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SUSTAINABLE DEVELOPMENT OF WATER RESOURCES, WATER SUPPLY AND ENVIRONMENTAL SANITATION

Looking for new horizons in water treatment at Thuruwila Lake

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Even though, the developed countries have put a great attention on the formation of disinfection by-products in chlorinated water, the developing countries still have to play a significant role on this. Consequently, the consumers are at a hidden threat, which has to be exposed. This paper talks about the possibility for formation of by-products in water treatment systems in Sri Lanka, giving special attention on formation of Trihelomethane. The Thuruwila Water Treatment Plant has been designed to provide water for the Anuradhapura Township and its suburbs. Even though the plant is equipped with advance water treatment technology, it faces many complex issues which are common for all the treatment plants, extract raw water from lakes or tanks at tropical conditions. However, there are many possible ways of contamination due to many anthropogenic activities such as excessive use of agro-chemicals, improper settlements, etc. The chemicals, consist of nitrogen and phosphorous, provide appropriate conditions to toxic algae for blooming at dry zone temperatures. This results very complex situation in water bodies, leading unknown health effects at the end. The writers of this paper expect to review the capability of advance water treatment technologies in surface water treatment and make critical evaluation on the available water treatment options to open new directions, regard to more convenient and acceptable water related infrastructure development in dry zone of the country.

Introduction

Formation of disinfection by-products due to chlorination has become an interesting topic with Rook's findings, published in 1974. Until that, people thought that the chlorination may find solutions for all the issues created by pathogens in raw water sources. Many researches done on this have proved the importance of studying about the level of carcinogenic chemicals present in treated water, as by-products of chlorination.

Disinfection by-products are produced in the water treatment process as a result of chlorination. The formation of these compounds is a function of precursor concentration, contact time, chlorine dose, and pH (APHA, 1995). Trihelomethane (THM) is the most famous disinfection by products as it is carcinogenic, mutagenic or possibly teratogenic. Aquatic humic and the fulvic acids are the main trihelomethane precursor, found in surface water bodies. It has been found that the THMs represent between 5% and 20% of the chlorinated products formed during the chlorination process. The main species of THM formation is chloroform (CHCl3), which represents about 82% of the TTHMs formed (Shafy et al., 2000).

Aside from THMs, many other compounds, comprising the chlorination by-products, have been found in treated waters. They are haloacetic acids, haloaldehyde, halopicrin, cyanogens chloride, halophenol and chloral hydrate etc. But most probably, these occur in water in the trace level of ppb (Lee et al., 2001).

Generation of THM has been shown that a function of the following factors (Clark et al., 2001). The effect from each factor may be more or less depending on the existence of them in different water bodies.

- Initial chlorine concentration,
- Total organic concentration,
- Type of organic precursor,
- pH: Increase in pH, increases THM concentration,
- Temperature: Increase in temperature, increases THM formation,
- Bromide level,
- Reaction time,
- UV-254 absorbency.

Most of the researches have found that greater the concentration of organic compounds higher the rate of forming THM. Further to that, during chlorination, the bromine is oxidized to bromine, which reacts more readily than chlorine with the organic precursors to form mainly brominated THM (Adin et al., 1990).

For most waters, the reactions of chlorine with NOM make up the majority of the chlorine demand. TOC concentration is indicative of the mass of material, whereas spectral absorbency relates more to specific structure and functional groups. DOC is the dissolved fraction of TOC. For NOM, the most commonly used spectral absorbency is the ultraviolet (UV) absorbency (UVA) at a wave length of 254 nm (UVA) which measures conjugated double bonds. The specific

UVA (SUVA) is the ratio of UVA to DOC. This value gives an indication of the NOM's nature. Further, higher values indicate more aromatic character (Clark et al., 2001).

Sri Lanka is an island, situated close by to the equator and having tropical climate. The average temperature of the country varies in-between 10-35o C and it blesses with two monsoons per annum, enriching both surface and ground water. The annual rainfall demarcates the country into two zones as dry and wet zones on its intensity.

Anuradhapura District is situated in the North Central Province of Sri Lanka, which covers part of the dry zone. Only 8% of the people were fortunate to have pipe borne water facility at the end of year 2000. There are 16 water supply schemes operated in the district and two of them can be considered as the major schemes, i.e. the Thuruwila and Anuradhapura water treatment plants.

The Thuruwila Water Treatment Plant is located at about 20 km away from the Anuradhapura Town. The plant has been designed to produce 04 MGD and it extracts water from the Thuruwila Tank, which is fed by Mahaweli water via Kala wewa. The water quality of the tank is presented in the Table 1.

