Groundwater quality in the suburban area of the city of Tijuana, Mexico

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Abstract

Over the last few decades the population growth of the city of Tijuana has had an annual rate of 6% and the city is estimated to reach a population of 3.5 million people by the year 2020. This growth has placed great demand on the regional water resources. Therefore, it is important to know the actual state of local groundwater quality to protect and manage this resource. The objective of this study was to evaluate groundwater quality in a suburban area of the city of Tijuana, Mexico.

Seven hand-dug wells and two surface water points were sampled during a period of 8 months for physicochemical parameters, bacteria and heavy metals.

The results have shown that the groundwater quality of the aquifer is poor because of the number of pollution sources that includes horticultural activities, on site sanitation, infiltration from a polluted stream and domestic rearing. High nitrogen concentrations suggest that the main source of contamination is wastewater infiltration and the manure used in the horticulture activities. Based on the results, groundwater in this aquifer is not suitable for human consumption unless it is treated, because the concentration values for chemical and microbiological parameters are higher than the Mexican drinking water standard.
Keywords: urban aquifer, suburban area, groundwater pollution, nitrogen, Tijuana, Mexico

1 Introduction

The city of Tijuana is located in the northwest corner of Mexico in the US-Mexico border. This region is characterized for its semi arid climate in which the main rains are in winter and early spring, except for very humid years where the Niño phenomenon is present. It results in scarce water resources for the rapidly urban population growth (6% annual) in the region. In 2000, its population is approximately 1,148,600 and it is estimated that the population could reach 3.5 million by 2020 [1]. Tijuana depends almost entirely on the imported water from the Colorado River Basin (more than 90%) and the rest comes from the local aquifer located beneath the valleys of the urban rivers that cross the city. The import of water may be inevitable but its high cost in capital investment and energy lead to a search for optimising water use and management of the local water resources in a sustainable way.

Suburban areas in developing countries usually favor the concentration of multipoint and diffuse sources of pollution [2]. They are traditionally the location of marginal or informal settlements and industrial facilities, as well as agricultural and domestic rearing activities. These informal settlements usually lack urban services such as sewerage, water supply, electricity and garbage collection. Therefore, the use of latrines and the existence of uncontrolled garbage dumping sites are common in these areas. All these factors contribute to the degradation of the environment and pollution of water resources.

The basis for a good management of the water resources is the improvement of the knowledge of the actual water quality. There is a lack of groundwater quality data for this area, because groundwater monitoring has been sporadic. Therefore, there is a need for reliable data for the management of this resource. The objective of this study was to evaluate groundwater quality in a suburban area of the city of Tijuana, Mexico and identify the potential pollution sources.

2 The study area

The study area is in a suburban area located northeast of the city of Tijuana (Figure 1) named the Alamar Creek zone. The approximate area is 9 km^2 and the average width of the alluvial canyon is approximately 760 m. The nature of the aquifer is alluvial with a water table ranging between 1-10 m, therefore the aquifer is highly vulnerable to contamination. The Alamar Creek is part of the Tijuana river basin, which has an area of approximately 4430 square kilometres with 1230 occurring in the United States and 3200 square kilometres in Mexico [3]. The region has a Mediterranean climate with distinct summer and winter seasons. The average annual rainfall is approximately 220 mm $year^{-1}$, with over 90% occurring during the period of November to April [4].

In natural conditions, the Alamar Creek was dry for most of the year. However, discharges from wastewater plants in Tecate (pop. 67,000) located approximately 20 km east of the study area have produced a perennial stream of poorly treated water. A recent monitoring study at Tecate river [5], upstream of the study area, found maximum total nitrogen concentrations of 62 mg/l, ammoniacal nitrogen 24 mg/l, nitrite 15 mg/l, phosphates 32 mg/l, chemical demand of oxygen 310 mg/l and biochemical demand of oxygen 150 mg/l. However, these concentrations are lower in the Alamar Creek because of the self-purification process that occurs in the stream.

The study area encompasses a suburban area with a mix of land uses: sewered and unsewered residential areas, small-scale horticulture, sand extraction and small utilities for animal rearing.

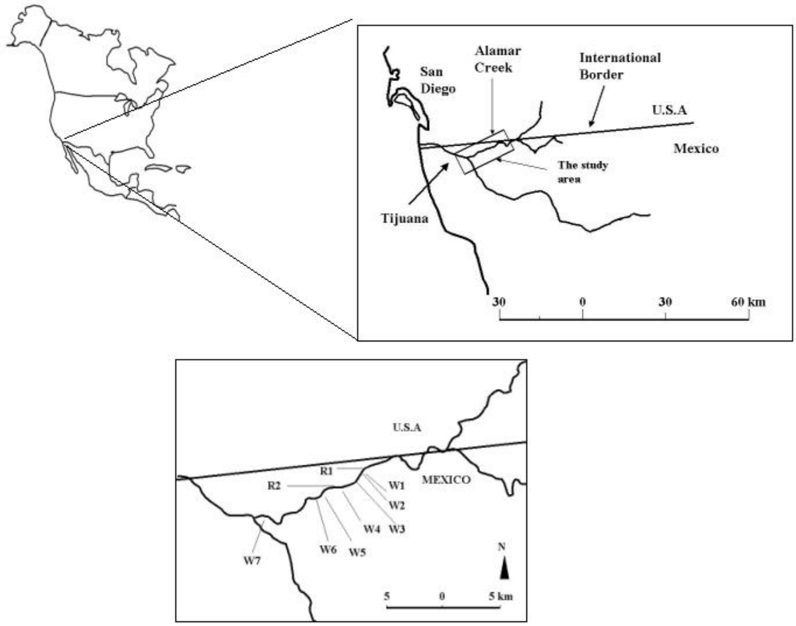

Figure 1: The study area and the location of the sampling points (W: wells, R: stream).

