CHEMICAL ENGINEERING TRANSACTIONS

VOL. 65, 2018

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Eliseo Ranzi, Mario Costa

ISBN 978-88-95608-62-4; **ISSN** 2283-9216

DOI: 10.3303/CET1865086

Microbial Community Change and Distribution in Tap Water Supply System

Junzhi Guo[a], Xiuwei Yang[b,*]

1 Kuancheng Manchu Autonomous County Water Supply Company, Chengde 68350, China
2 College of Urban and Rural Construction, Hebei Agricultural University, Baoding 071000, China
617184215@qq.com

The tap water quality safety in cities matters greatly for national economy and people's livelihood. This paper, based on the high organic matter and high ammonia nitrogen water supply and drainage system, explores what is the impact law of different water treatment processes on the water supply and drainage system, and suggests that the ambient temperature has a greater impact on the water temperature; what is the change laws of turbidity, ammonia nitrogen and oxygen consumption in the water supply and drainage system in different seasons and finds that there are seasonal differences significant in color and turbidity. The biological pretreatment process has little impact on the two. The ammonia nitrogen content in water source is slightly higher in summer than in winter. The pretreatment process can effectively reduce the ammonia nitrogen content in water; but the oxygen consumption drops a little after biological pretreatment. We make OUT statistical analysis and DNA matching in order to clarify the radial distribution in the space and diversity composition of the microbial community in the tap water supply pipeline. The results reveal that in large-diameter pipeline microorganisms disperse more on the top and bottom than in the middle. There are predominant bacteria on the top and bottom part but most diverse bacteria in the middle part. These fruits can provide the basis for improving the water supply and drainage treatment and water quality.

1. Introduction

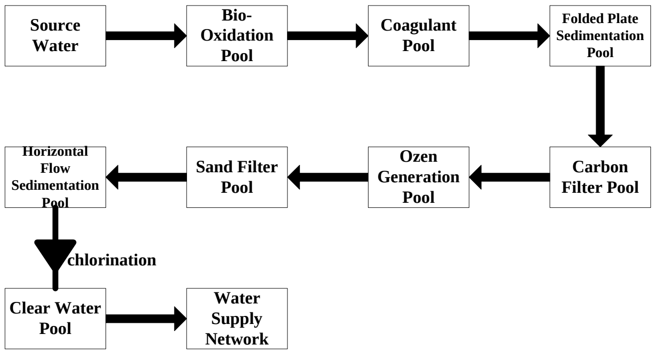
The urban water supply and drainage is an important livelihood issue that has been explicitly proposed in the *National Science and Technology Development Plan for the Twelfth Five-Year Plan* and needs to be addressed. In recent years, the treatment process for urban water supply and drainage systems has been continuously improved (Jack and Swaffield, 2009; Yan et al., 2018; Houria et al., 2017), and additionally, ozone-activated carbon, biofilm filtration and other advanced treatment processes are gradually added on the grounds of coagulation, sedimentation, filtration, and disinfection so that the urban water supply and drainage system has significantly improved the water quality (Hassanain et al., 2015). However, as for the microorganism in the water supply and drainage systems, up to now only six indicators have been supervised (Ramo and López, 2013). For this reason, the microbial community in tap water presents unstable, and worse, a breeding ground is provided for the growth of certain pathogenic bacteria.
The urban water supply and drainage system has a long pipeline distance, coupled with inconsistent dwell time, which make a room for the microorganisms in the water supply pipeline system to grow and proliferate, causing secondary pollution of water quality (Dragon et al., 2016; Fujimoto et al., 2008). It is extremely essential for us to discuss what are the ecological distribution and mutation laws of microbial communities in tap water supply pipes.
For this purpose, this paper takes a tap water quality in eastern coastal cities as the study case, combines tap feedwater treatment process and tap water supply pipeline system to study it in attempt to provide a basis for improving treatment process and tap water quality in this regard.

