

Environmental Contaminants and Their Impact on Some of Ground Water Quality, in Taiz, Yemen: Study Evaluation

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Abstract: The main aim of this study is to evaluate the quality of ground water supplies of Taiz city. The results shows that the most parameters analyses in the study samples such as Conductivity, TDS, Hardness, chloride, Fluoride etc. were higher than the permissible limit according to WHO and YSMO. The runoff water which carried sewage and other wastes are the main anthropogenic source of water contamination with interface with natural contamination by the rocks formation of the studied areas, the exacerbates of the problems are the lack of proper treatment of the city sewage, the lack of good drainage system around the wells, and there are no proper paving surrounding of the city wells.

Keywords: Water Samples, Sewage Samples, Physical Measurement, Chemical Analysis, Biological Tests

1. Introduction

The Water is one of the most important and abundant compounds essential for all living organisms on the earth that need water for their survival and growth [1].

Yemen is one of the most water constrained country in the world. Water availability per capita is 130 cubic meters per year, 10 percent of the average for the Middle-East, and only two percent of the world average per capita consumption. Of most concern are the trends in water use. With no significant perennial sources of surface water, Yemen relies almost exclusively on exploitation of groundwater. Water is taken from the shallow aquifers which are rechargeable, and increasingly from deeper aquifers which are generally considered not rechargeable, although some recharging has been accomplished significant difficulty and expense. In large parts of the country, water from the shallow aquifers is excreted at well over the recharge rate from the country's limited rainfall, thus, pumping is substantially from the deep (fossil) aquifers which are depleting rapidly. As these deep aquifers cannot be recharged, pumping is essentially a mining operation[2]. Scarcity of water in Yemen has become a crisis [3]. In Taiz, Yemen's third-largest city, residents are only allowed to access public water tanks once every 45 days [4].

- Objectives of the Study

- Identifying the major sources of pollution of groundwater basins which supply water to the city of Taiz, either directly or indirectly.
- Conducting of physical, chemical and biological analysis of different samples representative of the study area includes groundwater, surface water and wastewater.
- To assess the quality of groundwater through the results of different analyses and their suitability for different uses.
- To develop an appropriate scientific solutions and processors to reduce or minimize pollution.

2. The Study Area

The study area includes the well water, water tanks, wastewater and water spring belongs to the National Water and Sanitation Authority (NWSA) Taiz city, included the following areas:

South of the city- North of the city - East of the city - Hawban - Dabab - Hawgalah - Aamerah - Habeer - Alhaimah - Habel Salman - Ausaiferah - Wadi Qadi and Buraihi.

3. Material and Methods

3.1. The Collection of the Data and Visiting the Study Area

Data were collected with previous studies from several

sources belonging to the National Water Resources Authority (NWRA) Branch of Taiz and National Water and Sanitation Authority (NWSA) Taiz city, and depending on these investigation, we make a plan to visit different sites. We have visited 57 sites, including all the areas where the wells located, particularly those operating and supplying Taiz city with water, and the Foundation's local water, sanitation, areas adjacent to the wells and some springs and wastewater treatment plant.

3.2. Sampling

3.2.1. Water Samples for the analysis of Physical and Chemical Parameters

The water samples were collected from wells, water tanks and springs by clean and rings well plastic bottles with field measurements.

3.2.2. Sewage Samples

Six samples were collected from sewage in plastic

containers equipped with advance and in accordance with the standard methods of station assembly from wadi Gadeed and Wadi Qadi Station and from Buraihi waste water treatment station of Taiz city.

3.2.3. Water Samples for Biological Analysis

Twenty one water samples were collected in clean, sterilized plastic bottles for microbiological analysis, and other samples were collected in clean plastic cans for parasites studies.

3.3. Analysis of the Samples

3.3.1. Physical Measurements and Chemical Analysis of Water and Waste Water Samples

Analysing and measuring the chemical content of the samples of water and sewage referred to the Standard Methods for the Examination of Water and wastewater, American Public Health Association, APHA [5].

