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Groundwater Contamination and Controlling Pollution Factors Within a Coastal Industrial Area, Skikda, Algeria

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Abstract: To evaluate groundwater contamination in the industrial area, piezometric level and physico-chemical analyses have been monitored for 8 months using 17 piezometers. Groundwater is shallow (0.8 - 7 m) and found in the relatively permeable miopliocene alluviums comprised of sand and gravels. The industrial effluents were sampled from a drainage channel within the industrial zone. The average results of physico-chemical analyses (BOD5, COD, TSS, Total Hydrocarbons and some metals) showed 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 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.

Key words: Groundwater, pollution type, effluents, industrial area, Algeria

INTRODUCTION

Many cities in the world depend heavily on ground water resource. They have grown, urbanized and industrialized rapidly. However, the contamination of groundwater has been by effect of urbanization like Taejon area in Korea (Jeong, 2001) and industrialization like industrial development area, Medak District, Andhra pradesh in India (Rao *et al*., 2001).

Skikda city is located in the northeast of Algeria and occupies an area of around 4138 km^2. 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 water, agriculture water and domestic water. 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 per year being abstracted from the industrial zone.

Such large industrial demands on groundwater have caused water quality and the contamination of groundwater in this coastal zone to become an extremely important issue for industrial groundwater supply (Labar *et al*., 2006). 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 industrialization and land use patterns. We aimed to estimate to what extent the aquifer is polluted and to identify the most sensitive areas at risk.

Site characteristics: Unlike the majority of Algerian cities, Skikda has a large industrial zone that is located within 3km of the city center near to residential areas (Hamrouch Hammoudi). 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

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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 of humid type with an annual rainfall of 733 mm, a mean annual temperature of 18°C and the prevailing winds direction is from the industrial towards the residential part of the city.

The total infiltration in the alluvial water-table of Skikda is average 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 soil to the water table.

The studied zone, which is a part of northeast Algerian coast, is formed by a Paleozoic substratum overlaid by Mesozoic and mio-plioquaternary continental and lagoonal sediments. The aquifer system is characterized by a superficial table (alluviums 15 m of thickness) and a captive table which is fundamentally constituted by gravels (gravel table, 10-40 m of thickness).

MATERIALS AND METHODS

Many monthly surveys of the piezometric level and geochemical analysis have been monitored from September 2005 to March 2006. The analyses are carried out on network of 17 piezometers (one to two wells per km^2).

Three samples of industrial effluents were sampled from a drainage channel within the industrial zone (Fig. 1). The Temperature (T), pH and Electrical Conductivity (EC) were measured in situ using a handheld meter (WTW Multiline P3 PH/LF-SET, CellOx 325). The concentration of chloride (Cl^-), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Carbonates (HCO_3^-) and Sulfates (SO_4^{2-}) were measured using the volumetric method (AFNOR, 1989). The Total Suspended Solids (TSS) was determined by filtration through a standard GF/F glass fiber filter (NF EN 872).The Chemical Oxygen Demand (COD) was measured by COD meter (Tract 42 mm RIN 29/32 and refrigerant RIN 29/32). The Biochemical Oxygen Demand (BOD_5) was measured by intelligent system BOD meter (WTW DIN 38 409). The phosphate (PO_4^+), Nitrate (NO_3^-), Nitrite (NO_2^-) and ammonium (NH_4^+) were analyzed by colorimetery method using spectrophotometer (Spectronic 20 D). The heavy metals (Mn, Pb and Cr) were determined using atomic absorption spectrophotometer (Unicam 929 AA Spectrometer). The total hydrocarbons were determined by Infrared Red (IR) determination.

The piezometric level map was grided by the golden Software Surfer (Version 8.01), using the Kriging method.

RESULTS AND DISCUSSION

Piezometric level study: The groundwater table (Fig. 2) is characterized by shallow depths (generally inferior to 7 m with a minimum of 0.8 m). These depths were observed down the gradient of the drainage channel and in the coastal zone. The over flow direction of the

