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# The effect of water treatment stages in Al-Wathba water treatment plant in Baghdad city on the bacterial growth (applied study)

Mohammed Ali I. Al-Hashimi*, Ayat Hussein Mahdi, Rana Jawad Kadhim

*Building and Construction Department, Sanitary and Environmental Engineering Branch, University of Technology, Baghdad, Iraq*
*Email: mohashimi2003@yahoo.com*

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ABSTRACT

The aim of this research is to study the biological pollution in Al-Wathba water treatment plant stages (new extension) by taking water samples from the river, sedimentation tank, sand filter, pressure filter, and from three residential areas (Al-Atebaa neighborhood, Al-Amen neighborhood, and Al-Shorja), with the examination of bacterial growth, temperature, pH, and turbidity in each stage. Weekly samples have been taken for the period from January 2011 to May 2011 by studying the bacterial existence using total plate count, and also by testing for total and fecal coliform using presumptive and confirmed test because it is the evidence for bacterial pollution. There was high percentage of pollution in the sedimentation tank and less amount in sand filter due to lack of periodic cleaning. Fecal coliform reduced after pressure filtration; small amounts of chlorine were added to the filter to reduce the bacterial growth in filter media. After chlorination the removal efficiency was 99.99%. It was noticed that the chlorine dose added for disinfection was so high that it reached up to 3.5 mg/ L, which is dangerous especially for people near water treatment plants.

*Keywords:* Total plate count; Fecal coliform; Chlorination; Bacterial growth

## 1. Introduction

Water has long served as a mode of transmission of diseases. The most important of the waterborne diseases are those of the intestinal tract, including typhoid fever, paratyphoids, dysentery, infectious hepatitis, cholera, and some parasitic worm diseases [1].

Drinking water should also have a reasonable temperature [2].

It is not practical to test the water for all organisms that it might possibly contain. Instead, the water is examined for a specific type of bacteria which originates in large numbers from human and animal excreta and whose presence in the water is indicative of fecal contamination [3].

The most basic test for bacterial contamination of a water supply is the test for total coliform bacteria. Total coliform counts give a general indication of the sanitary condition of a water supply [4].

Total coliforms include bacteria that are found in the soil, in water that has been influenced by surface water, and in human or animal waste [4].

Fecal coliforms are a group of total coliforms that are considered to be present specifically in the gut and feces of warm-blooded animals. Because the origins of fecal coliforms are more specific than the origins of more general total coliform group of bacteria, fecal coliforms are considered as a more accurate indication of animal or human waste than the total coliforms [4].

*Escherichia coli* (*E. coli*) are the major species in the fecal coliform group; so, they are considered to be the

*Corresponding author.

best indicator of fecal pollution and the possible presence of pathogens [4].

## 2. Bacteriological health effect

The pathogenic agents involved protozoa which may cause disease that vary in severity from mild gastroenteritis to sever and sometimes fatal diarrhea, dysentery hepatitis, typhoid fever, cholera, and other illness. Most of them are widely distributed throughout the world [5].

It is not only by causing infection that microorganisms in drinking water affect human health. In some circumstances, cyanobacteria can produce toxins that may remain in water even when the cyanobacteria themselves are removed [5].

Total coliform bacteria ferment lactose at 35 or 37°C with the production of acid, gas, and aldehyde within 24–48 h. Fecal coliforms (thermotolerant coliform) are a subgroup of total coliforms having same properties except that they tolerant and grow at higher temperatures of 44–45°C [6].

Finally, there are some organisms whose presence in water is a nuisance but which are of no significance for public health [7].

## 3. The effect of water parameters on bacterial growth

Bacteria can enter water supply through infiltration by flood waters or by surface runoff. Flood waters commonly contain high levels of bacteria. Small depressions filled with flood water provide an excellent breeding ground for bacteria [8].

Treatment effectiveness is a function of disinfectant dose, contact time, temperature, and sometimes pH. Chemical disinfection to inactivate pathogens is an important treatment barrier [9].

