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Groundwater Quality in Taiz City and Surrounding Area, Yemen Republic

Abstract.: Fifty one water samples were collected from production wells used for human consumption from Taiz city and its surroundings, Yemen Republic. The water quality was investigated with respect to bacteriological and physico-chemical parameters. The achieved results revealed that most water samples, especially from private wells, contain a high number of total coliforms (TC) which exceed the permissible limit recommended by the World Health Organisation, WHO (1996). Also, faecal coliforms (FC) were recorded in the majority of polluted samples. A quantitative estimation was done for each of temperature (18-26^{O}C), pH (6.12-8.79), total hardness (58-2200 mg/L), electrical conductivity (218-4600M.Mohs), total dissolved solids (117-3700mg/L), nitrate (10-187mg/L) and type of aquifer (rocky and alluvium). It is worthy to notice that from the total of fifty-one wells, there was pollution in (65%) of them. Recommendations were suggested for the treatment of the water of such polluted wells and rigid government control in a trial to prevent human and animal illness.

Keywords: Yemen, Taiz, groundwater, pollution, Total coliform (TC) and Faecal coliform (FC)

نوعية المياه الجوفية في مدينة تعز وضواحيها بالجمهورية اليمنية

محمد رضا متولي

المستخلص: تم جمع 51 عينة ماء من مياه الآبار المنتشرة في مدينة تعز وضواحيها، و التي تستخدم للإستعمال الآدمي. هذا و قد أجريت دراسات بكتريولوجية وأخرى فيزيائية وكيميائية على العينات المختبرة و أثبتت النتائج أن معظم العينات التي تم إختبارها ملوثة خاصة الآبار المملوكة من قبل المواطنين حيث تحتوى على عدد كبير من القولونيات الكلية، و التي تفوق في عددها بكثير المواصفات القياسية لمياه الشرب. طبقاً لما هو منصوص عليه من قبل منظمة الصحة العالمية (WHO). كما ثبت أيضاً أن التلوث بالقولونيات البرازية في معظم العينات المختبرة . أثبتت النتائج على أن درجة حرارة الآبار، وقت أخذ العينة، تتراوح بين 18°-26° و الأس الهيدروجيني (6.12-8.79) و القساوة الكلية (58-2200 mg/L). و الموصلية الكهربية (218-4500 Mohs). و الأملاح الذائبة (3700-117mg/L) و النترات (10-187 mg/L) أيضاً تم معرفة نوع البئر ما إذا كان صخرياً أو طينياً .وجدير بالذكر أن الدراسة أثبتت أن نسبة التلوث حوالي 65% من جملة الآبار التي تم جمع العينات منها.

توصي الدراسة بضرورة معالجة الآبار الملوثة حتى تصبح صالحة للإستعمال الآدمي كما يجب فرض رقابة صارمة على مصادر المياه الطبيعية خاصة الآبار من قبل الدول وذلك من أجل الحفاظ على صحة الإنسان من الأمراض .

كلمات مدخلية: اليمن،تعز،مياه جوفية، تلوث، قلونيات الكلية، قلونيات برازية.

Introduction

Yemen is a developing country, with limited drinking water supplies. Yemen depends on groundwater as the main source of water supply for domestic needs (El-Din *et al.* 1993, Al-Subai 1995 and Abdul-Rahman *et al.*1995).

Taiz city is considered to be in a high rainfall zone, with average rainfall of more than 600mm/year (Ebraheem *et al.* 1997 and Final Report I and II, 1997). Only 10%-20% of the rainfall contributes to groundwater storage (Robertson, 1992 and Al-Subai, 1995).

Taiz is considered to be a polluted area, where many of the Yemeni industrial and economic activities are located. The improper sewage system of the Taiz area as well as the disposal of industrial liquid wastes in the surface lagoons and ponds constructed in unconsolidated material have caused severe surface and groundwater pollution, causing the spread of many infectious diseases.

Therefore, the main objective of the present work was to study the quality of groundwater in Taiz city and its surroundings in relation to bacteriological and physico-chemical analysis, to establish whether water used for human consumption contains either poisonous chemicals or pathogenic organisms which may lead the Yemeni people to suffer from community health problems.

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Materials and methods

Fifty one water samples were collected from different locations in Taiz city and its surrounding area, Yemen Republic. The sampling sites are shown in Fig.(1). Heat-sterilized bottles of 500ml capacity were used, and kept at 10°C in an ice box for further bacteriological and physico-chemical analysis.

