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Evaluation of the Suitability of Polymeric Casing Materials for Monitoring of Groundwater

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Summary. A series of field and laboratory studies for the hydrochemistry of groundwater in 17 production wells in the Delta aquifer, Nile aquifer and Nubian sandstone aquifer in Eastern and Western desert, were performed to evaluate the water quality and to determine the overall suitability of four different casing materials (polyvinyl chloride [PVC], polypropylene [PP], polyethylene [PE] and fiber glass reinforced plastic [GRP]) for groundwater monitoring applications. The results of analyses for the water quality parameters indicated that the water types were Na_2SO_4 of meteoric genesis, NaCl of marine genesis mixed with meteoric infiltration, $Ca(HCO_3)_2$ of meteoric water of shallow infiltration, $MgCl_2$ of marine genesis and $CaCl_2$ of old marine genesis. Polymeric casing materials were exposed to artificial water samples for 140 days to study some of the most aggressive environments that monitoring well casing would be exposed to. The polymeric materials were analyzed for their weight gain percentage and leaching or sorption of metal ions. The results showed that, all polymeric materials were inert, not degraded by any of the test samples, although the weight gain was < 1%. The changes in surface before and after exposure to artificial water samples were studied by using scanning electron microscope. The results of leaching and sorption studies showed that, the most suitable material in fresh and slightly brackish water was PP, in brackish water was PVC and in salt water was GRP or PVC.

Introduction

The ideal casing material is expensive, strong, not subject to degradation in the environment, and will not affect water-quality samples by either leaching chemicals into or sorbing them from the groundwater. There are a number of materials used to make well casings. These materials vary in chemical inertness, strength, durability, ease of handling and cost. One must always consider the intended use of well before selecting a material. What is the chemistry of groundwater and associated contaminants? Will any compound present in groundwater react with any of the possible casing material?[1]

This work aims to study hydrochemistry of different wells in the main groundwater aquifers, evaluation of water quality and determines its usefulness for domestic and agriculture use according to EMH (1995)[2] and FAO (1985)[3] and selection of suitable well casing material for groundwater monitoring applications.

Experimental

All reagents used were chemically pure grade. Deionized water was used for all the prepared reagent solutions. All control sample solutions were prepared and standardized by recommended procedure.[4] The four control samples were classified according to total dissolved salts (TDS): a: fresh water, b: slightly brackish water, c: brackish water, and d: salt-water intrusion. Water samples are collected[5] from different wells in Delta aquifer, Nile aquifer and Nubian sandstone aquifer in Eastern and Western desert. Water samples were analyzed; pH was measured by benchtop pH and pH/ISE Meters, ORION model 710Aplus, electric conductivity (EC) was measured at 25 ^{O}C, using ATC bench Electric conductivity meters, HANNA, model HI 8820, major anions: chloride (Cl^-), sulfate (SO_4^{2-}), nitrate (NO_3^-), and phosphate (PO_4^{3-}) were measured using ion chromatography (Dionex Ion Chromatography), model DX-500 chromatography system, carbonates (CO_3^{2-}) and bicarbonates (HCO_3^-) were measured using TitraLab 80 titration system, Radiometer Analytical, France, major cations and trace metal ions: Major cations (Ca^{2+}, K^+, Mg^{2+}, Na^+) and trace elements (B, Co, Ba, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn) were measured using the inductivity coupled plasma-emission spectrometry (ICP-OES), Perkin Elmer product model optima 3000 and well casing materials were scanned to study the changes due to dipping in different water samples using scanning electron microscope (SEM) model JEOL-100 S, Japan.

Result and Discussion

Hydrochemistry of groundwater

Wells under study are classified to fresh water in wells V001 and W001-W004, brackish water in wells D001-D004, E001-E003 and V002-V005 and saline water in well D005. pH of wells under study range between 6.8 and 8.8, low values are most often caused by lack of carbonate minerals. Wells under study are classified according hardness to: very hard water wells in D001-D005, E001-E003 and V003-V005, hard water in well V001, moderate range in well W001 and soft water in wells V001 and W002-W004.

