IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 4 Issue 4, April 2017
ISSN (Online) 2348 – 7968 | Impact Factor (2016) – 5.264
www.ijiset.com

Microbiological Quality of Riyadh Water Supplies and Effect of Intermittent Water Supply on the Bacterial Quality in the Water Distribution Network

Abdulrahman I. Alabdula'aly and Mujahid A. Khan

King Abdulaziz City for Science and Technology, P.O. Box 6086, Riyadh -11442, Saudi Arabia

abdulaly@kacst.edu.sa

Abstract

Water samples were collected from 53 locations of Riyadh water distribution network and analyzed for total coliform and heterotrophic plate counts in addition to temperature, turbidity, and residual free chlorine. Water temperature was found to vary between 29-39^{o}C, turbidity between 0.02-2.9 NTU, and residual free chlorine between 0.4-0.7 mg/L.Total coliforms were found to be absent in all samples whereas heterotrophic plate count varied between 4-212 counts/ml with an average value of 69 counts/ml. An attempt was also made to find a relationship between heterotrophic plate count and turbidity, residual free chlorine, and temperature. The effect of water scheduling on the water quality was also studied and it was found that no flow conditions in the distribution network affects the bacterial quality of water to an extent.

Keywords: *Microbiology, water distribution network, total coliform, heterotrophic plate count, no flow condition.*

1. Introduction

The safety of drinking water is assumed and taken for granted by consumers in most developed countries. Yet, the understanding of the microbial ecology of drinking water distribution networks is limited, partly as these environments are not easily accessible and because they have traditionally been considered as challenging environments for microbial life when compared with other aquatic ecosystems. However, available scientific literature indicates that drinking water distribution network are diverse microbial ecosystems microbial life from viruses to protozoa can be found (Szewzyk et al. 2000). Modern water treatment works can produce safe drinking water reliably, efficiently and effectively, starting from a variety of sources and initial qualities. While safe and of high quality, this water is far from sterile. Treated water is transported to end users through a diverse and complex water distribution infrastructure. Preventive measures are taken to control water quality, including microbial contamination, at treatment works and via the provision of disinfection residuals in the majority of drinking water distribution networks. Nonetheless, some microorganisms can persist after treatment and enter and live within distribution systems (Szewzyk et al. 2000). Microorganisms can also enter distribution networks during installation, repair or replacement of infrastructure and by net ingress under dynamic or other depressurization events (Besner et al. 2011). Once microorganisms are within a drinking water distribution network they will face a challenging environment, with limited nutrients and changing water flow and pressure fluctuations. More than 95% of the microbial biomass in a drinking water distribution network is attached to the pipe walls forming bio films (Flemming et al. 2002).

Drinking Water Distribution Systems are complicated engineering systems consisting of pipes, storage vessels, fittings, valves, etc. made of a variety of different materials such as cast iron, PVC and polyethylene that interact with the bulk water. The water that consumers drink at the tap has travelled potentially large distances taking significant durations through the distribution network and it is accepted that from leaving the treatment plant deterioration in quality might occur. This deterioration in water quality could be influenced by factors such as decay of disinfectant residual, temperature, hydraulic regime, water residence time and bacterial re-growth (Machell et al. 2010; Ramos et al. 2010). Recently a research by Douterelo et al. (2014) investigated the influence of pipe characteristics on the bacteriological composition of material mobilised from a drinking water distribution system and the impact of biofilm removal on water quality. High relative abundances of Alphaproteobacteria (23.3%), Clostridia (10.3%) and Actinobacteria (10.3%) were detected in the material removed from plastic pipes. Sequences related to Alphaproteobacteria (22.8%), Bacilli (16.6%), and Gammaproteobacteria (1.4%) were predominant in the samples obtained from cast iron pipes (Douterelo et al. 2014).

Inflow to the distribution system is normally disinfected but may undergo deterioration bacteriologically before it reaches the consumers. The presence of microorganisms in a distribution system may result from plumbing cross connections, reduction in line pressure, contamination of storage facilities, stagnant water in dead end pipes, seasonal temperature changes, particles deposition, low flow rates in pipes, line breaks and repairs (Geldreich et al. 1972). The accumulation of corrosion particles may also provide protection for bacteria, yeast, and other microorganisms. Once there, such organisms may reproduce and cause health related problems.