Table 1. Shows the methods and devices used in the analysis of physical properties and chemical contains of the samples studied.

Analytical methods	Parameters
Field pH-meter	pH
Field EC-meter	Electrical conductivity
Flame photometer	and K^+Na^+
Titration with 0.02N Na_2 (EDTA) using murexide indicator	Ca^{+2}
Titration with 0.02N Na_2 (EDTA) using Eriochrom Black T as an indicator	Ca^{+2} and Mg^{+2}
Titration with 0.02N H_2SO_4 (EDTA) using bromocresol green indicator	HCO_3^-
Titration with 0.02N $AgNO_3$ (EDTA) using potassium chromate indicator	Cl^-
HACK Spectrophotometer at a wave length of 500 nm	NO_3^-
HACK Spectrophotometer at a wave length of 450 nm	SO_4^{-2}
HACK Spectrophotometer at a wave length of 580 nm	F^-

3.3.2. Biological Analyses of Samples (Bacteria and Parasites)

Samples collected for bacteria analysing from wells, spring and water collection tanks, by sterilised plastic bottles (200

ml) and then transferred to an icebox until reaching laboratory. The samples for parasites tests were collected in clean plastic containers with capacity of two litters per sample then, transferred to the laboratory for a necessity test.

Table 2. Shows the equipment and tools used for biological analysis of water samples.

Tool used	Element
Bacteria	
Membrane filter technique (Sterilized membrane filter: Pore size 0.45, diameter 47 mm) using N-Coli blue broth (USA)	Total Coliform E.Coli
Parasites	
Microscope	Protozoa Helminthes

4. Results and Discussion

4.1. Physical Characteristics

4.1.1. Temperature

Water temperature plays an important factor which influences the chemical, bio-chemical characteristics of water body [6]. The results of the analysis are described in Table 3 that the studied samples are characterized by variation of the temperature between 27.5 °C as a minimum in AUSAIFERAH water spring and 57 °C as a maximum from the sample taken from the DABAB well (3). This is due to the presence of hot rocks contacted with ground water, especially at Dabab area

and the temperature increases towards the west direction of the area, while the temperature of wastewater ranges from 21.8 °C at Buraihi station to 25.4 at AUSAIFERAH station.

4.1.2. pH

pH values of the study samples ranged from 6.67 as a minimum at AUSAIFERAH water spring to 7.6 as a maximum value at AAMERAH well water (1). The variation on pH of the studied samples remains within the permissible limits (6.5-8) [7] and [8].

4.1.3. Total Dissolved Solids (TDS)

TDS was calculated by multiplying the value of the

electrical conductivity (EC) by (0.64) factor.

The study shown in Table 3 showed that the concentrations of TDS in the samples were ranged from 473.6 mg/l as a minimum in the sample taken from Habeer well (2) and 3648 mg/l as a maximum value in the sample taken from Wadi Gadeed well (3). The results also showed that the concentrations of dissolved solids in many of the samples studied were higher than the permissible limit of 1500 mg/l according to WHO and YSMO except Habeer wells (2, 3 and 6). The dissolved solids are closely linked with an electrical conductivity, table 3.

4.1.4. Electrical Conductivity

The results of the study samples showed different values of electrical conductivity given in the table 3. It ranged from 740 $\mu\text{mos} / \text{cm}$ as a minimum value in the sample taken from Habeer well (6) to 5700 $\mu\text{mos} / \text{cm}$ as a maximum in sample taken from Wadi Gadeed well (3), and the electrical conductivity exceeded the permissible limit of (2500 $\mu\text{mos} / \text{cm}$) [8] in many of the samples except a few wells, such as Habeer (2,3 & 6) and the Geser Gumhori well, the concentration of dissolved salts in these wells, especially Hawban wells because of the swamps salt in the area. In addition to the effect of those areas by different liquid waste by runoff and sewage disposal, the heavy pumping of well water is also contributed because of the scarcity of water which leads to the increase of the concentration of salt in the water.

