# Simulation of Chlorine Distribution in a Drinking Water Distribution Network: Case of the Wilaya Rabat-Sale Network

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***Abstract*** — *The retention of water quality within a drinking water distribution network requires a permanent maintain of minimum chlorine residual. To ensure this level in any point of the network, we have developed a decision support tool. This tool monitors the evolution of the chlorine concentration in the network, which allows a fast knowledge of the chlorine distribution in the network compared to a definite hydraulic regime, and reduces the cost of measures (sampling, travel ...). Performance tests of our decision support system were done on real sites of the Wilaya Rabat-Sale distribution network (Network of Morocco's capital).*

**Keywords —** *Simulation of chlorine distribution, drinking water distribution network, deficit nodes, Simulation results.*

## I. Introduction

Before distribution, the water is usually chlorinated in storage tanks [6]. In the distribution network, the chlorine submits degradations during its transit. This degradation depends as well of the physico-chemical and microbiological quality of water conveyed as the condition of pipes [5][14].

Indeed, chlorine reacts first, as an oxidant [5], with reducing agents likely to be in the drinking water, or glued to the pipe's surfaces, and as a disinfectant [13], it reacts with the microorganisms present in the distribution network [11]. These reactions therefore entail the decrease of more and more chlorine.

To simulate the chlorine distribution in a distribution network, it is necessary to define the decay of chlorine in the pipes, and the mathematical model representing the geometric characteristics of the network and its functioning state.

In the second section of this paper, we will present the method to simulate the chlorine distribution in any point of the network.

The third section will be devoted to the description of the diagram calculating the chlorine distribution over the network. The simulation results in some stages of the Wilaya Rabat-Sale distribution network will be the subject of the fourth section.

## II. Simulation of Chlorine Distribution in a Distribution Network

In order to control the water quality in the network, it is imperative first to model the degradation of chlorine in a pipe as a function of residence time. Other parameters needed for the concentration of chlorine, will implicitly be introduced into the reaction rate constant of chlorine. This will allow us to monitor the chlorine evolution in function of time throughout the distribution network.

The degradation of the chlorine concentration at each network point requires the establishment of a mathematical model describing the degradation of chlorine in the network.

The database for the chlorine distribution simulation in a network are, firstly, information relating to the nodes and pipes that represent the geometric structure and the hydraulic regime (flow distribution and residence time), secondly, the initial conditions which are the level of chlorine injected into the supply sources and the locations of the already implanted chlorination stations in the network.

By using these data, we simulated the distribution of chlorine in a distribution network

We represent in Figure 1, a node j, where the chlorine level well be determined, and that is served by three nodes whose value for the chlorine rate is known.

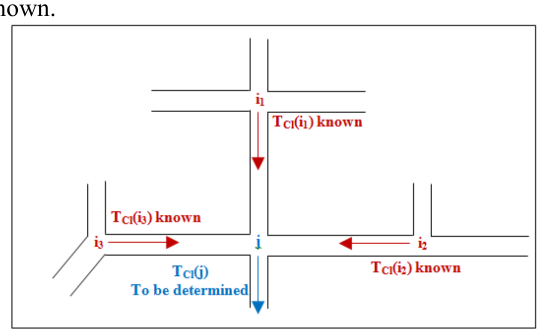


Fig 1: illustration schema of the chlorine concentrations in a distribution network

To calculate the chlorine level of the node j, we must first know the level of chlorine in each of the pipes (TCl (i) where i = i1, i2 and i3) that supply the node j.

We have two cases [3]:

- First case: when the pipe(i,j) has a chlorination station, then:

TCl(i,j) = setpoint of the station (initial rate that is assumed to be known)

- Second case: if absence of chlorination station on the pipe (i, j), then:

$$T_{Cl}(j) = \frac{\sum_{1}^{3} T_{Cl}(i,j).Q(i,j)}{\sum_{1}^{3} Q(i,j)} \quad (1)$$

Where :

$$T_{Cl}(i,j) = T_{Cl}(i) \times \exp(-k_{i,j} \times t_{i,j})$$

Where:

$t_{i,j}$ : the residence time of water in the pipe(i,j)

$k_{i,j}$ : coefficient of chlorine degradation in the pipe(i,j)

and Q(i,j) : the debit of the pipe (i,j)

Equation (1) is a weighted average of the partial chlorine rate of pipes serving the node j, with weighting coefficient the debit rate Q(i,j) transiting in each conduit.

