# OPTIMIZATION OF CHLORINATION STATIONS INTERMEDIARIES LOCATIONS IN A DRINKING WATER SYSTEM

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**ABSTRACT**

In this work provides for the publication of an optimal technique to end the problem of lack of chlorine in drinking water ends of the distribution network and ensure sufficient concentrations by chlorine injections through intermediaries chlorination stations to maintain the quality of drinking water to the consumer. This technique has two main objectives namely to minimize the number of chlorine deficit nodes and the number of stations to be set. This method is divided into two parts:
- The first can detect target areas (chlorine <standard), these areas will be classified in order of importance (number of nodes lover, number of nodes swallows, flow ...)
- Reduce the number of these nodes deficit up by chlorine injection.
To meet these two criteria, we have developed an optimization tool able to offer sound solutions to minimize both the number of loss and nodes and the number of stations to be set.

**Keywords:** drinking water, chlorination, classification, disinfection, network, optimization, graph theory.

## 1. INTRODUCTION

Resource conservation "drinking water" in terms of quality of our day becomes a major concern for the distribution of drinking water facilities. However, the drinking water network is home to multiple sources of contamination (Wable and al, 1991) (Sadic and Rodriguez, 2004); (Wigle, 2001).., particularly bacterial. Thus, the preservation of the quality acquired in the treatment plants before distribution, requires maintaining permanently a residual level of chlorine anywhere on the network. (Bermond *and al*, 1998) This is possible, in most cases, if there are provided chlorine injections in different network points through intermediate chlorination stations.

Given the high cost of implementation of such stations, the minimization of the number of these stations and the optimal choice of their locations are needed. To meet these two criteria, we have developed an optimization tool able to offer sound solutions to minimize both the number of loss and nodes and the number of stations to be set.

In this chapter we present the techniques used for such an undertaking. We opted for the techniques of dynamic programming and graph theory in search of optimum locations of intermediate stations of chlorination. A comparative study of these two approaches will retain the most suitable for our problem. We conclude with a presentation of the tool to aid decision.

The optimization of locations intermediate chlorination stations within an urban network of water distribution has two main objectives namely to minimize the number of loss chlorine nodes and the number of stations to be set.

### 1.1 Problematic

The network of the wilaya account a set of already implanted stations (8 to Rabat and a Salé) (M. Hafsi and all, 2004) proceeding to a higher and not a control of the concentration of chlorine on the conduits that carry the. This moves, therefore, the problem of excess chlorine in the vicinity of the tanks in the vicinity of the stations. Often the impact of these stations, the chlorine distribution in the network is reduced because of the choice of their locations. Yes, this choice is made intuitively, which often brings the problem that a local solution. Indeed, a position that is optimal when certain validity criteria are met:

- Stable zone with respect to the state of network performance. Indeed, according to the hydraulic state of the network, the flow in certain lines may change. Such pipes are therefore not fit to wear a chlorination station.

- Extended service area, means that the degree of influence the node upstream to the station must be as high as possible.

- The recovery must be the lowest among service areas already established stations.

- Lot availability for the realization of the retaining chlorination station.

The service area of an intermediate chlorination station matches the network zone that includes all nodes cleared the table directly or indirectly through the node just downstream to the station. While the degree of influence of a node represents the number of nodes it serves directly or indirectly in the network. The lack of effectiveness of certain already operating stations is offset by an increase in the chlorine concentration in the tanks. Indeed, the control to the output of a set of reservoirs, Table-1, showed that the chlorine content fluctuates between (0,5mg/l et 1, 4 mg/l).

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**Table-1.**

| Tank capacity (m$^3$) | Minimum chlorine (mg/l) | Maximum chlorine (mg/l) |
|---|---|---|
| Tank 30 000 | 0,5 | 1,2 |
| Castle 1000 | 0,6 | 1,4 |
| Tank 15 000 | 0,6 | 1,2 |
| Castle 600 | 0,6 | 1,2 |

However, it was agreed that the chlorine content in the output power sources, reservoirs and water towers, to be set at 0.6 (mg / l) that made the taste of chlorine in the water becomes apparent beyond this value. To avoid an excessive increase in the concentration of chlorine in the tanks, and therefore does not affect the flavor of the water supply must be provided chlorine injections inside the network. The choice of location must meet all the above criteria.

## 2. MATERIALS AND METHODS

### 2.1 Methods of optimization

The principle of optimization (Brion and Mays, 1991) and ( Lansey, 1994) is to assign to each drive a cost function corresponding to the number of remaining deficit nodes assuming that conduct chlorination door station. Thanks to the simulation module, we calculate the cost function for each of the network pipes. When this distribution is known, we retain the pipes or possessing the minimum cost. These pipes will be candidates for chlorination station implantation. However, if this minimum cost is not zero, then we proceed to the edge in selecting a location among those proposed. Then, as the chlorination station service modifies wholly or partly the distribution of chlorine in the network, so we proceed by step. And we consider each holding position in subsequent simulations. So this is the principle of dynamic programming (A. ALJ, 1990).