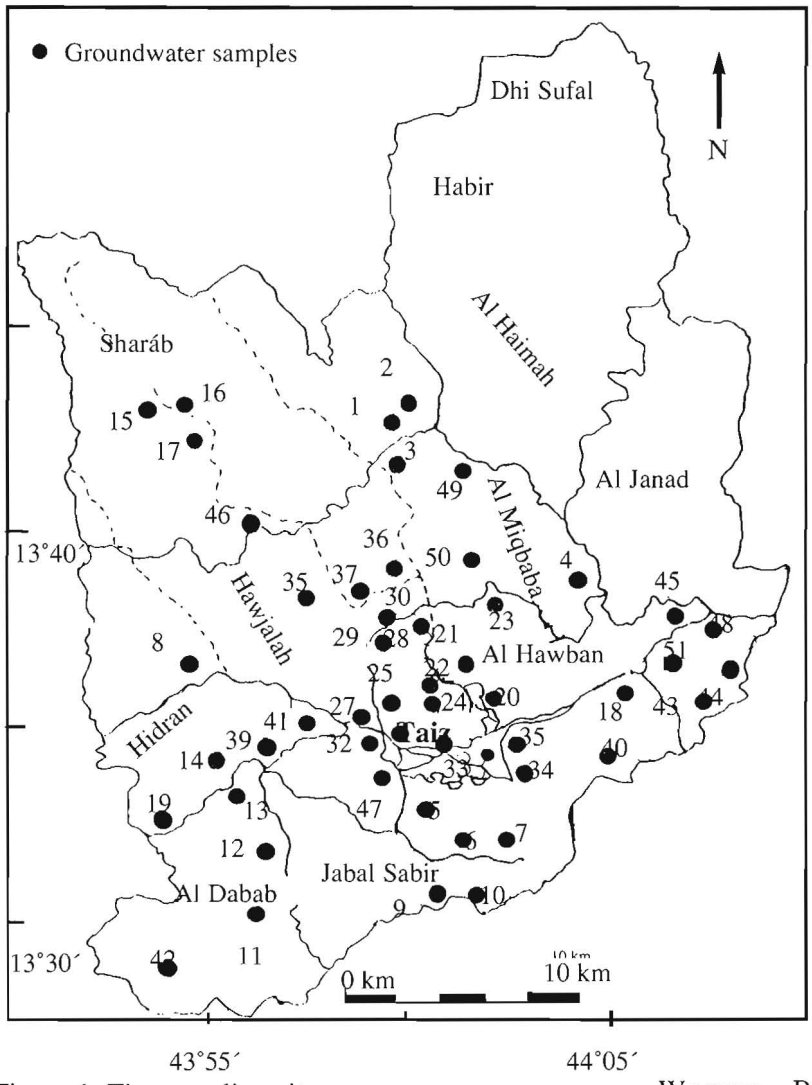

Figure 1. The sampling sites

Bacteriological analysis: Total and faecal coliform counts by MPN test was carried out using MacConkey broth for presumptive test and Eosin Methylene Blue agar (EMB) during comfirmation (WHO 1985).

Indicative physico-chemical parameters such as: temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH) and nitrates were estimated as recommended in the Standard Methods for Water & Waste-Water Analysis (APHA 1985).

Results and discussion

Variation of total and faecal coliforms is given in Table 1 (A, B and C). Of the fifty one water samples, twenty four of them (47.1%) were found heavily polluted with total coliforms (112->200cfu /100ml), (42->200) of them were found from faecal origin. Nine sampled waters (17.7%) were found suspicious, having relatively small counts of coliforms (3-20cfu/100ml), (0-16cfu /100ml) of them were from the type faecal. Seventeen water specimens (33.3%) were found bacteriologically potable (coliform-free).

Results showed that of the total of 51 wells, there was pollution in 64.8% of them. The average of pollution varied from one well to another. Most of the samples were highly polluted with coliforms because water produced from the tested groundwater area is mixed with highly polluted water of the collapsed water supply system of Taiz city and receives inflows of sewage and city runoff.

The results shown in Table 2 revealed that the most polluted wells were the private ones, 93.1% of which were polluted, while the rate of pollution in wells belonging to the National Water and Sewerage Authority (NWSA) reached 21%, and 37% in the samples coming from wells belong to the domestic water stations. The most polluted wells were numbers 2, 4, 7- 9, 12-24, 26-29, 31, 37, 40, 46, 48 and 49, of the following regions: El-Tourba, Warazan, Buraihi, Hawban, Hawjalah, Sharab, Dabab, El-Habeel and Jabal Sabir (Table 3). Pollution of these regions appears to be due to the following reasons. Water sources are very close to the sewage drainge and littered places (Buraihi, Hawjalah ,and Hawban). This leads to leakage of the sewage to underground water sources. The use of traditional ways are used to obtain water, such as digging wells, using buckets etc. Some farmers irrigate their fields with drain water, which pollutes soil, and underground and surface water sources. In addition, villagers living in mountainous areas store water in ground tanks, which are exposed to pollution during rainfalls (El-Tourba, Sharab, and

Jabal Sabir). Such assumptions seemed to be confirmed by Doorenobs and Pruitt, 1984 and Dubay, 1989; El Din *et al*,, 1993; Saleh El Din, 1995; Ward, 1995; and Final Report I, 1997.

