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Dissipation of Chlorine in Drinking Water of Bhubaneswar Water Supply System, Odisha, India

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Water samples were collected from 55 sampling stations of three water treatment plants at Bhubaneswar city, Odisha for analysis of residual chlorine. On the basis of distance from the source, the total study area was sub-divided into short (< 6.9 km), medium (6.9-10.4 km) and long (>10.4 km) distance. Average chlorine content was highest in short distance (0.934 mg/L) followed by medium (0.756 mg/L) and long distance (0.684 mg/L). One way ANOVA test on chlorine content of water supplied from treatment plants to different locations on the basis of distance showed a significant difference ($F = 90.522$; $p < 0.05$). The regression value for short distance was; r^2 = 0.816, 0.841 and 0.865 against linear, quadratic and cubic models. Similarly for medium distance; r^2 was 0.969, 0.969 and 0.969 and for long distance; r^2 was 0.867, 0.868 and 0.868 against linear, quadratic and cubic models respectively.

Keywords: Chlorine, Water supply system, ANOVA, Regression analysis.

INTRODUCTION

Drinking water contaminated with pathogenic microorganisms can be a major risk to public health. Pollution of water source with pathogen microorganisms result in transferring infectious diseases and other related diseases [1]. Disinfection is a method to destroy the pathogenic microorganisms in the water distribution systems. In order to prevent re-growth of pathogenic bacteria, it is desirable to maintain the disinfectant residue in the drinking water distribution system till it is used at the consumer end. Because the presence of free residual chlorine in drinking water indicates the possible absence of disease-causing organisms; therefore, it is used as one measure of the potability of drinking water [2]. Low chlorine dosing may lead insufficient residue at the consumer end of the distribution system which results in bacterial regrowth. Similarly, addition of excess chlorine in water can lead to the consumer's complaints about taste and odour, corrosion of pipe network and also the formation of carcinogenic by-products. Hence, it is important to maintain the residual chlorine concentration throughout the water distribution system till it reaches the consumer end. Chlorine is by far the most common and widely used agent to preserve the microbial quality of potable water [3]. Chlorine, added to water in the form of either as hypochlorous acid/hypochlorite ion or as chlorine gas, is still the most widely applied and most cost-effective disinfectant worldwide, despite the well-known problems of disinfection by-product formation [4].

Despite the effective use of chlorine as a disinfectant for potable water supplies, there are still regulatory failures in the quality of drinking water, which cause concern to the water utilities [5,6]. Water chemistry, temperature and other environmental factors can significantly affect chlorine demand and residual chlorine in water distribution systems [7]. Variability of chlorine reaction rates in different water qualities like raw, sand filtered and distributed water have been studied [8] and authors stated that, the reaction rates are governed by the initial chlorine concentration. Tiruneh *et al.* [9] have also studied on bulk decay rate of chlorine residuals at different initial chlorine doses.

Treatment of water and waste water plays an important role for protection of environment and human health. Some of the publications in the area of water treatment by chlorination are already reported [10-17] and in the area of biological waste water treatment are [18-26]. In the present research, an attempt has been made to monitor the dissipation of chlorine at different monitoring stations. Further the change in residual chlorine content with respect to distance is statistically interpreted by performing ANOVA test followed by regression analysis.

EXPERIMENTAL

Water samples were collected from 55 sampling stations, coming under the three water treatment plants (WTP) like Palasuni, Samantrapur and Munduli which supplies drinking water to Bhubaneswar city, Odisha. Water samples were collected from inlet of under ground reservoirs. Under Samantrapur water treatment plants, nine sampling stations were selected like; Airport, Baragada, Bhimatangi, Gautam Nagar, Judicial Campus, Mulapadia, Nageswar Tangi, Palaspalli and Sundarpada UGR of Bhubaneswar city. Similarly under Palasuni water treatment plants, 15 sampling stations are AcharyaVihar, Baragada, Blind School unit-9, Budheswari, GGP Colony, H.L. Tank, Kalpana UGR, Laxmisagar, Malisahi, Sahid Nagar, Sainik School, Satya Nagar, Unit-9 Control Room, VaniVihar and VSS Nagar. Further, under Munduli treatment plant the thirty one sampling stations are Aaiginia, Baramunga G.A., Baraminda OSHB, BDA, Bharatpur, Dharma Vihar, IRC Village-I, IRC Village-II, Jagannath Vihar, Kalinganagar K-4, Kalinganagar K-5, Kalinganagar K-6, Kalinganagar K-7, Kalinganagar K-8, Kalinganagar K-9, Khandagirivihar, KrushiVihar, LingarajVihar, MLA colony, Nayapalli, P.H. sub-divn-4, Pokhariput, Power house square, Rental, Sampur, Shastry Nagar, Siripur, Spring tank, Unit- 8 (UGR-2), Unit-8 (UGR-1) and Vetenary College.