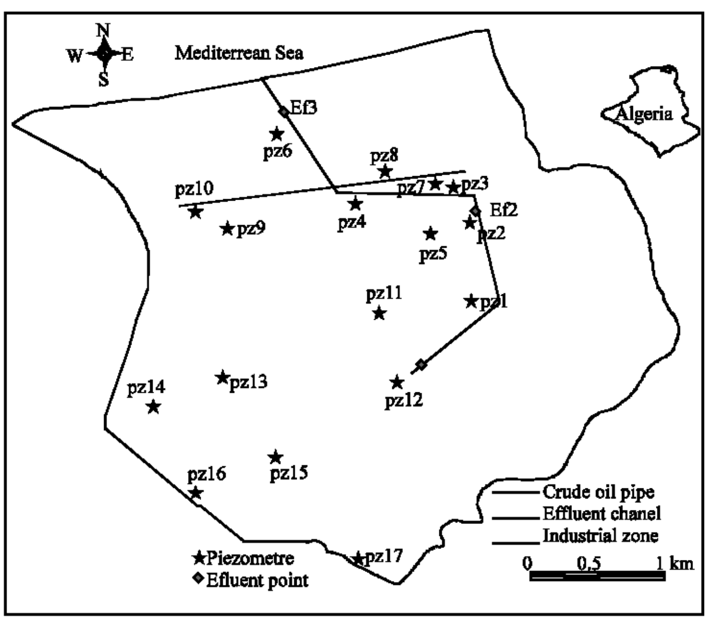

Fig. 1: Strategy sampling waters of piezometers and effluents

Table 1: Average chemical composition of the effluent of the Skikda, channel industrial zone (2005-2006)

pH	EC ms cm^{-1}	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

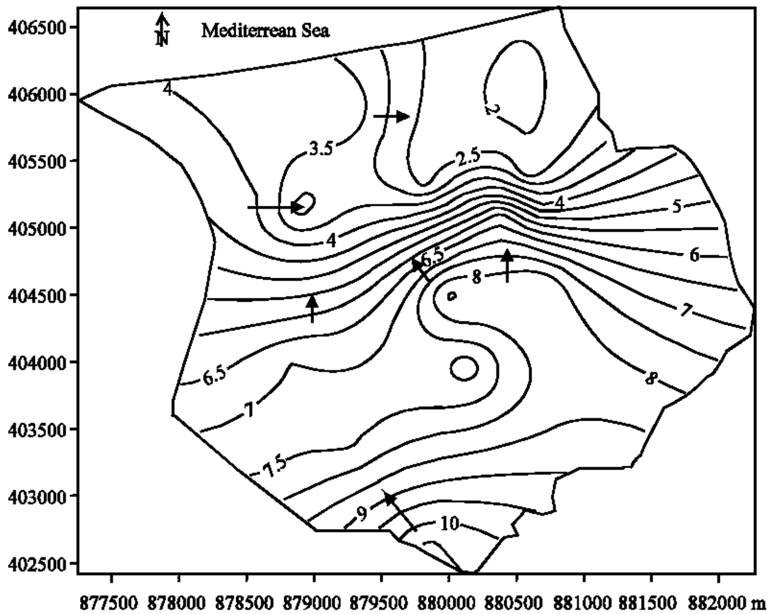

Fig. 2: Piezometric level map

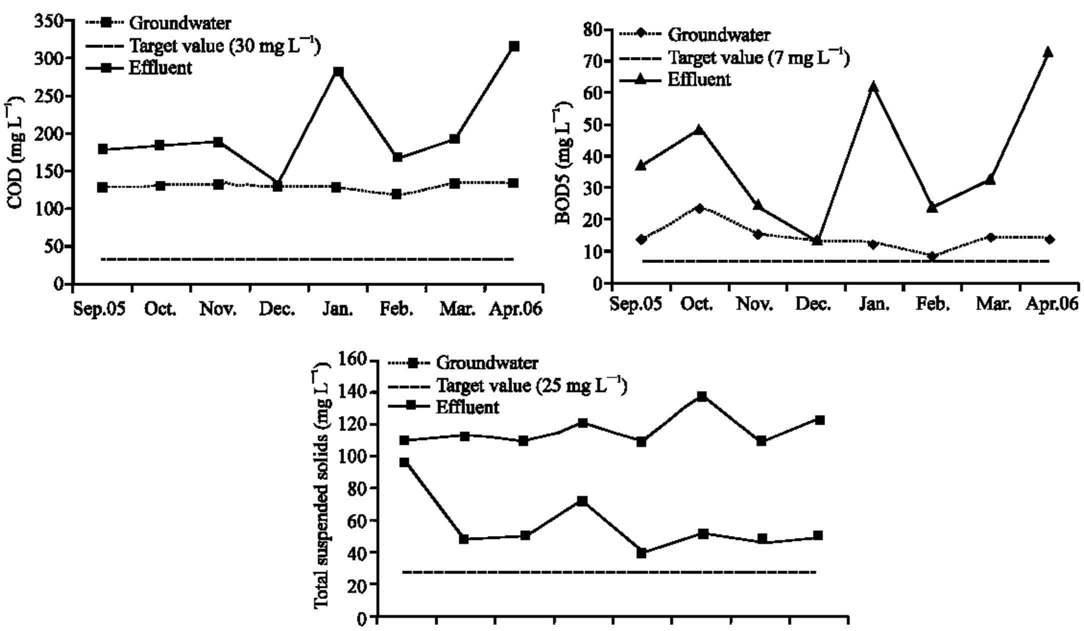

Fig. 3: Temporal evolution of biochemical pollution (BOD5, COD and TSS)

