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Research Article

Evaluation of the Groundwater Quality in Amizour Plain (North Algeria) Through the Application of Heavy Metal Pollution Index

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Abstract
The concentrations of Three metallic elements, cadmium (Cd), lead (Pb), and zinc (Zn), have been evaluated in thirteen groundwater sampling points (from open wells) located near industrial, domestic and agricultural dumps of the Amizour plain (North Algeria). The contamination factor (Fc), the contamination degree (Dc), and heavy metal pollution index (HPI) were the models evaluated in aim to estimate the groundwater quality and the potential sources of trace metallic-elements infection. The concentrations of both Cd and Pb have been found to be below the permissible referred limits of drinking water quality standards, while Zn concentration exceeded the standards in most of the sampling points (eleven wells have Zn level > 15 ppb). The HPI of groundwater has been found to be far below the permissible limit of 100 (HPI = 40.6). Our obtained results give the assumption that the contamination of the studied groundwater is with limited extent, despite the prolific use of fertilizers and the intensive spill of industrial and domestic wastes in the ecosystem. Therefore, the low HPI values, noticed in the study zone, are likely attributed to the impermeability of geological formation preventing thus contaminants reaching the aquifer.

Keywords Heavy metal pollution index, groundwater, Amizour plain, concentration factor.

Introduction

Sustaining the supply of fresh water to deal with the endless increase of requirements is a major worldwide concern for the growing populations [1]. The exponential demographic increase in various parts of the word over the recent decades has consequently led towards accelerated urbanization and fast industrialization, which in turn added supplementary pressures on water resources [2, 3]. Unfortunately, the quality of water is deteriorating globally mainly with heavy metal (HM) contamination. Certain trace metals such as copper (Cu), cobalt (Co), and zinc (Zn) are important for living organisms, but at higher doses may inflect physiological disorder. Metallic elements such as chromium (Cr), cadmium (Cd), and lead (Pb) are so noxious even at low concentrations [4].

It is noteworthy that up to 20% of the global freshwater is featured as groundwater stock, while it comprises just 0.6% of the world's water resources. The world civilizations have used fresh groundwater as a vital source for drinking, and currently more than the half of the world's population depends on groundwater for their survival [5, 6]. Critically, around the quarter of the world's population are utilizing unsafe water and 18% of people use water from sources with considerable pollution hazards [7, 8] inferred that human unsustainable practices and wastewater runoff are the most common sources of

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contamination for both surface and ground water [3, 7].

In Algeria, due to the lack in surface water within many localities, already exaggerated by global warming, groundwater constitutes a main source to provide the drinking water supply [9]. The groundwater quality lies not only in its accessibility and availability but also in its consistent acceptable quality, which makes it a typical provision for potable water [5]. The contamination of underground water table in the Amizour plain (North Algeria) by industrial and domestic discharges along with the intensive use of fertilizers has now become a local concern. Further, in this locality, groundwater is an important source for plant cultivation. Various studies, indeed, highlighted the detrimental effects of HM pollution on water sources [10, 11, 12, 13]. All these investigations consolidate the fact that there is an urgent need to gauge the quality of water on a constant spell, since the amplification in the concentration of metallic elements in fresh water will pose a serious threat for human well-being.

The pollution attributes selected for the evaluation of the quality in any environment highlight more insights for the pollution with reference to that particular parameter only. Quality indices are feasible in obtaining a composite impact to all attributes of global pollution. Quality indices can utilize of a compilation of judgements into a reproducible form and cluster all the pollution features into some easy-to-use approach. Numerous approaches have been suggested to enhance performance of quality indices for forecasting of surface water patterns conjugated with water quality parameters [14, 15, 16, 17, 18, 19]**.** Recently, Prasad and Kumari [10] and Kumar et al. [13] monitored the trace metallic contamination of groundwater by using heavy metal pollution index. Our study, thereby, was based on screening the degree of contamination (Dc), the contamination factor (Fc) as well as the heavy metal potential index (HPI). The results will assist to predict the source of pollution impacting the Amizour aquifer and to planning an efficient rehabilitation project if necessary.

Material and Methods

Study area

The plain of Amizour has an area of about 50 km^2, it is located in the right bank of the Soummam river, limited by the mountains of Barbacha and the massif of Oued Amizour in the North-West, by the commune of Oued Ghir, Tala Hamza in the North-East, and by the two communes of Boukhlifa and Semaoun in the East and the West, respectively. Its territory is split up in two parts: one is located on a plain and the other in a mountainous area. The latter covers more than 75% of the locality area (Fig. 1).

