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RESEARCH ARTICLE

PHYSICOCHEMICAL AND MICROBIAL QUALITY OF THAMAR CITY DRINKING WATER, YEMEN

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Abstract

This study aimed to evaluate the microbial, chemical and physical quali ty of drinking water in Thamar city, Yemen and assess the water chlori nation treatment effectiveness in water microbial quality. Samples inclu ded water from wells, main reservoirs and distribution systems from ho usehold tanks in some zones. The results showed that total bacterial cou nt was above the WHO and Yemeni standards which ranged between 3 3 - 52 × 10^3, 173 - 196 × 10^3 and 52 - 180 × 10^3 CFU/ml in wells, main reservoirs and household tanks water respectively, while total coliform bacteria didn't found in all wells and main reservoirs water samples but it was present in all water samples from household tanks except one gro up of regions included in this study which ranged between 4- 23 MPN/ 100 ml of water. Water treatment with sodium hypochlorite at 2 mg /l r educed its microbial load and improved its microbial quality. The result s also showed that all chemical and physical parameters of water sampl es were within WHO and Yemeni standards value except total alkalinit y level which was above these standards.

Introduction:-

Water has great importance in life where all organisms cannot live without it, and human needs around 2-3 litres/day on average, and the quality of drinking water is a priority, especially in developing countries.

Water can be obtained from a number of sources including rivers, springs, lakes, ground water and desalinated sea w ater, and the quality of water vary according to the source water quality and treatment applied before consumption b ecause the water is a major source of many diseases that afflict people in Africa, Asia and Latin America, especially when proper treatment is not available in particular the water disinfection process of pathogenic microbes, and drin king water contain different species of bacteria that have the ability to human injury serious diseases that affect the health and drinking contaminated water results in thousands of deaths every day, mostly in children under five years, in developing countries, (WHO, 2006).

Potable water is defined as water that is free from disease producing microorganisms and chemical substances deleterious to health, (Ihekoronye & Ngoddy, 1985).

Before water can be described as potable, it has to comply with certain physical, chemical and microbiological standards, which are designed to ensure that the water is potable and safe for drinking, (Tebutt, 1983).

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There are two types of water pollution, namely, point source pollution- which occurs as a result of release of harmful substances directly into the body of water, and non-point source pollution-which occurs as a result of indirect introduction of pollution into water bodies/sources from the environment, (Kerker, 2003).

Shittu et al., (2008) found that the total bacteria count in wells, rivers and streams water that used for drinking and s wimming purposes in Abeokuta state - Nigeria was ranged between 6.3×10^6 and 2.01×10^7 CFU/ml, and the highe st load was in rivers water, while the least was in the wells water at 1.0×10^2 CFU/ml, and the total coliform bacteri a ranged between 1600 and more than 1800 MPN/100 ml.

Antony & Renuga, (2012) microbiological study for Ananthanar channel water which is used for drinking and house hold purposes in many villages in India, reported that faecal coliform bacteria count was between 12 - 180 MPN/100 ml of water.

Whereas Ell-Amin et al. (2012) study reported that total bacteria count in Khartoum drinking water, Sudan was betw een 4×10^2 and 4.5×10^4 CFU/ml, while coliform bacteria count was between 23 - 1100 CFU/ml.

To prevent transmission of pathogens to humans by water, it is typically used a suitable method for water sterilizatio n.

Water disinfection treatment has important as final stages in drinking water treatment to prevent disease transmissio n through the water supply system, and the chlorination process is the most widely used methods of water disinfectio n, (Goel & Bouwer, 2004).

Almeida et al., (2015) mentioned that quality of treated water was better than untreated water and the treatment applied on drinking-water was effective, thereby, reducing the microbial contamination in environmental waters, thus, the remedy to water contamination is the treatment of all water supply sources.

As a result of lack in physiochemical and microbial studies for drinking water and its sources in Thamar city, this stu dy was conducted which aimed to estimate physiochemical properties and microbial quality of drinking water at hou sehold tanks, main reservoirs and wells of water in Thamar city and compare the results with Yemeni and WHO stan dards value for drinking water and evaluation of water chlorination treatment in improving of drinking water microb ial quality.

Materials and methods:-

Sampling:-

Water samples were collected from wells (7 wells), water main reservoirs (3 tanks) and water distribution systems fr om some household tanks in many zones in Thamar city (the city was divided into 4 groups (A, B, C, D) included 24 zones), the study lasted three months.

