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EQUILIBRIUM OF BABYLON WATER SUPPLY NETWORK USING EPANET PROGRAM

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Abstract

The aim of the present work is to measure the residual chlorine concentrations in potable water, which leaves Babylon University's water supply plants. The Babylon water network was selected as a case study to test the efficacy of the quantitative-qualitative model in EPANET software. This involved identifying the required onsite chlorine injection point number, locations and dose, to raise chlorine concentrations to acceptable limits in the other nodes of the network. 80 samples of tap water were tested from ten locations within Babylon University's water network between December 2016 and April 2017. These samples were checked (twice a week, three times a day) to identify the concentrations of residual chlorine. These readings were compared with WHO (1982) in order to verify that the water had been sterilized using the EPANET program injection. The results show that the range of residual chlorine (0.0-3 mg/l) and most of the measured values were less than the maximum permissible (0.2-5.0 mg/l) according to Iraqi standards (417/1974)The bulk decay coefficient was found to be -1.18/day, the wall coefficients between -0.01 and -0.91/day. The main conclusion of this study is that onsite injection can improve the chlorine concentration in Babylon University's water supply network.
Keywords: Water, network, chlorine, pipes, EPANET.

Introduction

Babylon University is one of the largest universities in Iraq. Over the last few decades, it has undergone substantial extension, this affecting infrastructure services such as water supply networks. Due to war and economic sanctions, these old networks have deteriorated resulting in many cracks in pipes and leakages. This deterioration has resulted in water pollution within the network. In order to solve this problem, maintenance and renewal e.g. new pipes, are required, a solution which is expensive and disruptive.

There are many water quality-testing points in the networks of Babylon University, these used to classify the water quality as defined by Iraqi Specification No. 417 (1989). A water quantitative-qualitative model can be built to evaluate the effectiveness of an onsite injection program where low concentrations of chlorine are identified Al–Qaisey and Jawad (2005).

Kafaji and Abud Zebala (2006) studied the remaining chlorine concentrations in the water networks of seven water plants in Baghdad City. The study continues from February to July 2004. The study included residual chlorine analysis, temperature and pH of the water samples. The data were analyzed statistically. Results show that residual chlorine within the limits of the Iraqi standard, except for some points where the chlorination concentration more than the permissible limit, due to the lack of control of the injection of chlorine doses, in addition to some areas of the network had tanks where additional doses of chlorine were added.

Al-Mhamdi and Jaid (2007) evaluated the performance of Al Hussein water plant in Karbala City with the rest of the water purification plants in the city. The study lasted from December to August 2005. The study included the analysis of turbidity data for raw water and the plant. Data were analyzed statistically. The results of the evaluation indicated that the operation of both sedimentation and filtration basins was poor.

Al-Baidhani *et al.* (2018) evaluated the performance of the water treatment projects by the compound units (AL-Obadi and AL-Oboor) in Baghdad City to show their ability to filter the raw water from the Tigris River and to evaluate the operating conditions in the two compartments. He examined the samples physically, chemically. The fieldwork continued in November 2005 Until July 2006, after that he analyzed the results statistically. The obtained results showed that the percentage of turbidity values exceeding the Iraqi specifications was 28% in Al-Obeidi compound and 24% in Al-Obour compound. The residual chlorine values were 1.464 mg/L for Al-Obeidi compound and 1.156 mg/L for Al-Obour compound. All water quality indicators were among the Iraqi standard specifications except soluble solids.

Recently, the concept of equalization of water has been used in advanced water treatment units to mix water and dissipate the excessive energy Almansori (2014), and Hashim *et al.* (2018).

Examine the levels of residual chlorine at specific points, they have direct or indirect influence on many of the commonly encountered problems such as improvement or stabilization of rivers or channels and flood ways for navigation and flood control Hassan *et al.* (2019) and AL-Mansori (2018). In addition, polluted water or defect in residual chlorine dose could cause serious water pollution phenomenon AL-Mansori *et al.* (2016) that limits the sources of fresh water Al-Mansori, (2017), Al-Suhili, and Al-Mansori, (2017), and Altufaily *et al.* (2018), which in turn requires efficient water treatment processes Altufaily *et al.* (2019), Al-Baidhani *et al.* (2019), and Hashim *et al.* (2019), such electrochemical treatment AL-Mansori, Muslim (2018), and biological units Al-Mansori (2017). Moreover, dredging of polluted water requires special soli treatment as it cause soil or ground water pollution AL-Mansori (2018), and Al-Mansori1 *et al.* (2018). Although some studies have been carried out to removal of algae from Uncovered tank of water treatment plants and other types of pollutants AL-Mansori (2016), handling of preservation of quality of water in uncovered tanks or reservoirs is still very costly process Dandy. Blaikie *et al.* (2004). Therefore, the most important justification for this study was to arrive at a logical scientific assessment of the quality of sterilization of drinking water through the field measurements on water samples from different sites in the network of the University of Babylon. The extent of conformity to Iraqi specifications to find treatment for zones where chlorine remaining less than the limit allowed by specification and determine the best site to install injection units, time and dosage required through (EPANET) program.