4.2. Chemical Analysis

4.2.1. Alkaline

The results of the study show that the highest concentration of alkaline in water samples studied was 532 mg / l of the sample taken from Hawban well (11) and the lowest concentration was 32 mg/l in the sample taken from the Dabab well (3) and through the analysis, the results show that some of the samples studied have higher concentrations more than the permissible limit of 250 mg/l according to [7] guideline (table 4).

4.2.2. Bicarbonate

The bicarbonate concentrations in the studied samples ranged from 39 mg / l as a minimum concentration in the sample taken from the Dabab well (3) to 650 mg/l as a maximum concentration in the sample taken from Hawban well (11). A few samples exceeded the permissible limit of 500 mg/l [7] and [8] except Habeer wells (2, 3, and 6) and Geser Gumhori well. The contribution of the high concentrations of sulfates, especially in Hawgalah (13) and Hawban wells is contamination with sewage. Through the analysis, the results show that a proportion correlation on the concentrations of bicarbonate concentration with alkalinity (table 4).

4.2.3. Total Hardness

The concentration of hardness in the studied samples ranged from 178 mg/l as a minimum of sample taken from Habeer well (6) to 1590 mg/l as a maximum of the sample

taken from Hawban well (11).

Most of the samples studied show concentration of total hardness more than the permissible limit of (500 mg/l) [7] and [8] except a few wells like Habeer (2, 3 and 6) and Geser Gumhori. The Hawban well (11) have the highest concentration of this element due to the floods near the well , which carry many of the solid and liquid waste, particularly sewage and the composition of the rocks containing some of the elements that cause hardness , such as calcium and magnesium.

4.2.4. Calcium

The results of studied samples given in the table 4 showed that the lower concentration of Calcium was 50 mg / l in the sample taken from Habeer well (6) and the highest concentration of calcium was 335 mg/l in the sample taken from AUSAIFERAH water spring. Calcium concentration exceeded the permissible limit of 200 mg/l [7] and [8] in Aamerah well (4), Hawgalah (13), Habeel Salman water collection tank, Hawban well (11) Dabab well (2 & 3), Beerarah well (1) and AUSAIFERAH water spring. And this was attributed to the composition of the rocks formation in the study areas, sewage disposal surroundings and the over-pumping of water scarcity.

4.2.5. Magnesium

Magnesium concentration of the studied samples ranged from 15 mg / l as a minimum value in the samples taken from Habeer well (6) to 248 mg / l as a maximum value of the sample taken from Hawban well (11) table 4. The concentrations of magnesium in many of the samples studied was less than the permissible limit of 150 mg/l [7] and [8] but there were a few wells have concentrations more than the permissible limit as Hawban well (11) and Hawgalah well (13). The reasons behind of the higher concentration of this element in these wells are the sewage disposal and the over-pumping of water scarcity as a result of an increase in the concentration of magnesium.

4.2.6. Chloride

The results of chloride concentration in the studied samples ranged between 46 mg/l as a minimum concentration in the sample taken from Habeer well (2) to 1033 mg / l as a maximum concentration of the sample taken from the Aamerah well (4). Most of the concentrations of chloride of the samples studied were higher than the permissible limit of 250 mg/l [7] except Habeer wells. The reason for the high concentrations of this in these wells is the location of the wells near the floodplain, where the waste carried out from various surrounding areas

4.2.7. Sulphates

The Concentration of sulphate in the samples studied ranged from 68 mg/l as a minimum in the sample taken from Habeer well (2) to 1220 mg / l as a maximum of the sample taken from Hawgalah well (13). The results of the analysis showed that most of the samples studied have concentration exceeded the permissible limit of 400 mg/l according to

WHO and YSMO guidelines, except samples taken from Habeer wells (2, 3 and 6) and the Geser Gumhori well. The reasons for the high concentrations of sulfates, especially in Hawgalah well (13), Hawban wells and Ausiferah spiring water was the contamination of those areas from sewage which contains high concentrations of this element and also contributes to over- pumping of water scarcity as a result of an increase in the concentration of sulfates.

