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Assessment of hydrochemical quality of ground water under some urban areas within sana'a secreteriat

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UWSS has covered 95 percent of the urban population and has improved its standards of delivery tremendously. Previous research on groundwater quality and drinking water supply between 1995 and 2000 has been carried out in Sana'a secretariat (Foppen, et. al., 2005), however ground water as an essential resource in Yemen shall regularly be monitored to ensure its protection from contamination. The present study focused on assessment of hydrochemical quality of ground water samples collected from wells located in three district of Sana'a secretariat, to compare the results with the different standards and to illustrate ground water suitability for utilizations in drinking, irrigation and industrial purposes through the calculation of some indices.

MATERIALS AND METHODS

Site of wells

Groundwater samples were collected form nine wells located in three districts of Sana'a secretariat. Well no. 1, located at AL- Durafi stadium, within ***AL-Tahreer*** district. Wells no. 4, 5, 6, 7, 8 and 9 located at Adhban, Tayseer, 22 May, Bin Maged, AL-Zubairy, AL-Baladiah zones respectively, within ***AL-Wahdah*** district and wells no. 2, 3 located at Shamlan and Asser zones respectively, within ***Maeen*** district.

Sampling

Groundwater samples were taken in 2003, 2004 from nine drilled wells located at the three different districts, as mentioned here above, where ***AL-Tahreer*** is considered as part of the city center, but ***AL-Wahdah and Maeen*** tend to be as part of the zone located in the western part of the sewered area of Sana'a secretariat, as indicated by Foppen, (2002). Submersible pumps were used to draw the samples into 2.5 letter acid-washed polyethylene bottles, which were thoroughly rinsed several times with distilled water, followed with a portion of the water sample prior to sampling. Samples were immediately cooled at 4º C using portable icebox and transported to the laboratory, where they were analyzed within 48 hours maximum.

Measurements and analyses:

All chemicals used in this study were of analytical grade and purchased from local distributors of BDH and Sigma companies in Yemen. The various parameters were determined according to the procedures stated in the American Public Health Association (APHA), standard methods for the examination of water and wastewater (1998).

Indices of calculations

Sodium adsorption ration (SAR), ratio of dissolved sodium (RDS) and residual sodium carbonate (RSC) indices were calculated according to formulae stated by Eaton, F.M., 1950, and lately used by Shaki and Adeloye, (2006), while saturation index (SI) was calculated according to formula stated by Soltan (1998).

RESULTS AND DISCUSSION

1. Physical and Chemical Properties of the Ground Water Samples

Mean values of the various parameters determined in the ground water samples drawn from the nine wells located at the three different districts, namely: ***AL-Tahreer***, ***AL-Wahdah and Maeen***, located in Sana'a secretariat, are shown in table (1).

that [Cl^-] is a major indicator that might be used to infer infiltration of waste water from cesspits into ground water (Foppen, J., 2002), and as it can be noted from table (1), [Cl^-] in ground water sample collected from well no. 1 was approximately equal to 9 mmol/L. Such mean value is considerably high and relatively comparable to the higher limit of [Cl^-], reported by Foppen, J., (2002) in ground water samples collected from wells located at the center and northern part below Sana'a secretariat. Ground water sample of well no. 1, located at Al-durafi stadium in ***AL-Tahreer*** district within the city center area is thus very likely contaminated with waste water that might be infiltrate into it from surrounded cesspits. This inference might be supported [NO_3^-], elaborated within the same table, where it is noted that [NO_3^-] in the ground water samples ranges from 4 - 40 mg/L, (highest in well no. 1 also). However, [NO_3^-] in well no. 1, as 40 mg/L (0.64 mmol/L) was fairly below the lower limit of range 1 to 3 mmol/L in ground water samples of aquifer below Sana'a secretariat, as reported by Foppen, J., (2002). Yet Fetouani, S. et al.,(2008) indicated that ground water is considered contaminated with waste water, when its [NO_3^-] exceeds 0.13 mg/L according to norms proposed by the WHO for drinking water. While lowest levels of sulphae [SO_4^{2-}] in well no. 8, as 28 mg/L, the highest level of the [SO_4^{2-}] was found in well no. 1 as 185 mg/L.