The activity of a disinfectant may be greatly affected by factors such as dilution, temperature, pH, or the presence of organic matter. A disinfectant needs appropriate conditions, at a suitable concentration, for an adequate period of time [10].

An increased risk of bladder cancer appeared to be associated with the consumption of chlorinated tap water [11].

Careful attention to pH control is necessary at all stages of water treatment to ensure satisfactory water clarification and disinfection. For effective disinfection with chlorine, the pH should preferably be less than 8 [12].

The pH of the water markedly influenced the survival of bacteria. The addition of lime to the raw water was an effective method of pH bacteria control. The results of a study done by Martin et al. illustrate the delicate balance that can exist between bacterial growth, pH, and chlorine residue [13].

Increasing the pH level over 7.2 can negatively affect chlorine action; it decreases its action on killing bacteria [14].

Water temperature directly or indirectly affects all the factors that govern microbial growth. Temperature influences treatment plant efficiency, microbial growth rate, disinfection efficiency, decay of disinfectant residuals, corrosion rates, and distribution system [15].

At temperatures above 15°C, the growth of nuisance organisms in the distribution system becomes a problem and could lead to development of unpleasant taste and odors [16].

The ideal temperature of water for drinking purpose is 5–12°C; above 25°C, water is not recommended for drinking [17].

To define the interrelationship between elevated turbidities and the efficiency of chlorination in drinking water, experiments were performed to measure bacterial survival, chlorine demand, and interference with microbiological determinations. Results indicated that disinfection efficiency was negatively correlated with turbidity and was influenced by season, chlorine demand of samples, and the initial coliform level [18].

Turbidity is of great importance, first because of aesthetic consideration and second because pathogenic organisms can hide on (or in) tiny colloidal particles [19].

Turbidity in rivers can change from 10 to over 4,000 NTU [20].

Turbidity level for treated water should not exceed 5 NTU, and should be under 1 NTU for efficient disinfection with chlorine [21].

## 4. Previous studies

Studies have been done to study water quality in water treatment plants. All these studies have indicated that water quality of the Tigris River in Baghdad is affected by the discharge of untreated sewage and wastes from industries and hospitals in to it.

Al-Malikey studied the effect of pollution of the Tigris River. He indicated that Al-Wathba water treatment plant, which is located in the middle of Baghdad, was not suitable for use as a source of drinking water due to exceeding number of total coliform bacteria [22].

Alwan stated that the bad quality of the drinking water can be attributed to two sources: first, the embargo which was imposed on our country lowered the efficiency of water treatment plants, and second most pipe networks are very old and need replacement [23].

This study indicates that Al-Wathba water treatment plant shows an improvement in its water quality.

## 5. Field work and sampling

This research was done to evaluate the water quality for Al-Wathba water treatment plant and study the microbiological effect. Samples of water were taken two times monthly from the following points: river water, sedimentation tank, sand filter, pressure filter, Al-Ateba neighborhood, Al-Ameen neighborhood, and Al-Shorja.

Samples were collected in soft, glass sterilized bottles with screw-top closures for the period from January to June 2011. All chlorinated samples were dechlorinated by adding a measured amount of prepared sodium thiosulfate solution to empty the sample bottle before sterilization to neutralize any residual chlorine and prevent the continuation of the disinfection action during the time the sample is in transit to the laboratory [24].

Bacteriological examination was done at the Al-Mustansirya University Engineering College (Environment laboratory). The examination included the total plate count (TPC), the presumptive test, and the confirmed test for total and fecal coliform. Temperature, pH, and turbidity were also tested at the site.

All apparatus were sterilized prior to use. New sterile pipettes for each sample and each dilution were used.

Lauryl tryptose broth (lauryl sulfate broth) was used for the presumptive test, which is a positive test for indicating that coliform bacteria may be present; after incubating the samples for 48 h at 37˚C growth, coliform bacteria were identified by the presence of bubbles in the inverted vial with production of gas. A negative reaction, either no growth or growth without gas, excludes the coliform group [24,25].