Chemical pollution in water is of the most important health significance for man and animals consuming such water. For this reason, the physico-chemical features of sampled water are shown in Table 1.

Table 1A: Bacteriological and physico-chemical summerized data of the study area in wells belonging to private owners.

Sample	Area	Aquifer	TC	FC	Temp.°C	pH	EC M.Mohs	TDS Mg/LMg/L	TH Mg/L	NO_3 Mg/L
1	Barakaney	Alluv	15	0	22	8.25	1400	514	200	65
2	El-Tourba	Alluv.	159	138	23	7.75	1732	2852	240	102
3	El-Nasham	Alluv.	20	6	22	7.25	1021	487	506	46
4	Warazan	Alluv.	>200	>200	21	6.8	1919	2441	180	124
5	Modam Sabir	Rocky	20	3	20	7.13	1840	437	100	30
6	Okaka	Rocky	80	0	25	7.29	841	407	282	25
7	Dar El-Nasre	Rocky	>200	20	25	7.33	1470	2224	870	98
8	El-habeel	Rocky	>200	190	18	8.07	1785	1380	1000	100
9	Jabal Sabir	Rocky	>200	>200	18	7.21	1253	1519	210	88
10	Jabal Sabir	Rocky	5	0	24	7.38	770	369	252	22
11	Dabab	Alluv.	0	0	24	6.98	800	250	120	20
12	Dabab	Alluv.	13	2	25	6.35	1000	600	220	22
13	Dabab	Alluv.	137	34	26	6.91	1539	2454	480	126
14	Hazran	Alluv.	181	66	25	8.17	3001	2006	1106	108
15	Sharab	Alluv.	>200	142	24	8.09	2980	2112	1300	99
16	Sharab	Rocky	>200	160	21	7.35	4600	2400	1610	101
17	Sharab	Rocky	>200	151	21	8.07	2040	1290	1860	125
18	Buraihi	Alluv.	>200	116	25	8.21	1650	1860	900	165
19	Ossaifrah	Alluv.	>200	136	24	7.17	3409	2100	506	166
20	Hawban	Alluv.	>200	190	23	6.22	3415	2140	1050	166
21	Hawban	Alluv.	>200	170	23	6.24	3429	2210	780	187
22	Hawban	Alluv.	>200	165	18	6.8	3393	2003	730	111
23	Hawban	Alluv.	>200	>200	23	6.29	3492	2240	1620	108
24	El-Madinah	Alluv.	15	5	20	7.58	2208	1030	270	58
25	El-Madinah	Alluv.	0	0	24	7.93	792	490	150	20
26	El-Madinah	Alluv.	18	10	20	8.79	590	1116	201	56
27	Hawjalah	Alluv.	>200	146	25	8.06	4415	3000	820	124
28	Wadi El-Kadey	Rocky	>200	>200	25	8.19	3000	1950	1003	120
29	El-Madinah	Rocky	40	16	23	7.71	1400	1100	260	18

Table 1B: Bacteriological and physico-chemical summerized data of the study area in wells belonging to NWSA.

Sample	Area	Aquifer	TC	FC	Temp.°C	pH	EC M.Mohs	TDS Mg/L	TH mg/l	NO_3 mg/l
30	Hawban	Alluv.	3	0	26	6.12	4500	1400	2200	115
31	Hawjalah	Rocky	112	42	26	8.10	3500	2950	800	143
32	Hajma	Alluv.	2	0	24	8.31	580	600	160	17
33	Wadi Elmodam	Alluv.	0	0	23	7.91	430	950	120	42
34	Attia	Alluv.	0	0	25	8.01	800	900	100	25
35	El-Nachla	Alluv.	3	0	24	7.79	580	950	202	30
36	El-Shoumairy	Rocky	0	0	24	8.07	950	850	175	15
37	El-Hendey	Alluv.	192	50	25	7.54	2375	2450	800	120
38	El-Gomhourey	Alluv.	0	0	24	7.45	1500	833	162	10
39	Ossaifrah	Rocky	3	2	25	7.6	800	916	110	30
40	Buraihi	Alluv.	120	60	24	8.41	4500	3700	300	160
41	Sala	Rocky	0	0	25	7.29	460	910	190	45
42	El-Measel	Rocky	3	0	25	7.91	600	850	110	52
43	El-Haussynia	Alluv.	0	0	24	7.89	218	600	180	25

Table 1C: Bacteriological and physico-chemical summerized data of the study area in wells belonging to the domestic water stations.