Please cite this article as: Junzhi Guo , Xiuwei Yang , 2018, Microbial community change and distribution in tap water supply system, Chemical Engineering Transactions, 65, 511-516 DOI: 10.3303/CET1865086

2. Impact of water supply and drainage system treatment process on distribution and mutation laws of microbial community

2.1 Water treatment system and process

In recent years, the tap waterworks have adopted four conventional processes, i.e. oxidation, coagulation, sedimentation and filtration (Mueller et al., 2011). In this case, we take samples from a water plant in the eastern city, while biological pretreatment and advanced treatment processes are also added for high-algae, high-organic, and high-nitrogen water sources. At last, water disinfected with chlorine flows into urban tap water pipelines. The process flow is shown in Fig. 1.



Figur 1: Schematic diagram of water works water process flow

2.2 Sampling analysis of water quality index

In order to ensure reliability and accuracy of test, in accordance with the technology process, 18 points (10 water sampling points and 8 microorganism sampling points) are analyzed with specific parameters as shown in Table 1 below.

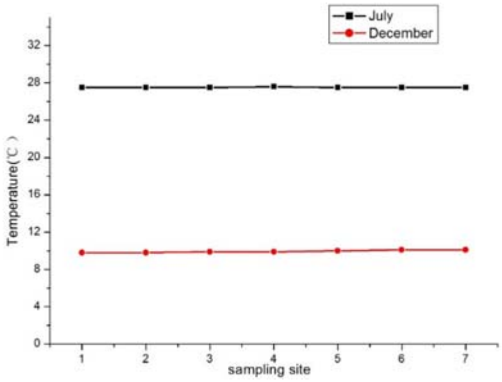
Table 1: Sampling Point Details

Process Flow	Water Sample	Microbe Sample
Source Water	√	
Bio-Oxidation Pool Inlet	√	√
Bio-Oxidation Pool Outlet	√	√
Folded Plate Sedimentation Pool Inlet	√	√
Folded Plate Sedimentation Pool Outlet	√	√
Horizontal Flow Sedimentation Pool Inlet	√	√
Horizontal Flow Sedimentation Pool Outlet	√	√
Sand Filter Pool	√	√
Ozen Generation Pool	√	
Carbon Filter Pool	√	√
Clear Water Pool	√	

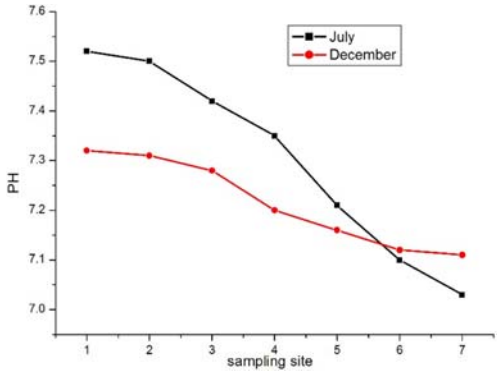
The selected supervision indicators are shown in Table 2 below.
The quality of water source is analyzed based on historical data about water supply and drainage system (2012-2017). The results of the water quality analysis are shown in Table 3. It is obvious that the water quality of the water supply and drainage system is the Class IV water of the river network, where there are pollutants phosphorus and ammonia nitrogen, heavy metal and permanganate; the total number of bacterial colonies is higher.

2.3 Impact of Different Treatment Processes on Water Quality

After a great deal of experiments, with reference to the findings from previous studies (Pauw et al., 2015; Baker et al., 2015; Nadilo, 2011), the paper investigates what is the impact of different treatment processes on the water quality temperature, pH value, chromaticity, turbidity, and ammonia nitrogen content, oxygen consumption, AOC, BGP, and microbial community population. Select the effluent from each process for continuous tests to obtain average temperature and pH data. As shown in Fig. 2, the water temperature is vulnerable to ambient temperature, but not prone to be affected by the different technologies. The proceses make the tap water pH drop a little, but obviously in the higher ambient temperature, for example, in July.