The confirmed test is used to substantiate, or deny, the presence of coliform in a positive presumptive test (polluted samples) by using (Brilliant Green broth) to find out (total coliform) and incubation for 48 h at 37˚C. EC broth is used to find out (fecal coliform) by using water bath at 45˚C for 24 h. If growth occurs with gas, the presence of coliform is confirmed [24,25].

TPC was done to discover the bacterial colonies per 1 mL of sample by using (nutrient agar) [24,25].

Fig. 1 illustrates stages of bacteriological examination.


Fig. 1. Stages of bacteriological examination.

## 6. Results and discussion

Total coliform consists of many types of bacteria including fecal coliform; so, comparison between total and fecal coliform was done at all sampling points, Figs. 2–8.

For all samples, there was an increase in the fecal coliform concentration in April. This was because of the rise in water temperature to about 22˚C which helps the bacteria to live, especially in river water and sand filter media concentrations of fecal coliform reached up to 180,000 MPN/100 mL of sample.

Sedimentation tank and sand filters need to be cleaned continuously from sediments, algae, and bacterial growth. Sediment accumulations affected the fecal coliform number and led to higher amounts than those of total coliform.

The turbidity increase causes a decrease in the effect of the chlorine dose. There are many reasons that influence this negative relation like season, chlorine demand, initial coliform, and total organic carbon as stated by Le Chevallier et al. [18]. Organic carbon could absorb chlorine on its particles creating chlorine demand. Figs. 9–11 illustrate the negative interrelationship.

Maximum concentration of chlorine dose appears in Al-Ateba neighborhood (a few meters from the water treatment plant), which reached up to 3.5 mg/L with turbidity of 0.2 NTU. This is a high dose which could be harmful for people living near the water treatment plant, especially this dose in January. In February, Chlorine dose reduced to 1.5 mg/L with turbidity 1.2 NTU.

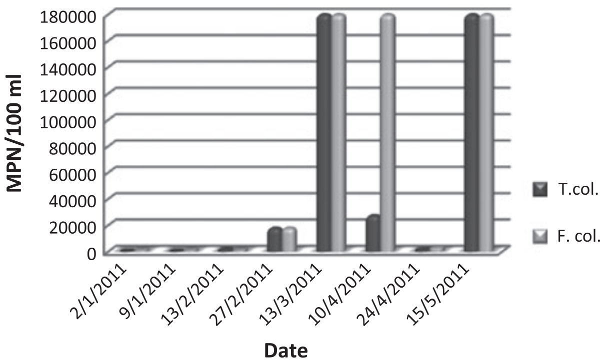


Fig. 2. Bacterial growth for Tigris River.

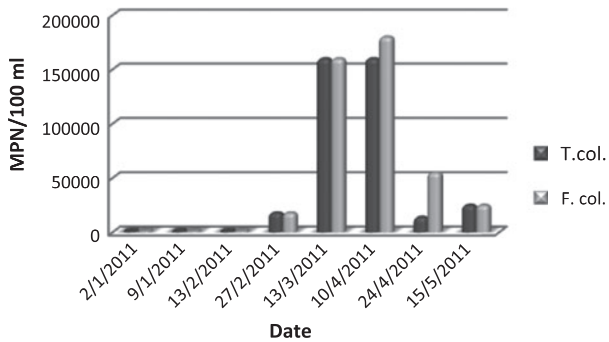


Fig. 3. Bacterial growth for sedimentation tank.

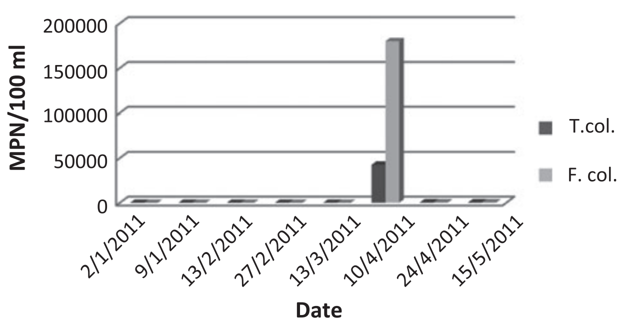


Fig. 4. Bacterial growth for sand filter.

