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Determination Of Flow Pattern And Depository Rate Of Contaminants In A Pipe Network – A Laboratory Scale Study

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Abstract: The aim of the present study is to determine the flow pattern and depository rate of contaminants in a pipe network developed at a laboratory scale, representing a three storied residential building. The water circulated through it after spiking with different physicochemical and microbial contaminants. The flow and depository pattern of parameters such as turbidity, dissolved organic carbon and microbial contaminants were analysed in running as well as in standstill condition. The observations were made for 24 hours. The turbidity reduced drastically from 130 NTU to 3 NTU in running condition and 130 NTU to 1 NTU in standstill condition. The Dissolved Organic Carbon decreases from 100 mg/L to 88 mg/L and 100 mg/L to 86 mg/L under running condition and standstill condition, respectively. The MPN test revealed steady increase in the microbial content during initial period and then increased drastically.
Keywords: Contaminant flow pattern, depository rate, pipe network.

Introduction

Of all the necessities of life, only few are as important as water. Providing safe drinking water to the public is one of the most essential tasks for the local administrative bodies and hence, they carry out essential treatments prior to the supply through the domestic water supply system in order to meet the water quality standards prescribed by the Bureau of Indian Standards (BIS). Though the local authorities ensure the quality of water before its supply into the domestic supply system, the frequent breaks and leaks in a supply system pave the way for the entry of various forms of contaminants to the system which gets deposited during low pressure or non supply period.

The contaminants get accumulated in the pipe system if the damage is unattended and they pollute every onward fresh water supply causing several health threats. Apart from these intrusions, water treatment itself adds suspended solids such as carbon, sand particles, aluminium or iron flocs and bio particles originating from bio filters into the water supply system[1]. The deposition of these particles enhances corrosion of the supply system which weakens the pipe causing breaks or leaks which further results in the intrusion of contaminants through it. Corrosion also shelters various micro organisms which even include pathogens ultimately resulting in severe health consequences and disease outbreaks. In most of the domestic supply pipes, iron oxidising bacteria are harboured in the tubercles formed from the corrosion scales[2].

The biofilms that grow inside the pipes provide a safe harbour for the microbes and pathogens which do not get washed as fast as the suspended cells. At increased flow rate, nutrient loading is also increased which results in the higher growth rate of the microbes. Most biofilms get accumulated at the entrance due to higher

consumption of nutrients[3]. The biofilm environment protects them from the external stresses such as the action of disinfectants and helps in their growth and multiplication. The main opportunistic pathogens involved in biofilm associated contamination are *Pseudomonas aeruginosa* and *Legionella pneumophila* which are mainly found in domestic supply systems[4].

All these factors ultimately results in severe disease outbreaks and associated health risks which may even lead to death. Hence, it becomes essential to understand the flow pattern and depository rate of the contaminants in the pipe network. With this in view, a laboratory scale pipe network has been developed and the water circulated through it after spiking with different physicochemical and microbial contaminants. The flow pattern and depository rate of various parameters such as turbidity, dissolved organic carbon (DOC) and microbial contaminants are studied and the results are discussed in this paper.

Materials And Methods

The pipe network has been developed at a laboratory scale, representing a three storied (three levels) residential building, to determine the flow pattern and depository rate of contaminants (Figure 1). The pipe network was made of PVC pipe with six taps in each level. The dimensions of the pipe network: length-2 m, width-0.5 m and height-1.5 m, by keeping the scale of 1:4 and 1:5 for vertical and horizontal, respectively.

