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Chlorine Concentration Decay In Water Distribution System

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Abstract: We report here, the first order kinematics decay model for calculating chlorine concentration decay in water distribution system. Furthermore, age factor is also included in our model. A detailed analysis of bulk decay coefficient, wall reaction coefficient, ageing factor and temperature are compared. The results showed that chlorine decay strongly depends upon the temperature ageing factor of the distribution system, time and wall reaction coefficients. Experiments were carried out to determine the chlorine decay in water distribution system and decay pattern was analysed every hour.

Keywords: Chlorine decay, wall reaction coefficients, bulk decay coefficients, first order kinematics and ageing factor

1. INTRODUCTION

Purified water is the need of every human being. Water is treated with the help of chlorine in reservoir i.e. tank and in the distribution system. Monitoring of chlorination in distribution system is a serious need of today’s world. Thus, this serious Problem must be investigated and it is necessary to be investigated the decomposition pattern of chlorine decay in the water distribution system. Many pioneer researchers ([3]; [10]; [4]) investigated the behaviour of chlorine decay, with the zero and first order of reaction. In their investigations, they analysed chlorine consumption pattern. Later [5], presented a model in which he explained that wall reaction coefficient is totally dependent to the bulk reaction coefficient. They explained that wall reaction coefficient is 10% of the bulk reaction coefficient. In their investigations, they explained that chlorine decay is totally reliant on temperature. [1] showed a second chlorine concentration decay model. They explained that there is no relationship between bulk chlorine decay coefficient and initial chlorine concentration, which was involved in the water. [8], showed that chlorine decay in the distribution system was totally dependent on fast and slow reacting agents, which were already present in the water distribution systems. [9] investigated that bulk decay coefficient depends on temperature and time varying conditions in the distribution system. [11], showed that chlorine concentration depends on pipe service age. They investigated that chlorine consumption rate is higher in newly built pipe and chlorine consumption rate is lower in old built distribution system. Many researchers have developed various mathematical models to calculate the chlorine concentration decay in the water distribution system. But they could not take all factors which involved in the water distribution system. In our paper we took all the factors which are involved in the water distribution system. In our Model we took bulk reaction coefficients, wall reaction coefficients, ageing factor of the distribution system, time and temperature. To verify our model, sample collection was from newly built distribution system and old aged distribution system was taken into the research consideration.

2. MATHEMATICAL MODEL

To ensure the residual chlorine concentration decay in water distribution system, various researches have been given through various models. In this paper, we consider various factors that affect the water quality in the distribution system. In this model, mass of the water mass depends on chlorine decay (i.e. bulk decay coefficient must be considered). Likewise, chlorine reaction rate with the pipe wall surface is considered. [5], in their studies they represented that the wall reaction coefficient k_w is presented 10% of the bulk decay coefficient ((k_b). We have considered two most of the important factors which affect chlorine decay in water distribution system i.e. temperature and ageing of the distribution system. In our model first order reaction rate is considered as

$$\frac{dc}{dt} - (k_b + k_w + k_a)C = 0 \quad \text{(i)}$$

Wherek_b, k_w and k_a is bulk decay coefficient, wall reaction coefficient and age factor of the distribution system respectively.

Initial chlorine concentration is taken as zero when time is zero

On solving above equation, we get

$$c = c_0 e^{-(k_b + k_w + k_a)t} \quad \text{(ii)}$$

Where c_0 is initial chlorine concentration decay when t>0.

3. STUDY AREA

An Water distribution treatment of the plant is situated at Rajpur Road, Dehradun , Uttarakhand (India).The study plant is made of cement and distribution pipe line is made of iron pipe line. More than, 300 samples were collected for sixth months and 20 sampling points were taken in the distribution system. Our treatment plant distributes the water to various colonies likewise, Rajpur Road, Sachivalya Colony, DL Road and Safera Basti. We collected data from these 20 points from the mentioned above locations and these samples were taken from house hold, restaurants and public drinking water tanks.

