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Full length research paper

Assessing groundwater contamination by hydrocarbons and heavy metals (Northeast of Algeria)

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Groundwater in the study area was shallow and found in the relatively permeable Mio-Pliocene alluviums comprised of sand and gravels. To assess groundwater pollution by hydrocarbons and heavy metals, piezometric level and physico-chemical data were monitored for eight months using 19 piezometers. The industrial effluents were sampled from a drainage channel within the industrial zone. The average results of physico-chemical analyses (TSS, Total Hydrocarbons and some metals) show an important qualitative degradation of the groundwater, especially in the parts situated in the down gradient area and in direct proximity of the drainage channel. Key factors influencing the extent of groundwater contamination include the depth of the water table, permeability of the soil, and therefore its infiltration rate. In order to prevent further deterioration of groundwater quality, effluent must be transported via pipes or impervious channels for treatment prior to discharge.

Keywords: Groundwater, Pollution, Effluents, Coastal aquifer, Northeast region, Algeria.

INTRODUCTION

Skikda is located in northeast Algeria and occupies an area of around 4138 km^2 near the Medeterean Sea. The population has increased greatly to some 800,000 inhabitants. The demographical development and the intensification of the economic industrial activities in Skikda have been accompanied by an increase in demand for water. Groundwater has been used for various purposes such as drinking, agriculture and domestic consumption. In this coastal zone, groundwater has been particularly exploited as a principal source of industrial water. There are about 135 groundwater wells in the Skikda region and the amount of groundwater abstracted from these wells has been estimated to be about 52 hm^3 per year with 12 hm^3 from the industrial zone.

Such large industrial demands on groundwater (Debeiche, 2002) have caused water quality and the contamination of groundwater in this coastal zone to become an extremely important issue for industrial groundwater supply. Therefore, groundwater contamination may be largely dependent on industrial waste and effluents. This study was designed to elucidate the hydrochemical characteristics and the contamination of groundwater according to industrialisation (Gurunadha et al., 2001) and land use patterns (Chan, 2001). We aimed to estimate to what extent the aquifer is polluted and to identify the most sensitive areas at risk.

Unlike the majority of Algerian cities, Skikda has a large industrial zone that is located within 3 km of the city center near residential areas. This industrial location can constitute a risk for the neighboring population. The study of the vulnerability of groundwater to pollution using natural characteristics by means of the DRASTIC method (Chaffai et al., 2006) has shown that our area is located in the zone of moderate to high vulnerability. The active zone covers 1200 ha that includes many sites where the water table ascends. This permanent contact with industrial effluents leads to significant water pollution. The climate is humid with an annual rainfall of 733 mm, a mean annual temperature of 18 °C and prevailing winds blowing from the industrial area towards the residential part of the city. The total infiltration on the alluvial

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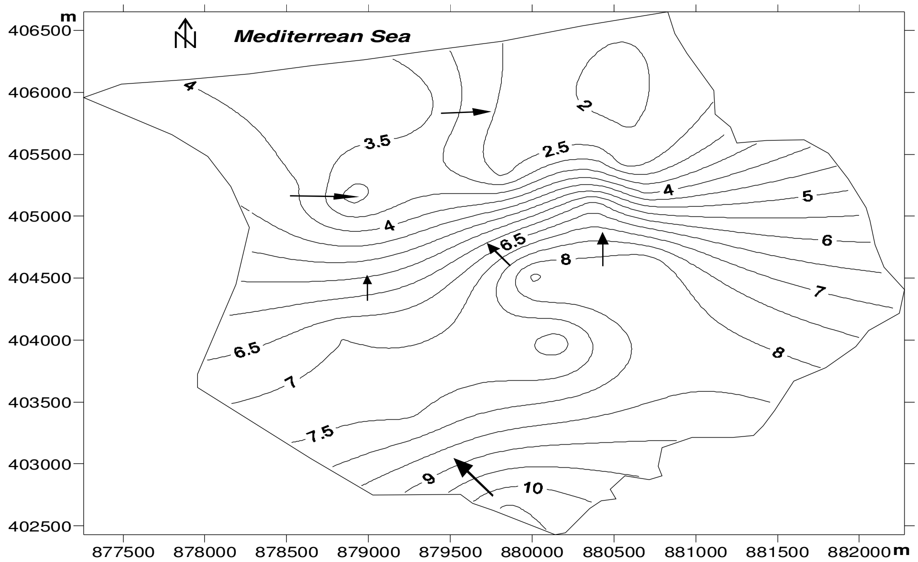