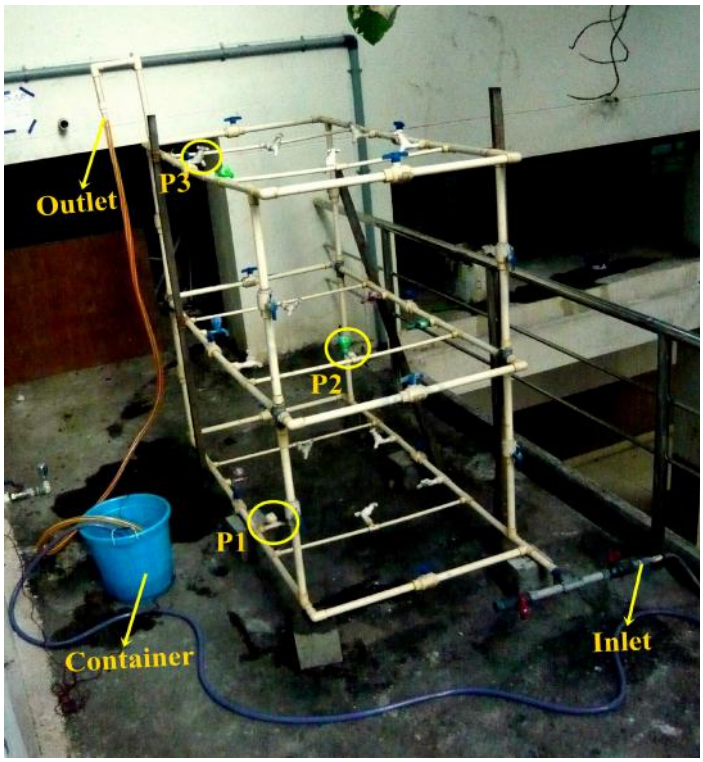

Figure 1. The pipe network used in the study

The water was circulated to the pipe network from a small container after spiking it with different physicochemical and microbial contaminants. A submersible pump with a flow rate of 6.4×10^{-4} m^3/s and velocity of 1.4 m/s was used for pumping the water. The inlet to the pipe network was provided at the bottom and the water gets collected back to the container from the third level.

The parameters under study i.e. turbidity and DOC were induced in the water used for circulation by spiking Potassium hydrogen phthalate and barium sulphate, respectively. Initially, the water used for circulation was prepared with the concentrations of 130 NTU and 100 mg/L for turbidity and DOC, respectively. The samples were collected from the pipe network outlet (tap) at each level at two different conditions, namely during circulation and during still condition. However, during circulation, as there is continuous flow of water, the

samples were collected only at the outlet. The samples were collected from three taps, one from each level; say P1, P2 and P3, respectively. The turbidity (induced by barium sulphate) was measured by the following the standard procedure prescribed in APHA standards[5] by using nephelometer (Make: Elico, India). DOC (induced by potassium hydrogen phthalate) was measured by the following the procedure reported by Deflandre and Gagne[6] using UV Spectrophotometer (Make: Cyberlab, USA) at a wavelength of 254 nm. In order to measure the microbial content, domestic wastewater was spiked into the water for circulation in the pipe network. The growth of microbial contaminants was determined using MPN test by following the standard multiple tube fermentation method as per the APHA standards[5].

Results And Discussions

Turbidity

In running condition, the samples were collected at one hour interval during initial period and later at specific interval. The collected samples were analysed and the results are presented in Figure 2. It can be observed from the figure that the turbidity reduced drastically from 130 NTU to 20 NTU within 2 hours and further reduced to 5 NTU in 5 hours beyond which there is no significant variation.

Under still condition, the samples were collected at 15 minutes interval during initial period (3 hours) as the solids settled rapidly and later at specific interval. The drastic reduction in turbidity can be noted from the Figure 3. A rapid decline of turbidity from 130 NTU to 18 NTU was observed within 30 minutes and further reduced to less that 5 NTU within 2.5 hours. This could be due to the fact that the suspended solids carried along with the flow of water settles immediately during low or no flow condition.