3 Methods

Seven hand-dug wells and two points on the stream were sampled four times, from February to September 2004. Where it was possible, samples were taken from irrigation pipes that were discharging for at least an hour, otherwise grab samples were taken from the hand-dug wells. Samples were refrigerated and analyzed in less than 48 hrs. Samples were analyzed in the field for pH, temperature, conductivity, total dissolved solids (TDS). Total nitrogen (TN), nitrate (NO_3-N), Nitrite (NO_2-N), ammoniacal nitrogen (NH_3-N), total phosphate, chemical oxygen demand (COD), sulphate, chloride and boron were analyzed using Hach spectrophotometric methods. Total hardness, calcium and magnesium by titration methods and heavy metals by ICP-MS. Finally bacteriological parameters were analyzed using the most probable number method.

4 Results

The results have shown that groundwater quality in this area is poor. High concentrations of nitrogen were observed. Total nitrogen average concentrations ranged from 8 to 54 mg/l and nitrogen ammonia concentration ranged 1.2 to 8.8 mg/l, all the samples were higher than the maximum concentration allowed for drinking water (0.5 mg/l). The concentrations of selected parameters are shown in Table 1, as well as the values of the Mexican standard for drinking water. It shows that except for chloride, all the parameter value concentrations are higher than the Mexican drinking water standard. All of the monitored wells have shown to be not suitable as source of drinking water without a pre-treatment.

Table 1: Average concentrations of selected parameters from groundwater and surface water (all the values in mg l^{-1} unless otherwise stated).

	W1	W2	W3	W4	W5	W6	S1	S2	NOM
TDS	1303	1580	1595	1572	2995	1870	1362	1533	1000
COD	29	24	46	40	74	24.6	77	72	NA
NO_3-N	0.6	1	1.3	1.3	3.2	1.7	3.5	4	10
NH_3-N	3.8	8.8	7.4	7.4	1.2	1.2	13.9	8.3	0.5
TN	8	30	28	23	54	20	40	32	NA
PO_4-P	15	5.6	13	10	0.5	1.8	18	16	NA
SO_4	519	573	515	513	764	559	548	570	400
Cl^-	110	100	117	120	230	160	107	131	250
Boron	0.67	0.6	0.7	0.6	0.7	0.7	0.7	0.8	
Fe[1]	19.1	1.80	8.10	0.94	0.97	NM	55.4	9.8	0.30
Al[1]	1.30	1.5	1.4	1.13	2.0	NM	51.8	10.6	0.2
Pb[1]	<0.1	<0.1	0.27	0.19	0.37	NM	0.38	0.25	0.025
Zn[1]	<0.1	<0.1	<0.1	<0.1	0.41	NM	0.66	0.14	5
Coliforms (MPN/ 100 ml)[2]	>1100	23 – 1000	240 - 1000	240 - 1100	>1100	93- >1100	$7x10^9$	NM	2

W: well. S: stream.
NOM: Mexican official standard of drinking water (NOM-127-SSA1-1994) [6].
[1]Result from a single sampling.
[2]From two sampling dates.

For most of the parameters, the trend was to increase from east to west (from less urbanized to more urbanized area). The concentrations of heavy metals may originate in an adjacent industrial zone as the result of infiltration of polluted storm water. The concentrations of heavy metal found in the soil of the industrial zone are chromium, 52.7 mg/kg, lead 25 mg/kg, cadmium 1.53 mg/kg and nickel 75 mg/l [7]. Placchi [8] measured heavy metals concentrations in storm water from this industrial zone. The concentrations found were chromium 0.128 mg/l, lead 0.0754 mg/l, cadmium 0.019 mg/l and nickel 0.148 mg/l. However, further research is needed in this area to evaluate the extension of heavy metal pollution.

It is known that on site sanitation systems, such as septic tanks and latrines, are major sources of groundwater pollution. According to INEGI [9], there are approximately 5000 persons in the study area that do not have sewerage. Of these, almost 50% use latrines. Therefore, the irregular settlements in this zone are a major potential contributor of pollutants.

The contribution of horticultural activities to the pollution of the aquifer in this area is unknown. It is known the irrigated horticulture can be a main contributor of nitrogen and pesticides to groundwater [10]. Based on observations and talks with the local horticulturists, inorganic fertilizers are not used. Instead, they use sawdust or manure applications three times a year, which may potentially leach nitrogen and other pollutants to groundwater.

High concentrations of NH_4, TN and bacteria show that the aquifer is being polluted by sewage infiltration, for which the highest contributor appears to be infiltrations to the aquifer from the stream. The main potential sources of groundwater pollution identified in the area are infiltration of the Alamar Creek, on-site sanitation systems, agricultural activities domestic rearing and possibly storm water infiltration.

5 Conclusions

The results have shown that the groundwater quality of the aquifer is poor because of a number of pollution sources, including horticultural activities, on site sanitation, infiltration from the Alamar Creek and domestic rearing. High nitrogen concentrations suggest that the main source of contamination is wastewater and manure used in the horticulture activities. Based on the results, groundwater in this aquifer is not suitable for human consumption unless it is treated, because the concentrations values for chemical and microbiological parameter are higher than the Mexican drinking water standard.

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