Determination of Optimum Dosage of Chlorine for Jabalpur City using EPANET

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Abstract— The purpose of this study is to determine free residual chlorine in water distribution system of Jabalpur city using EPANET software. The hydraulic data provided by the Jabalpur Municipal Corporation is used in the present work. The chloroscope is used for finding out the on-site free residual chlorine in the system. Total 540 observed readings are taken on-field using chloroscope. The chlorine decay coefficients are found by comparing the observed readings with predicted values from EPANET by trial and error method. This type of study is useful in understanding the movement of foreign particles in the water distribution system, to optimise the chlorine dosage at the water treatment plant and water storing facilities, to maintain limiting 0.2 mg/L of residual chlorine throughout the system.

Key words: Optimum Dosage of Chlorine for Jabalpur City, EPANET

I. INTRODUCTION

Water quality is a prime concern in the world. Many transmittable diseases are waterborne. Water distribution networks serve many purposes in addition to the provision of water for human consumption, which often accounts for less than 2% of the total volume supplied.

People in rural areas obtained water from unprotected ponds or tanks, wells, cisterns and sometimes streams and rivers. Mostly this water is unsafe for consumption. Consequently, the populations suffer from frequent epidemics.

The objective of any water distribution system is to make water available to the consumer in proper quantity and pressure, with acceptable quality in terms of flavour, odour, appearance and sanitary security.

Preserving the water quality throughout the distribution system is, therefore, one of the most challenging technological issues for suppliers. Therefore, source concentration must be large enough to maintain adequate residual free chlorine as minimum 0.2 mg/L (Drinking Water Specification IS: 10500, 2012). Chlorine disinfection presents the advantages of efficiency and durability. To guarantee the water supply system's disinfection, we need a residual concentration disinfectant to prevent recontamination by pathogenic or indicator micro-organisms, which can originate in the biofilm formed inside the system, as well as in negative pressure areas. There is a problem when water distribution systems have considerable proportions. Chlorine residual concentration disappears along the system. Knowing the aspects behind chlorine decay is in order if we are to develop a strategy capable of disinfecting a water supply system and, at the same time, preserving water quality until the point of use, without using more disinfectant than necessary.

Typically, chlorine is added near the final stages of drinking water treatment plants to disinfect. A certain residual amount is added to disinfect against any pathogens found in the inside walls of the distribution system piping. This residual chlorine is consumed on its journey through the piping system and the chlorine concentration should be at low concentrations at the point of consumption.. Computer-based mathematical models that able to predict the time history and the spatial distribution of constituents in water distribution networks are useful in network design and operation. Chlorine disinfectants interact with the natural organic matter in treated water to form disinfection by-products (DBP). Raising the pH of treated water may assist in controlling the corrosion but will increase the formation of trihalomethanes (by products of chlorine disinfectant). Since the THMs are carcinogenic, this is not desirable. There is a trade-off between providing enough residual to ensure the micro-biological safety of the water supplied, and adding too much disinfectant, which can lead to taste, odour, or by-product problems (Jea et al., 2012). Long retention times are very significant with regard to the concentrations of various contaminates and substances as they propagate through the system.

II. METHODOLOGY

Total five zones of Jabalpur city are selected for the study . Water samples are periodically collected on the day of water supply (on every 4th day), taken at 10 random locations where chlorine concentration is to be analyzed on-site with chloroscope.

III. ANALYSIS OF RESIDUAL CHLORINE

First the system hydraulic model (EPANET) is set up with all of the pipe, reservoir and junction data. All the data is obtained from Municipal Corporation, while bulk chlorine decay coefficient is obtained from literature and some model runs. Details of the network layout and hydraulics are fed to the software. Network of the selected zone is prepared. Value of the bulk decay coefficient -1.0 d-1 is selected from the literatures [(Mohammed et al., 2009), (Rossman 2000)]. The wall decay coefficient is found out by trial and error method by analyzing the residual chlorine values in the system (Toru et al., 2008). It is done by computing least square error between the data obtained from observed values and software predicted values. These coefficients are applied for the other zones also, and their validation purpose and good results are obtained. Water samples are periodically collected on the day of water supply, taken at 10 random locations of the zone where chlorine concentration is to be analyzed on-site with chloroscope.