To determine the residual chlorine in water, we use calorimeter with sodium thiosulfate sulphate. In this process, we take water sample from tap in the duplicate manner, so that we reduce the error while taking water sample. It is analysed that residual chlorine can be calculated by calculatingk_b, k_w, $k_a$time and temperature ,as well as, order of reaction. Various researchers ([6], [12]) took chlorine concentration sample and was measured at every time interval, until the chlorine concentration becomes zero and it was calculated only with the water in this whole process, wall reaction was not considered. The coefficient of k_b was calculated with the help of $c = c_0 e^{-(k_b)t}$ and then average of k_b is calculated. From Arrhenius model, it is concluded that k_b is the function of the temperature or k_b is directly proportional to temperature. It means increment of k_b depends on increment in temperature. In our study, it was completed in the months of April, May, June, July, August and September. Average temperature of every month is calculated 32, 36, 34, 29, 28 and 27 degree centigrade respectively. In our study various values of kb is taken .35* 10^{-6} .36* 10^{-6},.38*10^{-6}, .4*10^{-6}, .41*10^{-6}_and .43*10^{-6} was taken for six months. In our study we took k_b =10% of k_b as [5]. taken in his model.

4. RESULTS AND DISCUSSION

We introduced 3 mg/l chlorine in our over head tank and sample was taken from first entry point, which is situated at the bottom of the over head tank and then sample is also taken from 20 different entry points which is connected to over head tank. The entire collected sample was shown in the table 1. These samples were collected at different time intervals, at different collection points with 20-year-old aged water over head tank. It was analysed that chlorine was decreasing, due to aged water tank and temperature is inversely proportional to chlorine concentration decay.

Table 1: Sample Collection for July Month at 28 Degree Centigrade

Sample Collecting Location	**t** (Time per second)	Chlorine Decay at Temperature 28 Degree Centigrade
S1	0	3
S2	200	2.9
S3	400	2.5
S3	600	2.5
S4	800	2.5
S5	1000	2
S6	1200	1.5
S7	1400	1.5
S8	1600	1.5
S9	1800	1.5
S10	2000	1
S11	2400	1
S12	2600	1
S13	2800	1
S14	3000	0.5
S15	3200	0.5
S16	3400	0.5
S17	3600	0.2
S18	3800	0.2
S19	4000	0
S20	4200	0

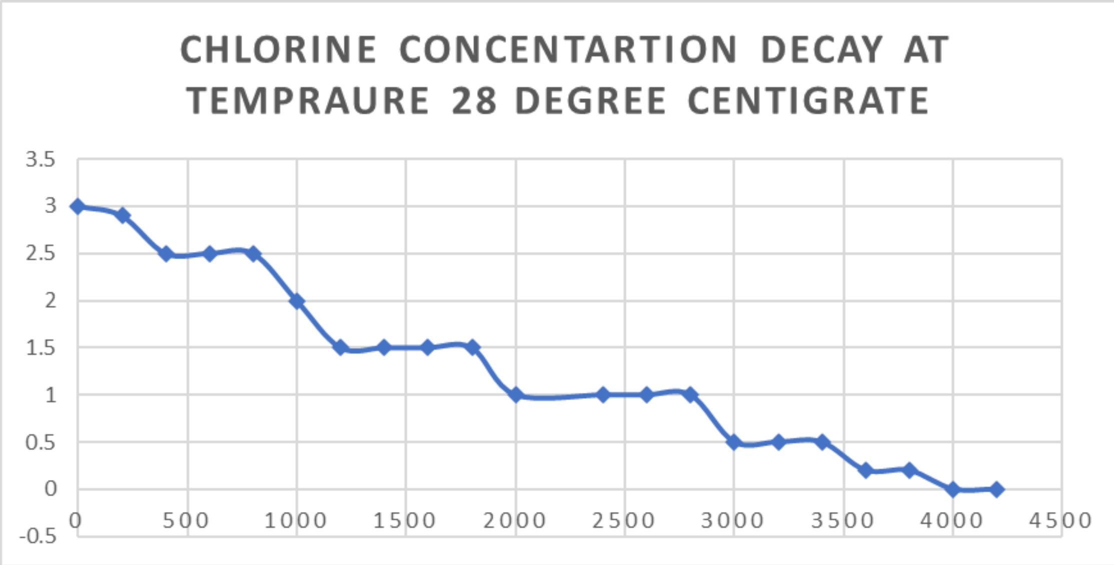

Figure 1: Variation Chlorine Concentration Decay at Different Time Intervals.