The complexity of the raw water chemistry has become crucial and the online turbidity & color meters imply some unusual behavior in the tank. This phenomena enhance by the longer traveling of water through different catchments with varies characteristics, before reaching to their destination at the tank. Usually, the pH of the raw water is above 8.00. This makes higher consumption of alum at coagulation. Among the bacteriological community, the presence of cynophyceae group is predominant. The total number of phytoplankton units per ml was greater than 25,000, within the observed period. This is common for all most all the lakes in dry zone as they provide a friendly environment for algal bloom. This leads for high consumption of chlorine at pre and post chlorination.

Table 1. Water quality data in Thuruwila Tank[1]

Parameter	Aug-05	Sep-05	Oct-05
Temperature (oC)	28.80	27.90	29.50
DO (ppm)	6.10	6.39	5.24
DO (%)	80	83	72
EC (µS)	403	438	429
Zsd (cm)	1.05	0.95	0.75
TSS (ppm)	18	13	14
pH	8.04	8.27	8.02
Alkalinity (ppm)	195	235	250
Diss. Si (ppm)	7	13	6
Cl- (ppm)	41	38	25
SO4-2 (ppm)	4	12	15
NH3-N (ppb)	20	11	13
NO3-N (ppb)	12	17	5
NO2-N (ppb)	62	92	91
TP (ppb)	56	75	77
DP (ppb)	6	6	5
Chl-a (ppb)	22	23	24
Cylindrospermopsis raciborskii	8,300	16,900	11,698
Merismopedia punctata	212	143	186

Thuruwila water treatment plant has been design with a chain filter just after the siphon intake at the tank. This is the only preliminary treatment unit, prevent the all floating bodies in the tank water. The size of the stainless steel mesh in this unit is 2 mm x 2 mm. Therefore, no one can expect any reduction in algal community at the preliminary level of treatment.

As a result, all the algae community undergoes the pre-chlorination step. This provides enough room to generate cacogenic byproducts, such as tirhelomethane. But, as per the unit arrangements at the plant, a considerable amount of gaseous compounds can be released to the air at the aeration stage.

But, the higher consumption of Cl at the post chlorination level implies that the provided strength and the contact time (C x t) is inadequate to oxidize all the compounds in raw water. The higher dosages (6 ppm -8 ppm) at the post chlorination are the only solution provided at the plant to maintain the residual chlorine level (0.2 ppm) in the distribution system. This situation provides enough room to generate disinfection byproducts, which are not measured at any stage of the consumption.

It is well known that the amount and complexity of pollutants, reaching to surface water bodies, have been increased at an alarming rate during the recent past. These factors have been correlated with the reactions of chlorine in aqueous solutions (Okun, 1996).

Chemistry of chlorination

In general, Cl reacts with both natural and synthetic organic matters in the water. It has been observed that Cl usually reacts with natuatral orgainc matters, such as humic and fulvic acids. It has been further observed that the relative contribution to the formation of THMs by the humic fraction is greater than that of fulvic fraction, since humic acids react more readily with chlorine (Elshorbagy et al., 2000).

It has been identified that the reactivity of the pipe wall will be a function of pipe diameter, hydrodynamic conditions, nature of the pipe material and amount and nature of deposits (Kiene et al., 1998). The following interesting results have been obtained in the same study:

- Chlorine consumption by synthetic materials is negligible and does not appear to be an important parameter for Cl decay analysis;
- In contrast, chlorine consumption of old cast iron pipes

whose internal surfaces are not protected by a coating can be considered as a major parameter for chlorine decay. For cast iron or steel pipes, the rate of Cl consumption can be directly considered under the dependence of corrosion phenomena.

- Cl decay due to bulk reactions is very much variable, according to the temperature and organic matter concentration. Variation of kinetics can be predicted by a simple model taking into account the TOC and the temperature.
- Cl decay due to fixed biomass varies according to the colonization time. Influence of biomass should become an important parameter, only for small diameter synthetic pipes fed with water characterized by high biodegradable organic compounds.

Methodology

The methodology of the test has been developed to find out the real effects of unoxidized agents, remaining in treated water and the pipe material itself.

Two parallel studies had been carried out to find the reasons for the unexpected Cl decay in the Vijayapura transmission line of the Thuruwila Water Treatment Plant. Tests were done at field and laboratory to compare the field observations with the laboratory results.

Laboratory test

Two laboratory tests were carried out to identify the individual contribution of pipe material and unoxidized compounds presence in treated water on residual Cl (RCl) decay. Water samples were collected to a container of DI pipe, just prior to the post chlorination. The testes were carried out at controlled conditions in dark bottle of 2L and a container made of DI pipe. The RCl was observed at the time intervals of 1, 5, 10, 15, 30, 60, 120 and 180 min. The results were plotted against the time to find out the effects from pipe material on the Cl decay and the contribution from the non oxidized agents, remaining in treated water.

