Environmental contaminants and their impact on some of ground water quality, in Taiz, Yemen: Study Case

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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 analyzed 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 and with interface with natural contamination by the rocks formation in 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 also there are no proper paving surroundings of the city wells.

Key words: Water samples, sewage samples, physical measurement, chemical analysis, biological tests.

Introduction

Water is one of the most important and abundant compounds essential for all living organisms that need water for their survival and growth on the earth (6). 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 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 (8). Scarcity of water in Yemen has become a crise (1). In Taiz, Yemen's third-largest city, residents are only allowed to access public water tanks once every 45 days (5).

Objectives of the study

- Identifying the major sources of pollution of groundwater basins supplying water to the city of Taiz, either directly or indirectly.
- Conducting physical, chemical and biological analysis of different samples of the study area including groundwater, surface water and wastewater.
- Assessing the quality of groundwater through the results and their suitability for different uses.
- Developing an appropriate scientific solutions to reduce or minimize pollution.

The study area

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

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

Material and Methods

The collection of the data and visiting the study area

Data were collected of 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. Depending on these investigations, a plan to visit different sites was made 57 sites were visited, including all wells areas, particularly those operating and supplying Taiz city with water, the Foundation's local water sanitation areas adjacent to the wells, and some springs and wastewater treatment plant.

Sampling

Water samples for the analyses of physical and chemical parameters:

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

Sewage samples:

Six samples were collected from sewage and were put 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 Wastewater Treatment Station of Taiz city.

Water samples for Biological Analysis

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

Analysis of the samples

Physical measurements and chemical analysis of water and waste water samples

The chemical content of the samples of water and sewage was analysed and measured to the Standard Methods for the Examination of Water and Wastewater, American Public Health Association (3).

Table 1: shows the methods and devices used in the analysis of physical properties and chemical content 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 bromocrysol green indicator	$HCO3^-$
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^-

Biological analyses of samples (bacteria and parasites)

Samples collected for bacteria analysis 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 the 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

Results and Discussion

Physical characteristics

Temperature

Water temperature plays an important factor which influences the chemical and bio-chemical characteristics of water body (4). The results of the analysis are described in Table (3), that the study samples are characterized by variation of 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.

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) (WHO, 1983, 1984, 1993, 1996, 2003 and YSMO, 1999).

Total Dissolved Solids (TDS)

TDS was calculated by multiplying the value of the electrical conductivity (EC) by (0.64) factor.

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 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.

Electrical conductivity

The results of the studied samples showed different values of electrical conductivity given in Table (3), it ranged from 740 µmos / cm as a minimum value in the sample taken from Habeer well (6) to 5700 µmos / cm as a maximum in the sample taken from Wadi Gadeed well (3). The electrical conductivity exceeded the permissible limit of (2500 µmos / cm) (YSMO, 1999) in many of the samples, except of few wells, such as Habeer (2,3,6) and the Geser Gumhori wells. The dissolved solids were closely linked with an electrical conductivity.

Chemical analysis

Alkalinity

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

Bicarbonate

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

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 showed concentration of total hardness more than the permissible limit of (500 mg / l) (WHO and YSMO) except of few wells, like Habeer (2, 3 and 6) and Geser Gumhori. The Hawban well (11) had the highest concentration of this element due to floods near the well, which carries many of the solid and liquid waste, particularly sewage and the composition of the rock containing some of the elements that cause hardness , such as calcium and magnesium.

Calcium

The results of the studied samples given in Table (4) showed that the lower concentration of Calcium was 50 mg / l in the sample taken from Habeer well (6), while 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 (WHO and YSMO) in Aaamerah 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.

Magnesium

Magnesium concentration of the studied samples ranged from 15 mg / l as a minimum concentration in the samples taken from Habeer well (6) to 248 mg / l as a maximum concentration 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 (WHO and YSMO) but there were few wells having concentrations more than the permissible limit, as Hawban well (11) and Hawgalah well (13). The reason for 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.

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 the concentrations of chloride of the samples studied were higher than the permissible limit of 250 mg / l (WHO) except Habeer wells. The reason for the high concentrations of chloride in these wells is the location of the wells near the floodplain, where the waste carried out from various surrounding areas.

Sulphates

The concentration of sulphate in the studied samples 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 were having the concentration that exceeded the permissible limit of 400 mg / l according to WHO and YSMO guidelines, except the samples taken from Habeer wells (2, 3 and 6) and the Geser Gumhori well. The reason for the high concentrations of sulfates, especially in Hawgalah well (13), Hawban wells and Ausiferah aspiring water was the contamination of those areas from sewage which contains high concentrations of this element is likely, and also contributes to over- pumping of water scarcity as a result of an increase in the concentration of sulphates.