Sample	Area	Aquifer	TC	FC	Temp.°C	pH	EC M.Mohs	TDS Mg/L	TH mg/l	NO3 mg/l
44	Gohmallia	Alluv.	3	0	21	7.53	250	730	180	10
45	Ogenat	Alluv.	3	0	20	7.14	600	650	270	12
46	Sharab	Alluv.	120	32	20	7.61	1440	2211	212	117
47	Haurish	Alluv.	0	0	21	7.72	330	540	116	12
48	Magalia	Alluv.	182	56	24	8.04	1671	1760	290	120
49	Ber Basha	Alluv.	152	62	25	7.91	1820	1800	312	116
50	Nachlan	Alluv.	3	0	24	8.07	847	117	58	17
51	Maareb	Alluv.	0	0	23	7.97	826	399	210	15

NWSA = National Water and Sewerage Authority; No. = Number; Tc = Total coliforms (cfu /100 ml); Fc = Faecal coliforms (cfu /100 ml); Temp. = Temperature; Ec = Electrical conductivity; TDS = Total dissolved solids; TH = Total hardness; Alluv. = Alluvium; NO_3 = Nitrate.

Table 2: Percentage of water quality of the studied wells.

Wells belong	Number of studied wells	Potable water		Contaminated wells	
		Count	%	Count	%
Private oweners	29	2	6.9	27	93.1
NWSA	14	10	71	4	29
Domestic stations	8	5	62.5	3	37.5

NWSA= National water and sewerage authority

Table 3: Summary of the studied wells in the studied areas.

Area	Number of studied wells	Potable wells	Contaminated wells
El-Tourba	2	-	2
Warazan	2	-	2
Buraihi	2	-	2
Hawban	5	-	5
Hawjalah	2	-	2
Sharab	4	-	4
Dabab	3	-	3
Taiz	25	17	8
Ossaifrah	2	-	2
Jabal Sabir	3	-	3
El-Habeel	1	-	1

Apparently, the water temperature did not show distinct variations between different studied areas (18°-26°C). Irrespective of some minor fluctuations at some times, generally it can be said that any increase or decrease in groundwater temperature is influenced by four factors, namely the mean annular air temperature, well depth (alluvial up to 70m. but volcanic from 600 to 700m. according to Final Report I, 1997); volcanic activity and rainfall amount. Such assumptions seemed to be in conformity with the findings of Bouwer, 1978, Dubay, 1992 and Final Report 1, 1997.

The alkaline pH values at most studied areas, except polluted locations (numbered 4,11,12,13,20,21,22,23 and 30) could be mainly due to activation of dense populations of living organisms. This is in accordance with the results obtained by Dubaie *et al*, 1995, Welle, 1997 and Final Report I,1997. The decrease of pH (6.12 - 6.98) may be attributed to the influence of agricultural run-off and industrial effluents dumped into groundwater sources. A detailed tracing of the changes in pH can be found in Welle, 1997.

A study of water quality and its relation to rock mineral composition, based on total hardness for domestic use and conformity to WHO standards showed that most water samples were very hard and hence are not suitable as drinking water (See Table 1).

It is to be noted that in the polluted areas, water samples always showed higher electrical conductivity (>4000M.Mohs), total dissolved solids (>3000mg/L) and nitrate (88-187mg/l), compared with unpolluted locations. As revealed from the data recorded in Table 1, highly nitrate concentrations are almost exclusively limited to the locations having high total dissolved solids.

It is evident that the quality of underground water sources varies from one region to another, depending on amount of rainfall, with better water quality found in areas of more rainfall, active recharge and type of aquifer. Natural water from volcanic rocks tends to have a higher electrical conductivity and total dissolved solids compared to alluvium aquifer except when the alluvium is polluted or the volcanic water is mixed with rainfall, with good quality found in areas of more active rainfall recharge. Such findings are consistent with those reported by some other authors. (Ramadan & Shehata, 1976; Haskoning, 1990; Gun & Ahmed, 1995; Kobbia *et al*,1995), and Final Report 1, 1997). Data given in Table 1 showed that water samples coming from volcanic rocks sometimes have a lower electrical conductivity and total dissolved solids than that coming from alluvium (numbers 6,10,35,36,39,41 and 42). This is expected since the alluvium aquifer is more sensitive to pollution sources, which include wastewater discharges from city and industries as well as storm run-off and return flow from irrigation, which contains concentrated salts as a result of the evaporation process. (Haskoning, 1990 and Final Report I, 1997).

Finally, the achieved results allow the conclusion that the presence of faecal indicator bacteria and some chemical contents in an amount higher than the permissible limit in water samples coming from polluted areas acts as an important health hazard for man and animals consuming such polluted water. Thus, recommendations were suggested for treatment of polluted water and rigid government control to obtain water of good hygienic specifications.

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