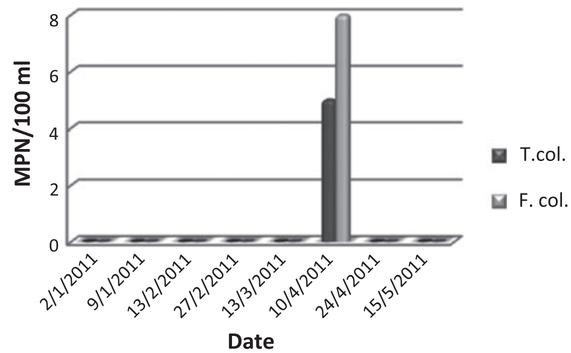


Fig. 5. Bacterial growth for pressure filter.

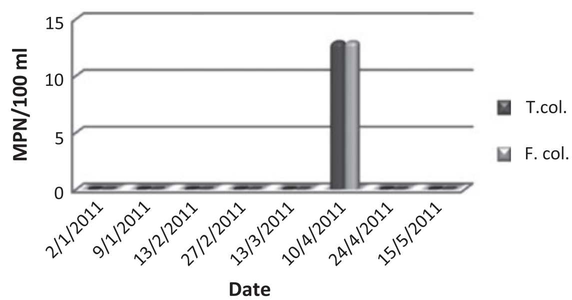


Fig. 6. Bacterial growth for Al-Atebaa neighborhood.

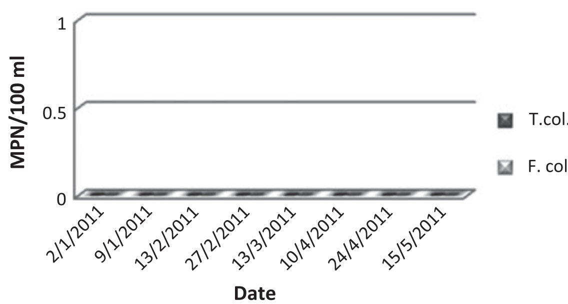


Fig. 7. Bacterial growth for Al-Amen neighborhood.

Pressure filter shows a fluctuating chlorine dose because of the difficulty to control the chlorine dose required for the pressure filter. Hence, it does not depend on the water turbidity entering the filter only, but also the filter may have an accumulative concentration of suspended solids on filter media, bacteria, and organic matter (Fig. 12)

Figs. 13 and 14 represent the fecal coliform and turbidity removal efficiency, respectively. Turbidity removal efficiency for sedimentation tank was better than its removal for fecal coliform; it reached up to 94% in April while fecal coliform removal efficiency was nearly 0%.

Sand and pressure filters' removal efficiency for fecal coliform ranged from 98 to 100%. In April, sand filter removal efficiency dropped to 0%.

Turbidity removal efficiency ranged from 13% in January to 73.3% in April for sand filter and from 93.5% in March to 69.3% in May in the pressure filter.

Turbidity of the water applied to the filters should not exceed 10 NTU and preferably 5 NTU [26].

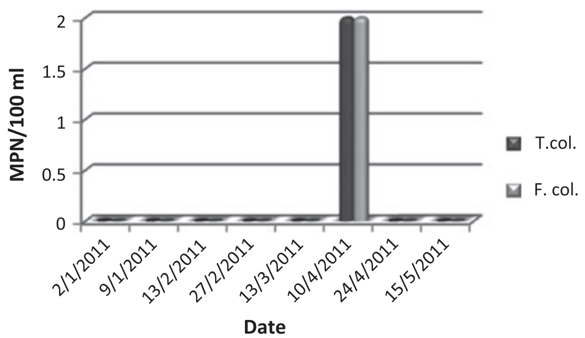


Fig. 8. Bacterial growth for Al-Shorja.