The objectives of this study are to examine the levels of residual chlorine at specific points within the Babylon University water network, then, compare them with Iraqi Specifications and test the ability of the quantitative-qualitative model (EPANET). To identify the required onsite chlorine injection point number, locations and dose, to raise chlorine concentrations to acceptable limits in other nodes of the network.

Material and Methods

The most well-known test is the DPD (diethylparaphenylendiamine) pointer test, utilizing a comparator. This test is the snappiest and easiest strategy for testing chlorine residual where a tablet reagent is added to an a sample of water, coloring it red. The quality of the shading is estimated against standard hues on a graph to decide the grouping of chlorine. The more grounded the shading, the higher the concentration of chlorine in the water. Sanda (2011)

The test was done by using a (LOVEBOND) disc with a detector DPD, which is a special powder used for each test made by chemical companies. The set is from HANA Company, the measurement process was done by adding 10 ml of the water sample and then adding a package from the detector DPD to the palm produces a pink solution. The degree of color varies according to the residual chlorine concentration in the sample. The cell then placed in (LOVEBOND) disk and the color of the test samples was compared with the color grades installed on the turntable on the set. Paul Boulos *et al.* (1990).

Babylon University water supply network was used to test chlorine concentrations between December 2016 and March 2017. Table 1 shows details of the nodes and the average concentration of chlorine in each node based on 76L/ student/d+ 10-15 % for loss and wastage.

Table 1: Details of the Nodes

No.	Node name	CL cons.(mg/l)				No. of served persons	Estimated average demand (L/min.)
		Dec.	Jan.	Feb.	Mar.		
1	Civil Dept.	0.05	0.233	0.35	0.167	385	23.36
2	Mechanical Eng.	0.2	0.3	0.45	0.833	309	18.75
3	Material Eng.	0.075	0.433	0.35	0.067	179	10.84
4	Central library	1.525	2.733	3.75	3.833	130	7.89
5	Information Technology	0.175	0.2	0	0	637	38.66
6	Presidency	0.825	1.433	1.25	1.6	900	54.62
7	Central cafe	0.175	0.233	0.3	0.033	2737	166.12
8	Literature	0.425	0.333	0.3	0	480	29..13
9	Biology	0.125	0.133	0.8	0.233	432	26.22
10	Science college	0.025	0.133	0.25	0	189	11.47

EPANET program

EPANET is a computer program that performs extended period simulations of hydraulic and water quality behavior within pressurized pipe networks. Figure 1 shows the names of the nodes with different pipe diameters while Table 2 provides details about the pipes in the Babylon University water network.

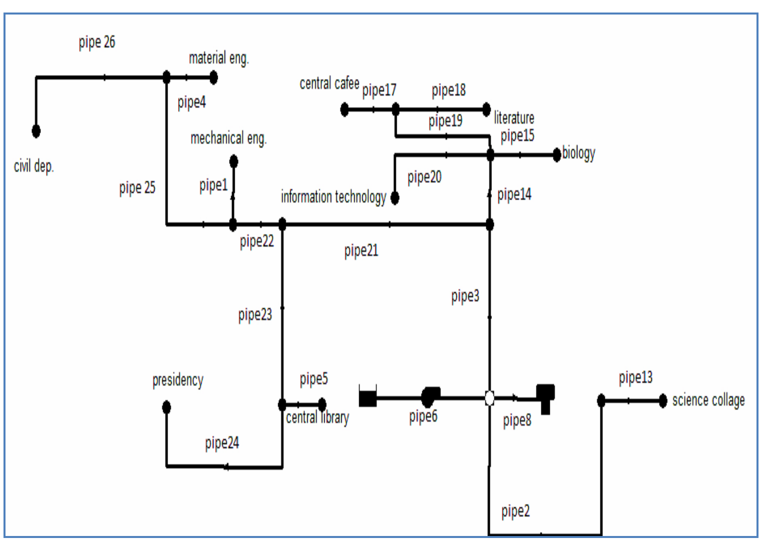

Fig. 1 : Names of Nodes in the Water Supply Network

Table 2: Details of Pipes in the Babylon University Water Network.

Pipe no.	Diam. (mm)	Length (m)	Pipe no.	Diam. (mm)	Length (m)
1	100	10	13	100	21
2	150	365	14	150	93.5
3	150	58.5	15	80	48
4	80	6	22	150	52
5	120	1000	17	80	22
23	100	50	18	80	130.5
24	100	87	19	100	148
8	120	1000	20	100	39
25	150	180	21	150	70
26	50	167			

Based on previous work by Paul Boulos *et al.* (1990) a first-arrange rot display was utilized as a response active model for chlorine in mass fluid while a zero-arrange rot show was utilized as a divider response active model.

$$Dc/dt\ Kb*C+(4/d)*kw \qquad ...(1)$$

Where:

C - free chlorine concentration mg/l

Kb - first- order bulk decay coefficient (1/day)

Kw - zero – order wall reaction decay coefficient mg/m^2/d

d: pipe diameter (mm)

Results and Discussions

Reactions can occur both within the bulk flow and with material along the pipe wall. This is illustrated in Figure 2.

