist between the variables studied.

The application of the PCA to the data of the waters of the study area allowed to identify the different correlations on a matrix (Table 2). These correlations can be positive or negative. The correlation values calculated between the physico-chemical parameters studied (pH, conductivity, suspended matter, BOD_5, COD, nitrogenous matter [nitrite, nitrate, ammonium]) are shown in Table (2), which presents the average values of analyses.

Table 2. Correlation matrix of physico-chemical parameters of the high water period

	pH	EC	SS	COD	BOD_5	NO^-_3	NO^-_2	NH^+_4
pH	1							
EC	**-0,892**	1						
SS	-0,551	0,372	1					
COD	-0,687	0,519	0,179	1				
BOD_5	**-0,850**	0,734	0,161	**0,864**	1			
NO^-_3	**-0,919**	**0,838**	0,798	0,472	0,632	1		
NO^-_2	**-0,984**	**0,926**	0,602	0,671	0,796	**0,945**	1	
NH^+_4	**-0,888**	**0,957**	0,213	0,513	0,807	0,755	**0,872**	1

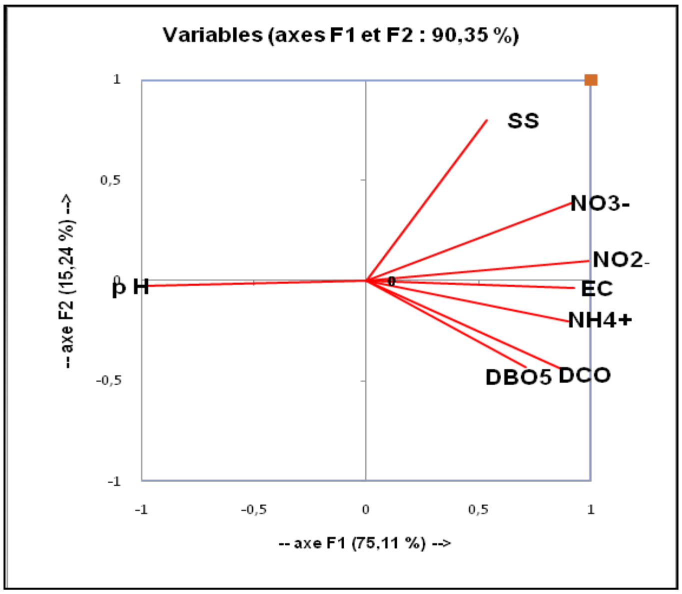

Fig. 16. Correlation matrix of physico-chemical parameters of the high water period

The factorial plane (F1, F2) shows an expression of over 90.35% (Fig. 16).
The F1 axis illustrates a variance equal to 75,11% which are expressed towards its positive pole by suspended matter, nitrates, nitrites, electrical conductivity, ammonium, COD and BOD_5 presenting a highly significant correlation between them.
The F2 axis illustrates a variance equal to 15.24% consisting of a highly significant correlation of pH in the negative pole. The correlation values calculated between the heavy metal parameters studied (Lead, Zinc, Copper, Iron, Cadmium) are shown in Table (3), which displays the average values of the analyses.

Table 3. Correlation matrix of heavy metals for the high water period

	Pb	**Zn**	**Cu**	**Fe**	**Cd**
Pb	1				
Zn	0,809	1			
Cu	0,530	**0,877**	1		
Fe	**0,818**	**0,955**	0,750	1	
Cd	**0,821**	**0,915**	0,727	**0,984**	1

