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 quality of drinking water in Thamar city, Yemen and assess the water chlorination treatment effectiveness in water microbial quality. Samples included water from wells, main reservoirs and distribution systems from household tanks in some zones. The results showed that total bacterial count was above the WHO and Yemeni standards which ranged between 3.3 - 52 × 10³, 173 - 196 × 10³ and 52 - 180 × 10³ 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 group 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 reduced its microbial load and improved its microbial quality. The results also showed that all chemical and physical parameters of water samples were within WHO and Yemeni standards value except total alkalinity 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 water, and the quality of water vary according to the source water quality and treatment applied before consumption because 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 drinking 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 swimming purposes in Abeokuta state - Nigeria was ranged between $6.3 \times 10^6$ and $2.01 \times 10^7$ CFU/ml, and the highest load was in rivers water, while the least was in the wells water at $1.0 \times 10^2$ CFU/ml, and the total coliform bacteria 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 household 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 between $4 \times 10^5$ and $4.5 \times 10^4$ 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 sterilization.

Water disinfection treatment has important as final stages in drinking water treatment to prevent disease transmission through the water supply system, and the chlorination process is the most widely used methods of water disinfection, (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 study was conducted which aimed to estimate physiochemical properties and microbial quality of drinking water at household tanks, main reservoirs and wells of water in Thamar city and compare the results with Yemeni and WHO standards value for drinking water and evaluation of water chlorination treatment in improving of drinking water microbial quality.

Materials and methods:-
Sampling: -
Water samples were collected from wells (7 wells), water main reservoirs (3 tanks) and water distribution systems from 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, where microbiological and physicochemical tests were drawn.

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 three steps:

Presumptive test: -
Most Probable Number (MPN) bacteria present in water sample has been estimated by using tubes containing Lactose Broth (3 tubes) and incubated at 37 C° for 48 hours.
Confirmatory test:-
Confirmatory test was performed by using Eosine 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 tables, (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 coliform counts were determine after this treatment and compared it with the counts of these bacteria in water before the chlorination.

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 indicated that the contamination in wells water was lower than main reservoirs water and it's also showed that the total bacteria counts have been varied from sample to another be due the variation in the place of wells which the wells that are in the same residential density had the same level of contamination and the sample from the wells that located in densely 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 total bacteria counts in main reservoirs water was ranged between 173 and 196 x 10^3 CFU/ml.
The total bacteria counts in all main reservoirs and wells water samples were without of WHO and Yemeni standards 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 counts were between 123 and 180 x 10^3 CFU/ml.
While total bacteria counts for water samples in group C and D were between 57 and $112 \times 10^3$ CFU/ml which was lower than A and B groups.

This may be a result of water contamination that occurred in distribution system pipes where sewage water pipes passing near it and that may lead to pollution, as well as occurrence of rust and holes in the distribution system pipes leading 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 water in Abia state, Nigeria was between 3.93 and $6.83 \times 10^4$ 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 $2.6 \times 10^5$ 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 counts in tap water of Utagba-Uno, Nigeria was $1.2 \times 10^2$ CFU/ml.

But these results are without WHO and Yemeni standards value for drinking water which identified microbial load in drinking water should not more than $1 \times 10^2$ 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          | $180 \times 10^3$                   |      | C          | $98 \times 10^3$, $95 \times 10^3$, $103 \times 10^3$, $91 \times 10^3$, $78 \times 10^3$, $89 \times 10^3$, $112 \times 10^3$, $83 \times 10^3$ |      |
|            | $169 \times 10^3$                   |      |            | $78 - 112 \times 10^3$              |      |
|            | $178 \times 10^3$                   |      |            | $93.62 \pm 4.59 \times 10^3$        |      |
| B          | $170 \times 10^4$, $157 \times 10^4$, $123 \times 10^7$, $139 \times 10^4$, $138 \times 10^4$ |      | D          | $62 \times 10^4$, $57 \times 10^4$, $75 \times 10^4$, $83 \times 10^4$, $92 \times 10^4$, $86 \times 10^4$, $52 \times 10^4$, $91 \times 10^4$ |      |
|            | $123 - 170 \times 10^3$             |      |            | $52 - 92 \times 10^3$               |      |
|            | $145.4 \pm 5.80 \times 10^4$        |      |            | $74.75 \pm 4.59 \times 10^3$        |      |

**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 from total coliform, despite presence turbidity in the test tubes, but did not notice gas production which indicates the presence of total coliform especially E. coli that produce a gas. These results may be due to the high depth of water wells 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 coliform 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 change 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.
Table 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 |            | 10^-1 | 10^-2 | 10^-3 |
| A          | 3     | 0     | 0     | 23         | 1     | 0     | 0     | 4           | 1     | 0     | 0     |
|            | 3     | 0     | 0     | 23         | 1     | 0     | 0     | 4           | 1     | 0     | 0     |
|            | 3     | 0     | 0     | 23         | 1     | 0     | 0     | 4           | 1     | 0     | 0     |
| B          | 2     | 0     | 0     | 9          | 2     | 0     | 0     | 9           | 1     | 0     | 0     |
|            | 2     | 0     | 0     | 9          | 2     | 0     | 0     | 9           | 1     | 0     | 0     |
|            | 2     | 0     | 0     | 9          | 2     | 0     | 0     | 9           | 1     | 0     | 0     |
|            | 2     | 0     | 0     | 9          | 2     | 0     | 0     | 9           | 1     | 0     | 0     |

These results are consistent with the results of Kurup et al. (2010) study on the water in Georgetown who found a high level of contamination by coliform bacteria in water sources and city distribution systems which was without WHO 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 Khartoum 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 microbial 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 total bacteria counts from 10^3 to 10^1 CFU/ml which indicated that effectiveness of chlorine treatment in water microbial load reduction.

These findings are consistent with Bishankha et al., (2013) study which illustrated that the presence of free chlorine in the water has reduced the total bacteria count and an inverse relationship between total bacteria count and free chlorine concentration in the water was found and the Log of inactivation for various organisms with the chlorine residual concentration at 0.2 mg/l were found to be less than 30 minute and greater than 60 minute for all eight different types 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                    |                     | 42×10^3           |
| 2          | 196×10^3                    |                     | 35×10^3           |
| 3          | 178×10^3                    |                     | 25×10^3           |

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 N o. | Before chlorination | After chlorination |
|-------------|---------------------|--------------------|
|             | Number of Positive Tubes in Dilutions. | MPN /10 0 ml | Number of Positive Tubes in Dilutions. | MPN /10 0 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 |

Physicochemical 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 mg/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 drinking water in Jigjiga town- Ethiopia, which all water parameters were within drinking water standard except EC and 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.
2. Contamination with coliform bacteria was found in some samples from household tanks but wells and main reservoirs water samples were free.
3. Water from wells that located in high population density region had higher pollution than water from wells located in a low population density region.
4. All physical and chemical water parameters were within WHO and Yemeni standards except total alkalinity which above these standards.
5. 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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