From Figure 1, it is concluded that chlorine is decreasing, as time is increasing. We introduced 3 mg/l liter chlorine in water distributed tank and we took sample from 20 sample points. After that, we analyzed that chlorine concentration is decreasing very fast, due to old aged water tank and higher temperature. The results obtained are plotted in figure 1 which show consistency with the results of [2]. After the time interval, the time interval 3400 second, chlorine becomes very less than the limit of WHO standard that suggested .5 mg/l [13].

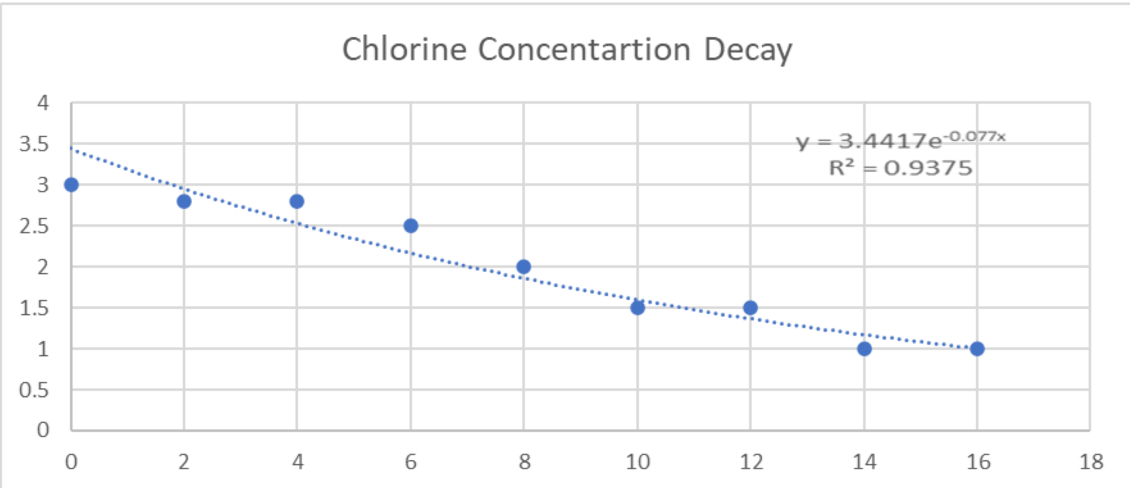

Figure 2. Variation of Chlorine Concentration Decay with Time

Figure 2, shows the sample collections at different time intervals. We introduced 3 mg/l chlorine in water tank and it is analysed that chlorine is decreasing when time is going to be increased. To analyse the variation in chlorine decay, a trend line is obtained i.e. $y = 3.4417e^{-0.077x}$ and R^2 value is also calculated i.e. $R^2 = 0.9375$. From 2 and trend line, it is concluded that chlorine concentration decay is inversely propositional to increase in time.

Table 2. Variation of Chlorine Concentration in old and newly Built Water tank

Sample Collecting Location	**t** (Time per second)	Chlorine Concentration Decay in 20 Years Old Ages	Chlorine Concentration Decay in Newly Built Water Tank
S1	0	3	3
S2	200	2.9	3
S3	400	2.5	3
S3	600	2.5	2.9
S4	800	2.5	2.5
S5	1000	2	2.5
S6	1200	1.5	2
S7	1400	1.5	2
S8	1600	1.5	2
S9	1800	1.5	2
S10	2000	1	1.5
S11	2400	1	1.5
S12	2600	1	1.5
S13	2800	1	1.5
S14	3000	0.5	1.5
S15	3200	0.5	1
S16	3400	0.5	1
S17	3600	0.2	1
S18	3800	0.2	1
S19	4000	0	1
S20	4200	0	0.5