Water samples were collected in 500 mL. Tarson bottle and were kept in ice-box, which were carried to the laboratory for immediate analysis.

Standard method were followed for analysis of residual chlorine (Standard Method [IS: 3025 (Part 26) – Reaffirmed, 2003] for estimation of residual chlorine in drinking water) [27].

Calculation:

$$\text{Residual chlorine (mg/L)} = \frac{V_1 \times N_1 \times 35.45 \times 1000}{V_2}$$

where, V_1 = Volume of sodium thiosulphate; N_1 = Normality of sodium thiosulphate; V_2 = Volume of sample; 35.34 = Equivalent weight of chlorine (1000 is multiplies to convert the sample from mL to L).

RESULTS AND DISCUSSION

Water samples for residual chlorine content were collected from 55 sampling stations under Bhubaneswar water supply system. The name of the stations with their mean chlorine content under Palasuni, Samantrapur and Munduli are shown in Figs. 1-3 respectively.

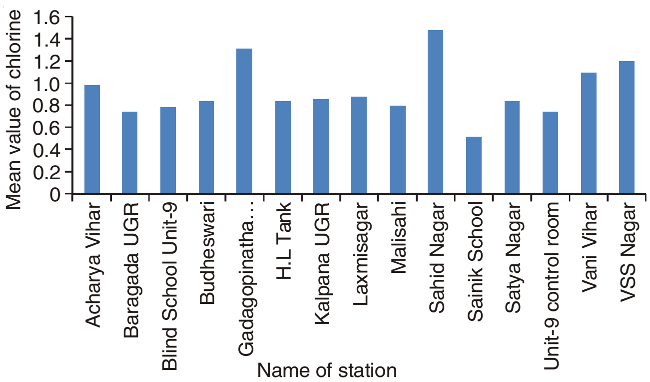

Fig. 1. Results of chlorine content (mg/L) under Palasuni water supply system

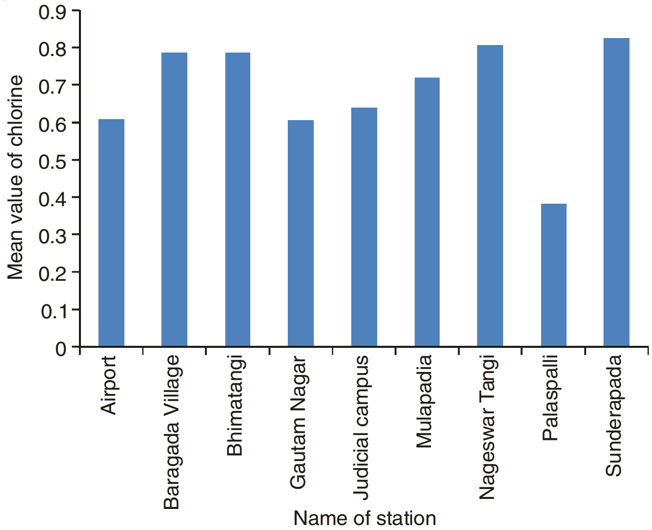

Fig. 2. Results of chlorine content (mg/L) under Samantrapur water supply system

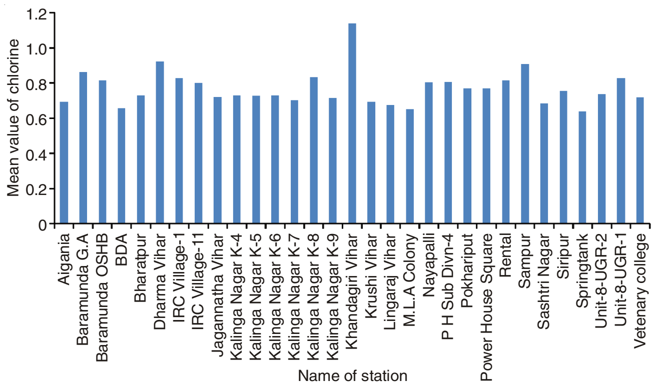

Fig. 3. Results of chlorine content (mg/L) under Munduli water supply system

Table-1 shows the mean, standard deviation, standard error of chlorine content (mg/L) of water supplied from different treatment plants to different locations on the basis of distance. For convenient the total distance of the study area were divided into short (up to 6.9 km) medium (6.9 to 10.4 km) and long (> 10.4 km) distance. The average chlorine content was found to be highest (0.934 mg/L) in short distance followed by medium (0.756 mg/L) and long distance (0.684 mg/L).