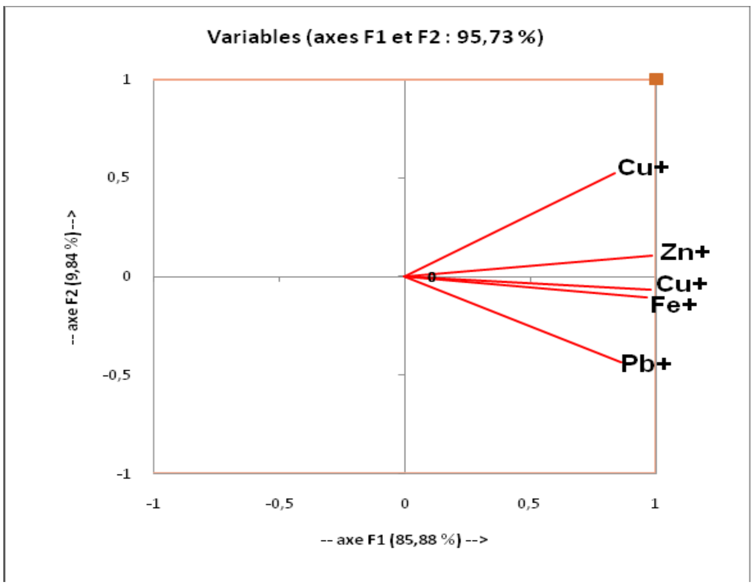

Fig. 17. Correlation matrix of heavy metals from the high water period

The factorial plane (F1, F2) shows an expression of over 95.73% (Fig. 17).
The F1 axis illustrates a variance equal to 85, 88%, which are expressed towards its positive pole by lead, zinc, copper, iron, cadmium, presenting a highly significant correlation between them. The F2 axis illustrates a variance equal to 9.84% constituted no significant correlation in the negative pole.

1- For the low water period.

The correlation matrix gives the significant links between the different variables necessary to study the variables for the study of the parameters used. These links are translated by the correlations that exist between the variables studied.

The application of the PCA to the data of the waters of the study area allowed to identify the different correlations on a matrix (Table 4). These correlations can be positive or negative. The correlation values calculated between the physico-chemical parameters studied (pH, conductivity, suspended matter, BOD_5, COD, nitrogenous matter [nitrite, nitrate, ammonium] are shown in Table (4), which represents the average values of analyses.

Table 4. Correlation matrix

	pH	**EC**	**SS**	**COD**	**BOD$_5$**	**NO$^-_3$**	**NO$^-_2$**	**NH$^+_4$**
pH	1							
EC	**-0,840**	1						
SS	-0,174	0,109	1					
COD	**-0,909**	0,768	0,496	1				
DBO$_5$	-0,782	**0,990**	0,110	0,706	1			
NO$^-_3$	**-0,924**	**0,921**	0,160	**0,912**	**0,869**	1		
NO$^-_2$	**-0,980**	**0,856**	0,179	**0,927**	0,806	**0,960**	1	
NH$^+_4$	**-0,854**	**0,918**	0,004	0,808	**0,888**	**0,969**	**0,921**	1

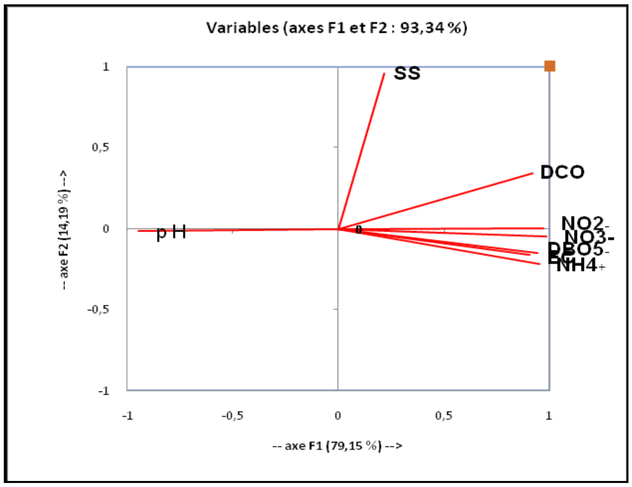

Fig. 18. Correlation matrix of physico-chemical parameters of the low water period

The factorial plane (F1, F2) shows an expression of over 93.34% (Fig. 18).

The F1 axis illustrates a variance equal to 79, 15%, which are expressed towards its positive pole by suspended matter, nitrates, nitrites, electrical conductivity, ammonium, COD and BOD$_5$, presenting a highly significant correlation between them.
The F2 axis illustrates a variance equal to 14.19% consisting of a highly significant correlation of pH in the negative pole. The correlation values calculated between the heavy metal parameters studied (Lead, Zinc, Copper, Iron, Cadmium) are shown Table (5), which shows the average values of the analyses.