Proceeding out from the source of supply (reservoir, wells ...) where the chlorine level is known, we can calculate step by step the rate of chlorine in every point of the network.

## III. DIAGRAM OF SIMULATION

To exploit the real functioning of a network, a mathematical model must be established and that can represent both the geometric characteristics of the network and its state of functioning (flow distribution, pipe length ...).

This representation should identify any node by its name, its rank among the other nodes, the numbers and codes of nodes that serve it. It must inform us as well on the characteristics of existing pipes between two specified nodes (length, diameter and breakages) as on physical quantities of flow including the speed, flow, residence time …

The diagram of calculating the chlorine distribution on a network [1] [2] is given in Figure 2:

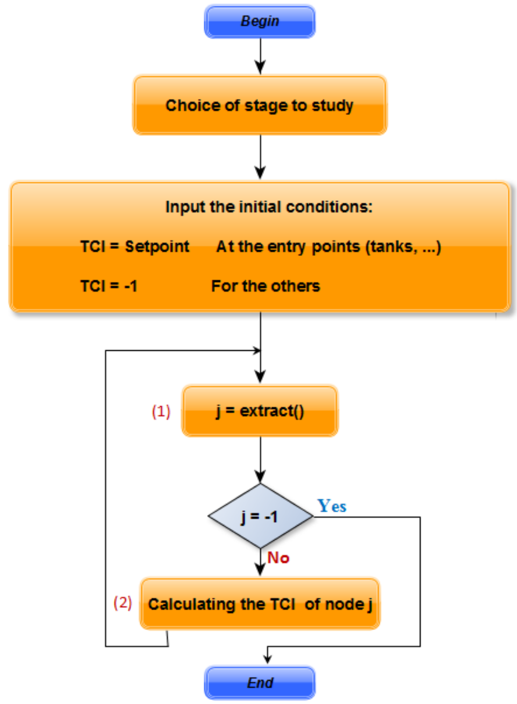


Fig 2: Diagram of chlorination

(1) The extract () function (Cf.Figure 3) returns the code of the first node whose chlorine rate is not yet calculated, and all the chlorine content of nodes which serve this node are known. If this function finds a node, it returns its code, else it returns -1.

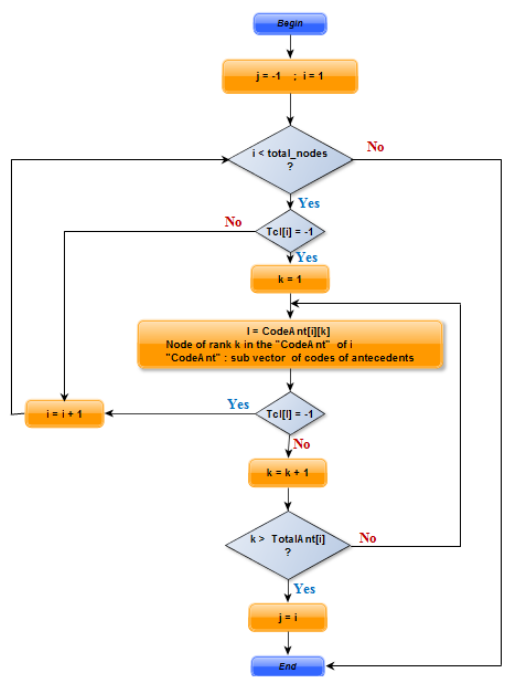


Fig 3: Diagram of the Extract() function

(2) The diagram of a node j chlorine rate calculation is the following:

