

CONTAMINATION OF GROUNDWATER BY ORGANIC CHEMICALS IN AL-GASSIM REGION, SAUDI ARABIA.

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ABSTRACT

Twenty-five of water samples from different wells of different depths located in Al- Gassim region of Central Saudi Arabia were analyzed spectrophotometrically. The three fundamental bands characteristic of aromatic hydrocarbons nuclei 240-250 nm were recorded. However, the very slight difference in absorption is observed. This result may be may from solvent interaction, as the medium analyzed is an aqueous solution. Absorption shifts towards longer wavelength due to fusion of aromatic nuclei in polycyclic systems around 280 nm were also observed. The ground water samples exhibited pH values ranging from slightly alkaline to a strongly alkaline, and a wide range of EC (1.0 - 17.7 dS m⁻¹). The average cations content in water samples were 325.5, 186.9, 696.6, and 126.1 ppm for Ca, Mg, Na, and K, respectively. The total anions in water samples ranges from 19-2774, and 24-165 ppm, for HCO₃⁻ and SO₄²⁻, respectively. Polycyclic aromatic hydrocarbons were detected in groundwater and the data were discussed in relation to the possibility of organic chemicals contamination by direct mixing of sewage water with underground water and/or leaching of agricultural chemical fertilizers and pesticides to reach the underground waterbed.

INTRODUCTION

Public concerns over health effects of consuming water contaminated by trace amounts of various organic chemicals have risen as reports of groundwater contamination have increased. Many of the organic chemicals pollutants are chemicals that are made up primarily of carbon and hydrogen atoms and smaller amounts of various other atoms such as chlorine, nitrogen, sulfur, and phosphorus. There are over 70,000 chemicals in commercial use. The U.S. Environmental Protection Agency (EPA) has designated 654 of these chemicals as being hazardous (Baies, 1994).

The movement of contaminants throughout soil to groundwater is affected by many variables, including properties of the contaminant itself, soil conditions and climate factor. Organic pollutants can enter groundwater in a number of ways. Pesticides applied to agricultural lands can be leached through the soil and eventually contaminate the aquifer. Municipal landfills, leaking underground storage tanks, and poorly designed septic tank systems could also contribute to contamination of an aquifer. Among the organic pollutants detected in groundwater are pesticides, solvents, degreasers, petroleum components, and various by-products of industrial manufacturing (Rao et al., 1983).

With rapid population growth, resulted in a groundwater resource extremely vulnerable to contamination. Numerous structures resulting from human activities throughout Al-Gassim region have the potential to contribute to groundwater contamination. There are tens of thousands of point sources such as surface water impoundments, drainage wells, underground storage

tanks, flowing saline artesian wells, septic tanks, and landfills. Most of the landfills are unlined, increasing the chance that rainwater which percolates through them may dissolve harmful chemicals and ultimately reach the groundwater.

Characterizations as well as quantitative determination of chemicals dissolved in water have received considerable attention during the last two decades. This particular attention is obviously due to the dramatic relation of water to public health, plant and animal existence and to the environmental hazards that might arise from harmful or even toxic chemical constituents of water (Hashim, 1990; Wallim and Bassett, 1990 and Abdi-Magid, 1997). Hence, drinking water, natural or processed, and irrigation water were the usual targets for investigation a research (Rees and Bassett, 1990; Rees, 1989; Eychaner *et al.*, 1989).

Some of organic chemicals such as polycyclic aromatic hydrocarbons (PAHs) are quite toxic. Among the chemicals suspected to produce carcinogenic effects in humans are: vinyl chloride, a component of some resins used in construction; benzene, a product of petroleum refining and used as a solvent; and benzo(a)pyrene (Bales, 1994). The hydrocarbons exhibit low solubility in water and are strongly lipophilic and for example, the simplest PAH (naphthalene) has a water solubility of about 30 mg L^{-1} and this decreases with increasing molecular weight of PAH (McAuliffe, 1966). PAHs are slightly more active than other compounds as the carbon-hydrogen bonds are not all equal in strength. The delocalized nature of the electronic in this aromatic compound makes either structure more suitable (Fessenden and Fessenden, 1982).