Table 5. Correlation matrix for heavy metals during the low water period

	Pb (June)	Zn (June)	Cu (June)	Fe (June)	Cd (June)
Pb (June)	1				
Zn (June)	**0,914**	1			
Cu (June)	**0,851**	**0,860**	1		
Fe (June)	**0,912**	0,786	**0,916**	1	
Cd (June)	-0,400	-0,660	-0,742	-0,481	1

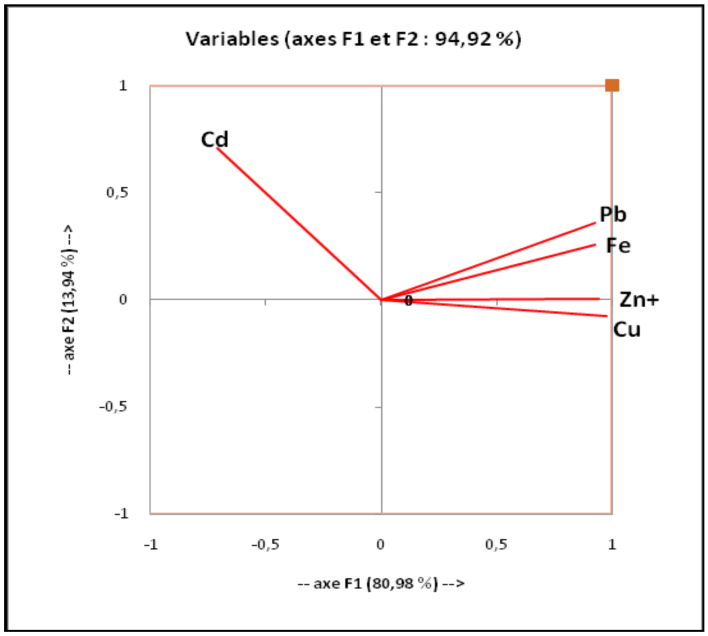

Fig. 19. Correlation matrix of heavy metals of the low water period

The factorial plane (F1, F2) shows an expression of over 94.92% (Fig. 19). The F1 axis illustrates a variance equal to 80, 98% which are expressed towards its positive pole by lead, zinc, copper, iron, showing a highly significant correlation between them. The F2 axis illustrates a variance equal to 13.94% consisting of a significant correlation with cadmium in the negative pole.

CONCLUSION

With the industrial development and the accentuation of the anthropic activities, the contamination of the surface waters by the heavy metals became the current problem of several water courses, especially for the paid ones in the process of development like the case of our paid, Algeria. The present study allowed to characterize and quantify the metal trace elements (TME) of Oued El Harrache, wilaya of Algiers (North of Algeria) which is a highly polluted watercourse and receptacle of all kind of waste.

The results obtained from the pollution parameters reveal that all the results of the physico-chemical analyses exceed the standards set by the WHO and show that this wadi is highly polluted by nitrates, nitrites, chlorides, suspended solids, ammoniums, with a hydrogen potential that is clearly acidic and a very high electrical conductivity rate. Also this wadi is very loaded by trace metal elements that are higher than the maximum standard tolerated set by the WHO, such as lead (Pb), zinc (Zn), copper (Cu), iron (Fe) and cadmium (Cd), which come from different sources, namely industrial, urban and agricultural, and which can destroy the fauna, flora of this river and affect the human being and the environment.

Fortunately, according to the journalist Mohamed Mendaci of the newspaper El Moudjahid (12-09-2022), we were informed that the Minister of Environment and Renewable Energies said that the depollution of Oued El-Harrach is a national priority that is part of the improvement of the living conditions of citizens and the fight against pollution, which is one of the commitments of the President of the Republic who attaches great importance to the environment and its protection, offering a good model for sustainable development. In addition, the depollution of this watercourse remains the major and main solution to protect our environment.

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