4.2.8. Nitrates

The results of the analysis showed that, the lower concentration of nitrate was 4.5 mg/l from the studied sample taken from the Aamerah well (1) and the highest concentration of nitrate was 314 mg/l from the studied sample taken from Hawban well (11). It was found throughout the results of samples studied that, many of wells contained high concentration of nitrates exceeded the permissible limit of 50 mg / l [7] and [8]. It is noticed that the high concentrations of this element were high in some wells because of the influenced of sewage disposal and by water runoff near these sites that contain also some fertilizers from agricultural areas near the sites.

4.2.9. Sodium

The results showed that the concentration of sodium ranged from 72 mg/l as a minimum from of the sample taken from Habeer well (2) to 824 mg/l as a maximum concentration that taken from Wadi Gadeed water tank table 4. The results also showed that the concentrations of many samples studied were higher than the permissible limit of 400 mg/l [8] and 200 mg/l [7]. The high concentration of sodium, especially in Wadi Gadeed water tank, Aamerah well and Ausaiferah water spring was due to geological rock's

composition of these areas and the location of the wells beside the floodplain that washed away with many of the residues and waste, particularly the sewage. It also contributes to over- pumping of water scarcity.

4.2.10. Potassium

The results of the analysis of water samples showed that the concentrations of potassium ranged from 1.5 mg/l as a minimum concentration in the sample taken from Habeer well (2) and to 19.5 mg/l as a maximum in the sample taken from Gadeed well (table, 4). The study results showed that the concentration of potassium in the studied samples is less than the permissible limit of (12 mg/l) [7] and [8]. Few wells showed high concentrations of this element, as in the Hawgalah wells, Hawban wells and Wadi Gadeed well. This is due to the composition of the rocks containing this element in those areas and from waste containing this element near study sites. The excess suction of water from these wells are increased the concentration of potassium in the water.

4.2.11. Fluoride

The concentration of fluoride in the studied samples ranged between 0.65 as a minimum of the sample taken from Habeer well (6) and 4.6 mg/l as a maximum of the sample taken from Geser Gumhori well. Many of samples have concentration more than permissible limit of 1.5 mg/l [7] and [8] except a few samples have lower concentrations of this element such as Dabab well (5), Aameriah well (4) and Habeer wells (2, 3 and 6). The reason of the high concentration of fluoride in those samples was due to the composition of rock formation that contains this element surrounding study areas. Many citizens on those studied areas affected by fluoride element.

Table 3. Shows the areas of collecting samples of water, sewage and field measurements.

Samples type	Place of collection	Field measurement			
		Temperature (°C)	pH	TDS	EC(μmos/cm
Geser Gumhori well	Gumhori	34.7	7.16	1299.2	2030
Ausaiferah water spiring	Ausaiferah	27.5	6.76	2707.2	4230
Bearahah well-1	Beararh	31	7.46	2214.4	3460
Dabab well 3	Down the Dabab valley	57	7.50	2169.6	3390
Dabab well 2	Central of Dabab Valley	48.5	7.02	2220.8	3470
Dabab well 5	The top of Dabab valley	41.4	7.41	1664	2600
Hawban well 11	Hawban	27.7	6.97	3084.8	4820
Habeel Salman water collection tank	Habeel Salman	53.3	7.5	2416	3775
Hawgalah well 13	Hawgalah	27.6	7.11	3174.4	4960
Wadi Gadeed water tank	Wadi Gadeed	30.5	7.2	2905.6	4540
Aamerah well 4	Aamerah	32.4	7.04	2931.2	4580
Aamerah well 1	Aamerah	31	7.6	2739.2	4280
Wadi Gadeed well	Wadi Gadeed	29	7.1	3648	5700
Habeer well 3	Habeer	30.7	7.02	506.88	792
Habeer well 2	Habeer	28.5	7.02	473.6	740
Habeer well 6	Habeer	38.5	7.1	529.9	828
Shaib Saleet well	Wadi Qadi	27	7.36	1804.8	2820
Buraihi wastewater Station	Buraihi	21.8	7.86	2572.8	4020
Ausaiferah wastewater Station	Ausaiferah	25.4	7.6	2688	4200

Table 4. Shows the chemical concentration (mg / l) of water samples in the study area.