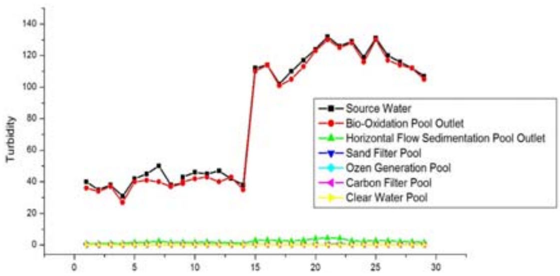


(a) Temperature

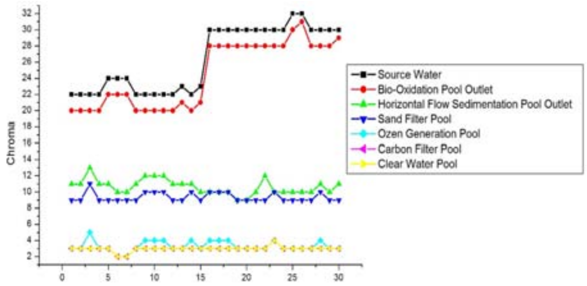


(b) PH

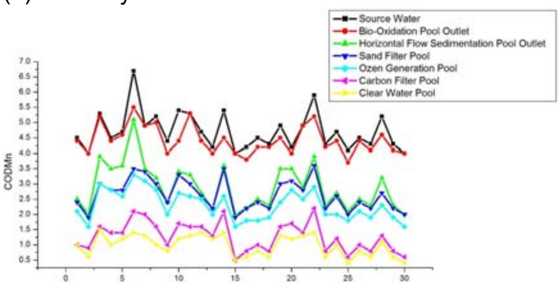
Figure 2: Water temperature and PH change



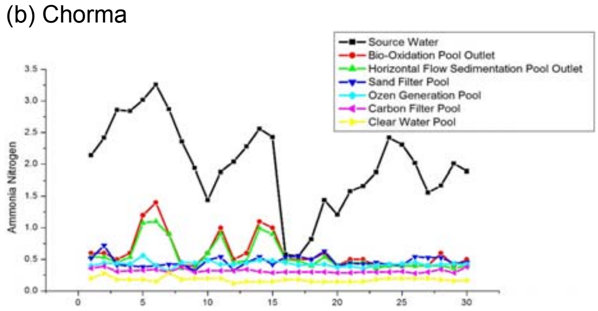
(a) Turbidity



(b) Chorma

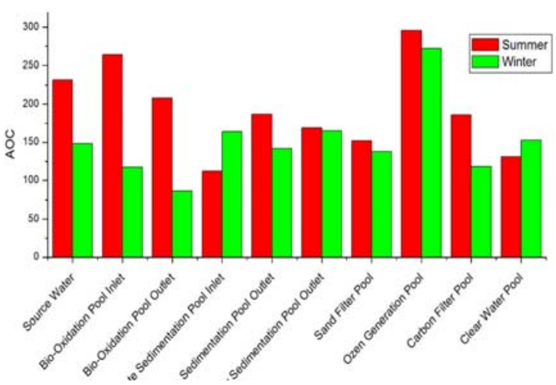


(c) Chorma

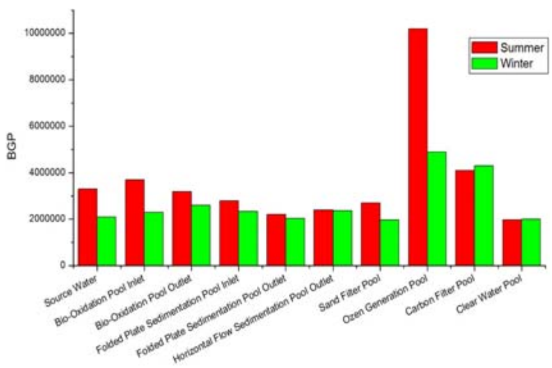


(d) Ammonia Nitroge

Figure 3: Chorma, Turbidity, Ammonia Nitrogen, COD_{Mn} Contents in City Water Process Flow



(a) AOC Contents



(b) BGP Contents

Figure 4: AOC and BGP Contents in City Water Process Flow

Select the effluent from each process to investigate the changes in color, turbidity, ammonia nitrogen content, and oxygen consumption in summer and in winter of 2017, for resultant curve, see Fig. 3, where 1-15 stands for summer, and 16-30 for winter. As can be seen on the map, the seasonal differences in terms of color and turbidity are obvious. The biological pretreatment process has little impact on the two. Coagulation, sedimentation, and sand filtration can reduce color and turbidity by more than 85%. Ozone and activated carbon adsorption can further reduce the color and turbidity; the ammonia nitrogen content in water is slightly higher in summer than in winter, and the pretreatment process can effectively reduce the ammonia nitrogen content in water; the oxygen consumption declines a little after biological pretreatment; in water source, coagulation, precipitation, filtration and ozone activated carbon adsorption can remove about 50% oxygen consumption, as a major COD process.