Figure 1. Piezometric level map (m)

water-table of Skikda averages 80 mm per year (Chaffai et al., 2006). So, in our study area around 33% of the total rainfall, approximately 240 mm per year, infiltrates through the soil to the water table.

The studied zone, part of the northeast Algerian coast, is formed by a Paleozoic substratum overlain by Mesozoic and Mio-Plio-Quaternary continental and lagoonal sediments. The aquifer system is characterized by a superficial table (15 m-thick alluvium) and a captive table, which is fundamentally comprised of gravels (10-40 m thick).

MATERIAL AND METHODS

Eight monthly surveys of the piezometric level and a geochemical analysis were conducted from September 2009 to April 2010. The analyses were carried out on a network of 19 piezometers (one to two wells per km^2). Three samples of industrial effluents were collected from a drainage channel within the industrial zone.

Temperature (T), pH, electrical conductivity (EC) and dissolved oxygen were measured in situ using a handheld meter (WTW Multiline P3 PH/LF-SET, CellOx 325). The concentrations of chloride (Cl^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), carbonates (HCO^-_3) and sulfates (SO^{2-}_4) were measured using the volumetric method (Afnor, 1987). Total suspended solids (TSS) were determined by filtration through a standard GF/F glass fiber filter (NF EN 872). Phosphate (PO_4^+), nitrate (NO^-_3), nitrite (NO^-_2), and ammonium (NH^+_4) levels were calculated by colorimetry using a spectrophotometer (Spectronic 20 D). Heavy metal concentrations (Mn, Pb, and Cr) were determined using atomic absorption spectrophotometry (Unicam 929 AA Spectrometer). The total petroleum hydrocarbons (TPH) were calculated by Infrared (IR) determination (Ftir – 8300). The piezometric level map was gridded using Golden Software Surfer (Version 8.01) by the Kriging method.

RESULTS

The groundwater table around Skikda is characterized by shallow depths (Figure 1) (generally less than 7 m with a minimum of 0.8 m) (Labar et al., 2006a). These depths were observed down the gradient of the drainage channel and in the coastal zone. The over flow direction of the aquifer is SW-NE. The presence of a shallow-depth piezometric level within the coastal area indicates a seawater intrusion in the industrial zone (Labar et al., 2006a; Hedbani, 2006). However, this potential source of pollution has been stimulated by effluent seawater pumped to chill hot industrial equipment. So, the conductivity in the source of the pumped effluent seawater in the drainage channel is about 22 ms/cm and 8 ms/cm (Labar et al., 2006a) (average 4 ms/cm in all effluent points, Table 1), but in the groundwater at the same area is about 2 ms/cm (Labar et al., 2006a). In addition, the leachates from urban landfill situated in our study area has been shown to have high conductivity (23 ms/cm) (Labar et al., 2006b ; Chofqui et al., 2004), but leachates of the industrial solid waste within the industrial zone has been observed to have low conductivity (1 ms/cm) (Labar et al., 2006b) .

The effluents originating from industrial factories (labar et al., 2005) are highly concentrated (Table 1) with copper sulfate (938 mg/l), nitrates (24 mg/l) and phosphates (9 mg/l).