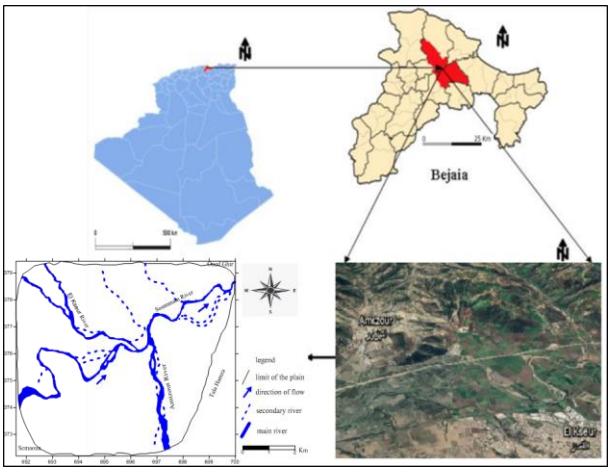


Figure 1. Location map of the study area

Geology and pedology

The geological study was carried out to identify the origin of the three metals (namely, Zn, Cd, and Pb) whether it is geogenic (natural) or anthropogenic (agricultural or industrial activity). On the other side, the pedological assessment was established to evaluate the relation of transport and dispersion for these three metals between the top layer and the aquifer.

Based on the geological map of the Soummam valley (Fig.2), the plain was formed by an old and current alluvial deposits on the major bed of the Soummam River. In the other part of this plain; there are a siliceous substrate on the entire north-facing slope and a limestone substrate dominating most of the south-facing slope, with a marly-clay zone extending from El Kseur to Sidi Aïch. In the outskirts, there are petrographic units; siliceous for the Akfadou and Djurdjura massifs, limestone for the Gouraya-Arbalou Djebels and the Babors chain in its southern part, the Soummam valley (Fig.2) is made up with alluvial deposits of a formation composed of pebbles, and most often by sandstone gravel and sand attributed to the Miocene. The coarse Miocene reaches 10 to 15 m in thickness at Ilmatten and 10 to 25 m in the region of El Kseur to where the studied area belongs [20].

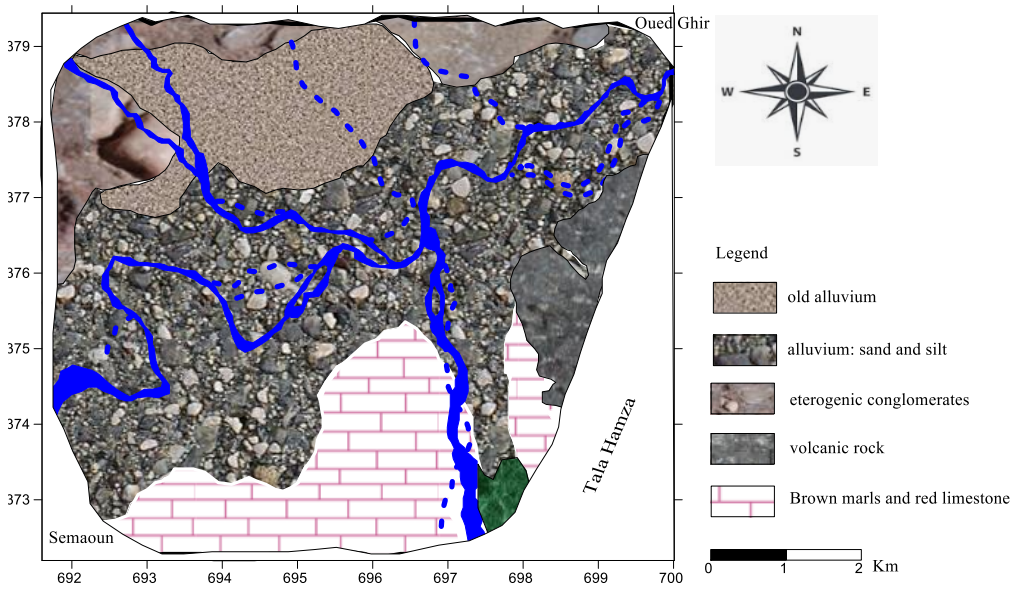


Figure 2. Geological and pedological map of the Amizour plain

In the upstream zone at Sidi Aïch and Oued Amizour, the aquifer is free or semi- confined, in the downstream zone at the Oued Amizour valley, the aquifer is loaded by silt whose thickness increases from upstream to downstream. Table 1 displays the hydrogeological interest for each soil formation [21].