Select each process to obtain the AOC and BGP curves, as shown in Fig. 4, where 1-15 represents summer, and 16-30 represents winter. We can learn from the curves that the concentrations of AOC and BGP are higher in summer than in winter. After biological pretreatment and carbon filtration, AOC decreases significantly. After the ozone process, the AOC rapidly increases to the peak. The AOC content remains constant in other processes. BGP slightly hikes up slightly after the biological pretreatment process, and tops off after ozone treatment, but swoops after activated carbon adsorption.

After AOCs in the water source and clean water pool are compared, we find that the AOC value in clean water declines significantly in summer but remains almost constant in winter. The AOC in final effluent still exceed 120 μg/L (153 μg/L in winter and 131 μg/L in summer). There is lack of effective new technology to control AOC, which will lead the development trend of the tap water treatment process in the future.

The OTU curve obtained by different processes in different seasons is shown in Fig. 5. As an important indicator that reflects the diversity of aquatic microflora, the following OTU laws can be obtained from Fig. 5:

(1) After biological pretreatment, sand and carbon filtrations, the OUT goes up, so does the microbial diversity level; while OTU declines after coagulation and precipitation, and OTU tumbles to the lowest level after ozone generation pool and chlorination.

(2) The OTUs in most processes are higher in summer than in winter, which suggests that the water temperature in summer is more suitable for microbial growth.

(3) The OTUs in final clean water pool are consistent and extremely low, which implies that the current technology process has better controlled the diversity of microorganisms.

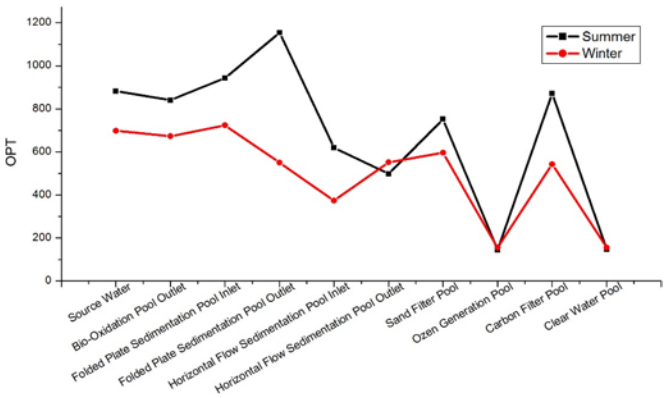


Figure 5: Water Sample and Microbe Sample OTU in Summer and Winter

3. Radial distribution of microbial communities in large diameter pipeline

Water treated by the tap waterworks has met the national drinking water standards. However, in the pipe network from water plant to the users, there is secondary pollution from microorganisms which attach to the pipeline and grow up (Kemp et al., 2011; Ortloff and Crouch, 2011). Aiming at the microorganisms of urban water pipe network, the paper analyzes and investigates the distribution and mutation laws of microbial communities in the feedwater pipelines.

The paper randomly chooses three trunk pipelines that have run for more than a decade, and studies the total microorganisms on the top and bottom and in the middle of the pipeline, as well as the composition of pathogenic bacteria, so as to lay the foundation for pipeline technology transformation. All pipelines are sampled on the upper, middle and lower parts and stored separately. The basic information about sampled pipelines is shown in Table 2.

Table 2: Sample Pipes Details

ID	Material	Age(Year)	Diameter(mm)	Speed (mm/s)
P1	DCIP	10	DN300	100
P2	GCIP	15	DN600	60
P3	GCIP	19	DN600	30

3.1 Bacterial population of microbial community in radial pipeline

The total bacterial population and HPC test results are shown in Table 3 and Fig. 6. The total population of bacteria in radial pipeline is not uniform. In other words, there are few in the middle and more bacteria on top and bottom part. The total bacteria per unit area is positively correlated to the diameter and service life of the pipeline and is inversely correlated to the flow rate. For relative proportion of the microbes in the subarea, they concentrate on the top and bottom of the pipe, and the total population of microbes on these two areas reaches as high as 87% ~96%.

