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Fluoride enrichment in groundwater of semi-arid urban area: Khan Younis City, southern Gaza Strip (Palestine)

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ABSTRACT

The aim of this study is to determine fluoride enhancement in the groundwater of semi-arid urban area of Khan Younis City, southern Gaza Strip. Physicochemical data for a total of 200 groundwater samples were analyzed. The fluoride concentrations were varied from 0.3 to 6.45 mg/L with average value of 2.87 mg/L. Correlations between fluorides with other measured ions were relatively observed, negative correlation with calcium and the positive correlation with pH, bicarbonate and sodium increase the dissolution/solubility of fluoride bearing minerals, leading to fluoride leaching into the groundwater. Fluoride enrichment in the groundwater of the area is due to water hydrochemistry, mineral–water interaction (mainly calcite and fluorite), fluorite resulted from fluorapatite dissolution. The saturation indexes evaluation indicated that 42% of the samples are over saturated with respect to calcite and 35.5% under saturated with respect to fluorite, while 40.5% approached equilibrium with respect to both calcite and fluorite. At fluoride concentrations of less than 2.2 mg/L fluorite saturation indexes show under-saturation condition for fluorite and at higher fluoride concentrations show near saturation condition.

1. Introduction

Fluorine element is the lightest and the most electronegative element of the halogen groups (Pauling, 1960). Because of its high reactivity in nature it never occurs in the elemental state. It is the 13th most abundance element in the crust (Weinstein and Davison, 2004) abundant as fluoride bearing mineral as a trace element (Tavener and Clark, 2006) with range of average concentrations of about 0.06–0.09% and average crust abundance of 500–1000 mg/kg (Naseem et al., 2010; Wedepohl, 1995). The most common fluoride bearing minerals found in environment are fluorite (CaF_2), fluorapatite ($Ca_5(PO_4)_3F$), micas and amphiboles, cryolite (Na_3AlF_6), villiaumite (NaF), and topaz ($Al_2(SiO_4)F_2$) (Ozsvath, 2009).

In groundwater, fluorine occurs as fluoride ions (F^-) which forms complexes with inorganic and organic compounds. The ion is released into groundwater during weathering process of rocks, minerals and through anthropogenic pollution (Beg, 2009). Enrichment of F^- concentration in groundwater depends on many factors: the geological, chemical and physical characteristics of aquifers (e.g., porosity and acidity of soils and rocks, temperature, depth, etc.) (Jacks et al., 2005; Abu Rukah and Alsokhny, 2004), groundwater age, well depth, hydrologic condition, residence time (Kim and Jeong, 2005). As rainwater infiltrates through the soil and reaches the water table, it dissolves F^- from its bearing minerals in the bedrock of the groundwater, where the bedrock mineralogy is the primary factor for the variations of its concentration of the water (Chae et al., 2007). Presence of excessive F^- in groundwater may persist for years, decades or even centuries, so in order to mitigate this excess, it is essential to determine and monitor the causal factors for F^- enrichment in the groundwater in time and space (Todd, 1980).

Fluoride is not an essential plant element, but it is essential for humans and animals. For humans fluoride is good for the teeth and helps to prevent dental caries. In excessive doses, however, it will lead to a chronic fluoride poisoning, fluorosis. Groundwater is a major source of human intake of F^- even though food items like tea sometimes contribute substantially (Cao et al., 2000). Higher fluoride occurs naturally in groundwater in many parts of the world, where about 75–90% of the daily intake of fluoride by humans throughout the world is through drinking water (Zohouri and Rogg-Gunn, 2000). WHO (1984) drinking water standard recommended F^- concentration in drinking water should remain less than 1 mg/L in areas such as the Gaza Strip, while

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WHO (2011) drinking water standard suggests that the lowest desirable limit of F^- concentration is 0.5 mg/L and the maximum permissible limit is 1.5 mg/L for drinking purpose.

Bosch (1997) indicated that Gazans are exposed to high F^- concentrations in their groundwater and also in the fish and the tea that are staple foods, and WHO (1999) indicated that there is a high dental fluorosis index in Gaza Strip. Assaf (2001) linked the high F^- concentration in the groundwater with teeth discoloration and mottling is at the present time vividly observed in the teeth of adult Palestinians in the southern Gaza Strip where the study area is located, and Shomar et al. (2004) indicated that the highest F^- concentration in the Gaza Strip were found in the Khan Younis area where dental fluorosis was easily recognized, and a high positive correlation (94%) was found between fluoride concentrations in groundwater and occurrence of dental fluorosis among school children. The main objective of this study is to determine and evaluate the processes for fluoride enrichment in the groundwater beneath the urban area of Khan Younis City, southern Gaza Strip.

2. Study area

2.1. Location and demographic information

The study area (Fig. 1) is the urban area of Khan Younis City (which is the main city in Khan Younis Governorate) located in the Southern part of Gaza Strip. The city is considered as the second largest city of Gaza Strip at latitude of 31,3439 (31°, 20′, 38.040″) north and longitude of 34,3025 (34°, 18′, 9.000″). It is generally flat covers an area of about 6.5 km^2 (about 1.8% of the Gaza Strip total area), located after 4 km from the seashore with topographic elevation of about 45 m above the mean sea level.