Samples	Alkalinity	bicarbonates	T. hardness	Calcium	Magnesium	chloride	sulphate	Nitrate	Sodium	Potassium	Fluoride
Geser Gumhori well	276	336	250	75	15	285	316	17	319	7	4.6
Ausiferah aspiring water	350	427	1340	335	122	678	1200	220	600	7	2.1
Bearahah well-1	350	427	1205	287	118	773	610	36	500	6.6	1.9
Dabab well 3	32	39	665	263	78	563	755	6.2	393	7.3	3.6
Dabab well 2	116	142	770	220	53	480	652	18.1	335	6.4	3.5
Dabab well 5	213	260	680	136	83	380	523	8.8	288	4	1.3
Hawban well 11	532	650	1590	229	248	1021	1046	314	685	13	1.9
Habee Salman water tank	65	80	955	255	78	613	801	8.2	347	6.5	4.5
Hawgalah well 13	484	591	1485	231	221	998	1220	219	738	12.4	1.5
Wadi Gadeed water tank	138	163	650	139	69	950	892	68	842	9.2	1.8
Aamerah well 4	168	205	696	208	43	1033	644	88	715	7	0.9
Aamerah well 1	106	129	585	130	93	985	722	4.5	750	8	1.9
Wadi Gadeed well	339	449	895	92	100	460	624	76	352	19.5	3
Habeer well 3	237	289	251	55	27	55	70	5.3	74	1.8	0.7
Habeer well 2	264	322	244	57	24	46	68	14.7	72	1.5	0.77
Habeer well 6	156	190	178	50	13	61	93	11.5	73	1.9	0.65
Shaib Saleet well	339	454	895	192	101	463	624	74	353	19.4	3.2

4.3. Sewage Samples Analysis

The sewage samples were taken from six sampling sites, the results show high concentration of BOD, COD and Total Solids as a result of a load of high organic material associated

with lack of water use in bathrooms and kitchen and also no proper sewage treatment that is observed by sewage colour (table 5).

Table 5. Shows the characteristics of domestic wastewater (mg / l) of Taiz city.

Characteristics	Ausaiferah wastewater collection station	Buraihi sewage treatment Station				outlet
		Station Inlet	Lagoon 1	Lagoon 2	Lagoon 3	
Temperature	26	25	22	24	24	22
pH	6.95	7.38	7.8	7.9	8.24	8.27
Total Solids	3315	3315	3510	3510	3250	3250
EC	5100	5100	5400	5400	5000	5000
BOD5	1012	796	612	166	109	129
COD	2850	1970	1090	655	545	570

4.4. The Results of Biological Tests

21 samples were selected for biological tests from different sites within the city and its surrounding.

4.5. The Results of Bacterial Test

Public and environmental health protection requires safe drinking water that means it must be free from pathogenic contaminate. Enteric pathogens are among the pathogens disseminated in water sources and the most frequently

encountered. As a consequence, sources of fecal pollution in water devoted to human activity which must strictly be controlled [9].

4.5.1. Coliform Bacteria (Total Coliform)

The coliform group has been used extensively as a universal indicator for water quality and protection concept [9].

The analysed samples showed that, the colonies were not countable of coliform group in the samples taken from

Ausaiferah water spring and Habeer well (2) and there were different colonies growth in some samples that, were taken from Aamerah, Hawgalah, wadi Gadeed tank, Haimah well (6), Wadi Gadeed well (3), Shaib Saleet and Hawgalah well (13), where the growth as 120, 78, 30, 22, 6, 6, 4 and two colonies respectively. The rest of the samples did not show any bacterial growth (table 6).

4.5.2. *E. Coli Bacteria*

The results of the analysed samples showed that the growths of *E. coli* were present in two samples only. The highest number during the growth of these bacterial was 282 colonies in the sample taken from Ausaiferah water spring, and the least bacterial growth, two colonies only was in the sample taken from Habeer well (6).