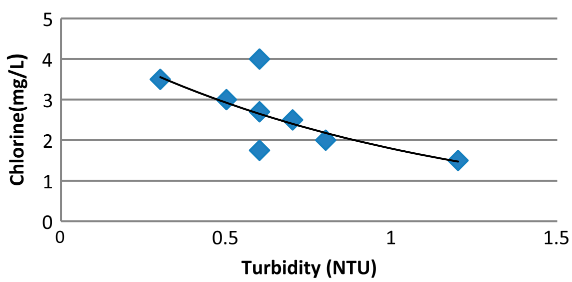


Fig. 9. Turbidity effect on chlorine dose in Al-Atebaa neighborhood.

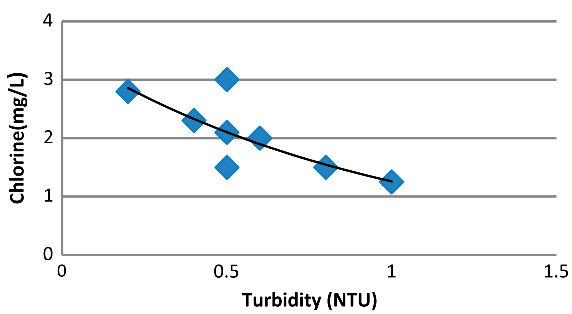


Fig. 10. Turbidity effect on chlorine dose in Al-Amen neighborhood.

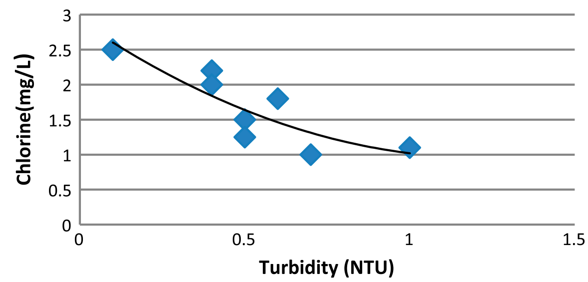


Fig. 11. Turbidity effect on chlorine dose in Al-Shorja.

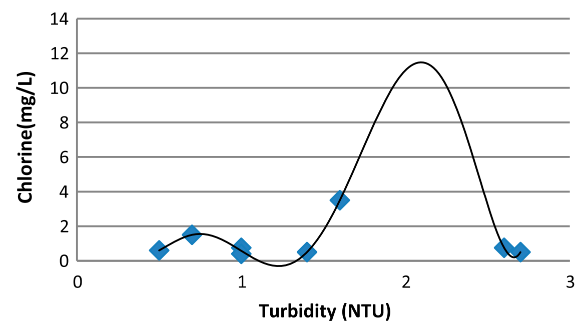


Fig. 12. Fluctuating chlorine dose in the pressure filter.

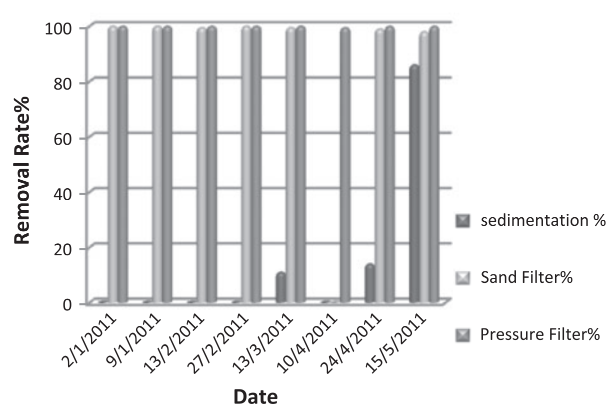


Fig. 13. Fecal coliform removal efficiency.

Turbidity reduced frequently. The maximum turbidity level was reached in April, 150 NTU, and the average raw water turbidity was 66 NTU; the average turbidities for the water treatment plant stages are shown in Fig. 15.

Fecal coliform found in water reduced frequently at the stages of treatment till it dropped to 0% after chlorination (Fig. 16).