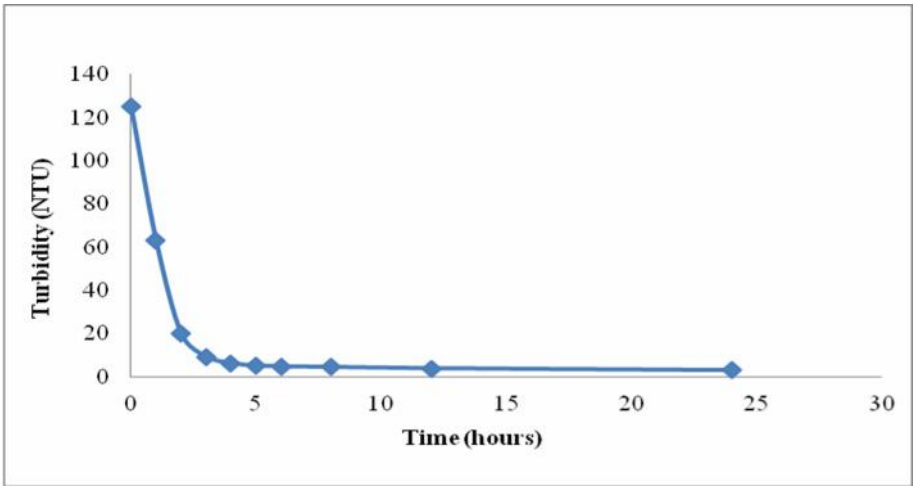

Figure 2. Variation of turbidity under running condition

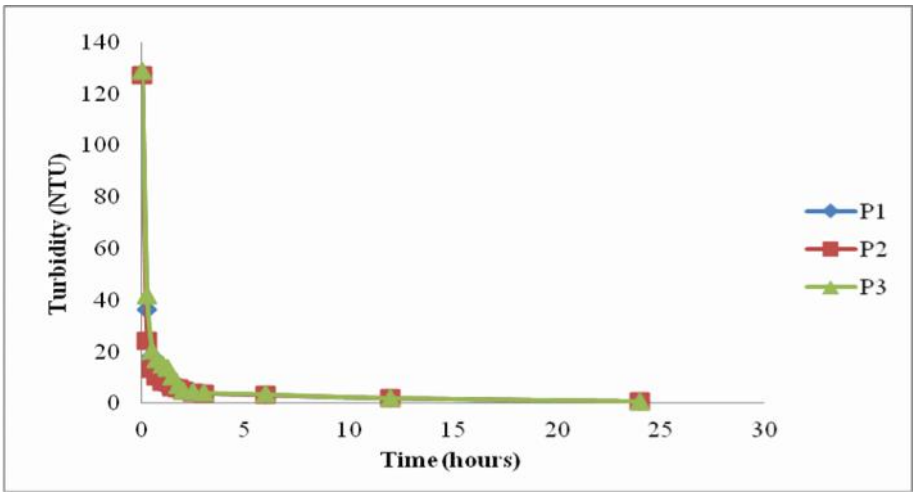

Figure 3. Variation of turbidity under still condition.

Dissolved Organic Carbon

The standard calibration curve was prepared for DOC calculation by analysing organic carbon at various concentration (5mg/L, 10mg/L, 25mg/L, 50mg/L, 100mg/L and 200 mg/L) present in the potassium hydrogen phthalate solution.

In running condition, the water spiked with potassium hydrogen phthalate was circulated in the pipe network and the observations were made for 24 hours at different intervals. It can be observed from the Figure 4 that there is a constant reduction in DOC and hence, the obervation was continued beyond 24 hours. Further, it can be noted that the reduction in concentration of DOC was observed till 48 hours in which there is no significant variation after 40 hours and the total concentration was reduced from 100 mg/L to 70 mg/L.

Since there was a constant reduction in DOC concentration, an attempt was made to understand the possiblity of microbial presence in the pipe network. Hence under still condition, microbial tests were also performed along with DOC. The samples were collected from each taps from the three floors viz. P1, P2 and P3 and the results are presented in the figures 5, 6 and 7, respectively. It can be noted from all the figures (5 to 7) that a similar trend for all three taps was observed in which the concentration of DOC was decreasing meanwhile concentration of microbes increased simultaneously.

This could be due to the fact that the microbes in the pipe network might be consuming the availabile nutrients like organic carbon which influences bacterial re-growth and biofilm formation in drinking water systems[7].

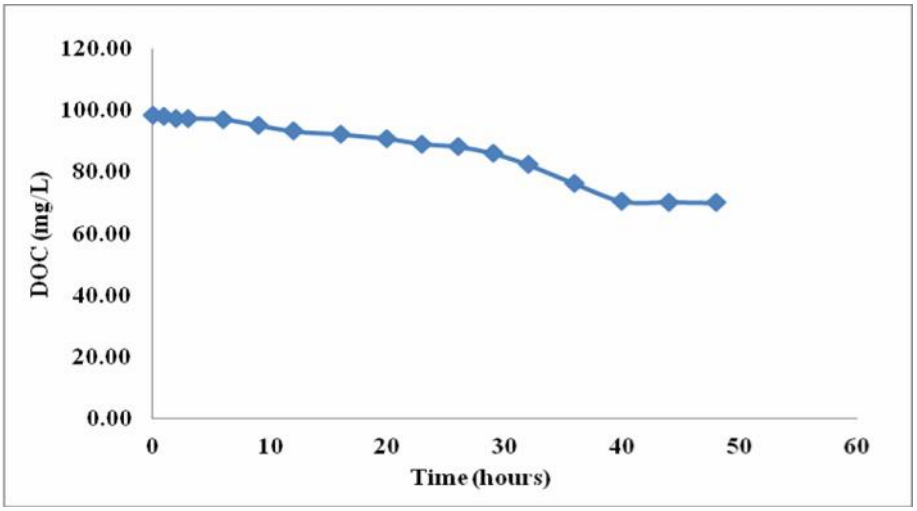

Figure 4. Variation of DOC concentration under running condition.