Samples were carried in sterile plastic bags to the laboratory of biotechnology and food Technology Department, wh ere microbiological and physicochemical tests were draw.

Microbiological analysis of water samples:-

Total bacteria counts:-

Total bacteria count was performed by Plate Count Agar (PCA) method and decimal dilution series for samples with sterile saline (0.9% sodium chloride) and 1ml of each dilution was plating in plate count agar in duplicate plates and incubated at 37 ºC for 24 – 48 hr, (APHA, 1989).

Total Coliform counts:-

Estimation *of total coliform* in drinking water samples were done by the Most Probable Number method (MPN) in t hree steps:

Presumptive test:-

Most Probable Number (MPN) bacteria present in water sample has been estimated by using tubes containing Lacto se Broth (3 tubes) and incubated at 37 C° for 48 hours.

Confirmatory test:-
Confirmatory test was performed by using Eiosine methylene blue (EMB) and incubated at 37 C° for 48 hours.

Complementary test:-
Tubes containing Lactose Broth were used to perform this test and incubated at 37 C° for 48 hours.
The numbers of the positive tubes per dilutions were determinate and calculated the MPN index from the MPN table s, (Pepper and Gerba, 2004).

Physicochemical analysis of water samples:-
Physical analysis:-
Water pH, total dissolve salts (TDS) and electrical conductivity (CE) were determined by TDS & CE meter, Hanna Company, while turbidity was measured by using HACH Dr / 890 Colorimeter, HACH Company, USA.

Chemical analysis:-
The chemical parameters of water were measured by using HACH Dr/890 Colorimeter, HACH Company, USA.

Water chlorination:-
Water sample treated with sodium hypochlorite at 0.2 mg/l for 10 – 30 minutes and total bacteria and total colifom c ounts were determinate after this treatment and compared it with the counts of these bacteria in water before the chlo rination.

Results and discussions:-

Bacteriological analysis:-
Total bacteria counts:-
Wells and main reservoirs water:-
Results in table (1) shows the total bacteria counts for wells and main reservoirs water in Thamar city, and it's indica ted that the contamination in wells water was lower than main reservoirs water and it's also showed that the total bac teria counts have been varied from sample to another be due the variation in the place of wells which the wells that a re in the same residential density had the same level of contamination and the sample from the wells that located in d ensely populated residential zones have relatively high in bacteria count.

The total bacterium counts in wells water was ranged between 33 and 58 x 10^3 CFU/ml.
Table 1:- Total bacteria counts in wells and main reservoirs water of Thamar city.

The wells.	**Total bacteria counts.** (CFU/ml)	**Water main reservoirs.**	**Total bacteria counts.** (CFU/ml)
Almohafezah	47 x 10^3	Thamer	196 x 10^3
Alseaid	33 x 10^3	Herran	182 x 10^3
Alastad alryady	58 x 10^3	Algarn	173 x 10^3
Mahata alazeraq	45 x 10^3		
Shaeibah	52 x10^3		
Aldurah	36 x 10^3		
Algeded	41 x 10^3		

The table (1) also shows total bacteria counts in water samples taken from main reservoirs in the city and its microbi al loads was higher than the wells water, which indicates water contamination was occurred during water pumping fr om wells to the main reservoirs or may be due a deficiency in main reservoirs annual cleaning process, because the a nnual cleaning process for water tanks can protect water from pollution as mentioned by (Levesque et al., 2008).

The total bacteria counts in main reservoirs water was ranged between 173 and 196× 10^3 CFU/ml.
The total bacteria counts in all main reservoirs and wells water samples were without of WHO and Yemeni standard s value of drinking water.

Household tanks water:-
Table (2) shows the results of bacteriological evolution for household tanks water in Thamar city, and the results of group A and B indicated that presence of pollution in water samples more than other groups which total bacteria cou nts were between 123 and 180 × 10^3 CFU/ml.

While total bacteria counts for water samples in group C and D were between 57 and 112 × 10^3 CFU/ml which was l ower than A and B groups.

This may be a result of water contamination that occurred in distribution system pipes where sewage water pipes pas sing near it and that may lead to pollution, as well as occurrence of rust and holes in the distribution system pipes lea ding to allow microorganisms interning to distribution system pipes from the surrounding sources.