Potassium contents are within the range 1.7-118 mg/l, sodium contents are within the range 22-4853 mg/l, magnesium contents are within the range 5-558 mg/l, calcium contents are within the range 85.6-675 mg/l, bicarbonate contents are within the range 50.00–426.88 mg/l, nitrate contents are within the range <0.2– 45.5 mg/l, phosphate contents are within the rang <0.2-1.7 mg/l, chloride contents are within the range 30-8779 mg/l, sulphate contents are within the range 28-4045 mg/l, iron contents are within the range <0.01-4.60 mg/l, manganese contents are within the range <0.01-1.29 mg/l, zinc contents are within the range <0.005-0.239 mg/l, lead content ranges between <0.005-0.064 mg/l, nickel contents are within the range <0.005-0.058 mg/l, cadmium contents are within the range <0.005-0.003 mg/l, copper contents are within the range < 0.002-0.033 mg/l, barium contents are within the range 0.013-0.624 mg/l, chromium contents are within the range <0.005-0.042 mg/l and cobalt contents are within the range <0.005-0.011 mg/l.

Semi logarithmic representation and Collin's graph,[6] Figure 1, showed that the water composition is dependent on the interaction between water and rocks. The results showed that, water types were NaCl, this reflects the marine origin of the water in wells D001, D003-D005, V001, V002, V004, W003, W004 and E001-E003, $Ca(HCO_3)_2$ high concentration of bicarbonates, particularly sodium and calcium, is common for recent meteoric genesis of water in wells D002, W001 and W002, $CaSO_4$ or Na_2SO_4; this indicates the old meteoric deep in wells V003 or V005, respectively, presence of $MgCl_2$; indicate that the origin of this water is marine in wells D003 and D005, while presence of minor amount of $CaCl_2$ indicates that this origin is old marine in well V004.