Sampling and analysis

The realization of this study required the evaluation of water contamination with Zn, Pb, and Cd. To carry this investigation, 13 wells were selected randomly from the Amizour plain in February 2020. The samples were gathered from open wells. All the targeted wells are used for domestic, agricultural and industrial activities. During this investigation, the water samples intended for the chemical analyzes were gathered in polyethylene bottles with a volume of 1 L, previously disinfected with nitric acid and rinsed afterwards abundantly by distilled water. In the field, the bottles were rinsed many times with sterile H_2O before being used. After that, the bottles were entirely filled and hermetically sealed to avoid any gas exchange with the outer environment. The samples were kept in a cooler set at 4°C, and once at the laboratory the analysis were implemented immediately upon the collected simples (within one hour limit from collection). Digestion and condensation were carried out on all samples in aim to analyzing the concentration of each selected metals by using atomic absorption spectrophotometer (AAS) methods (model M Series Thermo Fisher) [22]. During the sampling, the geographical coordinates of the studied points was checked via a GPS (see Fig. 3 and Fig. 4) highlighting thus the spatial position of the wells.

Table 1.

The hydrogeological interest of the lithological formations in the plain

location	the study area	North and South of land
formation	Sand, silt and gravel	Clay and sandstone medium
thickness	+10m	+15m
Hydrogeological interest	permeable (very important interest)	semi permeable (important interest)

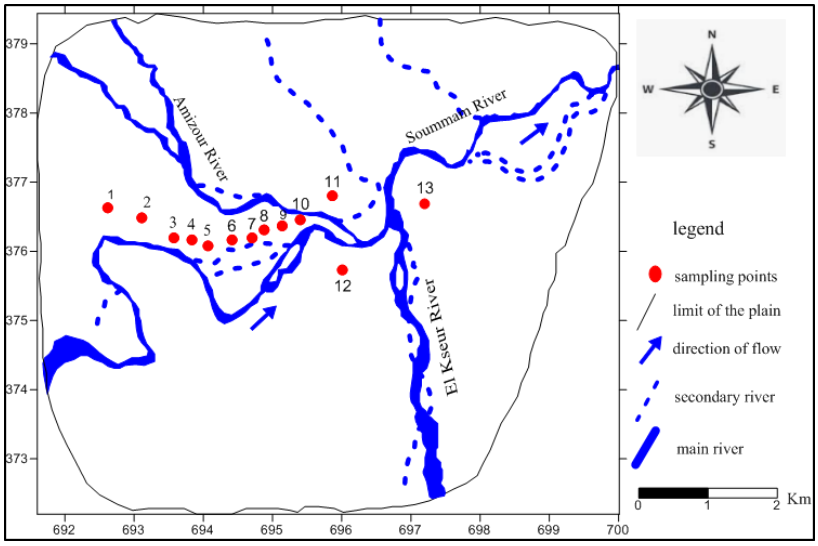


Figure 3. Map of sampling points (February 2020)



Figure 4. Illustrations of some groundwater sampling points in the Amizour plain (February 2020)

Pollution evaluation indices

Three pollution indices linked to the quality of drinking water were calculated; Contamination factor (Fc), the degree of contamination (Dc) and the level of pollution by heavy metal (HPI: heavy metal pollution index)

Contamination factor (Fc)

This factor is known as a proportion introduced by Hakanson [23]. It is a simple and effective index to monitor contamination of the environment by heavy metals [24]. It enables to exhibit the existence or not of contamination in the medium with trace elements and to determine the level of contamination. The Fc is expressed by the ratio of concentration with the element measured in the groundwater sampled and the standard permissible values (according to World Health Organization-WHO) (2017). Equation 1 shows the calculation method.

$$Fc = \frac{concentration\ of\ ETM\ in\ water}{standard\ permissible\ values\ (WHO)} \quad (1),$$

being Fc<1, 1<Fc<3, 3<Fc<6, and Fc>6 indicated low, medium, high, and very high contamination, respectively.

Degree of contamination (Dc)

The level of contamination is used as a standard to assess the degree of water contamination by metals [25]. It does not take into account the level of water pollution [26]. The degree of contamination was calculated from equation 2

$Dc = \sum_{i=1}^{n} Fci$ (2),

where; Fci is the contamination factor of the ith setting; and n, the normative value of the ETM. The Dc is split into three groups, namely: weak (Dc < 1), medium (Dc = 1 to 3) and high (Dc > 3) [27, 28, 29].