Table 3: Different Position Colonies Number in Pipe Samples

ID	Position	Colonies Qty (Nos/cm^2)	HPC (CFU/cm2)
	Top	$1.5x10^7$	$8.3x10^6$
P1	Middle	$5.5x10^6$	$2.7x10^5$
	Bottom	$1.6x10^8$	$3.5x10^5$
	Top	$4.3x10^7$	$1.8x10^5$
P2	Middle	$2.7x10^6$	$1.0x10^5$
	Bottom	$6.6x10^6$	$1.6x10^5$
	Top	$3.7x10^8$	$2.2x10^7$
P3	Middle	$8.1x10^7$	$6.1x10^5$
	Bottom	$3.1x10^8$	$1.1x10^7$

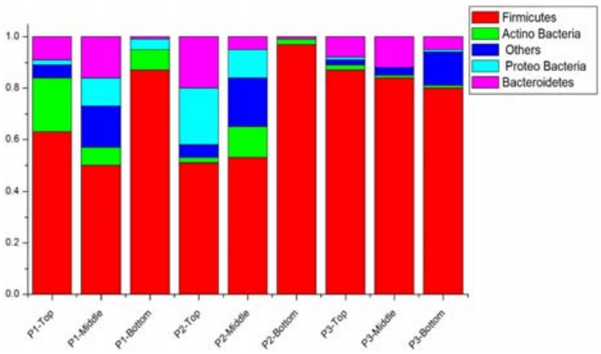


Figure 6: Proportion of Colonies Number in Pipe Samples

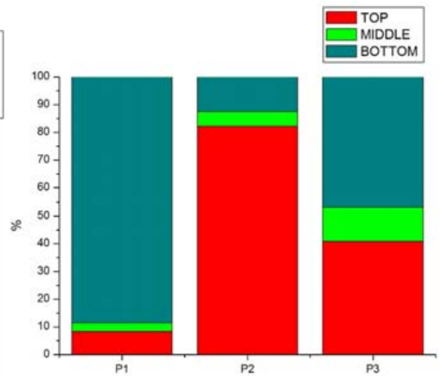


Figure 7: Abundance of Microbe main phylum in bilfilm

For microbial community on the top and bottom, OTU analysis is made on diversity composition as shown in Fig. 7. It is obvious that the microbe community on the upper part of pipe is mainly pseudomonas, flavobacterium, and methylobacillus, and on the lower part, fiber archetype, colony unicellular bacteria and red ring fungus are predominant. It also showed that other microbial communities other than bacteria also have a law of radial space distribution. The detection rate of pathogenic bacteria on the top and middle parts is higher than that on the bottom, and the pathogenic bacteria in the middle part are the maximum. After the DNA sequence obtained by high-flux sequencing procedure is matched with the database of pathogens, we discover that the pathogenic bacteria are Escherichia coli, Staphylococcus epidermidis, Salmonella, Streptococcus pneumoniae, Brucella species, Pseudomonas aeruginosa, and Corynebacterium ulceration, Acinetobacter acetate which are detrimental to human health. The detection rate of E. coli hits upon 100%, with an average abundance of 1.42%. It appears at maximum in the middle of the P1 pipeline with an abundance of 8.1%. The detection rates of Brucella species, Streptococcus pneumoniae and Staphylococcus epidermidis are also high, over 39%. In summary, it is found from study results that there is a radial distribution law of microbiological community in the pipeline, that is, there are more bacteria on the top and bottom than in the middle. The total population of bacteria in the pipes with equivalent diameter and small flow rate is more; the microbial diversity in different parts of the pipeline is distinctive. There are distinct dominant species at the top and bottom. The level of diversity in the middle is highest; the abundance of pathogenic bacteria is highest in the middle pipeline; there are many kinds of pathogenic bacteria, but E. coli is the most.

4. Conclusions

After we study water sample and feedwater treatment processes at a tap water works in the eastern area, given the seasonal factors, the control effect of each process on water turbidity, chroma, TOD, ammonia-nitrogen AOC, BGP and other indicators are analyzed. The following conclusions have been drawn.