aquifer was SW-NE. The presence of shallow depth piezometric level within the coastal area indicates a seawater intrusion in the industrial zone (Labar *et al.*, 2006a, b; Hedbani, 2006). However, this potential source of pollution has been stimulated by effluent of seawater pumped to chill hot industrial equipments. So, the conductivity in the source of the effluent of seawater pumped is about 22 ms cm^{-1} and 8 ms cm^{-1} (point Ef3, Fig. 1) in the drainage channel (average 4 ms cm^{-1} in all effluent points, Table 1) but in the groundwater at the same area is about 2 ms cm^{-1} (PZ6, Fig. 1). In addition, the leachates from urban landfill situated out our area study has been shown by high conductivity (23 ms cm^{-1}) (Labar *et al.*, 2006) like in morocco(26 ms cm^{-1}) (Chofqui *et al.*, 2004). But leachates of the non urban solid waste within the industrial zone has been observed by low conductivity (1 ms cm^{-1}) (Labar *et al.*, 2006).

Chemical composition of effluents: The effluents originating from industrial factories are highly concentrated (Table 1) with copper sulfate (938 mg L^{-1}), nitrates (24 mg L^{-1}) and phosphates (9 mg L^{-1}). These high values of nitrates and phosphates explain the eutrophisation of ground water in this industrial zone.

Characterization of pollution

Biochemical pollution: A biochemical pollution has shown (Fig. 3) above target value by a high concentration of BOD and COD for all eight months which is the same case for the most rivers (Kebir-Est, Bounamoussa and Seybousse) of El-Tarf region (Labar *et al.*, 2005). In order, the suspended solids of groundwater which are much higher than the effluent have another source which is supposed the crude oil from pipe. This is shown clearly in Fig. 4 where the high values of BOD and COD are near effluent points. However, the suspended solids concentrations have the contrary spatial evolution (BOD5, COD and TSS).

Inorganic pollution: The inorganic (mineral) pollution type (Chery and Mouvet, 2000) of groundwater by effluent (Fig. 5) was found for all eight months with a high temporal evolution of metals. The undesirable metal (Mn) and the toxic metals (Pb, Cr) were much higher than the acceptable upper limits suggested by the European Union (50 μg L^{-1} for Mn, Pb and Cr) (CEE, 1980). However, the last world guideline values for chemicals of health

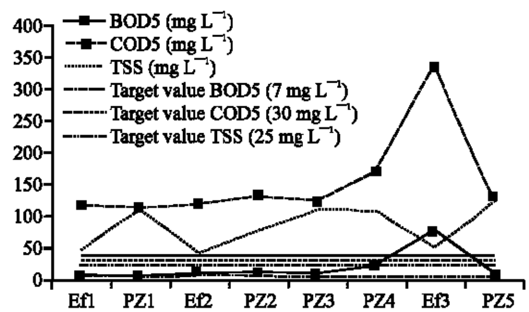

Fig. 4: Spatial evolution of biochemical pollution (BOD5, COD and TSS)