Little in-depth information is available in literature on the identity of all heterotrophic organisms that can be found in water supplies. However, the spectrum of organisms may include many gram-negative bacteria like coliforms, pseudomonas, chromobacter, enterobactor, and Klebsiella pneumonia etc.

The National Academy of Science (1986) reported that high bacterial levels should be expected in water that has been stagnant or has remained in pipes overnight. It has been found that an average colony counts in seven Florida distribution systems were about three times higher at temperature 20^{o}C than at 10^{o}C (Hanson et al. 1987). It has been shown that high turbidity in water supply is usually accompanied by an increase in bacterial levels (Geldreich, 1975).

For total coliforms, the World Health Organization (WHO) (1984) and the United States Environmental Protection Agency (USEPA, 1989) have set a guide line value of zero coliforms /100 ml samples. Because of its lack of specificity, the heterotrophic plate count (HPC) cannot be correlated with any waterborne disease outbreak. However, drinking water having any positive HPC level might contain many, few, or no pathogens. The significance of the HPC lies in its indication of poor general biological quality of drinking water. Five hundred colonies per ml have been suggested an upper level above which corrective actions should be taken.

The present paper, describes the results of a study carried out on the drinking water microbiological quality in the Riyadh water distribution network. The effect of water scheduling on bacteria has also been presented.

2. Study Area Scenario

The study was carried out in Riyadh, the capital city of Saudi Arabia, with a population of about 5 million inhabitants. About 66% of the total water supply is desalinated sea water supplied from the Arabian gulf about 400 km east of the city. The remaining 34% is supplied from ground water being treated in six water treatment plants (AlWasia, Manfouha I & II, Buwaib, Salboukh, Shemessy and Malaz)located in the vicinity of the city. The plants water treatment process include cooling, chemical softening, filtration, reverse osmosis and disinfection.

The Riyadh water distribution network has more than 9000 km of pipes with ages varying between less than 10 to over 30 years for both new and old parts of the system. The average pressure in the network is between 2 and 5 bars (Al-Dhowalia and Shammas, 1991) High pressures give rise to leakage in the network due to pipe cracks and joint failure etc. Leakage may have direct impact on the distribution system water quality. Leak points can be the source of contamination as they provide access to the contaminants due to the water table rise and seepage from septic tanks. Consequently bacteria, toxic metals, and other elements may be injected into the distribution network where water quality could be affected. Due to limited supply of potable water and its large demand, water scheduling is also resorted to in Riyadh. In general, each district is supplied with water for a period of 3-4 days in a week. During no flow periods, there is a likelihood of increased bacterial activity in the distribution network resulting in water quality deterioration.

3. Materials and Methods

3.1 Sampling

Samples were collected from 53 locations within 48 city districts in Riyadh. Sample location selection was based on the system age, presence of high water table rise, and sewer connection availability. Samples were collected from user's water meters (point of entry). Samples for bacteriological analyses were collected in pre-sterilized

Millipore Whirl Pack sampling bags containing sodium-thiosulfate to remove any trace of residual chlorine. To study the effect of water scheduling on the network bacterial quality, samples were collected from one selected location for a period of two hours at specified intervals. All samples were transported to the laboratory in ice boxes.

3.2 Analyses

The samples were analyzed for temperature, turbidity, residual free chlorine, total coliform, and heterotrophic plant counts. Temperature, turbidity and residual chlorine were measured in the field. Total coliform and heterotrophic plate counts were determined using Membrane Filter Method. All the analyses were carried out as described in the Standard Methods (1992). For bacteriological analyses, pre-sterilized filters, filter pads, and petriplates from Millipore were used. Filtration funnels, forceps, and other accessories were steam autoclaved to avoid any possible external contamination.

3.3 Total Coliforms

Total coliform determination by membrane filtration method provides a thorough examination by using a larger sample size. One hundred ml sample was filtered through 47 mm diameter Millipore HA type membrane filters of 0.45 µm pore diameter. After filtration, the membrane filters were placed in petriplates on sterile filter pads previously saturated with 2.0 ml of M. Endo broth. Inoculated plates were incubated for 24 hr at 35 ± 0.5^{o}C and then examined for typical metallic sheen producing colonies. Analyses were performed in triplicate for each sample.