Orthotolidine solution is used in the analysis. For this, 10 ml water sample is taken in clean glass tube. 1-2 drops of orthotolidine solution is mixed in the sample. The yellow colour would form if residual chlorine is present. Then, this tube colour is compared with the comparator tubes in the chloroscope and the reading is noted down. Two sets of readings are collected on each day of analysis of which one set contains 10 readings starting from ESR to the 10th selected node of the study area zone. After collection of 1st set of readings which takes 1 to 1.5 hour, 2nd set of readings is taken from ESR to 10th selected node.

IV. Result and Discussion

Total 5 number of zones: - Bhawartaal, Shrinath, Town hall, Gupteshwar, Futataal of the Jabalpur city are studied and analyzed for the prediction of residual chlorine in the water distribution system. The residual chlorine is found out on site using Chloroscope instrument. The results obtained from the field tests and that of EPANET software are calibrated and the coefficient of wall decay is obtained for all these zones along with the minimum initial required chlorine dosage in the ESR.

The data obtained from observed values and that of EPANET software is calibrated to find the Kw value. This Kw value is then validated by applying it to the other four zones and satisfactory results are obtained.

From literatures it is found that in most cases, the ideal calibration is to be done by comparing the predicted and observed data by use of Root Mean Square Error Method (RMSE).

The predicted values for all zones are obtained by varying the value of Kw as -0.45/day, -0.50/day, -0.55/day, -0.60/day and Kb= -1/day is kept same for all zones.

A. *RMSE Analysis*

The root-mean-square error (RMSE) is a measure of the differences between values (sample and population values) predicted by a model or an estimator and the values actually observed.

These individual differences are called residuals when the calculations are performed over the data sample that are used for estimations, and are called prediction errors when computed out-of-sample.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}$$

Where n= number of readings in a set,
y = observed reading
y^ = predicted reading

From the readings given in the Annexure, following RMSE values are obtained

Kw, Kb	-0.45, -1	-0.50, -1	-0.55, -1	-0.60, -1
% RMSE	3.95	3.82	3.79	3.99

Table 1: RMSE obtained for Bhawartaal

Kw, Kb	-0.45, -1	-0.50, -1	-0.55, -1	-0.60, -1
% RMSE	3.46	3.12	2.94	3.0

Table 2: RMSE obtained for Shrinath

Kw, Kb	-0.45, -1	-0.50, -1	-0.55, -1	-0.60, -1
% RMSE	3.0	2.74	2.75	2.91

Table 3: RMSE obtained for Town hall

Kw, Kb	-0.45, -1	-0.50, -1	-0.55, -1	-0.60, -1
% RMSE	3.28	3.07	2.9	3.43

Table 4: RMSE obtained for ZONE Gupteshwar

Kw, Kb	-0.45, -1	-0.50, -1	-0.55, -1	-0.60, -1
% RMSE	5.43	5.23	5.2	5.2

Table 5: RMSE obtained for Futataal

Though the differences between the errors for different Kw values are small, the Kw corresponding to the least RMSE is of great importance.

Thus from the above data, the value of coefficient of wall decay Kw= -0.55/day is determined for the Jabalpur City.

V. Minimum Initial Required Residual Chlorine at ESR

The minimum initial required residual chlorine at the ESR is also found out with the help of EPANET software with the condition to have minimum 0.20 mg/L residual chlorine at the tap of consumer of the zone with Kb = -0.55/day, Kb= -1/day.

If the above concentrations are maintained at the respective ESR, then there will be atleast 0.20 mg/L of residual chlorine in each house of the zone which is the minimum requirement according to Indian Standard Drinking Water Specification (Second Revision IS:10500,2012).

Zone	Minimum Initial Required Residual Chlorine at Esr
Bhawartaal	1 mg/L
Shrinaath	0.4 mg/L
Town hall	0.5 mg/L
Gupteshwar	0.5 mg/L
Futataal	0.4 mg/L

Table 6: Minimum Initial Required Residual Chlorine at ESR

VI. Conclusion

- The initial minimum residual chlorine at the ESR for zone 14 is found to be 1 mg/L with need of external disinfection at node 16 only.
- The initial minimum residual chlorine at the ESR for zone 15 is found to be 0.5 mg/L.
- The initial minimum residual chlorine at the ESR for zone 10-A is found to be 0.5 mg/L.
- The initial minimum residual chlorine at the ESR for zone 5-A is found to be 0.4 mg/L.
- The initial minimum residual chlorine at the ESR for zone 2 is found to be 0.4 mg/L.

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