Al-Gassim region is the central semi-arid part of the Kingdom of Saudi Arabia. The main source of drinking and irrigation water is the underground water of AL-Sag aquifer. The water level in this aquifer is varying considerably in its depth from 52 to 1000 m. Chemical analysis of underground water of Al-Gassim region received very little attention with regard to organic constituents. With recent widespread reports of trace quantities of organic pollutants being detected in drinking-water supplies, public attention and regulatory focus has shifted from surface water to groundwater protection. Groundwater contamination has been called the problem of the '80s (Rao *et al.*, 1987). This study examines the possibility of groundwater contamination with organic constituents.

The main objective of this research is to survey and screen the possibility of underground water contamination with organic chemicals such as aromatic polycyclic hydrocarbons. In order to accomplish this task, twenty-five of underground water samples, were collected from wells of different depths and locations and analyzed spectrophotometrically.

MATERIALS AND METHODS

Twenty-five underground water samples were collected from different locations in Al-Gassim region, Saudi Arabia. The Chemical analysis of underground water samples is given in Table (1). In addition, the depth of the wells and absorption regions together with absorption shifts of studied

samples are shown in Table (2). The alkaline earth cations namely Ca, Mg, K, and Na, were measured employing an IL Video12 atomic absorption spectrophotometer and flame emission analyses. The pH was measured potentiometrically using an Orion combined pH-electrode. Bicarbonate was determined by titration against standard dilute sulphuric acid and sulphate was determined turbidmetrically using model ANA-14A Turbidmeter (Tokophoto-electric Co., Japan). Spectrophotometer was employed to determine the absorption characteristics of PAHs compounds. Measurements were recorded at the regions of absorption of 200-300 nm in order to include characteristic absorption of aromatic nuclei (240-250 nm). The spectrophotometer employed in this study is Varian Carry 50, UV-Visible.

RESULTS AND DISCUSSION

The results of the chemical analysis of underground water samples are given in Table (1). In addition, the depth of the wells and absorption regions together with absorption shifts of studied samples are shown in Table (2). The data of groundwater chemical analysis indicates that the ground water samples exhibited a range of pH values from slightly alkaline (pH of 7.5) to highly alkaline (pH of 8.3), and a wide range of electrical conductivity (EC) from very low of 1.0 ds m⁻¹ to very high of 17.7 ds m⁻¹.

In addition, the total cations content in underground water samples ranges in the following: 45-751 ppm for calcium, 20-515 ppm for magnesium, 154-2450 ppm for sodium, and 3-243 ppm for potassium. The total content of sulphate and bicarbonate in water samples ranges from 19-2774, and 24-165 ppm, respectively. The depth of wells (Table 2), where underground water samples collected from for this study, varied significantly from 23-750 m and with an average depth of 175.5 m.

Table 1: Chemical analysis of underground water samples.

Well & Sample no.	EC dS/m	Ca	Mg	Na	K ppm	(HCO ₃) ⁻	(SO ₄) ²⁻	PH
1	10.6	525	359	1268	236	165	1920	7.9
2	1.0	45	20	171	29	134	19	8.2
3	7.7	537	236	925	106	147	1226	7.8
4	6.0	469	274	678	30	143	1450	8.0
5	7.9	579	344	895	66	122	2078	7.5
6	7.9	549	295	1113	122	144	1697	7.6
7	7.8	580	266	1105	111	165	1714	7.6
8	11.9	670	378	1750	157	144	2021	7.9
9	16.7	751	515	2450	243	24	2774	7.9
10	1.3	74	65	203	22	131	334	8.0
11	3.7	141	68	610	51	134	689	8.1
12	1.1	55	57	161	35	96	331	8.3
13	1.1	60	34	154	34	116	166	8.2
14	3.2	184	121	230	16	114	640	8.3
15	2.7	112	129	365	13	101	682	8.3
16	2.6	79	164	318	3	111	821	8.2
17	7.5	559	314	885	78	115	212	8.2
18	2.3	141	67	510	50	125	980	7.9
19	1.2	55	34	230	29	134	798	7.8
20	8.0	629	275	1213	122	155	985	8.1
21	6.6	569	274	778	33	160	1850	8.3
22	1.6	94	65	183	23	145	1750	8.1
23	7.5	540	240	870	111	132	1080	8.3
24	1.5	65	33	161	35	106	350	7.7
25	2.3	75	45	189	65	89	870	7.9

Table2: The depth and fundamental absorbance and shifted absorbance for the twenty-five underground water samples.