3.4 Heterotrophic Plate Cont

Four sample dilutions viz 5%, 10%, 25% and 50% were prepared in sterile phosphate buffer and filtered through 47 mm diameter Millipore HA type membrane filters of 0.45 µm pore diameter. After filtration, the membrane filters were placed in petriplates on sterile filter pads previously saturated with 2.0 ml of Millipore's sterile total count medium. Inoculated plates were incubated for 48 hr at 35^{o}C.

4. Results and Discussion

The maximum, minimum, and average values of the measured parameters are presented in Table 1. The results indicate that the temperature throughout the network was in the range of 29-39^{o}C. The residual free chlorine was found in appreciable amounts and varied between 0.4-0.7 mg/L, whereas the turbidity was found to vary between 0.02-2.9 NTU.

4.1 Total Coliforms

Results indicate that total coliforms were absent in all the samples collected from Riyadh Water Distribution Network. Coliform presence may indicate possible fecal contamination and the likely presence of microbial pathogens (Scarpina et al., 1987). If present, coliform have capacity of sustaining and replicating within the distribution network.

4.2 Heterotrophic Plate Count

The heterotrophic plate counts varied between 4-212 plate counts per ml (PC/ml) with an average value of 69.0 counts/ml. The maximum 212 PC/ml were found for a location in the south west side of the city. Sixty seven percent of the samples had < 100 PC/ml whereas the rest of the samples had values between 101-212 PC/ml. The ranges of heterotrophic plate counts for the different samples have been provided graphically in Figure 1. The relatively high plate count values at some sampling locations may be attributed to one or more of the following: network conditions; ground water table rise; septic tanks.

However, all the samples had plate counts less than the stipulated maximum value of 500 PC/ml.

4.3 Relationship between Turbidity and Heterotrophic Plate Count

The turbidity was low throughout the distribution network. About 87% of the samples had turbidity below 0.5 NTU. The maximum obtained turbidity was 2.9 NTU whereas the minimum turbidity was 0.02 NTU. In general the network water turbidity was quite similar to the product water of different treatment plants and desalinated water. The different treatment plants product water namely AlWasia, Manfouha, Buwaib, Salboukh, Shemessy, Malaz and the desalinated water line had turbidity measurements of 0.02, 0.85, 0.23, 0.23, 0, 0.22, 0.15 and 0.05 NTU, respectively. Therefore, due to the less significant variation in the turbidity values, no relationship could be established between turbidity and plate counts density. However, turbidity monitoring in the distribution system is a good quality control practice. Values in excess of 5 NTU may signal the need to flush the distribution system and to search for areas of pipe corrosion that must be brought under control (Organisms in Water Committee Report, 1987).

4.4 Relationship between Residual Free Chlorine and heterotrophic Plate Count

Residual free chlorine was present in appreciable amounts. It varied between 0.4-0.7 mg/L. Stability of disinfectant during water supply distribution is important particularly to reduce or prevent colonization by surviving organisms and to inactivate bacteria associated with the intrusion of contamination in the pipe network. In an extensive study involving 986 samples taken from Baltimore and Frederik, MD., distribution network, the maintenance of free residual chlorine was the single most effective measure for maintaining a low standard plate counts (Snead et al., 1980). In fact a study of 969 public water systems, Szewzyk et al. (2000). revealed that standard plate counts of 10 organisms or less were obtained in over 60% of these distribution systems that had residual chlorine approximately 0.3 mg/L. In the present study though no clear cut relationship could be established between the increasing residual free chlorine and the bacterial count but in general it was observed that above a certain residual chlorine level (0.5 mg/L), very few samples (9%) were found to contain any bacterial count.

4.5 Relationship between Water Temperature and Heterotrophic Plate count

Water temperature above 50^{o}F (10^{o}C) accelerates the growth of some organisms. Data available from water networks located in geographical areas of pronounced seasonal temperature changes suggest that abrupt surges in heterotrophic plate counts may occur in summer (Geldreich et al., 1977). In the present study comparatively higher plate count values found at some sampling locations may also be attributed to the water temperature in the network pipes. However no direct relationship between increase in temperature and plate counts could be established due to the fact that the temperature range is low (29-39^{o}C).