Nitrates

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

Sodium

The results of studied samples showed that, the concentration of sodium ranged from 72 mg / l as a minimum in 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 (YSMO) and 200 mg / l (WHO).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 that is 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.

Potassium

The results of the analyzes 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) (WHO and YSMO). 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 rock containing this element in those areas and from waste containing this element near study sites. The excess suctions of water from these wells are increased the concentration of potassium in the water.

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 the samples were having concentration more than the permissible limit of 1.5 mg / l (WHO and YSMO) except a few samples that were having lower concentrations of this element, such as Dabab well (5), Aameriah well (4) and Habeer wells (2, 3 and 6). The reason for the high concentration of fluoride in those samples was due to the composition of rock formation that contains in this element surrounding study areas. Many citizens on those studied areas were severed 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 (^{0}C)	**pH**	**TDS**	**EC(µmos/cm**
Geser Gumhori well	Gumhori	34.7	7.16	1299.2	2030
Ausiferah water spiring	Ausaiferah	27.5	6.76	2707.2	4230
Bearahah well-1	Bearath	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

Sewage samples analysis

The sewage samples were taken from six sampling sites, the results showed high concentration of BOD, COD and Total Solids as a result of a load of high organic material associated with the lack of water use in bathrooms and kitchens, and also no proper sewage treatment was 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

The results of biological tests

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

The results of bacterial test

Public and environmental health protection requires safe drinking water that means it must be free of pathogenic contaminate. Enteric pathogens are among the pathogens disseminated in water sources and were the most frequently encountered. As a consequence, sources of fecal pollution in water devoted to human activity must strictly be controlled (2).

Coliform bacteria (Total Coliform)

The coli form group has been used extensively as a universal indicator for water quality and protection concept (2).

The analysis samples showed that the colonies were not countable of coliform group in the samples taken from Ausaiferah water spring and Habeer well (2), whereas 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).

E coli bacteria

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

Analysed sample for a parasites

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

Interpretation of the biological results of water samples

Analysis of bacterial

Coli form group

The results of the analysed samples throughout the study are shown in Table (8). 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 were caused by contamination of collection water tank used by citizens or for getting water samples for test.

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

E. coli Bacteria

Throughout the analysis, the results showed 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 of water 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 (WHO), 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.

Parasites

The results from the analysis samples studied 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 usually gets filtered of 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	E. Coli/100ML	
Gumhori gesr well	Negative	Negative	No Parasites seen
Ausaiferah water spring	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

Conclusion

From the present study, it is concluded that most of the ground water in Taiz city is unsuitable for drinking because of its high content of different chemical pollutants and, therefore, the citizen depends 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 use it because of the lack of other suitable sources of water.

Recommendation

- Constructing water treatment units and water quality system in the city is needed before pump water to the collection tanks and then distributed to houses.
- Building a proper wastewater treatment plant for treating and testing wastewater before being discharged.
- Household- waste must be collected in a timely manner by the container allocated for this purpose and not leaving it on the sidewalks next to the residential homes where they may drift with the flood waters and, thus, becomes 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 prevent any agriculture, building or road construction within this belt.

- Suitable drainage systems and paving areas were to be placed around the wells to protect them from the arrival of pollutants through the floods.

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الملوثات البيئية وأثرها على جودة المياه في مدينة تعز، اليمن: دراسة حالة

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الملخص

الهدف الرئيسي من هذه الدراسة هو تقييم جودة المياه الجوفية التي تغذي سكان مدينة تعز. أظهرت النتائج أن معظم عناصر التحليل افي العينات الدراسة مثل الموصلية الكهربائية ، والناصر الصلبة الذائبة،عسر الماء، والكلوريد والفلوريد إلخ كانت أعلى من الحد المسموح به وفقا لمنظمة الصحة العالمية للمواصفات القياسية اليمنية للمياه. مياه الجريان السطحي التي تحمل معها مياه الصرف الصحي والنفايات الأخرى وتعد من أهم المصادر البشرية المنشأ تلوث المياه بالإضافة إلى عوامل تتداخل معها وهي التركيبة الصخرية لمنطقة الدراسة حيث تتواجد الآبار. ويزيد من تفاقم هذه المشكلة الافتقار لوجود معالجة صحيحة لمياه الصرف الصحي بالمدينة وكذلك الافتقار لوجود نظام تصريف جيد ورصف مناسب حول الآبار المدروسة.

الكلمات المفتاحية: عينات المياه، عينات مياه الصرف الصحي، قياس فيزيائي، تحليل كيميائي واختبارات بيولوجية.