TABLE-1
MEAN, STANDARD DEVIATION, STANDARD ERROR OF CHLORINE CONTENT (mg/L) OF WATER SUPPLIED FROM DIFFERENT TREATMENT PLANTS TO DIFFERENT LOCATIONS ON THE BASIS OF DISTANCE

Distance	N	Mean	Standard deviation	Standard error
Short	133	0.934	0.222	0.019
Medium	105	0.756	0.070	0.006
Long	147	0.684	0.117	0.011
Total	385	0.798	0.182	0.009

Table-2 presents the results obtained on application of one way analysis of variance (ANOVA) on chlorine content of water supplied from treatment plants to different locations on the basis of distance. Accordingly, the F value has been calculated as 90.522 between distances which have been found to be significant at 5 % level ($p < 0.05$). It may be concluded that the variation in chlorine content in water supplied from treatment plants is significant with respect to distance from delivery point. It may be noted that, the variation in chlorine content at three treatment plants have no importance as efforts are made to maintain constant chlorine content.

TABLE-2
ANALYSIS OF VARIANCE ON CHLORINE CONTENT (mg/L) OF WATER SUPPLIED FROM DIFFERENT TREATMENT PLANTS ON THE BASIS OF DISTANCE

	Sum of squares	df	Mean square	F
Between distance	4.079	2	2.040	
Within distance	8.607	382	0.023	90.522*
Total	12.686	384		

*Significant at 5 % level ($P < 0.05$).

Further regression analysis (linear, cubic and quadratic) to establish the relationship between distances with residual chlorine content were made.

Table-3 demonstrates the results obtained on application of these three regression models between the chlorine contents (mg/L) as dependent and distance (km) as independent for short distance. The r^2 values have been found out as 0.816, 0.841 and 0.865 against linear, quadratic and cubic models. The highest r^2 value (0.865) shown against cubic model demonstrates the best explanation of the data in the regression *i.e.* 86.5 % of the data is explained by leaving out the remaining 13.5 % unexplained. Further, the r^2 value against linear (0.816) also shows that 81.6 % data is also explained in this regression. As both are very close to each other, linear regression may be considered for establishing the relationship between two. Accordingly, the estimated mathematical relationship may be cited as;

$$\text{Chlorine} = 1.630 - 0.138 \times \text{Distance}$$

Fig. 4 shows this relationship in graphical manner. The downward trend of the line indicates that as the distance increases, the chlorine content in the water decreases.

Table-4 demonstrates the results obtained on application of these three regression models between the chlorine contents (mg/L) as dependent and distance (km) as independent for medium distance. The r^2 values have been found out as 0.969, 0.969 and 0.969 against linear, quadratic and cubic models.

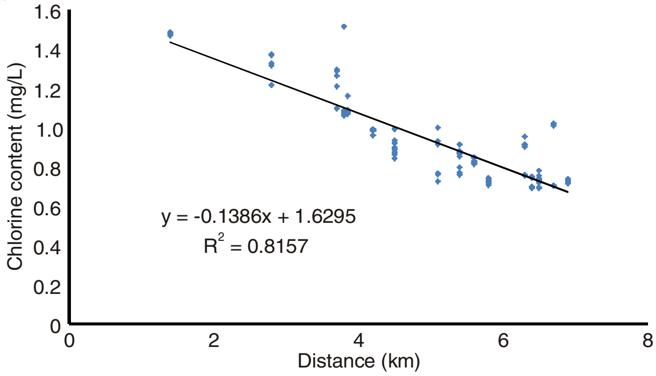

Fig. 4. Regression of chlorine content (mg/L) with short distance (km)

The r^2 value (0.969) shown against all models demonstrates almost equal explanation of the data in the regression *i.e.* 96.9 % of the data is explained by leaving out the remaining 3.1 % unexplained. As all are very close to each other, linear regression may be considered for establishing the relationship between the two. Accordingly, the estimated mathematical relationship may be cited as;

$$\text{Chlorine} = 1.802 - 0.137 \times \text{Distance}$$

Fig. 5 shows this relationship in graphical manner. The downward trend of the line indicates that, as the distance increases, the chlorine content in the water decreases.