4.6 Effect of Intermittent Water Supply on Bacterial quality of Water in the distribution Network

Due to the high demand of water in Riyadh, its distribution to the different parts of the city follows a certain schedule. Pumping of water is stopped for as long as four days in different part of the city by rotation. During this period when there is no flow of water, there is a likelihood of increased bacterial activity in the network. For that and due to the fact that parts of the city do not have sewer connections in addition to the existence of high water table rise, it would be then expected that the bacterial quality in the distribution network may deteriorate especially in areas with network leakage. Therefore, to investigate the effect of scheduling on water bacterial quality, one location was selected and samples were collected at 0, 2, 6, 10, 15, 20, 25, 30, 35, 40, 50, 60, 80, 100, and 120 min after the start of water pumping (Figure 2). Results show that no flow conditions in the distribution network due to water scheduling affects the bacterial quality of water but not to a degree that would warrant corrective actions at least in the location studied.

5. Summary and Conclusion

Water samples from 53 locations representing 48 districts of Riyadh were collected from its water distribution network and analyzed for temperature, turbidity, residual free chlorine, total coliform and heterotrophic plate counts. Temperature varied between 29-39^{o}C, turbidity between 0.02-2.9 NTU, and residual free chlorine between 0.4-0.7 mg/L. Total coliform were found to be absent whereas heterotrophic plate counts varied between 4-212 counts/ml. The effect of water scheduling on water quality was also studied and it was found that no flow conditions in the distribution network affects slightly the water bacterial quality. The results showed that the drinking water bacterial quality was good in Riyadh water distribution network as evident by absence of coliforms and low plate counts. However, the effect of water scheduling on plate count and other parameters in different districts should be studied in detail.

Table1 **:** Maximum, minimum, and average values with standard deviation of different measured parameters in water samples of Riyadh Water distribution network.

Parameters	Maximum	Minimum	Average	Standard deviation
Temperature (°C)	39	29	36	2.2
Turbidity (NTU)	2.9	0.02	0.41	0.59
Residual free chlorine (mg/L)	0.7	0.4	0.46	0.06
Total Coliforms	Absent	Absent	-	-
Heterotrophic plate count (per ml)	212	4	69	67.8