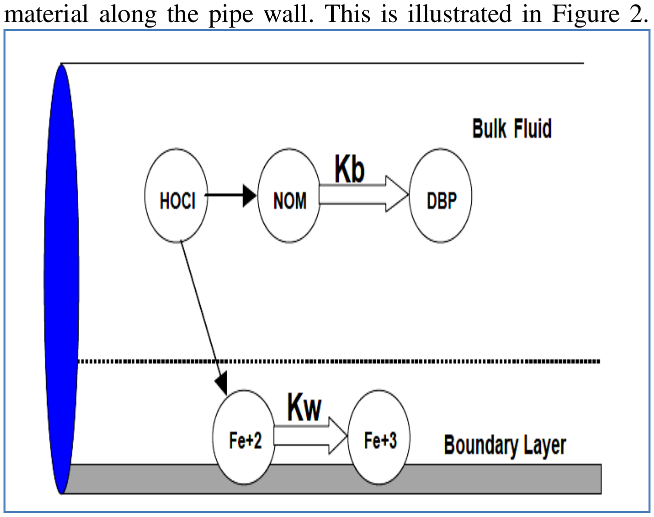

Fig. 2 : Reaction Zones within a Pipe

R = kb * C^n ...(2)

Where Kb - the bulk reaction rate coefficient

C - reactant concentration (mass/volume)

n - reaction order. Kazantzis (2002).

The data of log (concentration of residual chlorine at any time CL/ initial concentration Co) versus time is plotted as shown in Figure 3, the bulk decay coefficient was the slope of this line (-1.1819)/day.

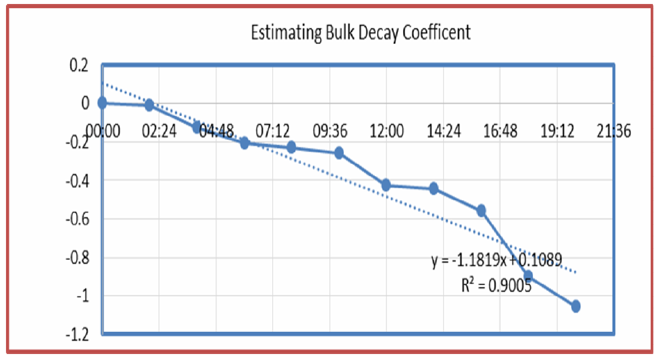

Fig. 3 : The Slope of Line Kb.

The rate of water quality reactions occurring at, or near, the pipe wall, can be considered dependent on the concentration in the bulk flow expressed by:

R = (A/V) * kw * C^n ...(3)

Where Kw- a wall reaction rate coefficient

A/V - the surface area per unit volume within a pipe (equal to 4 divided by the pipe diameter). Daniel (1996).

The wall decay coefficient can be estimated using EPANET by a trial and error approach. This can be accomplished by assuming a wall decay coefficient for all, or for each individual pipe. After running the hydraulic and quality analysis using EPANET, the concentration of chlorine in other nodes can be estimated. If these values compare well with the measured values, the assumed wall decay coefficients may be considered as real values. If these values are significantly different, adjustments of the assumed values are carried out until a good match is obtained. Rossman and Boulos (1996).

Table 3 shows the final wall decay coefficients for each pipe while Table 4 shows the average of residual chlorine for all nodes. These are estimated using the average measured concentration values in Table 4.

Table 3 : Pipe Wall Decay Coefficients

Pipe no.	Wall Decay Coefficient	Pipe no.	Wall Decay Coefficient
1	-0.2	14	-0.8
2	-0.2	15	-0.8
3	-0.8	17	-0.01
4	-0.1	18	-0.9
5	-0.1	19	-0.2
6	-0.7	20	-0.2
8	-0.9	21	-0.9
13	-0.9	22	-0.2

Table 4: Avg. Cl for Nodes

No.	Node Name	cl cons.(mg/l)				Avg.Cl.
		Dec.	Jan.	Feb.	Mar.	
1	Civil Eng. Dept.	0.1	0.2	0.4	0.2	0.2
2	Mechanical Eng.	0.2	0.3	0.5	0.8	0.4
3	Material Eng.	0.1	0.4	0.4	0.1	0.3
4	Central library	2	3	4	4	3
5	information technology	0.2	0.2	0	0	0.1
6	Presidency	0.8	1.4	1.3	1.6	1.3
7	central café	0.2	0.2	0.3	0	0.2
8	Literature	0.4	0.3	0.3	0	0.25
9	Biology	0.2	0.1	0.8	0.2	0.3
10	science collage	0.1	0.1	0.6	0	0.2

Fig. 4 : Shows the comparison between measured and estimated values, this revealing a good match.