Table 1: Average chemical composition of the waste water (2009-2010)

pH	EC ms/cm	Cl^- (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	SO_4^{2+} (mg/l)	HCO_3^- (mg/l)	NO_3^- (mg/l)	NO_2^- (mg/l)	NH_4^+ (mg/l)	PO_4^{3+} (mg/l)
8	4.1	699	266	111	938	624	24	0.11	17	8.7

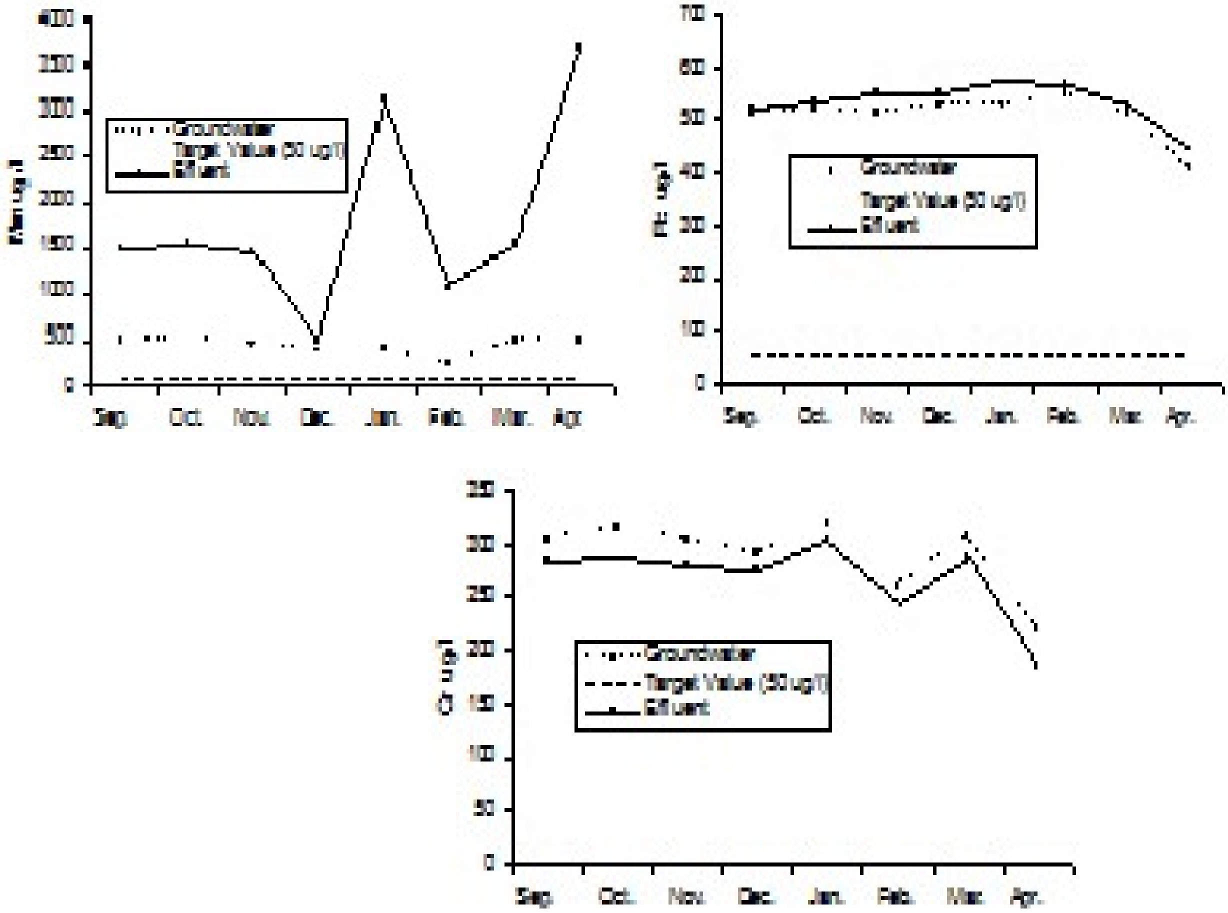

Figure 2. Temporal Evolution of metals (Mn, Pb and Cr)

DISCUSSION

The high values of nitrates and phosphates explain the eutrophication (Vinten et al., 2001) of ground water in this industrial zone.