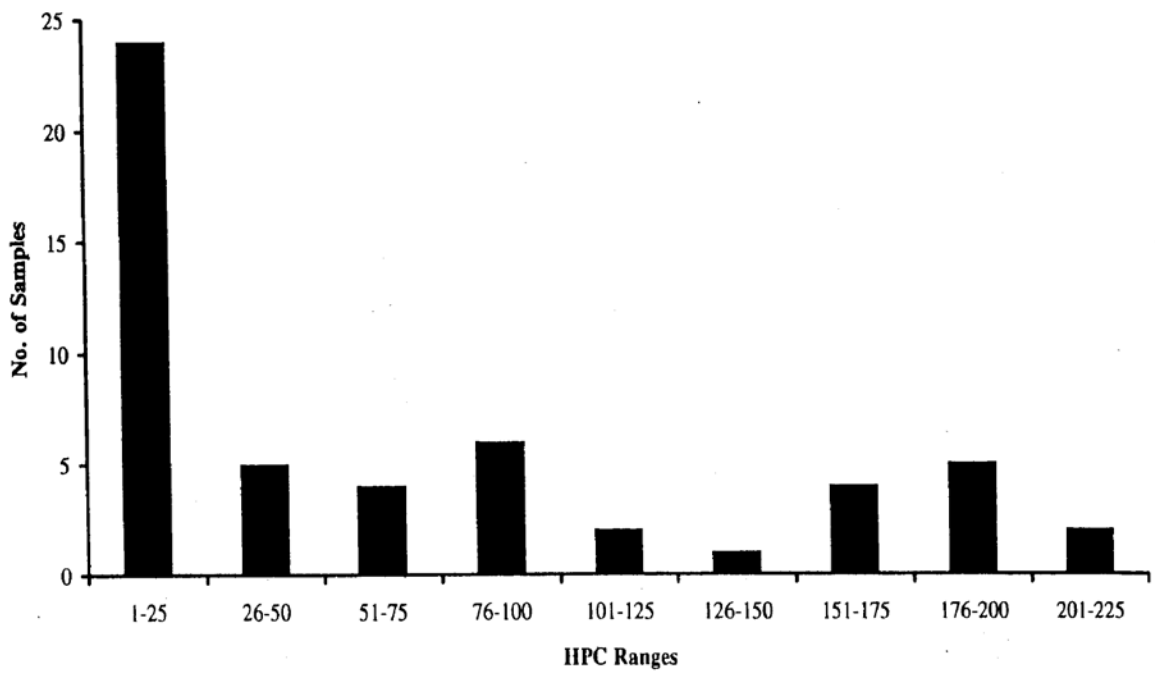

Figure 1. Range of heterotrophic plate counts at different sampling locations.

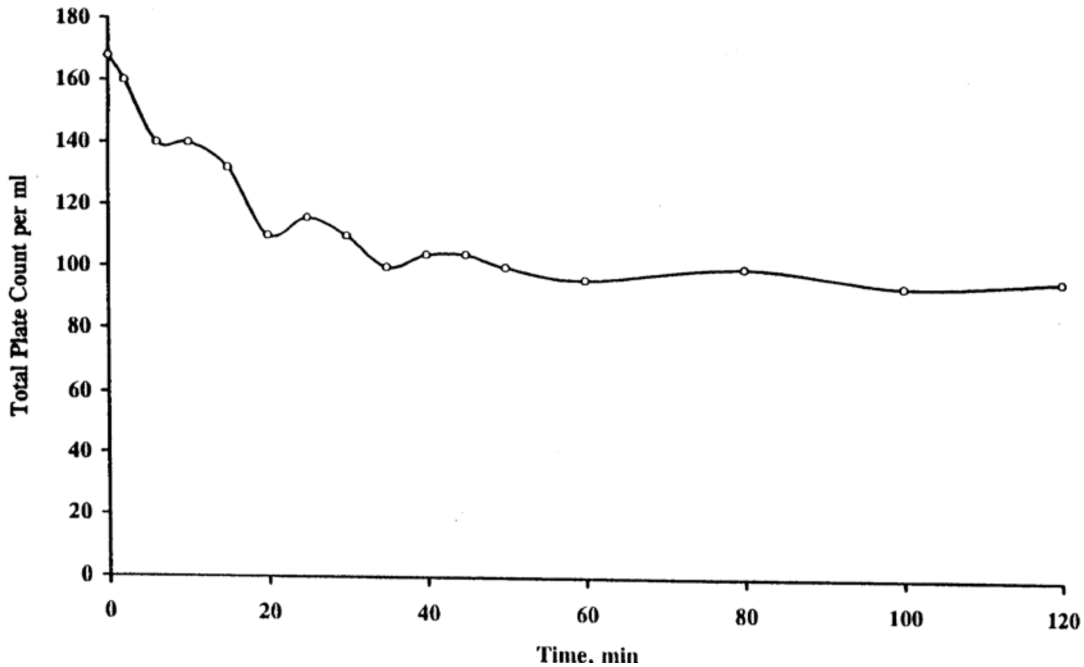

Fig. 2. Effect of water scheduling on Heterotrophic Plate Counts in the Riyadh Water Distribution Network

Acknowledgement

This work was financially supported by King Abdulaziz city for Science and Technology (KACST), Riyadh, Saudi Arabia.

Acknowledgement

This work was financially supported by King Abdulaziz city for Science and Technology (KACST), Riyadh, Saudi Arabia.

References

[1] Al-Dhowalia, K.H., Shammas, N.K., 1991, Leak detection and quantification of losses in a water network, Water Resources Development, 7 (1), pp. 30-38.

[2] Besner, M.C., Prevost, M., Regli, S., 2011, Assessing the public health risk of microbial intrusion events in distribution systems: conceptual model, available data, and challenges. Water Res. 45 (3), pp. 961-979.

[3] Douterelo, I., Husband, S., J.B. Boxall, J.B., 2014, The bacteriological composition of biomass recovered by flushing an operational drinking water distribution system, Water Research, 54, pp. 100 -114.