Well and Sample no.	Depth (M)	Fundamental Absorption bands (nm)	Shifted Absorption bands (nm)
1	70	205-240	250-278
2	300	200-238	250-278
3	90	200-235	250-278
4	80	200-235	260-278
5	40	210-258	250-278
6	70	200-238	250-278
7	80	200-238	247-278
8	25	200-235	250-278
9	23	200-235	250-278
10	140	200-238	250-278
11	750	200-240	250-278
12	500	200-238	250-278
13	500	200-240	250-278
14	45	200-238	250-278
15	50	220-238	250-285
16	150	210-245	260-285
17	48	200-238	250-278
18	120	200-238	250-278
19	250	200-235	250-278
20	70	200-238	250-278
21	90	200-238	250-278
22	110	200-240	260-285
23	30	210-245	250-278
24	450	200-240	250-285
25	230	200-258	250-278

Organic and non-organic chemicals pollutants can enter and contaminate groundwater in a number of ways. These includes 1) the presence of harmful chemicals present in the neighboring soils such as lead, cadmium, mercury, arsenic and others, 2) direct mixing of contaminated water such as sewage, mines and factory's residue water with groundwater, 3) chemicals utilized in agriculture such as fertilizers, pesticides, and herbicides, which find their way through sandy soil particles to reach the underground water bed by the aid of rain or irrigation water, and 4) decomposing organic mater of plant, animal or microorganisms that get leached down to the aquifer through soil profile.

Absorption bands characteristics of unsubstituted aromatic hydrocarbons appeared exactly at the expected region (Figs 1, 2, 3, and 4) however, absorption shift toward higher wavelength around 280 nm where also recorded indicating the presence of fused aromatic nuclei (polycyclic systems), as contaminates of underground water (Wingrove and Carel, 1981). All twenty-five underground water samples investigated in this study were found to be contaminated with aromatic hydrocarbons as is evidenced by the presence of absorption bands at the vary region characteristics of such compounds (240-250 nm). However, the very slight difference in absorption is due to solvent interaction as the medium analyzed is an aqueous solution.

Moreover, shift of absorption towards longer wavelength (280 nm) was also observed indicating the presence of polycyclic aromatic hydrocarbons. These findings are in full concord with observation of Wallim and Bassett, (1990) and Rees (1989) who reported contamination of underground water by polycyclic aromatic hydrocarbons in an area very rich in mining and/or processing activities in Arizona.

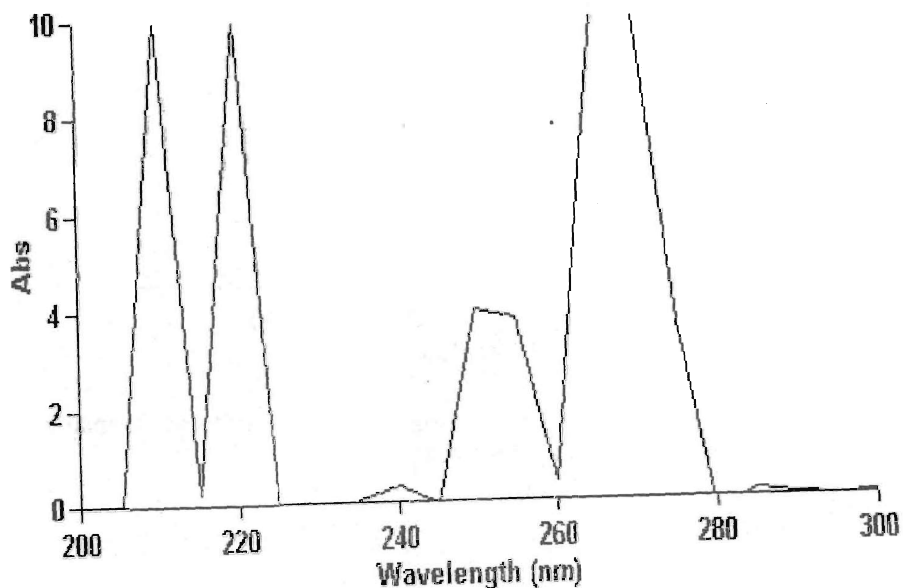


Figure 1: Absorption bands characteristic of unsubstituted aromatic polycyclic hydrocarbons of sample 5.