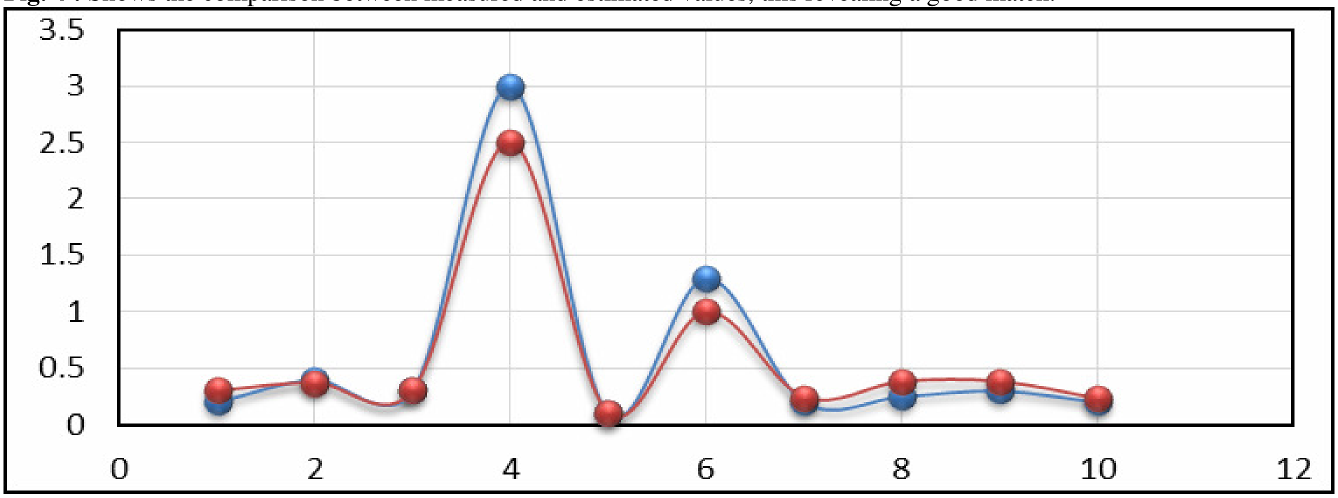

Fig. 4 : Comparison between Measured and Estimated Values of CL.

In order to find the locations of the required injection points and the dose required the EPANET water quality model was applied. This model is used for the expected hydraulic condition of the network. The hydraulic pattern is either constant daily demand (average), or a daily variation demand pattern. In order to apply the EPANET model, the values of the bulk decay coefficients and the wall decay coefficients of the pipes are fed into the software.

Following this, different onsite injection proposals are trialed to establish which proposal will raise chlorine concentrations at the nodes to acceptable levels. Since this network functions on a daily operation base, the plan is to use patterns of injections to raise the concentration of chlorine to acceptable values during times of high demand. Two cases were selected.

Injections of chlorine at nodes 4 and 13 (3 mg/lit) were administered every two hours. The results of the chlorine concentrations at different nodes are shown in Figures (5 to 14) below where it can be seen that the injections raised the concentration of chlorine to an acceptable value for all nodes.

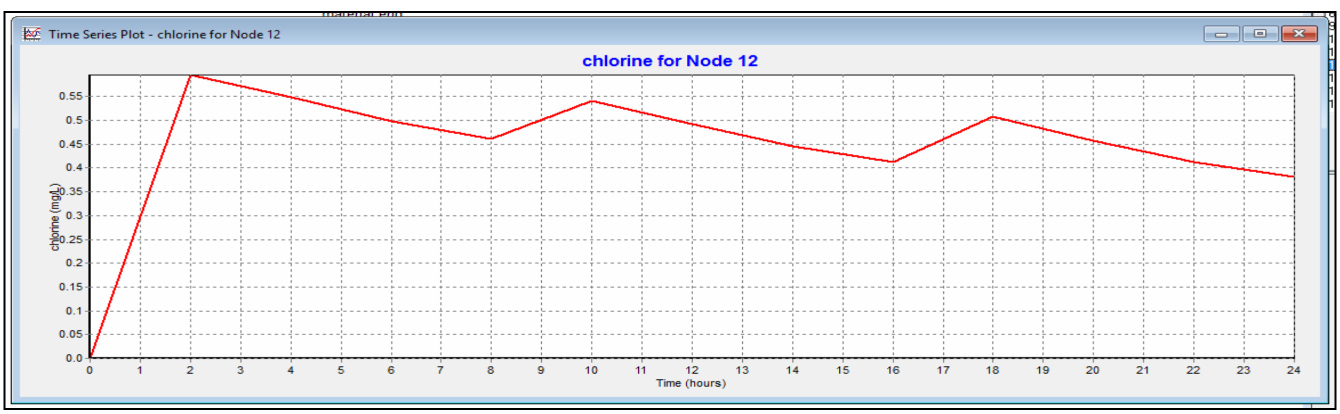

Fig. 5: concentration of chlorine at node 12.biologyical Dept.