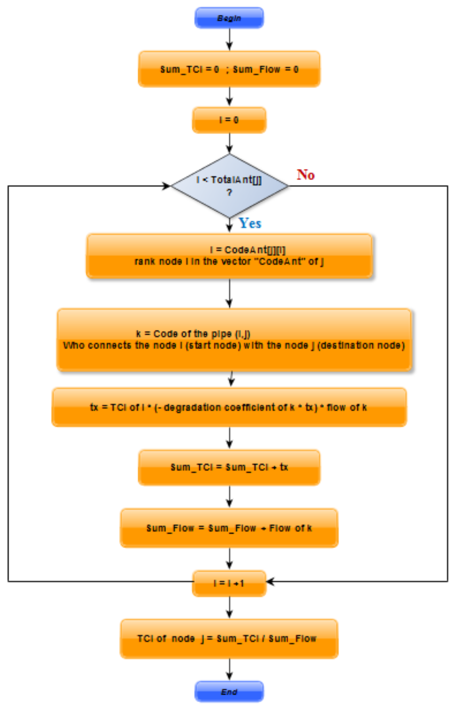


Fig 4: Diagram of a node j chlorine rate calculation.

## IV. SIMULATION RESULTS

For this study, we took as chlorine minimum threshold the value 0.25 mg / l below which a node is counted among the deficit [12]. Indeed, this value, which is defined by the World Health Organization (WHO) [3] [4] ensures effective disinfection and maintain water quality in the network.

We want to find a setpoint value (chlorine level in tanks) associated with each stage of the Wilaya of Rabat-Sale that leaves any node of the network with deficit in chlorine.

The distribution network of the Wilaya of Rabat-Sale is divided into several pressure stages [7][8]. In view of their importance extended, we will only present the following stages: Stage of "Temara bas", Stage "61 of Agdal", Stage of "86-réduit" and Stage of "Skhirat".

- **Case of "Temara Bas":**

This stage is supplied by a storage tank of 3500 m3 [9]. The number of nodes within the stage is 26 and the number of pipes is 29 (Cf. Figure 5).

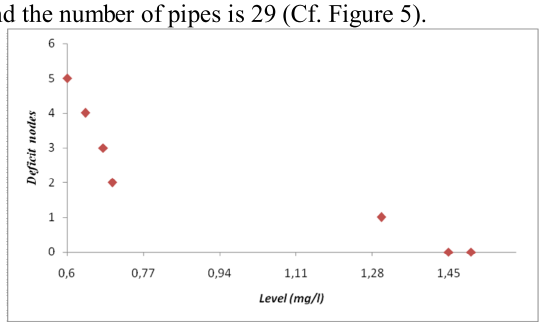


Fig 5: Variation in the number of defective nodes according to the setpoint (Case of Temara bas)

The figure 5 illustrates the variation of the number of defective nodes according to the setpoint. The study of this figure shows that the best value of the setpoint is 1.45 mg / l. Indeed, beyond this value the number of defective nodes becomes null.

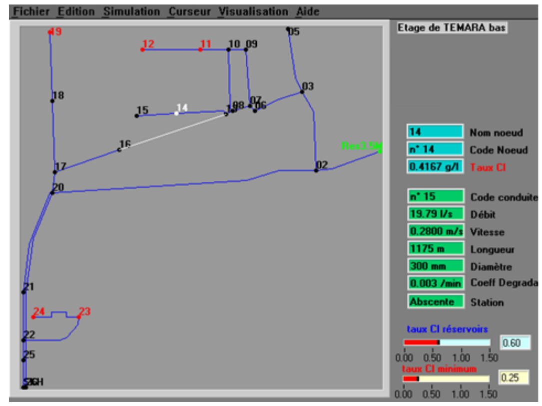


Fig 6: The stage "Temara bas" represented by our support tool for decision

- **Case of "Stage 61 of Agdal":**

The stage 61 is a distribution network that includes neighborhoods: "Médina, l'Océan and Orangers". The two reservoirs of that stage have an overall storage capacity of 6000m3. It is called this way because the altimetry side of the reservoirs of "stage 61" is about 61.28 m [7].