4.5.3. *Analysed Sample for Parasites*

The results of the analysed samples with replicates did not show the presence of any type of parasites.

4.6. *Interpretation of the Biological Results of Water Samples*

4.6.1. *Analysis of Bacterial*

(i) *Coliform Group*

The results of analysed samples throughout the study are shown in Table 6. Many wells contaminated with a coliform group, may be due to contamination of these studied samples with sewage water which reach the water spring while other samples was caused by contamination of collection water tank which used by citizens or for getting water samples for

test.

The results of coliform group test shown in the table 6. The number of colonies in all contaminated samples exceeded the limit of 3 colonies [7] makes that water unsafe for drink with the possibility of the presence of pathogenic microbes in those samples unless it is sterilized and processed in appropriate manner, except of the sample taken from Hawgalah well (13) where the colony growth was 2 colonies only.

(ii) *E. Coli Bacteria*

Throughout the analyses the results show that the growth of this type of bacteria was only on two samples Ausaifrah water spring by 282 colonies and Habeer well (1) by two colonies the reason for contamination of these samples is the mixing with sewage during runoff and contamination of the collection tank by citizens of the region.

In both cases, the number of bacterial growth exceeded the permissible limit of one colony [7], therefore the polluted samples are made unfit for drinking and the possibility of the presence of pathogenic microbes, unless it is sterilized and processed by an appropriate treatment.

(iii) *Parasites*

The results did not show the presence of any kind of a parasite in the samples because most of those samples are a ground water type which is located at depths exceeding 100 m below the earth surface and thus the soil filtered out all types of parasites, and the streaming water does not allow the survival of the parasites in the water.

Table 6. Analysis of biological parameters of water in the studied areas.

Samples	Bacterial tests		Parasites
	Total Coliform/100ML	<i>E. Coli</i> /100ML	
Gumhori gesr well	Negative	Negative	No Parasites seen
Ausaiferah water spiring	T.N.T.C	282	No Parasites seen
Berarah well 6	30	Negative	No Parasites seen
Dabab well 2	Negative	Negative	No Parasites seen
Dabab well 3	Negative	Negative	No Parasites seen
Dabab well 5	Negative	Negative	No Parasites seen
Hawban well 11	Negative	Negative	No Parasites seen
Dabab water collection tank	Negative	Negative	No Parasites seen
Hawgalah well 13	2	Negative	No Parasites seen
Aamerah and Hawgalah and Wadi Gadeed tank	120	Negative	No Parasites seen
Aamerah well 4	Negative	Negative	No Parasites seen
Aamerah well 1	Negative	Negative	No Parasites seen
Habeer well 3	Negative	Negative	No Parasites seen
Habeer well 2	T.N.T.C	Negative	No Parasites seen
Habeer well 1	78	2	No Parasites seen
Shaib Saleet well	4	Negative	No Parasites seen
Haimah well 27	6	Negative	No Parasites seen
Shaib Kadem well	22	Negative	No Parasites seen
Salah well	Negative	Negative	No Parasites seen
Wadi Gadeed well 3	6	Negative	No Parasites seen

5. Conclusion

From the present study, it is concluded that, most of the ground water in Taiz city is unsuited for drinking because of its high content of different chemical pollutants. Therefore the citizens depend on treated water from small units distributed over all the city, also it is unsuitable for most of other uses such as bathing; however, the citizens used it because of the lack of other suitable sources of water.

Recommendation

- Construction of water treatment units and water quality system in the city are needed before pump water to the collection tanks and then distributed to houses.
- Build of a proper wastewater treatment plant for treating and testing the wastewater before being discharged.
- Household- waste must be collected in a timely manner by the container allocated for this purpose and do not leave it on the sidewalks next to the residential homes where they may drift with the flood waters and thus become the source of pollution of surface water and groundwater.
- The areas where the groundwater is extracted from and used for water supply to the communities must be enclosed with a belt and then prevent any agriculture, building or road construction within this belt.
- A suitable drainage systems and paving areas are to be placed around the wells to protect them from the arrival of pollutants through the floods.

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