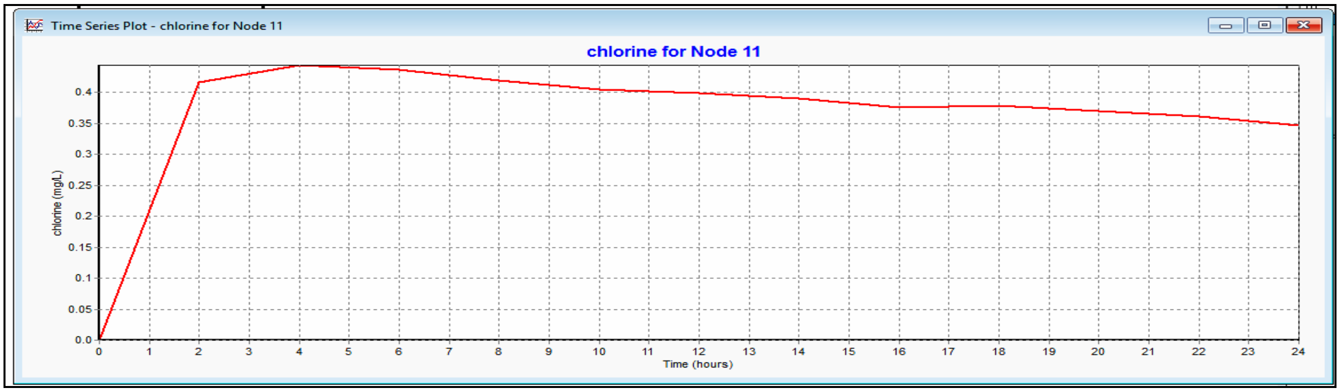

Fig. 6 : Concentration of chlorine at node 1.literature Dept.

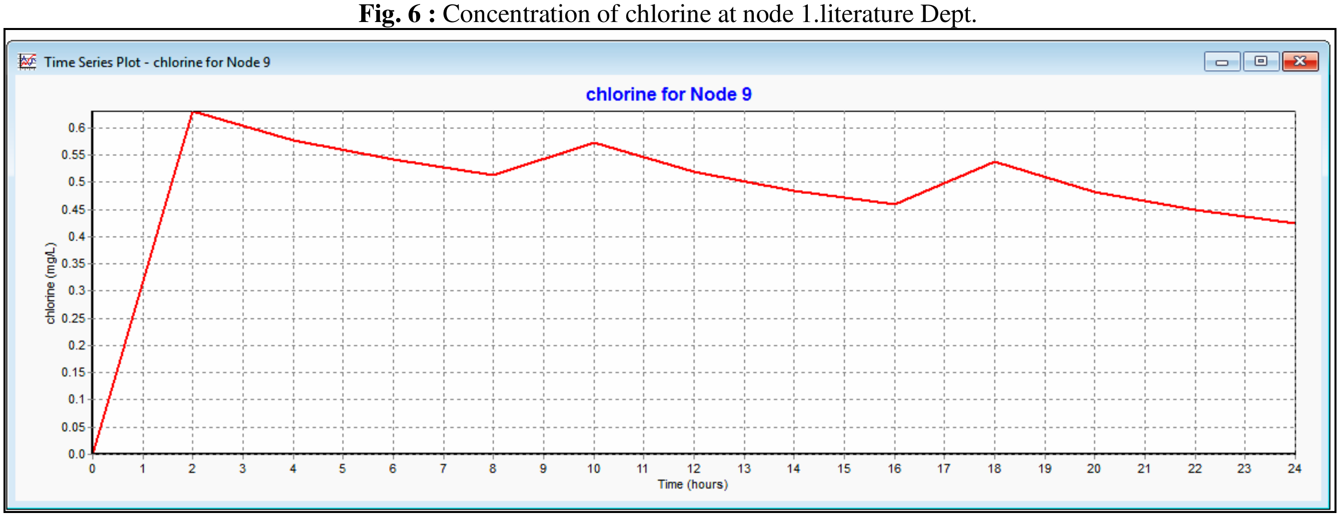

Fig. 7 : Concentration of chlorine at node 9 (Central café).