The Palestinian Central Bureau of Statistics estimated the population of Khan Younis City in 2013 as about 225,535 (constitutes 7.2% of the total population in the Gaza Strip) and expected to increase to about 236,235 inhabitants in 2016 (PCBS, 2012).

2.2. Climatic information

The climate of Khan Younis area is characterized by semi-arid Mediterranean climate, with, mild winters and dry hot summers, subject to drought rainfall which is the main source of almost all water for the only available water source (the groundwater) (UNEP, 2009). The area characterized by two well defined seasons: wet season starts from October and dry season starts from April, with annual rainfall of about 300 mm. It receives higher rainfall during the period from December to end of March. The average daily maximum temperature range from 29 °C to 17 °C in summer and from 21 °C to 9 °C in winter, with annual solar radiation of 2200 J/cm^2/day. The daily relative humidity fluctuates between 65% in the daytime and 85% at night in the summer, and between 60% and 80%, respectively in winter. The monthly average evaporation varies between maximum of 174 mm in July (summer) and

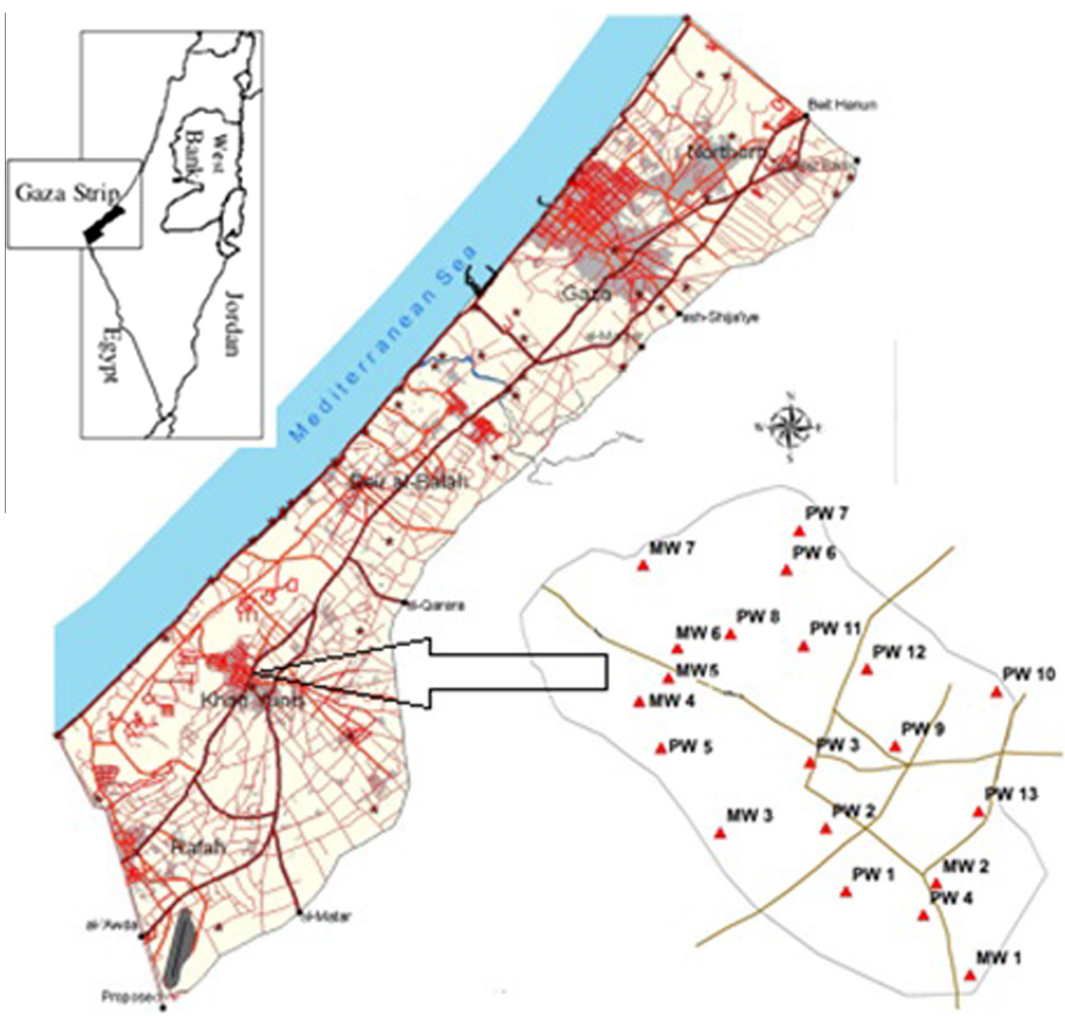

Fig. 1. Location of the study area and monitoring wells.