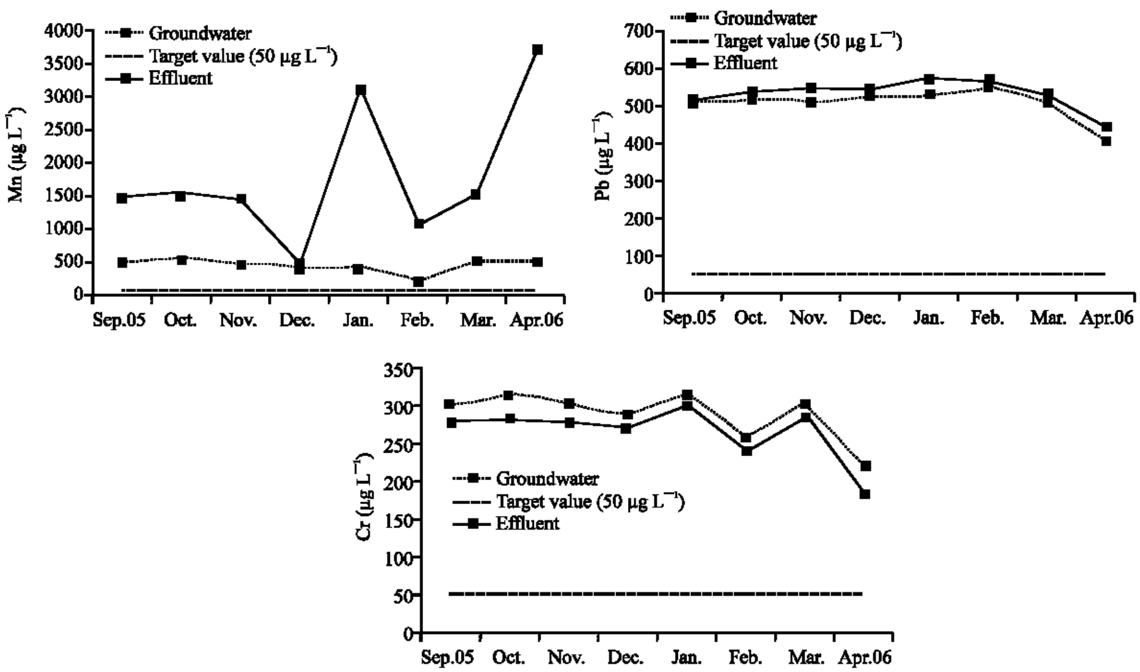

Fig. 5: Temporal evolution of inorganic pollution (Mn, Pb and Cr)

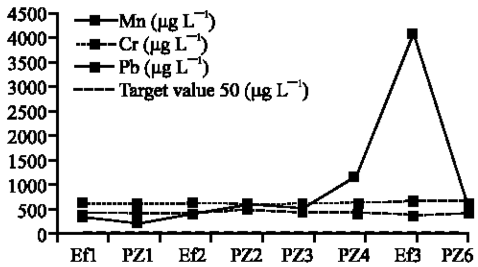

Fig. 6: Spatial evolution of inorganic pollution (Mn, Pb and Cr)

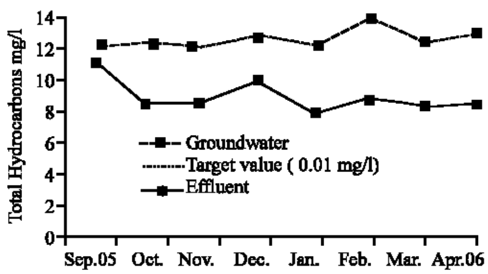

Fig. 7: Temporal evolution of organic pollution (Total hydrocarbons)

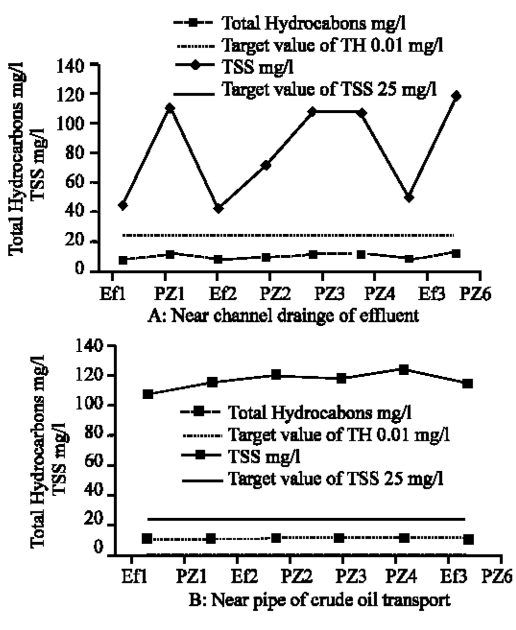

Fig. 8: Total hydrocarbons and suspended solids

significance in drinking-water are 400, 50 and 10 µg L^{-1} respectively for Mn, Cr and pb (WHO, 2006). The spatial inorganic pollution of ground water (Fig. 6) is clearly shown by high values of metals (Mn, Pb, Cr) for the wells located down gradient near the drainage channel of industrial effluents.

Organic pollution: Pollution of groundwater by organics was shown by high values of total hydrocarbons (Fig. 5) above limit suggested by the European Union (0.01 to 0.0002 mg L^{-1}) (CEE, 1980)on all 8 months. But, the concentrations were higher in groundwater than effluents.

Also, at many locations the total hydrocarbons in groundwater are much higher than effluents (Fig. 8 A), more than 10 mg L^{-1}, with a maximum exceeding sometimes 20 mg L^{-1}. Another study observed a high concentration average 200 mg L^{-1} near the source of effluent (Meghzili *et al.*, 2006).

However, the wells located near pipe of crude oil (Fig. 1) are observed with a very high concentration of total hydrocarbons (Fig. 8B). This last figure shows thats the high values of Total Suspended Solids (TSS) are in relation the crude oil supposed leaked from pipe.

CONCLUSION

Our hydrochemical study shows that groundwater in the vicinity of industrial effluents are characterized by high level of biochemical and organic contamination and moderate level of physical and mineral contamination which is especially due to its locations near drainage channel and pipe.

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;
- Introduce impermeable surfaces in the drainage channels e.g. using clay or high density polyethylene geomembrane;
- 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).

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