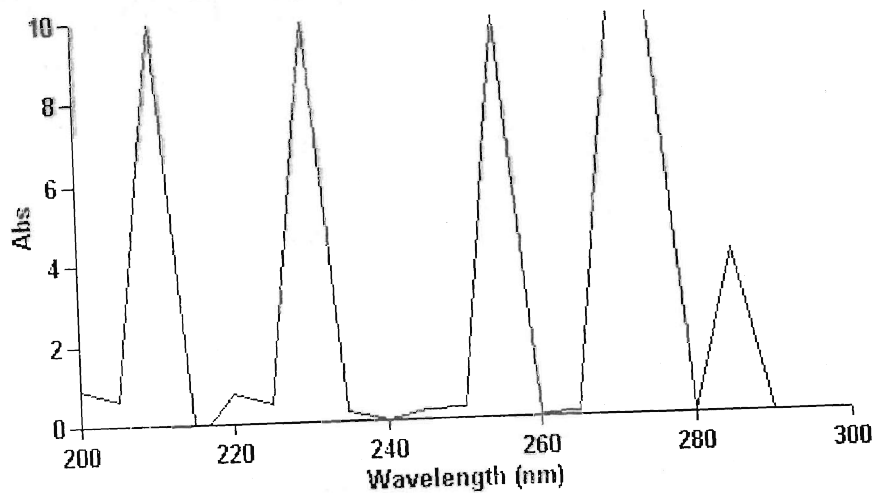


Figure 2: Absorption bands characteristic of unsubstituted aromatic polycyclic hydrocarbons of sample 12.

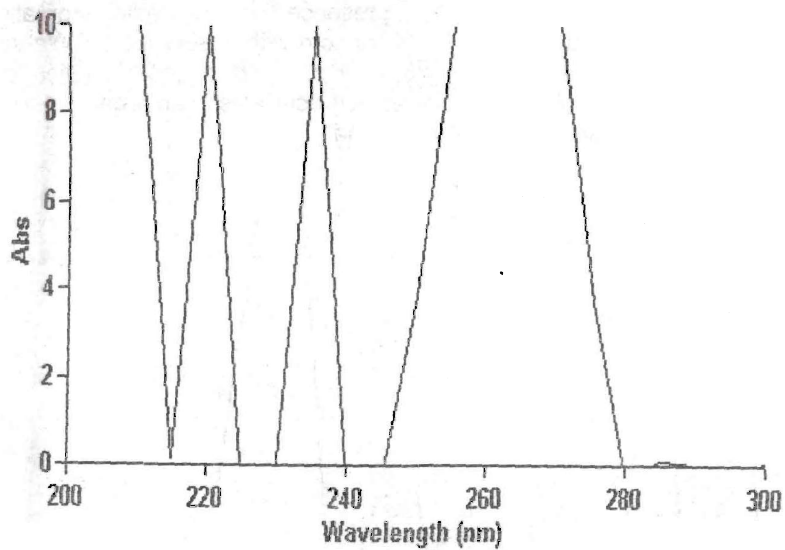


Figure 3: Absorption bands characteristic of unsubstituted aromatic polycyclic hydrocarbons of sample 18.

