Determination of Wall-Decay Coefficient (Kw) for Water Distribution System of Dhule City using EPANET

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Abstract: *The purpose of this study is to determine wall decay coefficient (Kw) for water distribution system of Dhule city using EPANET software. Dhule Municipal Corporation has provided hydraulic data which is used in the present work. For finding out the on-site free residual chlorine in the system, chloroscope is used. Total 540 observed readings are taken on-field using chloroscope. By comparing the observed readings with predicted values from EPANET by trial and error method, the chlorine decay coefficients are found. This type of study is useful in understanding the movement of foreign particles in the water distribution system, to optimize 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.*

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 obtain 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 of 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 of chlorine residual concentration disappearing 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 the inside the 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 are 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.

METHODOLOGY

Total five zones of Dhule 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.

Analysis of Residual Chlorine

First the system hydraulic model (EPANET) is set up with all 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 per day 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 for their validation purpose and satisfactory 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.

RESULT & DISCUSSION

Total 5 number of zones: - (1) Zone 14- Oxidation Pond ESR Zone, (2) Zone 5A- Nehru Nagar ESR Zone, (3) Zone 15- Kumar Nagar ESR Zone, (4) Zone 2- Mohadi ESR Zone & (5) Zone 10A- Police Parade Ground ESR Zone of Dhule 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.

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

Table 1: RMSE obtained for Zone 14

Kw, Kb	-0.44, -1	-0.51, -1	-0.54, -1	-0.60, -1
% RMSE	3.94	3.81	3.78	3.95

Table 2: RMSE obtained for Zone 5(A)

Kw, Kb	-0.44, -1	-0.51, -1	-0.54, -1	-0.60, -1
% RMSE	3.46	3.12	2.94	3.0

Table 3: RMSE obtained for Zone 10(A)

Kw, Kb	-0.44, -1	-0.51, -1	-0.54, -1	-0.60, -1
% RMSE	3.1	2.73	2.74	2.90

Table 4: RMSE obtained for Zone 15

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

Table 5: RMSE obtained for Zone 2

Kw, Kb	-0.44, -1	-0.51, -1	-0.54, -1	-0.60, -1
% RMSE	5.42	5.22	5.23	5.21

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 Dhule City.

CONCLUSION

- EPANET can track the residual chlorine in water in each pipe. It is a research tool for improving our understanding for movement of water within distribution system.
- EPANET incorporated first order model is found to be satisfactory in terms of prediction of residual chlorine.
- Once the hydraulic and water quality model set up and properly calibrated, we can rely on EPANET predictions.

- There is relevant reliability in simulation of water quality in water distribution systems using EPANET program.
- The decay is faster for higher values of initial residual chlorine at ESR than those of lower values.
- The coefficient of wall decay is found out to be Kw= -0.55/day for Dhule city from the data analysis of total 5 zones.
- For zone 14, RMSE= 3.79% with help of 40 data sets of observed values
- For zone 15, RMSE= 2.90% with help of 3 data sets of observed values
- For zone 10-A, RMSE= 2.75% with help of 3 data sets of observed values
- For zone 5-A RMSE= 2.94% with help of 4 data sets of observed values
- For zone 2, RMSE= 5.2% with help of 2 data sets of observed values

SCOPE FOR FUTURE WORK

The present study is initiated with an objective to identify a modelling of chlorine residual in water distribution network. It is recommended to carrying out the research work on some of the following issues-

- Modelling of the movement of a non-reactive tracer material like Fluoride through network over time example- tracing the percent of originating from a specific node using EPANET
- To improve the accuracy of simulation outcomes, it is important to evaluate the properties of pipes in a distribution network model and improves the reproducibility of water flow conditions
- Modelling the movement and fate of a reactive material as it grows e.g. a disinfectant by- product, DBP like trihalomethanes

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