Filed test

RCl level of the treated water along the transmission line was measured at sampling points and the results were plotted against the time and the length of the line at ambient conditions. These results can be used to check the reliability laboratory results under actual conditions.

Results

The laboratory test results are presented in the figure 01. The effects from unoxidized compounds in treated water is presented by the line 01 of figure 01.The RCl level has reduced drastically within first ten minutes due to the reaction of fast reducing compounds in water. The effect of slow reducing agents on RCl decay is comparatively not significant as it is represented by a line with low gradient.

The line 02 represents the effects of both reducing agents in treated water and pipe material itself on the RCl decay.

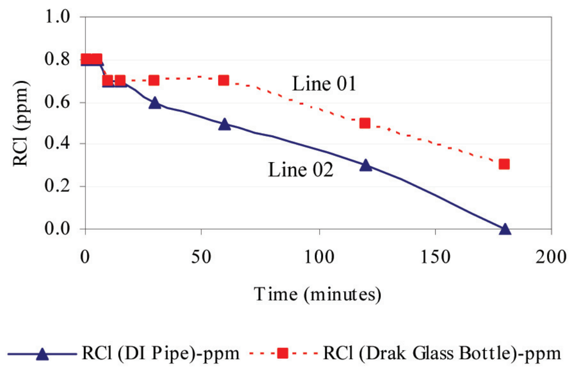

Figure 1. RCl decay in the laboratory test

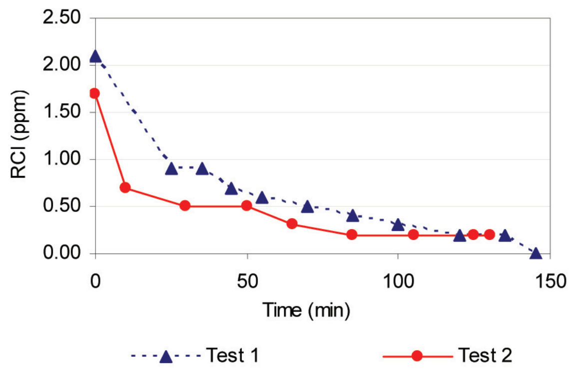

Figure 2a. RCl decay against time in the field test

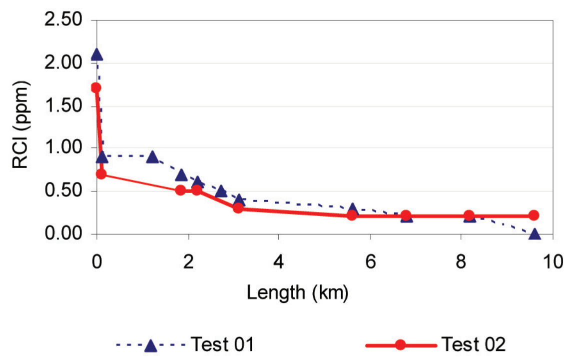

Figure 2b. RCl decay against length in the field test

Therefore, the gap between two lines represents the real contribution of pipe surface on the RCl decay. This complies with the experiments done at different conditions (Kiene et al., 1998).

The figure 02(a) & 02(b) represents the field test results against time and distance along the selected transmission line of 600mm ductile iron (DI) respectively. As per the above, the effect of fast reducing agents has taken place within the first ten minutes of travel in the line. Similarly, the effects on slow reducing agents on the RCl decay were not significant.

As per the variation presented in figure 02 (b), the RCl level has reduced drastically within a very short distance. Therefore, the removal of fast reducing agents will be effective on maintaining the RCl level at the far end of the distribution system.

Conclusion

The observation of the above research clearly proves that the effects of algae in raw is significant on treated water. The various remedies used in Sri Lanka, such as micro strainers at Polonnaruwa water treatment plant, the DAF system installed at Ampara have been failed without given proper removal. Therefore, the designers should take this into severe consideration at the design stage of water treatment plant fed by lake water, especially in the dry zone.

The present practice of using higher dosages at the post chlorination will facilitate for generation of cacogenic byproducts, such as tirhelomethane. Therefore, the treated water of these water treatment plants has to be checked for major four compounds of tirhelomethane (CHCl3, ChCl2Br, CHClBr2, and CHBr3) at least three times per annum.

In addition, suitable water quality standards have to be developed to monitor the concentrations of these above four compounds as in other developed and developing countries. The USEPA has recommended the maximum permissible of THM is 100 ppb, while United Kingdom has become more stringent by reducing it further as 80 ppb.

Footnote

1. Algal study done by Prof. E.I.L. Silva, Institute of Fundamental Studies, Sri Lanka as per the request of National Water Supply and Drainage Board, Sri Lanka.

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