Bacterial colonies appeared obviously after testing in Petri dishes for 1 mL of sample of raw water and sedimentation tank water. The average TPC reached up to 400 CFU/mL in raw water sample and 250 CFU/mL in sedimentation tank sample. Colony count reduced after treatment (Fig. 17). European Union Standards indicate that colony count for drinking water must not be more than 100 CFU/mL at 22°C and 20 CFU/mL at 37°C [27].

Generally, average disinfection efficiency at Al-Wathba water treatment plant for total and fecal coliform was 99.99%; percentages of fecal to total colifrom are shown in Table 1.

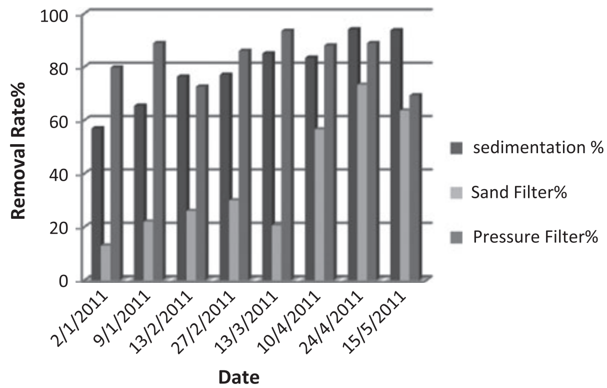


Fig. 14. Turbidity removal efficiency.

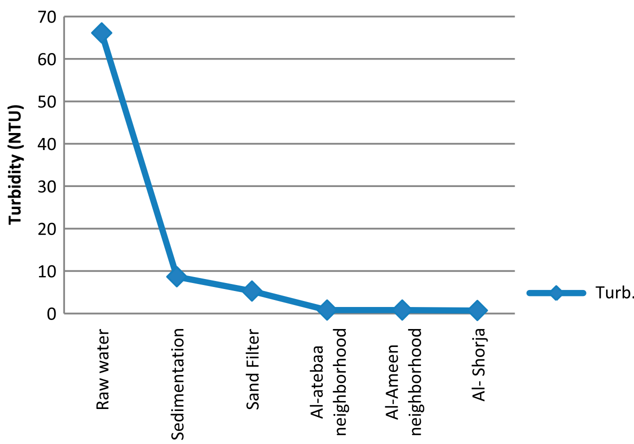


Fig. 15. Average turbidity at water treatment plant stages.

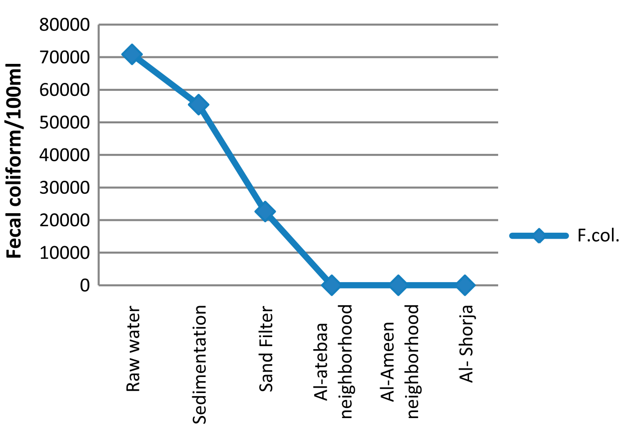


Fig. 16. Average fecal coliform at water treatment plant stages.

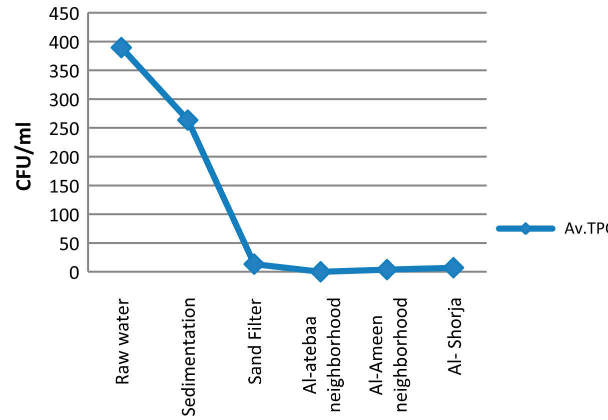


Fig. 17. Average TPC at water treatment plant stages.