Mineral pollution (Chery and Mouvet, 2000) of groundwater (PZ) by effluent (Ef) (Figure 2) was found all eight months with a high temporal evolution of metals. The undesirable metal (Mn) and the toxic metals (Pb, Cr) (Jonathan et al., 2005) were much higher than acceptable upper limits suggested by the European Union (50 ug/l for Mn, Pb and Cr) (CEE, 1980). However, the latest world guideline values for chemicals that are of health significance in drinking water are 400, 50, and 10 ug/l respectively for Mn, Cr and Pb (WHO, 2006).

The spatial-mineral-pollution of groundwater (Figure 3) is clearly shown by high values of metals (Mn, Pb, Cr) for the wells located down gradient near the drainage channel of industrial effluents.

Pollution of groundwater by organics was shown by high values of total hydrocarbons (Figure 3) above limits suggested by the European Union (0.01 to 0.0002mg/l) (CEE, 1980) for all eight months. But, the concentrations were higher in groundwater (PZ) than the effluents (Ef) (See figure 4).

Also, the total hydrocarbons in groundwater are much higher than in the effluent (figure. 5A), more than 10 mg/l, with a maximum sometimes exceeding 20 mg/l. Another

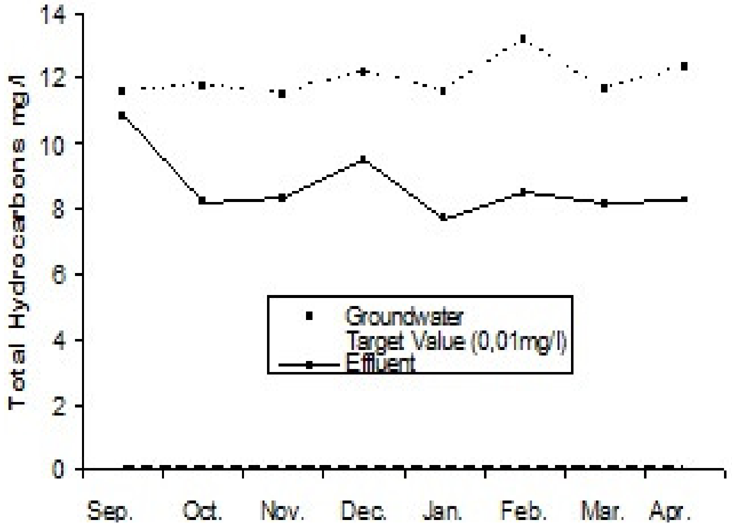

Figure 3. Temporal Evolution of Total Hydrocarbons

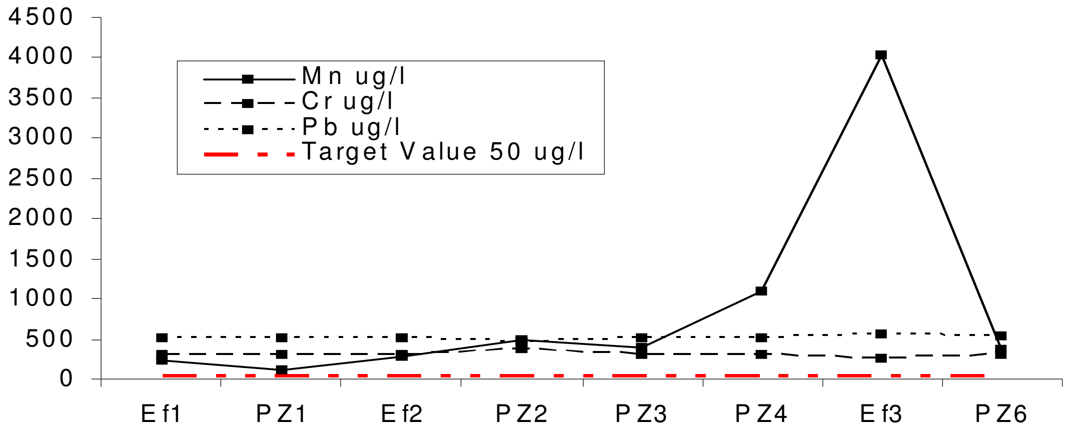

Figure 4. Spatial Evolution of metals (Mn, Pb and Cr)

study observed a high concentration average of 200 mg/l near the source of the effluent (Meghzili et al., 2006).