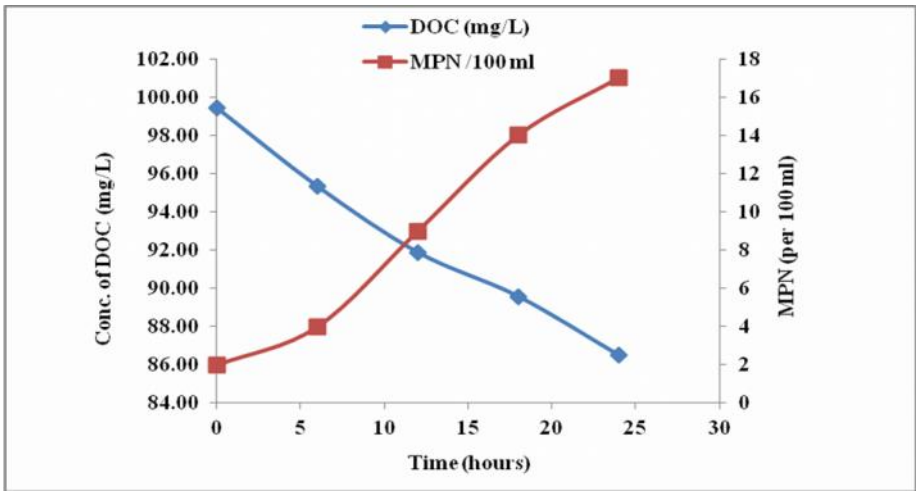

Figure 5. Variation of DOC and MPN for tap P1

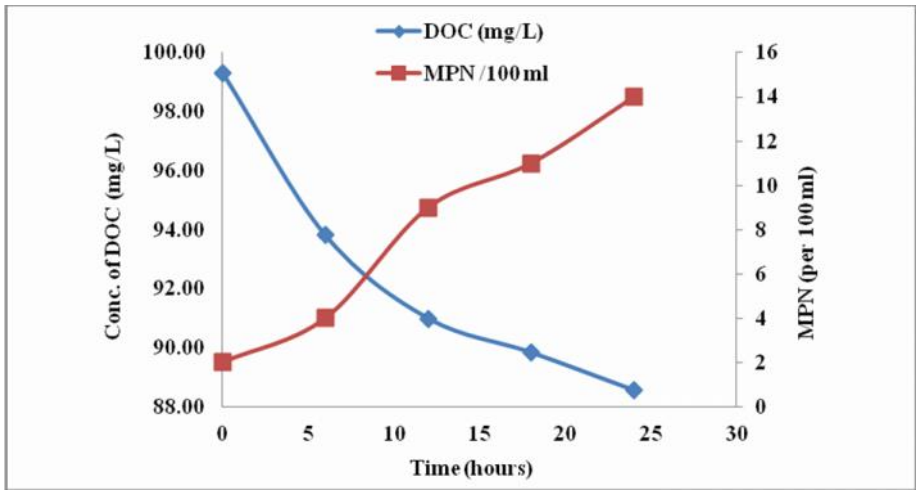

Figure 6. Variation of DOC and MPN for tap P2

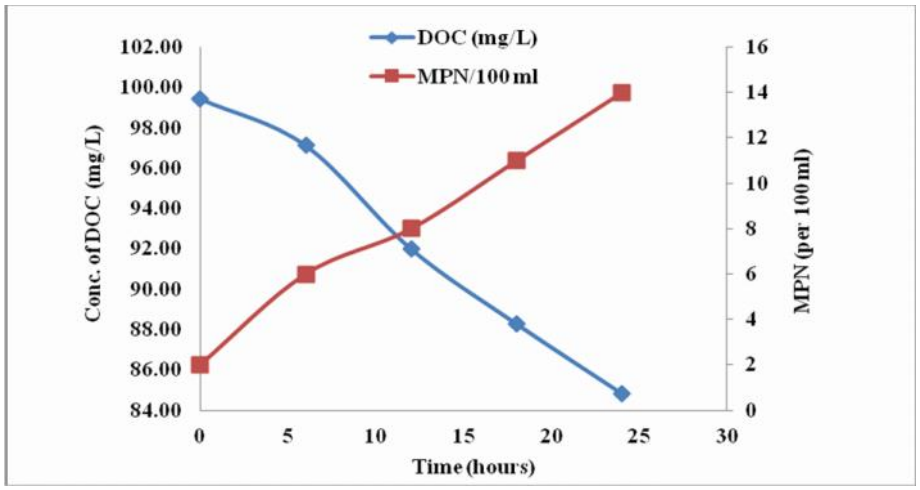

Figure 7. Variation of DOC and MPN for tap P3

Microbial Contaminants

The experiments were conducted for microbial contaminants under still condition only, as under running condition there is a possibility of erroneous results due to higher growth rate of microbes in the spiked solution container. For still condition, the water was spiked with domestic wastewater and introduced into the pipe network. The samples were collected at 6 hours interval and the results are presented in Figure 8. It can be observed from the figure that the growth of microbes was steady upto 12 hours and further increasing rapidly. The microbial growth was found to be more at the inlet of the pipe network.