From Table 1 it appears that the percentage of fecal coilform is high in raw water. It was 6%, which means the percentage of fecal coliform bacteria was 6% from the total coliform found in water. The remaining 94% was another type of bacteria from the fecal type. This percentage reduced after chlorination in Al-Atebaa, and in Al-Shorja neighborhood it was 100%, which means that most of the coliform bacteria were from the fecal type. This indicates that there may be some leakages from sewage pipes in the surrounding area. The percentage of fecal to total coliform was 0% in the Al-Amen neighborhood.

Concerning sand and pressure filters, the percentages were very high due to the increase the percentage of fecal coliform in filters which hide on (or in) the filter media; these filters need continuous cleaning to eliminate bacterial growth.

Table 2 represents the International Standards for drinking water. Some readings were higher than the standards, especially in April, but the average results of the samples collected were identical to those in the table.

Table 1
Percentages of fecal to total coliform in Al-Wathba water treatment plant stages

| Location | Fecal coliform (Fc) | Total coliform (Tc) | Fc/Tc (%) |
|---|---|---|---|
| River water | 1,579 | 28,919 | 6 |
| Sedimentation tank | 1,425 | 47,800 | 3 |
| Sand filter | 22,627 | 54,406 | 416 |
| Pressure filter | 1 | 0.625 | 160 |
| Al-Atebaa neighborhood | 2 | 1.625 | 100 |
| Al-Ameen neighborhood | 0 | 0 | 0 |
| Al-Shorja | 0.25 | 0.25 | 100 |

Table 2
National requirements for drinking water parameters [28]

| Parameters | Concentration or value maximum |
|---|---|
| Enterococci/100 mL | 0 |
| *Escherichia coli* (*E. coli*)/ 100 mL | 0 |
| Coliform bacteria /100 mL | 0 |
| *Colony count 22°C | 100/mL |
| *Colony count 37°C | 20/mL |
| *Hydrogen ion concentration [H+] | 6.5–9.5 |
| Aluminium, µg/L | 200 |
| Colour, mg/L Pt/Co | 20 |
| Iron µg/L | 200 |
| Manganese µg/L | 50 |
| Odourm dilution number | <1 at 25°C |
| Sodium mg/L | 200 |
| Taste, dilution number | <1 at 25°C |
| Tetrachloromethane µg/L | 3 |
| Turbidity NTU | 4 |

*Drinking Water Inspectorate, Ergon House, Horseferry Rd, London, 2010 [27]

## 7. Conclusions

(1) Fecal coliform bacteria were reduced gradually during treatment. In April, an increase in the fecal coliform was found in the Al-Atebaa neighborhood. This increase may be because of leakages from wastewater pipes.
(2) Fecal coliform percentage increased sometimes due to sediments in sedimentation tank and filters.
(3) Chlorine dose negatively affected the increase of turbidity, causing lack of chlorine residue.
(4) Removal efficiency for total and fecal coliform was 99.99%.
(5) There was no clear relation appearing with pH value.
(6) To control water quality, the treatment plant needs a periodic maintenance and inspection for all treatment stages (especially, sedimentation tank and filters) with annual evaluation for treatment efficiency.