Heavy metal pollution index (HPI)

The HPI is the degree of purity of water in relation to the existence of HMs, generally the HPI is founded on the calculation of the weighted arithmetic mean of the water purity based on in two stages: first, using a scale of evaluation for each chosen approach; and second, by opting the pollution parameter or rating system that has a arbitrary value ranged from 0 to 1. Zn, Pb, and Cd have been selected to calculate the HPI index. The HPI model was computed as proposed by Mohan et al. [30]:

$$HPI=\frac{\sum_{i=1}^{n} WiQi}{\sum_{i=1}^{n} Wi} \quad (3)$$

where; W_i is the unit weightage of each chosen parameter or Si reciprocal value, Q_i is the sub-index of the ith parameter, and n is the quantity of selected parameters.

Q_i is estimated as follow:

$$Qi=\sum_{i=1}^{n} \frac{\{Mi(-)Ii\}}{(Si-Ii)} \times 100 \quad (4)$$

Mi : the obtained value of each HM,
Ii : the ideal value of ith parameter,
Si : the standard value of ith parameter in ppb.
The sign (-) means the digital proportion of the two values, neglecting the algebraic value.
As long as the HPI value never exceeds 100, the people who dwell around the Amizour plain will be safe from a potential detrimental infection of drinking water.

Results and Discussion

The concentration of Zn in the groundwater samples ranged from nearly 7 up to 1000 ppb (Table 2). Considering the WHO (2017) benchmark permissible limit of Zn in water (i.e. 15 ppb), almost all the sampling points have a concentration exceeding this threshold (Fig. 5). In fact, the average concentration of Zn in groundwater is 270.53 ppb (Table.3). The greatest concentration of Zn (1000 ppb) was observed in the well 10 situated in the middle of the plain, where there is a tremendous anthropogenic pressure especially reflected with an intense agricultural activity. The Zn is often used in agriculture as a fertilizer, mainly to mitigate the dreadful impact of calcareous soils (Fig. 2) [31].

Table 2.

Fc calculation for groundwater of Amizour plain (February 2020)

well name	X(Km)	Y(Km)	Zn(ppb)	Pb(ppb)	Cd(ppb)	Pb/50	Zn/15	Cd/10
			Standard permissible values;15ppb	Standard permissible values;50ppb	Standard permissible values;10ppb			
W1	692,61865	376,629939	127	2	3	0,04	8,46666667	0,3
W2	693,11128	376,485051	10	8	9	0,16	0,66666667	0,9
W3	693,57492	376,195274	242	1,1	5	0,022	16,1333333	0,5
W4	693,83572	376,166296	31	3	4	0,06	2,06666667	0,4
W5	694,06754	376,079363	7	6	6	0,12	0,46666667	0,6
W6	694,41527	376,166296	654	2	4	0,04	43,6	0,4
W7	694,70505	376,195274	249	2	7	0,04	16,6	0,7
W8	694,87892	376,311184	100	4	5	0,08	6,66666667	0,5
W9	695,13971	376,36914	18	5	4	0,1	1,2	0,4
W10	695,40051	376,456073	1000	6,4	5	0,128	66,6666667	0,5
W11	695,86416	376,803805	58	3	2	0,06	3,86666667	0,2
W12	696,00905	375,73163	934	2	2	0,04	62,2666667	0,2
W13	697,19713	376,687895	87	3	6	0,06	5,8	0,6