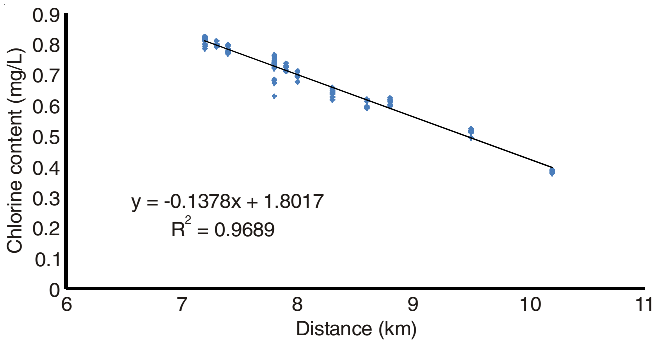

Fig. 5. Regression of chlorine content (mg/L) with medium distance (km)

Table-5 demonstrates the results obtained on application of these three regression models between the chlorine content (mg/L) as dependent and distance (km) as independent for long distance. The r^2 values have been found out as 0.867,

TABLE-3
REGRESSION OF CHLORINE CONTENT (DEPENDENT) WITH DISTANCE (INDEPENDENT) FOR SHORT DISTANCE LOCATIONS

Equation	Model summary					Parameter estimates			
	R square	F	df_1	df_2	Sig.	Constant	b_1	b_2	b_3
Linear	0.816	579.879	1	131	0.000	1.630	-0.139		
Quadratic	0.841	343.857	2	130	0.000	1.884	-0.267	0.014	
Cubic	0.865	274.590	3	129	0.000	1.383	0.211	-0.113	0.010

TABLE-4
REGRESSION OF CHLORINE CONTENT (DEPENDENT) WITH DISTANCE (INDEPENDENT) FOR MEDIUM DISTANCE LOCATIONS

Equation	Model summary					Parameter estimates			
	R square	F	df_1	df_2	Sig.	Constant	b_1	b_2	b_3
Linear	0.969	3212.134	1	103	0.000	1.802	-0.137		
Quadratic	0.969	1594.491	2	102	0.000	1.706	-0.115	-0.001	
Cubic	0.969	1596.069	2	102	0.000	1.726	-0.124	0.000	-6.024×10^{-5}

TABLE-5
REGRESSION OF CHLORINE CONTENT (DEPENDENT) WITH DISTANCE (INDEPENDENT) FOR LONG DISTANCE LOCATIONS

Equation	Model summary					Parameter estimates			
	R square	F	df_1	df_2	Sig.	Constant	b_1	b_2	b_3
Linear	0.867	946.911	1	145	0.000	1.155	-0.030		
Quadratic	0.868	473.744	2	144	0.000	1.064	-0.016	0.000	
Cubic	0.868	473.744	2	144	0.000	1.064	-0.016	0.000	0.000

0.868 and 0.868 against linear, quadratic and cubic models. The r^2 value (0.867) shown against all models demonstrates almost equal explanation of the data in the regression *i.e.* 86.7 % of the data is explained by leaving out the remaining 13.3 % unexplained. As all are very close to each other, linear regression may be considered for establishing the relationship between the two. Accordingly, the estimated mathematical relationship may be cited as;

$$\text{Chlorine} = 1.155 - 0.029 \times \text{Distance}$$

Fig. 6 shows this relationship in graphical manner. The downward trend of the line indicates that as the distance increases, the chlorine content in the water decreases.

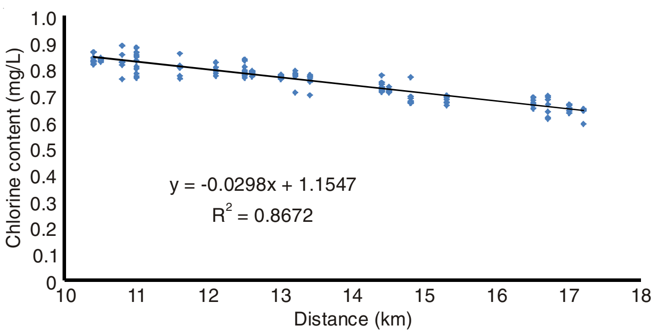

Fig. 6. Regression of chlorine content (mg/L) with long distance (km)

Chlorine decays occurs in long distribution systems and in areas where the chlorine concentration drops below a minimum desired level (0.2-0.8 mg/L). Therefore, booster chlorination has to be installed so as to protect an enough chlorine level in the water [6,28].

Conclusion

Water samples for residual chlorine content were collected from fifteen different locations under Palasuni water treatment plants, nine locations under Samantrapur water treatment plants and thirty one locations under Munduli water treatment plants. Among the different distance, the average chlorine content was found to be higher in short distance followed by medium distance and the lowest average value was found in long distance. It may be noted that the variation in chlorine content at three treatment plants have no importance as efforts are made to maintain constant chlorine content. Chlorination can be made more economically in the water treatment plants and chlorine dosing may be made in between as per the requirement. In UGRs, the detention time period can be calculated in ordered to maintain the residual chlorine at 0.2 mg/L at the consumer end.

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