It is proved what is the impact of different feedwater treatment processes in all seasons on the distribution law of microbial communities. Ambient temperature has a great impact on water temperature. Different processes have little impact on water temperature. Each process reduces the pH of tap water; chromaticity and turbidity have significantly seasonal differences, and biological pretreatment plays a little effect on the two. Ammonia nitrogen content in water source is slightly higher in summer than in winter, and the pretreatment process can effectively reduce the ammonia nitrogen content in water; the oxygen consumption drops a little after biological pretreatment; By using OUT statistical analysis and DNA match, we have clarified the radial space distribution and diversity of microbial communities in large-diameter pipelines of water supply systems. The results show that the large-diameter pipes are distributed with more microorganisms on the top and bottom than in the middle, the dominant bacteria concentrate on the top and bottom, and the highest level of diversity is in the middle. When exploring the population and the distribution law of bacteria, the detection rate of E. coli reaches 100%, and Brucella species, Streptococcus pneumoniae, and Staphylococcus epidermidis are higher in this regard. The pathogenic bacteria reach the peak abundance in the middle of the pipeline, which provides reference for the biofilm tightness arrangement in the water supply and drainage pipelines.

References

Baker B.H., Kröger R., Brooks J.P., Smith R.K., Czarnecki J.M.P., 2015, Investigation of denitrifying microbial communities within an agricultural drainage system fitted with low-grade weirs, Water Research, 87, 193-201, DOI: 10.1016/j.watres.2015.09.028.

Dragon K., Kasztelan D., Gorski J., Najman J., 2016, Influence of subsurface drainage systems on nitrate pollution of water supply aquifer tursko well-field, poland, Environmental Earth Sciences, 75(2), 100, DOI: 10.1007/s12665-015-4910-9.

Fujimoto Y., Ouchi Y., Hakuba T., Chiba H., Iwata M, 2008, Influence of modern irrigation, drainage system and water management on spawning migration of mud loach, misgurnus anguillicaudatus c, Environmental Biology of Fishes, 81(2), 185-194, DOI: 10.1007/s10641-007-9188-7.

Hassanain M.A., Fatayer F., Al-Hammad A.M., 2015, Design phase maintenance checklist for water supply and drainage systems. Journal of Performance of Constructed Facilities, 29(3), 04014082, DOI: 10.1061/(asce)cf.1943-5509.0000613.

Houria H.S., Bariza Z., Djamel H., Hocine B., 2017, DMFC water management in presence of heat sources, Mathematical Modelling of Engineering Problems, 4(1), 59-62. DOI: 10.18280/mmep.040112

Jack L.B., Swaffield J.A., 2009, Embedding sustainability in the design of water supply and drainage systems for buildings, Renewable Energy, 34(9), 2061-2066. DOI: 10.1016/j.renene.2009.02.009.

Kemp P., Sear D., Collins A., Naden P., Jones I, 2011, The impacts of fine sediment on riverine fish, Hydrological Processes, 25(11), 1800-1821. DOI: 10.1002/hyp.7940.

Mueller M., Pander J., Geist J, 2011, The effects of weirs on structural stream habitat and biological communities, Journal of Applied Ecology, 48(6), 1450-1461, DOI: 10.1111/j.1365-2664.2011.02035.x.

Nadilo B, 2011, Water supply and drainage system and waste water treatment plant in Karlovac, Gradevinar, 63(3), 273-284, DOI: 10.1007/1-4020-4685-5_9.

Ortloff C.R., Crouch D.P., 2001, The urban water supply and distribution system of the ionian city of ephesos in the roman imperial period, Journal of Archaeological Science, 28(8), 843-860, DOI: 10.1006/jasc.2000.0604.

Pauw P.S., Baaren E.S.V., Visser M., Louw P.G.B.D., Essink G.H.P.O., 2015, Increasing a freshwater lens below a creek ridge using a controlled artificial recharge and drainage system: a case study in the Netherlands, Hydrogeology Journal, 23(7), 1-16, DOI: 10.1007/s10040-015-1264-z.

Ramos H.M., López-Jiménez P.A., 2013, Optimization of retention ponds to improve the drainage system elasticity for water-energy nexus, Water Resources Management, 27(8), 2889-2901, DOI: 10.1007/s11269-013-0322-3.

Yan L.E., Yi N.P., Zhang X.G., Xu S.C., 2018, Numerical investigation on the effect of variation of water level on the stability of soil-cement column reinforced waterway side slope, International Journal of Heat and Technology, 36(1), 344-352. DOI: 10.18280/ijht.360146