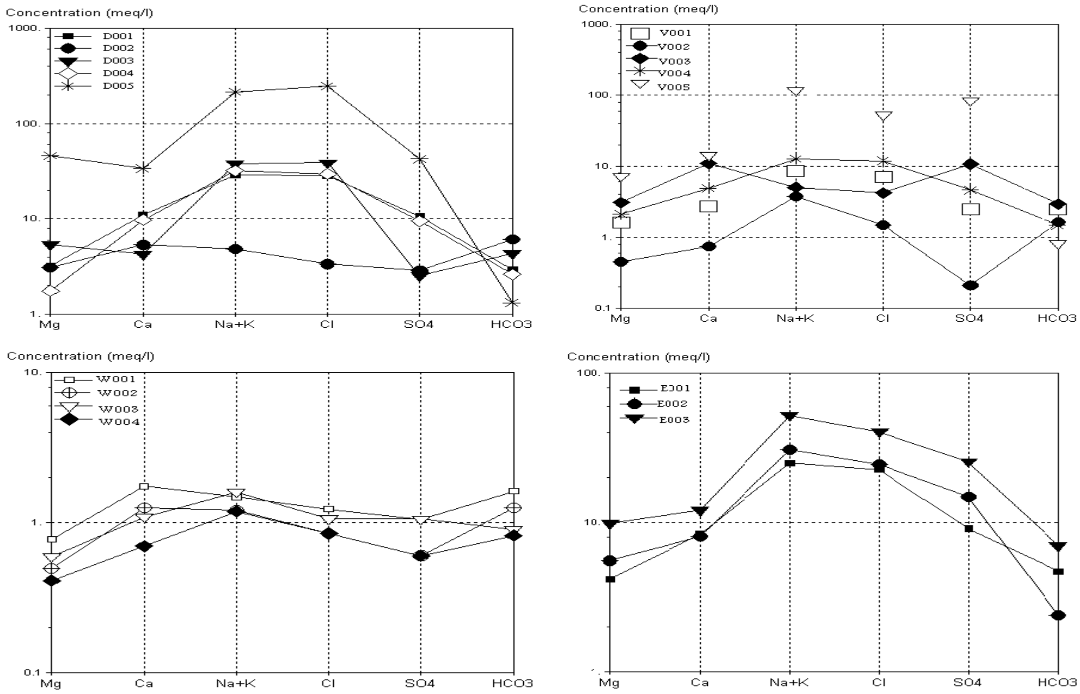

Figure 1. Semi logarithmic representation for the studied wells

Evaluation of groundwater and its availability to use

All the studied wells are unsuitable for domestic uses except well V001 and V002. Wells W001-W004, V001 and V002 are excellent for drinking all classes of livestock and poultry. Wells W001-W004 are excellent and can be used for all type of soils, crops and suitable for agriculture uses.

Plastic well casing materials

All polymeric materials were inert. The percentage of weight gain was less 1%. These weight gains lead to changing of the surface structure of the polymeric materials. The change in the surface structure of the scanned materials, after dipping in control samples relative to the blank ones is observed for PP (Figure 2), PE, PVC and GRP respectively.

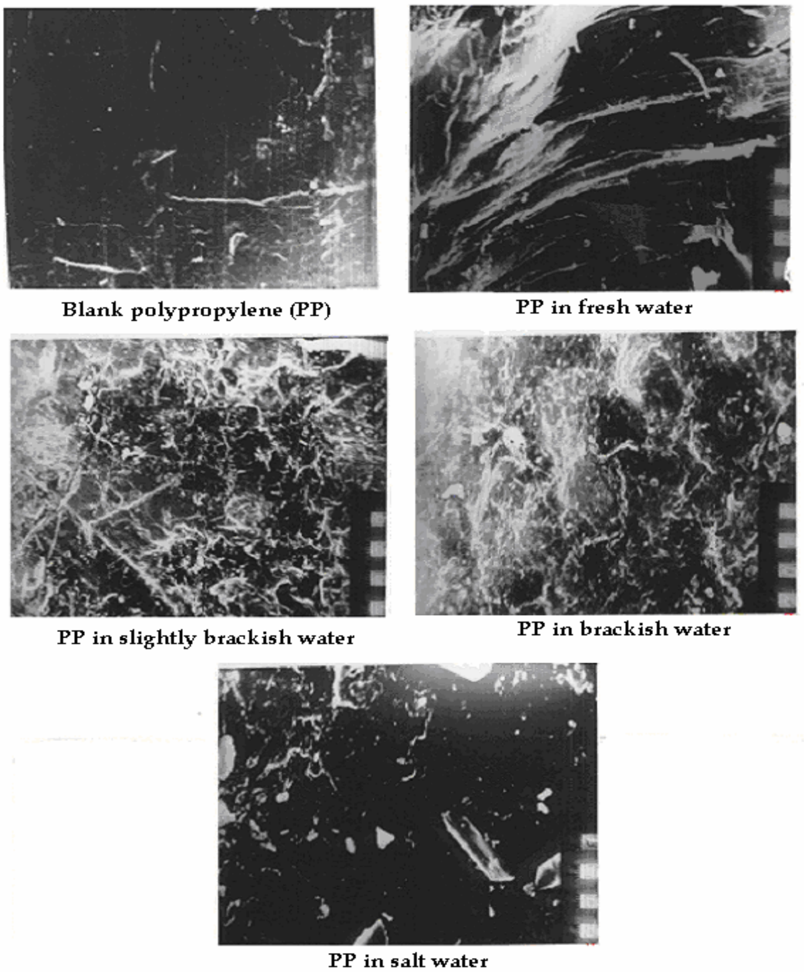

Figure 2. Electron microscopy scanned surfaces for polypropylene casing materials before and after exposure to control samples.