The highest calcium concentration [Ca^{2+}] was found in ground water sample of well no. 1, as 269 mg/L and the lowest, in ground water sample of well no. 9, as 3.2 mg/L. Though [Ca^{2+}] of ground water sample collected from well no. 1 was beyond the higher Yemeni permissible limit, none of the other ground water samples analyzed in this study for [Ca^{2+}], however exceeded such limit. Magnesium concentration [Mg^{2+}] in the ground water samples were in the range of 2.9 and 38 mg/L. The lowest and the highest were in well no. 9 and well no. 1 respectively, but even in well no. 1 [Mg^{2+}] was within the range limits (30 – 150 mg/L), stated in the Yemeni permissible level. Iron concentrations [Fe^{3+}] in ground water samples range from zero to 0.98 mg/L, and none of the samples analyzed for iron in this study exceeded the permissible limits of the WHO and Yemen. Mean values of potassium [K^+] and sodium [Na^+] were found to be in the ranges 0.5-6.3 mg/L and 30-103 mg/L respectively. Even though ground water samples collected from well no. 3, located in ***Maeen*** district, were of the highest in concentrations of both potassium and sodium, ground water samples collected from wells no. 6 and 7 were of the lowest concentrations of the two cations. Yet, wells no. 6 and 7 are located in ***AL-Wahdah*** district.

2-Classification of the ground water samples according to different criteria:

Classification of the water ground samples that were under investigation for this study is demonstrated in table (2).

respectively, were classified to be deep meteoric water percolation type, and those of well no. (3, 4, 5, 7, 8, & 9) were classified as surface and shallow meteoric water percolation type. Such classification was judged based on the values of hydrochemical parameters rK/Cl, rNa/rCl, rMg/rCl, rCa/rCl, and rSO_4/rCl of the ground water samples under study, where (r = mq/L) for these parameters in each sample compared with that of the standard values of sea water as demonstrated by Abdel Moneim, A.A. (1998).

3- Suitability of the ground water samples for irrigation and industrial purposes:

Table (3) shows values of parameters that are typically used as indices for inferring suitability of ground water for irrigation and industrial uses.

Table (3). Parameters indicating suitability of the ground water samples for irrigation and industrial uses.

Well site & No.	Parameter			
	SAR (meq/l)	RDS (Na%)	RSC (meq/l)	SI
Al-Durafi stadium (Well No.1)	0.57	9.0	- 12.54	0.3
Shamlan area (Well No.2)	1.38	32.5	- 0.02	- 0.21
Asser area (Well No.3)	4.87	70.8	2.31	0.35
Adhban aeria (Well No.4)	2.17	48.2	1.41	0.08
Al-tayseer (Well No.5)	4.05	66	1.66	0.6
22 may area (Well No.6)	0.69	15.2	- 3.28	0.31
Bin Maged (Well No.7)	9.26	90.9	1.26	0.21
Alzubairy garden (Well No.8)	5.29	77.4	1.29	1.28
Albaldiah area (Well No.9)	11.50	92.5	2.32	0.73

Sodium Adsorption Ratio (SAR) $= \dfrac{Na^{+}}{\sqrt{\dfrac{(Ca^{++} + Mg^{++})}{2}}}$ meq/L

Ratio of dissolved sodium (RDS) Na% $= \dfrac{Na^{+}}{Na^{+} + Ca^{2+} + Mg^{2+} + K^{+}} \times 100$

Residual sodium carbonate (RSC) = $(CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$,

(-) Value indicates no residual carbonate, and (+) Value indicates presence of residual carbonate.
Saturation Index (SI) is $\mathbf{pH_c} = (pk_2 - pk_s) + pCa^{2+} + pAlk$

(-) Value indicates suitability for industrial purposes, and (+) Value indicates unsuitability for industrial purposes.

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