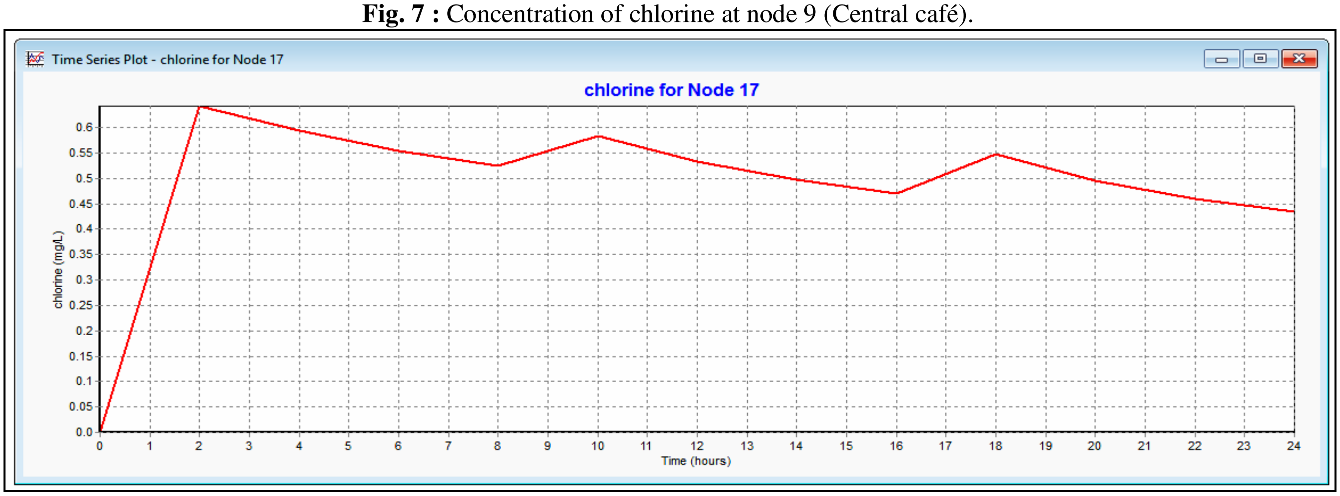

Fig. 8 : Concentration of chlorine at node 17 (Information Technology).

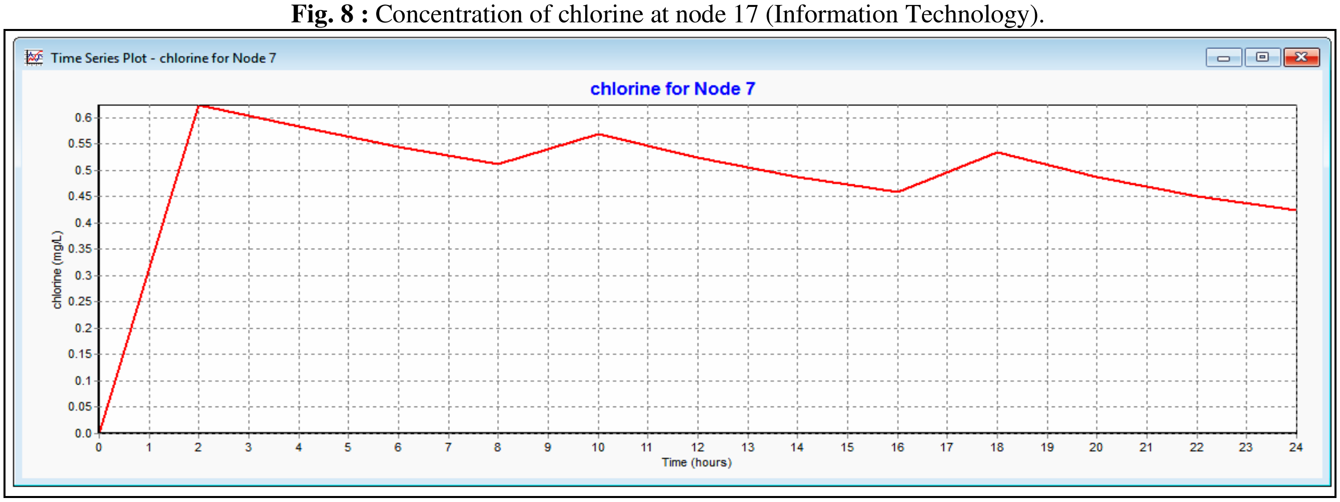

Fig. 9 : Concentration of chlorine at node 7(Mechanical Eng)

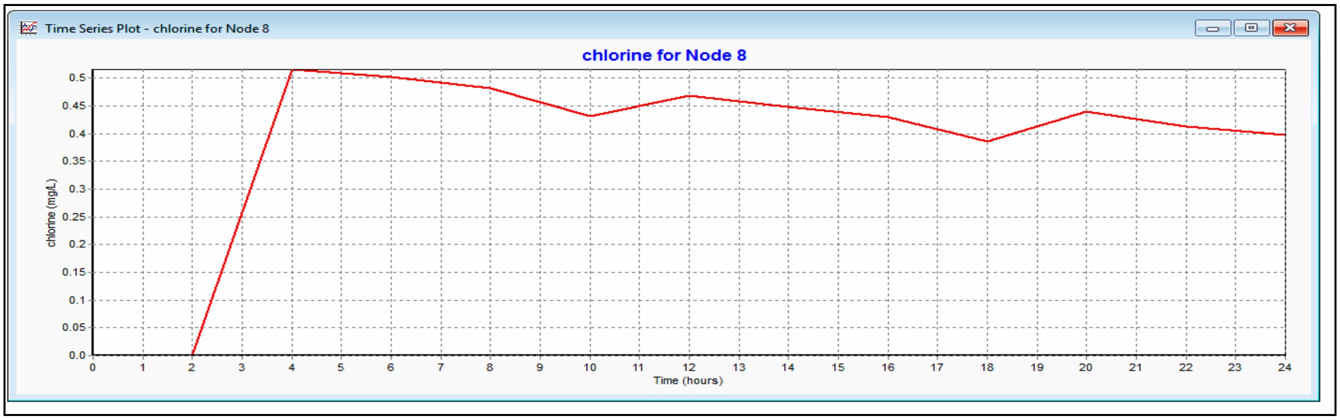

Fig. 10 : Concentration of chlorine at node 8 (Material Eng).