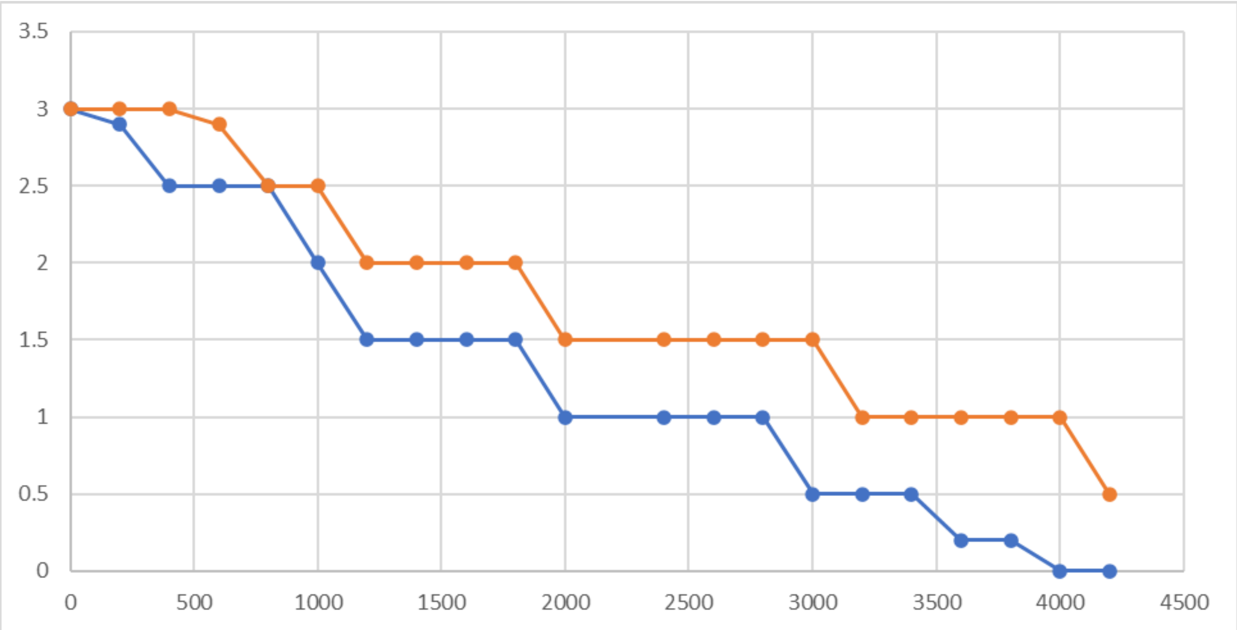

Figure 3. Variation of Chlorine Concentration Decay between Old Age and Newly Built Water tank

Chlorine decay was analysed between old and new aged water tank. In old aged water tank chlorine decays rapidly, while in chlorine decreases slowly in newly built water tank. The graphical representation can be shown in figure 3, with the help of table 2. This could be explained on the basis that in newly installed tank there is less chance of bio-films and corrosion of internal surface hence the flow remains steady. But with increase in tank service age, the thickness of bio-film increases, also due to oxidation and water hammering effect internal surface, pitting happens which lead to corrosion-erosion and deterioration of pipe material [7].

5. CONCLUSION

To calculate chlorine concentration decay in drinking water distribution system, bulk decay coefficient is calculated in different temperatures and 300 water samples were taken from 20 different locations for six months. It is observed that chlorine is decreasing, due to increment in bulk decay coefficients which happens, due increment in temperature. It is also concluded that chlorine decay is also dependent to wall reaction coefficient and to the age of water distribution system. It means more chlorine will be consumed in more aged water distribution system. To improve the water quality, municipality must repair water distribution system or they must install a new distribution system, so that human being may drink purified water, according to W.H.O guidelines. With the help of our model, one can calculate the chlorine decay, so that municipality can introduce needed quantity of chlorine in water distribution system.

6. REFERENCES

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