These findings are in agreement with the results of Eze & Madumere, (2012), who showed that microbial load of wa ter in Abia state, Nigeria was between 3.93 and 6.83 × 10^4 CFU/ml.

but it was less than the results that found by Sunday et al.,(2014) who found that the microbial load of water used in domestic purposes in Edo state, Nigeria was 1.8 and 2.6 × 10^5 CFU/ml which more than WHO standard value.
But its more than the results founded by Kolawole and Obueh, (2015) who found that total heterotrophic bacteria co unts in tap water of Utagba-Uno, Nigeria was 1.2 × 10^2 CFU/ml.

But these results are without WHO and Yemeni standards value for drinking water which identified microbial load i n drinking water should not more than 1 × 10^2 CFU/ml.

Table 2:- Total bacteria count in household tanks water from Thamar city zones.

Zone group	Total bacteria count (CFU/ml).	Range	Mean	Zone group	Total bacteria count (CFU/ml).	Range	Mean
A	**180 x 10^3**	**169 - 180 × 10^3**	**175 ± 7.49 × 10^3**	**C**	**98×10^3**	**78 - 112 × 10^3**	**93.62± 4.59 × 10^3**
	169 x 10^3				**95×10^3**		
	178 x 10^3				**103×10^3**		
					91×10^3		
					78×10^3		
					89×10^3		
					112×10^3		
					83×10^3		
B	**170×10^3**	**123 - 170 × 10^3**	**145.4 ± 5.80 × 10^3**	**D**	**62×10^3**	**52 - 92 × 10^3**	**74.75 ± 4.59 × 10^3**
	157×10^3				**57×10^3**		
	123×10^3				**75×10^3**		
	139×10^3				**83×10^3**		
	138×10^3				**92×10^3**		
					86×10^3		
					52×10^3		
					91×10^3		

Total coliform counts:-

Wells and main reservoirs water:-

Total coliform presumptive test results for well and main reservoirs water showed that all water samples were free fr om total coliform, despite presence turbidity in the test tubes, but did not notice gas production which indicates the p resence of total coliform especially E. coli that produce a gas. These results may be due to the high depth of water w ells which reach more than 100 meters as mentioned by Water Foundation of Thamar governorate.

These findings were within WHO and Yemeni standard value for drinking water, where it's required that total colifo rm count in drinking water shall not be exceed than **0 CFU/100 ml**.

Household tanks water:-

Table (3) showed that the results of complementary test in three regions groups in Thamar city which it results were positive in the confirmatory tests, and a similar results for probability test was found where gas production and chan ge in the colour of the media, total coliform counts were 23 MPN/100 ml in group A and 9 MPN/100 ml in group B, while lowest count was in the water samples from group C which reaching 4 MPN/100 ml of water.

Tale 3:- Complementary test for total coliform in water samples from household tanks in Thamar city zones.

Zone group	**Number of Positive Tubes in Dilutions**.			MPN /100 ml	**Zone group**	**Number of Positive Tubes in Dilutions**			MPN /100 ml
	10^{-1}	**10^{-2}**	**10^{-3}**			**10^{-1}**	**10^{-2}**	**10^{-3}**	
A	3	0	0	**23**	**C**	1	0	0	**4**
	3	0	0	**23**		1	0	0	**4**
	3	0	0	**23**		1	0	0	**4**
B	2	0	0	**9**		1	0	0	**4**
	2	0	0	**9**		1	0	0	**4**
	2	0	0	**9**		1	0	0	**4**
	2	0	0	**9**		1	0	0	**4**
	2	0	0	**9**		1	0	0	**4**

These results are consistent with the results of Kurup et al. (2010) study on the water in Georgetown who found a hi gh level of contamination by coliform bacteria in water sources and city distribution systems which was without WH O standard and it reached to more than 250 CFU/ml, and also its consistent with the results of Pavendan et al., (2011) study for the water from various sources in south India, who found that total coliform count in the most cases was higher than 250 CFU /100 ml.

As well as consistent with the study of Sunday et al., (2014), who found that total coliform count in water that used in homes in Edo state -Nigeria was between 7 and 14 MPN /100 ml which was more than WHO limit, and with the results of Kolawole and Obueh, (2015) study which showed that total coliform count in the tap water of Utagba-Uno, Nigeria was 18 MPN/ 100 ml.

Its consistent also with the results of Ell-Amin et al.,(2012), study who found that coliform bacteria count in Khartou m drinking water, Sudan were between 23 and 1100 CFU/ml.