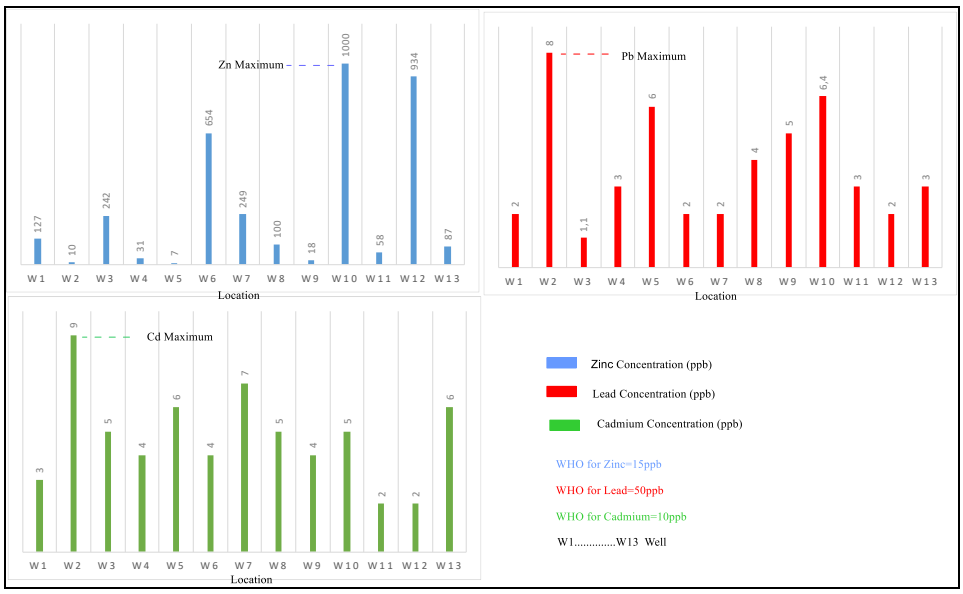


Figure 5. Depiction of concentration of heavy metals in the groundwater for the Zinc, lead and cadmium

The supply with this trace element significantly increases the occurrence of certain infections (e.g. pneumonia and diarrhoea) among children in developing countries indeed [32]. Overall, an over uptake of Zn in soils can cause a phenomenon of toxicity, jeopardizing thus plant's biomass production in substrates amended with Zn-rich sludge [33, 34]. Even though they manage to grow on Zn-polluted soils, plants emerging in contaminated sites will subsequently assimilate significant concentrations of this metal that can usually exceed international food quality standards, harming hence human health [35].

The concentration of Pb and Cd ranged from 1.1 to 8 ppb and 2 to 9 ppb, respectively (Table 2). Luckily, neither of these two metals exceeded the WHO (2017) standards (50 ppb for Pb and 10 ppb for Cd) (Fig.5). The lowest concertation of Pb was observed in well 3 (1.1 ppb), whereas the maximum Pb value was noticed in well 2 (8 ppb). In this latter well the greatest value of Cd (9 ppd) was recorded either, while the minimum concentration of Cd (2 ppb) was showed in the wells 11 and 12.

The highest classes of contamination factor Fc for Zn is generally found in the middle of the study zone and the southern part where there is a proliferation of anthropogenic activity making this zone vulnerable. The class of very high contamination (> 6) and considerable contamination (3 to 6) cover most of the study zone (ca. 77%). On the other side, medium and low contamination classes cover only 23% of the region resulted in the existence of mountain formations protecting therefore the underground water quality. The factor of contamination for Cd and Pb is featured by just one class, with Fc less than 1 (Low contamination).

The degree of contamination directly related to the number of pollutants (ETM), unfortunately we establish our study only on 3 metals which gave us two classes (Fig. 7): medium and high contamination representing 32 and 68% of the study area surface, respectively.

The HPI calculated with mean concentration values of the three selected metals, in the period of high water (February 2020), including all groundwater samples was 40.69 (table. 3). This value is so far under the critical index of 100, above which the overall pollution degree is viewed as inadmissible for water purity, indicating that groundwater samples are not harmfully threatened with metallic trace elements. However, according to Kumar et al. [36] classification, our study region is ranked with high HPI, since they split up this model into three groups: low (<19), medium (19–38) and high (>38). Besides human activities, the soil texture, unsaturated zone thickness, and irrigation method were the main factors effectively contributing in groundwater pollution process.

The approach implemented to estimate HPI has been found to fit with the prediction of all pollution levels that includes many parameters and is further a useful tool to assess globally the degree of pollution with respect to metal uptake.

Table 3.
HPI calculation for groundwater of Amizour plain (February 2020). Σwi = 0.12006; ΣwiQi = 4.09075; HPI = 40.69

Heavy metals	Mean concentration values (Mi)(ppb)n=13	Standard permissible value (S_i) (ppb)	Highest desirable value (I_i) (ppb)	Unit weightage (W_i)	Sub index (Q_i)	Wi×Qi
Pb	3.65	50.000	-	0.020	7.3	0.146
Cd	4.76	10.000	-	0.100	47.6	4.76
Zn	270.53	15.000	5.000	0.0006	2655.3	0.0015

Conclusions

The model of HPI established in this study has been proven to be an accurate element in evaluating the overall pollution groundwater in terms of HMs. The HPI calculated for groundwater of Amizour plain do not exceed the value of 100. This reflects that the groundwater is safety and not dreadfully impacted with HMs despite the existence of industrial wastes and the intensive use of pesticides in agriculture. Even so, measurements should be taken into consideration to cope against the rise of Zn levels and to sustain the safety of this zone, so we suggest:

-Raising awareness among citizens and farmers about the consequences of intensive agricultural practices and especially the trace elements.

-Studying the perimeters of protection for the water table and a possible socio-economic development in the region.

-Producing periodic risk maps to prevent contamination of aquifer formations.

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