It is expected that the sampling point P1 at the ground level have a maximum microbial count compared to the other two points, as most microbial activity occur near to the inlet. The similar observations were reported by Van der Wende[3]

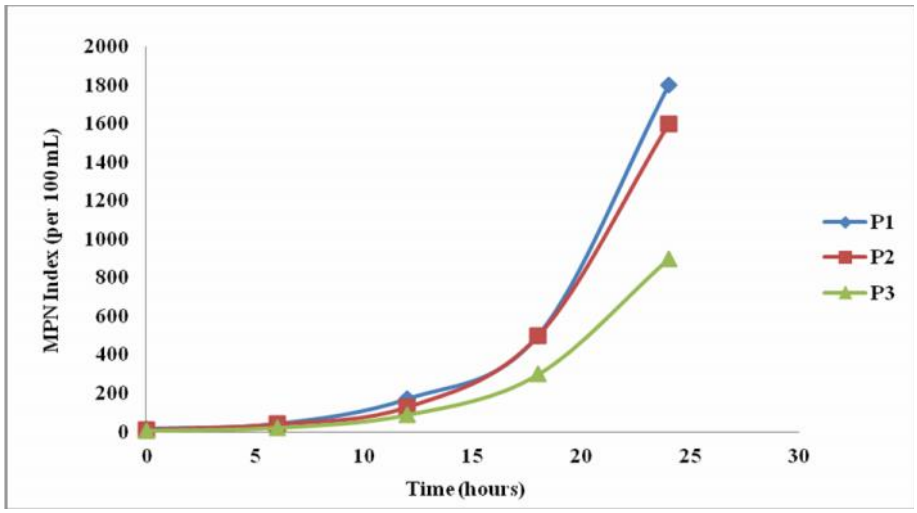

Figure 8. Variation in Microbial count with time in still condition.

Conclusion

The flow pattern and depository rate of various physicochemical contaminants were determined by spiking the contaminants in water and circulating it through a pipe network. The turbidity suffered a drastic reduction in running and still condition, the later being at a higher rate. In running condition, turbidity was reduced from 130 NTU to 20 NTU within 2 hours and further reduced to 5 NTU in 5 hours beyond which there was no significant variation whereas in still condition, turbidity was reduced from 130 NTU to 18 NTU within 30 minutes and further reduced to less that 5 NTU within 2.5 hours. The DOC concentration in running condition was found to reduce constantly for 24 hours and hence, observation was continued for another 24 hours. The total concentration was reduced from 100mg/L to 70mg/L for 48 hours. In still condition, microbial tests were also performed along with DOC concentration, to understand the possibility of microbial presence in the pipe network. The samples collected from all taps showed a similar trend in reduction of DOC concentration along with a simultaneous increase in the microbial count. The microbial count was found to increase at a steady rate for the first 12 hours and then further increasing rapidly. The sample collection point close to the inlet showed a higher growth rate as compared to the one close to the outlet.

References

1. Vreeburg, J.H.G., Schippers, D., Verberk, J., Van Dijk, J.C. (2008). “Impact of particles on sediment accumulation in a drinking water distribution system”. Water Research, 42, 4233-4242
2. Lin, J., Ellaway, M., Adrien, R. (2001). “Study of corrosion material accumulated on the inner wall of steel water pipe”. Corrosion Science, 43, 2065-2081
3. Van der Wende, E., Charaklis, W.G., Smith, D.B. (1989). “Biofilms and bacterial drinking water quality”. Water Research, 23, 1313-1322
4. Moritz, M.M., Flemming, H., Wingender, J. (2010). “Integration of Pseudomonas aeruginosa and Legionella pneumophilia in drinking water biofilms grown on domestic plumbing materials”. International Journal of Hygiene and Environmental health, 213, 190-197
5. APHA (1995). ‘Standard Methods for the Examination of Water and Wastewater’, 19th edition, American Public Health Association, American Water Works Association, Water Environment Federation, 1995.
6. Deflandre, B., Gagne, J., (2001). “Estimation of Dissolved Organic Carbon (DOC) concentrations in nanoliter samples using UV spectroscopy”. Water Research, 35, 3057-3062.
7. Chu, C., Lu, C., Lee, C. (2005), “Effect of inorganic nutrients on the regrowth of heterotrophic bacteria in drinking water distribution system”. Journal of Environmental Management, 74, 255-263.

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