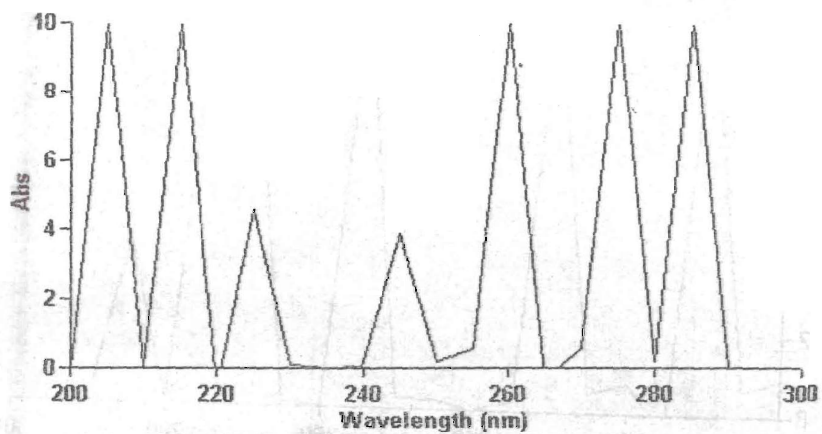


Figure 4: Absorption bands characteristic of unsubstituted aromatic polycyclic hydrocarbons of sample 20.

It is most probable that contamination of underground water in Al-Gassim region by such compounds is attributed to organic chemicals used in agriculture and/or sewage water direct mixing. In addition, chemicals reaction may occur between these different compounds initiating chemical transformations leading to the formation of new compounds, which were not originally present in the mixture.

It is generally a common practice that farmers in this heavily cultivated region utilize organic and mineral fertilizers in order to increase soil fertility and to improve its chemical and physical properties. In addition, most of the investigated wells are located in well infiltration sandy soil classified as Torrifluent and Torripasmment (Mashhdy *et al.*, 1980). Thus, the leaching downwards of such chemicals is not far remote.

A striking feature of the data including in (Table2) is that the observed fundamental absorption bands as well as shifted absorption bands corresponding to aromatic polycyclic hydrocarbons are nearly identical with no significant differences. PAHs contain two or more benzene rings and they have many divers origins. There are three main routes of formation in the environment which are 1) pyrolysis of organic matter, 2) generation in sedimentary organic matter and fossil fuels, and 3) biosynthesis by organisms (La Flamme and Hites, 1978). The PAHs are rapidly adsorbed onto particulate matter in aquatic areas. Connell (1982) found that in Hudson Raritan Estuary the petroleum hydrocarbons present were substantially adsorbed onto the bottom sediments.

Some of the found organic contaminates may it be driven directly from a mixing with sewage due to the leakage in wells case or an infiltrated fertilizers or pesticides along with sewage and rain water through the soil profile. PAHs can occur in wastewaters such as domestic and industrial effluents, sewage, and urban runoff. Bagg *et al.*, (1981) have results indicating the highest concentrations of PAHs in marine sediments adjacent to urban areas.

These findings encourage future researchers to include quantitative determination of the actual organic polycyclic aromatic contaminates to further assess the environmental hazards that might originate from the presence of these chemicals in underground water.

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تلوث المياه الجوفية بمنطقة القصيم بالمواد الكيميائية العضوية

سعود سييل العود

قسم التربة والمياه - كلية الزراعة والطب البيطري فرع جامعة الملك سعود بالقصيم - بريده ص ب ١٤٨٢ المملكة العربية السعودية

تم تحليل خمسة وعشرون عينة مياه جوفية بمنطقة القصيم , المملكة العربية السعودية, بهدف اختبار احتمالية تلوث المياه الجوفية بالمواد العضوية. وقدر محتوى هذه المياه الجوفية من الكاتيونات والأنيونات. وتم الكشف عن وجود مركبات متعددة الحلقات وذلك بواسطة جهاز الأمتصاص المرئي- فوق البنفسجي وذلك كدليل على تلوث هذه المياه الجوفية بالمواد العضوية. ووجدت ثلاثة حزم ضوئية مميزة للمركبات العطرية في موقعها المعروف بين طول موجات منحصرة بين ٢٤٠-٢٥٠ نانوميتر. كما وجد أيضاً الموجات الناتجة عن امتداد الأمتصاص النري الطيفي في الموقع المحدد ٢٨٠ نانوميتر. وقد يكون هذا التلوث ناتج من ان طبقات التربة فوق هذه المياه الجوفية عبارة عن رمال مما ساعد على تظل هذه المواد العضوية لتربة ووصولها الى المياه الجوفية. وقد يكون مصدر هذه الملوثات مياه الصرف الصحي والأسمدة والمبيدات التي تستخدم بكثرة في هذه المناطق المدروسة.