These results were without the WHO standard which recommended that total coliform count in drinking water shall not be exceed than 0 CFU /100 ml, so such water needs to be treated before it used in order to reduce water microbia l contamination.

Water chlorination treatment:-

Total bacteria counts:-

Results in the table (4) showed that the effective of water chlorination treatment at 2 mg /l caused a reduction in the t otal bacteria counts from 10^3 to 10^1 CFU/ml which indicated that effectiveness of chlorine treatment in water microb ial load reduction.

These findings are consistent with Bishankha et al., (2013) study which illustrated that the presence of free chlorine i n the water has reduced the total bacteria count and an inverse relationship between total bacteria count and free chlo rine concentration in the water was found and the Log of inactivation for various organisms with the chlorine residu al concentration at 0.2 mg/l were found to be less than 30 minute and greater than 60 minute for all eight different ty pes of organisms tested.

Table 4:- Effect of water chlorination treatment in total bacteria counts.

Sample No.	**Total bacteria count** (CFU /ml)	
	Before chlorination	**After chlorination**
1	263×10^3	42×10^1
2	196×10^3	35×10^1
3	178×10^3	25×10^1

Total coliform counts:-

Table (5) showed effect of water chlorination treatment in total coliform counts which indicated that efficiency of chlorination process in eliminating coliform bacteria, and water chlorination treatment led to eradicate coliform bacteria in water samples where all MPN tubes were appeared a negative results after water chlorination treatment the MPN index reached to < 3/ 100 ml.

Table 5:- Effect of water chlorination treatment in total coliform counts.

Sample No.	Before chlorination				Sample No.	After chlorination			
	Number of Positive Tubes in Dilutions.			MPN /100 ml		Number of Positive Tubes in Dilutions.			MPN /100 ml
	10^{-1}	10^{-2}	10^{-3}			10^{-1}	10^{-2}	10^{-3}	
1	3	1	1	75	1	0	0	0	< 3
2	2	1	0	15	2	0	0	0	< 3
3	2	1	1	20	3	0	0	0	< 3

Physicchemical parameters of water:-

Table (6) shows the physical and chemical parameters of drinking water in Thamar city, and these results confirmed that all physical parameters of water were within the limits of WHO and Yemeni standard for drinking water, where pH value was 8.05, total dissolve salts was 180 - 195 mg /l of water, while the electrical conductivity was 391µs/cm and water turbidity was 1 NTU.

The table (6) also shows chemical parameters of water that have been studied, and all chemical parameters of water were within WHO and Yemeni standard for drinking water (YSMO, 2005) except the total alkalinity that was 126 m g/ml which it above WHO and Yemeni standards and this high value of total alkalinity may be due the high depth of water wells.

Table 6:- physicochemical parameters of drinking water in Thamar city.

Water parameters	Thamar city drinking water	WHO standard	Unit
pH	8.05	6.5 – 8.5	-
TDS	180 -195	500 –1000	ppm
EC	360 - 391	450– 1500	µs/cm
Turbidity	1	1- 5	NTU
Nitrate	21.6	10- 50	mg/l
Sulphate	8	200 – 400	mg/l
Total hardness	140	100-500	mg/l
Iron	0.04	0.3-1	mg/l
Total alkalinity	126	100	mg/l
Bicarbonate	220	100-250	mg/l
Chloride	54	250	mg/l
Phosphate	0.12	0.4-5	mg/l
Calcium	100	75-200	mg/l
Magnesium	42	30-150	mg/l

These results are similar the results founded by Werkneh *et al*., (2015) in his study for physicochemical quality of dr inking water in Jigjiga town- Ethiopia, which all water parameters were within drinking water standard except EC a nd total hardness which was above these standard and its value was 1143 µs/cm and 362.67 mg/l respectively.

Conclusions:-

1. High total bacteria counts were found in all water samples which above the WHO and Yemeni standard values.
1. Contamination with coliform bacteria was found in some samples from household tanks but wells and main rese rvoirs water samples were free.
2. Water from wells that located in high population density region had higher pollution than water from wells locat ed in a low population density region.
3. All physical and chemical water parameters were within WHO and Yemeni standards except total alkalinity whi ch above these standards.
4. Annual cleaning and disinfection process for main reservoirs, water chlorination treatment and maintenance of distribution systems pipes should be apply in order to improve the microbial quality of water.

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