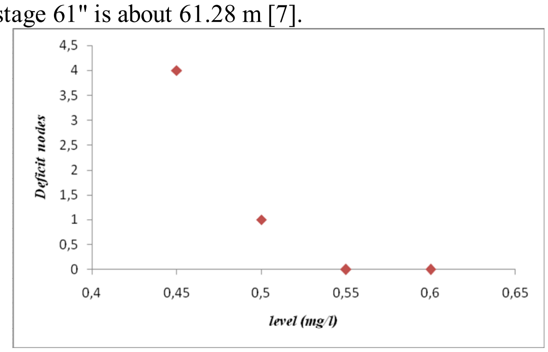


Fig 7: Variation in the number of defective nodes according to the setpoint (Case of stage 61)

We deduce from Figure 7 that the number of deficit nodes decreases when the value of the setpoint increases. We also note, that from the value 0.55 mg / l, the number of defective nodes become null. Therefore, this value will be considered the value of the searched setpoint.

- **Case of Stage "Skhirat":**

This stage is supplied by a 2500m3 storage tank, the coast of its raft is 68.5 [10].

Figure 8 shows the evolution of defective nodes number according to the setpoint. By this figure, we can see that the value of the searched setpoint is the value 0.65 mg / l.

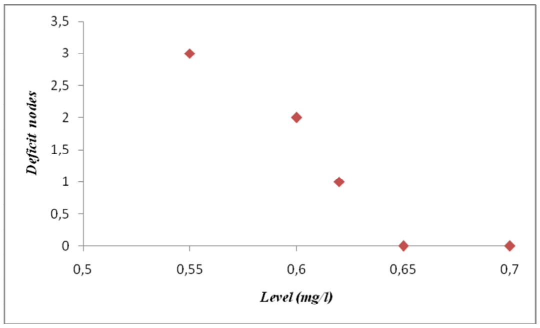


Fig 8: Variation of the number of defective nodes according to the setpoint
(Case of stage "bas de skhirat")

- **Case of stage "68-réduit":**

The pressure stage "68-réduit" is a distribution network created following the separation of the stage 61 into two parts [7].

Figure 9 shows the evolution of the number of defective nodes in chlorine. The study of this figure will allow us to deduce that the value of the searched setpoint is the value 5.3 mg / l. Indeed, from this value the number of defective nodes becomes null.

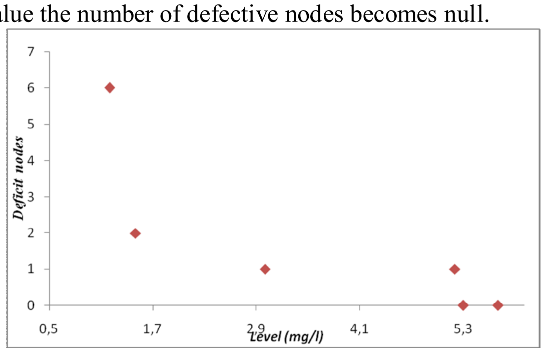


Fig 9: Variation of the number of defective nodes according to the setpoint (Case of stage "86-réduit")

## V. Conclusion

In this article, we presented a mathematical model describing the evolution of the chlorine concentration in a network. This modeling will allow us to get a rapid knowledge of the chlorine distribution and thus reduce the cost of measures (sampling, travel ...).

Besides that, the study of the number of defective nodes evolution according to the setpoint, in the stages of the "Wilaya Rabat-Sale" distribution network, showed that to permanently maintain minimum residual level of chlorine (0.25 mg / l), at any point of the network, it is necessary to increase the initial level of chlorine in the tank outlet. However, this solution may disturb the taste and smell of water for consumers near the tanks [4]. Actually, the taste of chlorine becomes noticeable beyond a chlorine rate of about 0.6 mg / l [3][15].

Therefore, to avoid increasing chlorine at the outlet of the tank, it is necessary to implant intermediate chlorination stations in the network. We envisage as a perspective, to propose approaches in order to optimize the number of locations of these stations.

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