At a given chemical concentration diffusion of chemical into polymer will proceed until equilibrium conditions are attained. Due to the inter polymer diffusion of these chemicals, polymer may dissolve, swell due to absorption and diffusion or may stress crack by selectively absorbing solvents. Mean normalized concentrations, Table (1), represents the concentration of each element in control samples after exposure to well casing material relative to its initial values at 70 and 140 days. If the mean normalized concentration equal 1.0, there is no interaction with the casing materials; if this value drops to less than 1.0, this means that the elements are sorbed by the casing material; while if it rises above 1.0, the element is being leached from the casing.[7]

Conclusion

The most suitable material in fresh and slightly brackish water was PP, in brackish water was PVC and in salt water was GRP or PVC.

Table 1. Mean normalized concentrations of metals leached into or sorbed from control samples.

	Control sample (1)								Control sample (2)							
Metals	PVC		PP		PE		GRP		PVC		PP		PE		GRP	
	Contact time, days								Contact time, days							
	70	140	70	140	70	140	70	140	70	140	70	140	70	140	70	140
Ba	2.1	2.03	2	2.03	2.05	1.83	2.35	1.37	1.54	0.68	0.74	1	0.77	1	1.12	1.96
Cd	>4	1	>2	1	>6	1	>2	1	<6	1	1	1	1	1	1	1
Cr	1	1	1	1	1	1	1	1	1	1	>3.5	1	1	1	1	1
Pb	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Co	1	1	1	1	>1	1	1	1	>1	1	1	1	1	1	>1.4	>1.2
Cu	1.4	0.26	1.9	0.61	0.96	0.23	0.09	0.28	1.59	0.06	0.31	0.80	1.6	0.02	2.6	0.67
Ni	1	1	1	1	>2.4	1	1	1	>2.4	1	>1.8	1	>1.2	1	>1.6	>1.2
Zn	3.35	2.19	2.6	3.02	3.08	13.1	4.7	0.71	0.66	10.6	0.16	0.90	0.41	4.18	0.88	2
Fe	1.01	0.96	0.79	0.69	0.71	1.07	0.67	1.09	1.88	<0.0	0.69	0.80	1.10	0.02	2.17	0.67
Mn	1.05	0.72	1.00	0.72	0.94	0.71	0.83	0.85	6.1	0.37	8.48	4.48	1.03	4.25	0.79	10.2

	Control sample (3)								Control sample (4)							
Metals	PVC		PP		PE		GRP		PVC		PP		PE		GRP	
	Contact time, days								*Contact time, days*							
	70	140	70	140	70	140	70	140	70	140	70	140	70	140	70	140
Ba	0.92	0.95	1.19	1.25	0.88	0.51	0.76	1.42	1.07	1.11	0.97	1.37	0.91	1.19	0.82	0.90
Cd	>0.9	>1.1	>1	>1.1	>0.9	>1.2	>0.8	>1.2	0.66	0.85	0.77	0.94	0.63	1.17	0.72	0.80
Cr	>8.2	>4	>4	>12.	>2.5	>15	1	>15	0.8	0.93	0.91	0.76	2.07	0.98	0.78	0.67
Pb	1	>0.6	1	1	1	>0.2	1	1	0.67	0.78	0.76	0.67	0.43	0.76	0.75	0.66
Co	>1	>1.3	>0.8	>1.7	>0.9	>1.5	>0.7	>1.8	0.9	1.13	0.82	0.88	0.83	1.25	0.71	0.86
Cu	1.04	0.38	1.3	0.16	1.1	0.14	1.3	0.16	1.16	0.63	1.16	0.61	0.87	0.74	0.77	0.66
Ni	1.09	1.08	0.92	1.08	0.86	0.91	0.84	1.19	0.85	0.92	0.91	0.5	0.83	0.94	0.88	0.71
Zn	1.47	1.47	1.3	1.5	1.68	1.61	0.84	0.88	1.5	0.23	0.8	0.8	1.42	0.24	0.83	0.85
Fe	1.56	0.6	1.19	0.43	1.46	0.55	1.09	0.45	0.97	1.08	1.04	0.86	0.93	1.17	0.86	0.77
Mn	0.84	2.55	1.01	0.86	1.15	1.07	0.8	0.93	1.04	1.05	1.21	0.84	0.96	1.12	0.91	0.89

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