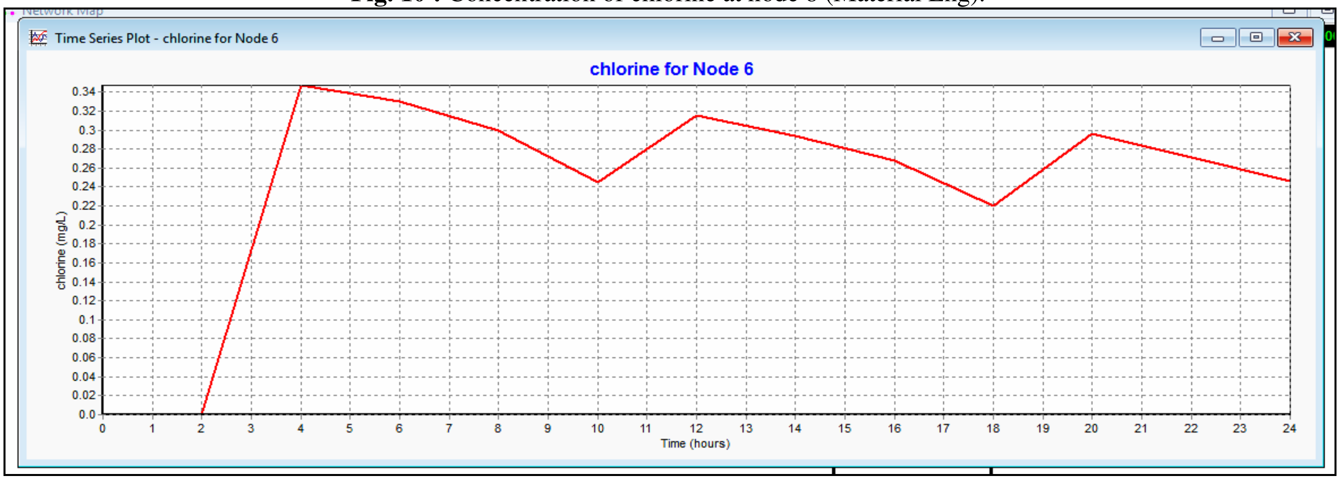

Fig. 11 : Concentration of chlorine at node 6 (Civil Eng. Dept.).

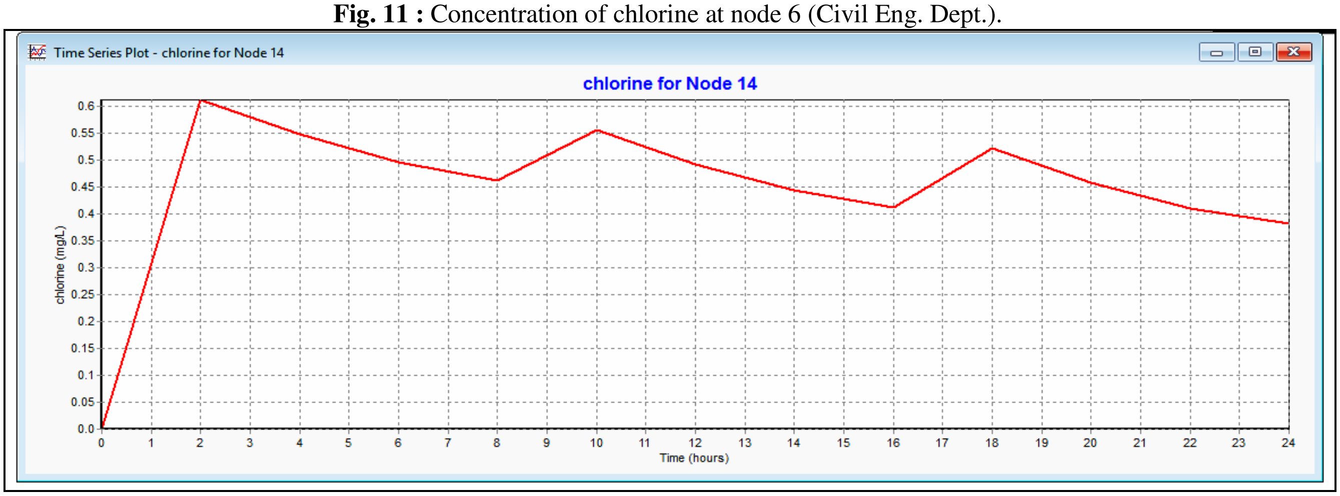

Fig. 12 : Concentration of chlorine at node 14 (Central Library).