So, the wells located near crude oil pipes (Figure 1) are observed with a very high concentration of total hydrocarbons (Figure 5B). Figure 5 shows that the high values of TSS are related to crude oil supposedly leaked from pipes.

CONCLUSION

Our hydrochemical study shows that groundwater in the vicinity of industrial effluents are characterised by high levels of biochemical and organic contamination and moderate levels of physical and inorganic contamination strongly related to its location in the coastal zone. Like this, the effects of other potential sources of groundwater contamination are leaking crude oil transport pipes.

To prevent further deterioration of groundwater quality a number of measures are recommended, namely:

-To establish an appropriate system for the collection, treatment and discharge of effluents;

-To introduce impermeable surfaces in the drainage channels (e.g., using clay or high density polyethylene geomembranes);

-To carefully monitor groundwater quality across a network of representative wells over an extended time period.

The treatment of water polluted with crude oil and toxic metals can be efficiently carried out by bioremediation means of a constructed wetland with a proper size and located in regions with suitable geological and hydrogeological conditions (Groudeva et al., 2001).

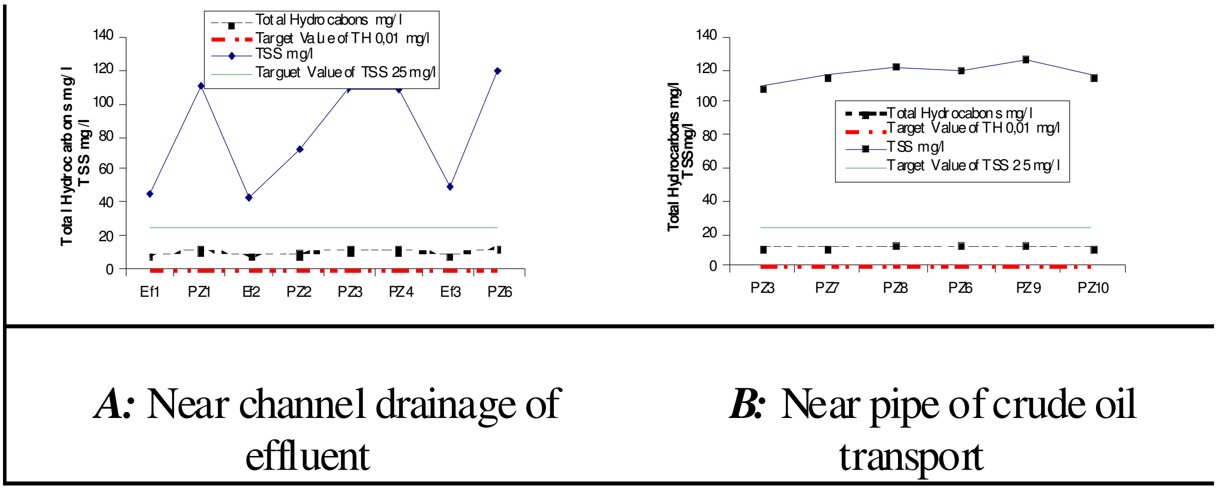

Figure 5. Total Hydrocarbons and Suspended solids

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