## References

[1] R.Q. Syed, M.M. Edward, Z. Guang, Water Works Engineering, PHI Learning, New Delhi, 2000.
[2] B. Wisner, J. Adams, Environmental Health in Emergencies and Disasters: A Practical Guide WHO, 2002. www.who.int/water-sanitation-health/hygiene/emergencies
[3] F. Colin, Monitoring of Water Quality, Elsevier Science, Oxford, 1998.
[4] New York State Department of Health, Center for Environmental Health, West Publishing, Washington, DC, 2011.
[5] World Health Organization, Surveillance of Drinking Water Quality, fourth ed., vol. 4, Amman, Jordan, 2000.
[6] R.E. Ralph, Environmental Microbiology. Division of Applied Science, Harvard University, Wileyliss, Cambridge, New York, NY, 1992.
[7] A.K. Payment, A Prospective epidemiological study of drinking water related gas trointestinal illnesses, Water Sci. Technol. 20(9) (1991).
[8] Extension Educator, Source of Bacteria in Drinking Water, 2004.
[9] G. Stanfield, M. Le Chevalier, M. Sonzzi, Assessing microbial safety of drinking water, improving approaches and methods, improving approaches and methods, Proceedings of IWSA International Conference, IWA Publishing, London, 1998.
[10] G.C. White, Handbook of Chlorination for Potable Water and Wastewater Cooling Water Industrial Processes, and Swimming Pools, Litton Educational Publishing, New York, NY, 1997.
[11] K. Cantor, Bladder cancer drinking water sources and tap water consumption: A case control study, J. Environ. Health Perspective, 70(20) (1996).
[12] World Health Organization, 2003, pH in Drinking Water, Background document for development of WHO Guidelines for Drinking –Water Quality, second ed., vol. 2. Health Criteria and other Supporting Information www.who.int/water-sanitation-health/dwq/chemicals.pdf
[13] R.S. Martin, W.H. Gates, R.S. Tobin, D. Grantham, P. Forestall, Factors growth in distribution system, J. AWWA 74(1) (1982).
[14] World Health Organization, Guidelines for Drinking – Water Quality. 2nd ed., vol. 2. Health Criteria and other Supporting Information, Geneva, 1996.
[15] P. Singleton, Bacteria in Biology Biotechnology and Medicine, 4th ed., Wiely, London, 1997.
[16] J.K. Silvey, D.E. Henley, J.T. Wyatt, Plank tonic blue-green algae: Growth and odor-production studies, J. AWWA 64(35) (1972), reprinted 1995, Date Modified: 6/2/2009.
[17] R.S.N. Raju, Water Supply and Wastewater Engineering, McGraw Hill, New York, NY, 1995.
[18] M.W. Le chevalier, T.M. Evans, R.J. Seidier, Effect of Turbidity on Chlorination Efficiency and Bacterial Persistence in Drinking Water, American Society for Microbiology, 2011, http://www.intl-aem-asm.org
[19] R.R. Pierce, E.K. Weiner, Free chlorine versus ammonia chlorine: Disinfection, TLAM, formation and zooplancion removal, J. AWWA 75(4) (1988).
[20] MWH, Water Treatment Principles and Design, 2nd ed., Wiley, Hoboken, NJ, 2005.
[21] A.C. Twort, F.M. Law, F.W. Crowely, D.D. Ratnayaka, Water Supply, 4th ed., John Wiley & Sons, London, 1994.
[22] S.J. Al-Malikey, 1993, Effect of Tigris River pollution on the performance of water treatment plants in Baghdad City, M.Sc. Thesis, College of Eng., University of Baghdad.

[23] R.H. Alwan, 2001, The Impact of the blockade and economical sanction on the drinking water quality in baghdad city and their harmful effect on the population health, M.Sc. Thesis, College of Eng., University of Baghdad.
[24] M.J. Hammer, Water and Wastewater Technology, 2nd ed., Wiley, London, 1986.
[25] APHA, Standard Methods for the Examination of Water and Wastewater, 18th ed., American Public Health Association, Washington, DC, 1995.
[26] E.W. Steel, T.J. McGhee, 1982, Water Supply and Sewerage, McGraw-Hill.
[27] EU Drinking Water Standards–2011, Lenntech BV www.lenntech.com/applications/drinking/standards
[28] Drinking Water Inspectorate, Ergon House, Horseferry Rd, London, 2010. Guardians of drinking water quality. Drinking water Inspectorgate, pp. 2–5. dwi.enquiries@defra.gsi.gov.uk, www.dwi.gov.uk