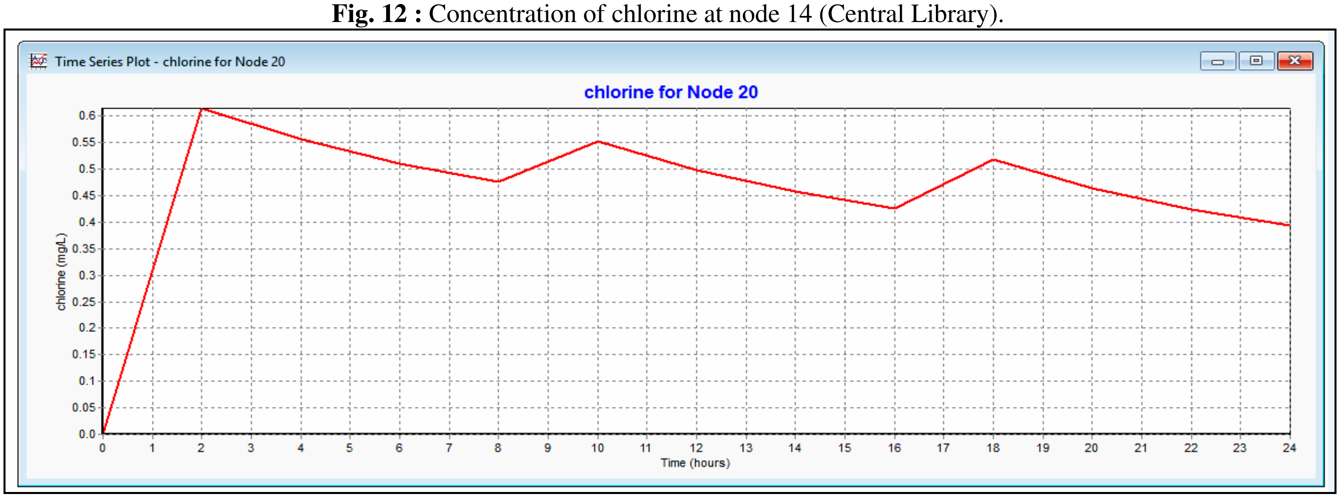

Fig. 13 : Concentration of chlorine at node 20 (Presidency).

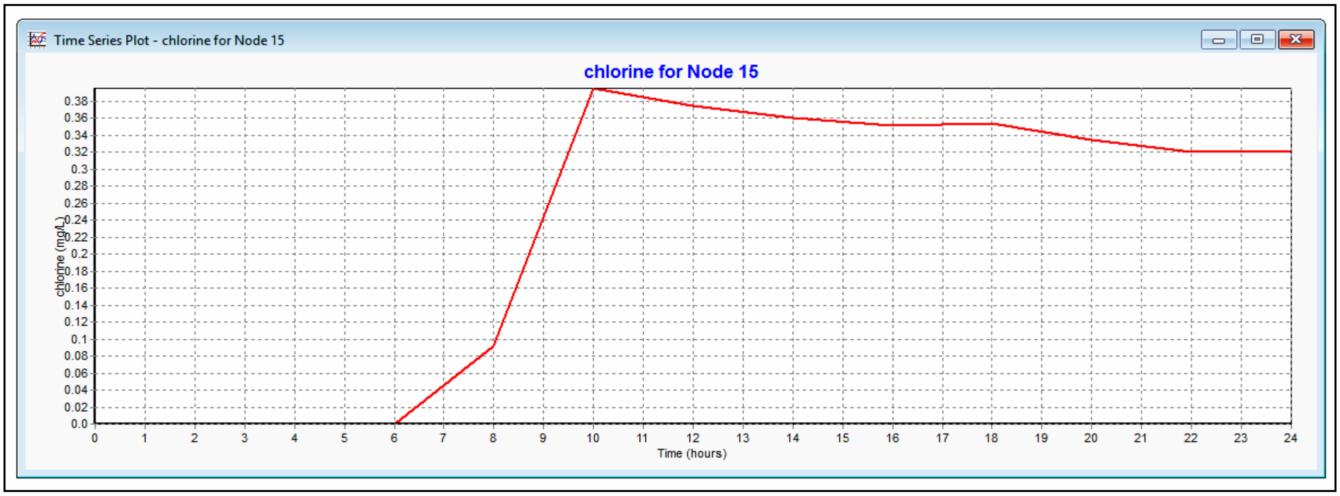

Fig. 14 : Concentration of chlorine at node 15 (Science College).

Conclusions

- There is no obvious chlorine-testing program for Babylon University water networks managed by the authorities responsible for this. However, temporal variation is tested is on monthly basis.
- The number of locations where there are low concentrations of chlorine increases over the summer months due to chlorine depletion. Areas of low chlorine concentrations are usually located some distance from the treatment plants, which indicates that these low concentrations are due to conveyance issues.
- The current experimental work indicated that the bulk decay coefficient for the water network of the selected case study is -1.18/ day.
- The wall decay coefficients, found using EPANET, for all the pipes in the network, lies within the range -0.01 to -0.9. EPANET can be used to find the most effective injection strategy for a selected network.

Application of onsite injections comprised injections at nodes 4 and 13 of 3 mg/lit chlorine during every 2 hrs. The results indicate that node injection is preferable since it raises the concentration of chlorine to acceptable limits between 0.2 and 2 mg/lit.

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Conflicts Of Interest

The authors declare that they no conflicts of interest regarding the publication of this paper.

Ethics

The corresponding author hereby confirms that ethics were considered for this research and that the article is original, and its contents are unpublished. The co-author has read and approved the manuscript for submission.

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