[4] Flemming, H.C., Percival, S.L., Walker, J.T., 2002, Contamination potential of biofilms in water distribution systems. Innov. Convent. Adv. Water Treat. Process. 2, pp. 271-280.

[5] Geldreich, E.E. , Nash, H.D., Reasoner, D.J., Taylor, R.H., 1972, The necessity of controlling bacterial populations in potable waters, Community Water Supply". J. AWWA, 64 (9), pp. 596.

[6] Geldreich, E.E. ,1975, Handbook for evaluating water bacteriological laboratories, 2nd ed, EPA 670/9-75-006, Cincinnai, OH: USEPA, August 1975, pp. 19.

[7] Geldreich, E.E., Nash, H.D., Spino, D., 1977, Characterizing bacterial populations in treated water supplies: A progress report, Proc. Am. Water Works Assoc. Water Tech. Conf., Knsas City Mo. December 1977.

[8] Hanson, F.H., Hasted, S.S., Mueller, L.M., Goff, D.R., 1987, Deterioration of water quality in distribution systems, AWWA Research Foundation, Denver, Colorado, pp.158.

[9] Machell, J., Mounce, S.R., Boxall, J.B., 2010, Online modeling of water distribution systems: a UK case study. Drink. Water Eng. Sci. 3, pp. 21-27.

[10] National Academy of Science, "Drinking Water and Health", 1986, Vol. 6, Safe Drinking Water Committee, National Research Council, Washington, D.C., National Academy Press, pp. 37.

[11] Organisms in Water Committee Report, Microbiological considerations for drinking water regulation revisions, 1987, J. AWWA, 79 (5), pp. 81.

[12] Ramos, H., Loureiro, D., Lopes, A., Fernandes, C., Covas, D., Reis, L.F., Cunha, M.C., 2010, Evaluation of chlorine decay in drinking water systems for different flow conditions: from theory to practice. Water Resour. Manag. 24, pp. 815-834.

[13] Scarpina, P.V., Kellner, G.R., Cook,H.C., 1987, The bacterial quality of bottled water", J. Environ, Sci. Health, A, 22 (4), pp. 357-367.

[14] Snead, M.C., Olivieri, V.P., Kawata, K., Kruse, C.W., 1980, Biological evaluation of benefits of maintaining a chlorine residual in water supply systems, Water Research, 14, pp. 403.

[15] Szewzyk, U., Szewzyk, R., Manz, W., Schleifer, K.H., 2000, Microbiological safety of drinking water. Annul Rev. Microb. 54, pp. 81-127.

[16] Standard Methods for the Examination of Water and Wastewater, 1992, AWWA,APHA,WPCF, 18th Edition, Washington D.C.

[17] USEPA, 1989, Guidance manual for compliance with the filtration and disinfection requirements for public water supplies using surface waters, National Technical Information Services PB 90 148016/AS.

[18] World Health Organization. "Guidelines for Drinking Water Quality", 1984, Geneva.

First Author: Prof. Abdulrahman I. Alabdulaaly received his Ph.D degree from the University of Rhode Island in the year 1987 in Environmental Engineering. After that he joined King Abdulaziz City for Science & Technology, Riyadh, Saudi Arabia as Research Scientist. In 1990, he became Director General of a research funding department in the same organization. During his research career he published large number of research papers in journals of good scientific repute. He has also attended a number of conferences. Dr. Alabdulaaly received the coveted Prince Sultan International Prize for the ground water research. He was also awarded four patents by the US department of Patents.

Second Author: Dr. Mujahid Ali Khan received his Ph.D degree from A. M. U. Aligarh, India in the year 1983 in Chemistry. After that he joined A.E. S. Testing and Research Laboratory, New Delhi, India as Chief Analyst. In 1993 he joined King Abdulaziz City for Science & Technology, Riyadh, Saudi Arabia as Research Scientist. During his research career he published large number of research papers in journals of good scientific repute. He has also attended several conferences. Dr. Khan received the coveted Prince Sultan International Prize for the ground water research along with Dr. Alabdulaaly in the year 2006. He has also been awarded four patents by the US department of Patents.