### 2.1.1 Dynamic programming

Dynamic programming is often applied to optimization problems can be formulated as decisions sequences (Belman, 1954). Indeed, when a problem is decomposed into n phases (Figure-1), where each step is characterized by:

- Its input state vector $E_{i-1}$ represents the state of the system studied;
- His decision vector $X_i$ expresses the intervening decisions to phase i ;
- Sa Its transfer function $T_i$ gives the output vector $E_i = T_i(E_{i-1}, X_i)$ ;

Its return function $R_i$ ri develops the result of decision in step i, $r_i = R_i (E_{i-1}, X_i)$.
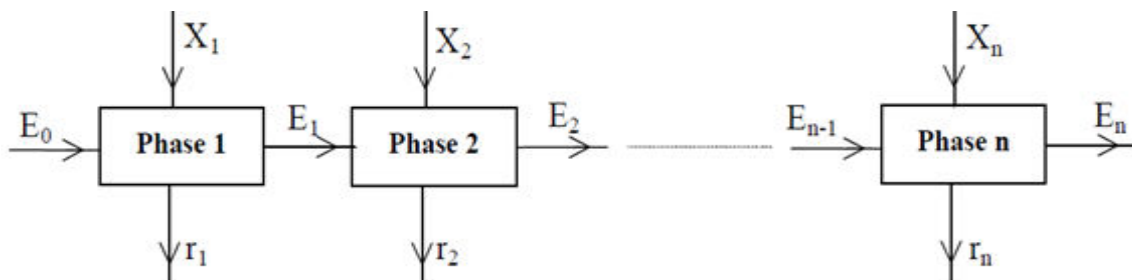


**Figure-1.** Decomposition of a problem.

The optimization problem comes, therefore, to search for decisions X1, X2, …, Xn leading to an overall optimum return function R, in actual values, itself dependent return functions for each phase:

$$OPT_{X1,X2,...,Xn} R[r1(E0,X1), r2(E1,X2), ..., rn(En-1,Xn)] \quad (1)$$

Or Ei ϵ Ê Space eligible state vectors in Phase I, and Xi ϵ X̂ space decisions Vectors eligible for phase i and depending only on the state $E_{I-1}$: Xi ϵ X̂$_i$(E$_{I-1}$).

#### 2.1.1.1 Practical implementation

From the calculation of the chlorine in the distribution network, we identify the nodes deficit and

Since R is a decomposable function, there are two functions R1 and R 'such that:

$$R = R1[r1(E0,X1), R'[r2(E1, X2), …, rn(En-1, Xn)]] \quad (2)$$

R 'is broken again in R2 and R2, and so step by step, through the optimality theorem (Kaufman, 72), optimization of the overall function R is reduced to the following solution:

$$OPT_{X1} R = OPT_{X1} R1[r1(E0,X1), OPT_{X2} R2[r2(E1,X2), ..... OPT_{Xn} Rn[rn(En-1,Xn)] ...]], \quad (3)$$

their number. The location of a chlorination station which reduces the number is obtained by associating with each of the corresponding number of pipes deficit nodes. When all pipes are tested, we retain the positions (lines) that give the minimum of nodes deficit.

## a) Identification

For the purposes of the implementation of this optimization approach, we will proceed with the identification of the various parameters of the system shown in Figure-1:

- states (Ei) are the network information (lines, nodes, control set at the tanks and the minimum threshold below which a node is declared deficit) ;
- decisions (Xi) are the possible locations of a chlorination station in the network (all lines except those that already have and those for the end tanks) ;
- returns functions (ri) offer optimal locations;
- transfer functions (T) calculates the distribution of chlorine in the network.

## b) Optimization algorithm

The algorithm developed at the base of dynamic programming is the following:

```
Beginning
Tclini ; /* Initial chlorine level in reservoirs */
Tclmin ; /* Minimum chlorine level below which a node is declared deficit */
Repeat
X ; possible locations of a station;
total pipes ← ombre shadow of X pipes;
K ←0 ;
Simulation (0) ; /* initial distribution of chlorine */
Cost ← Cost (0) ; /* Cost (0) : initial number of nodes deficit */
Repeat
K ←K+1 ;
Initialize "nodes" and "conduct" ;
Simulation (k); / * Chlorination station on driving K */
Cost (K) ← Number of Nodes deficit Remaining;
Until (K >= total pipes) ;
Cost ←min (Cost (K)) ;
View optimal locations; / * K mains of cost (k) = cost */
If Cost > 0 then /* There are still loss-nodes */
Fix optimal station / * choose among the proposed locations * /
Up (cost = 0);
End
```

**Tclini:** Represents the chlorine content at the outlet of the feed points (tanks, pits and existing stations).

**Tclmin:** is the minimum chlorine level below which it is said deficit node.

**simulation (k):** calculating the distribution of chlorine assuming that a chlorination station exists on the line k5.

**cost (k)** is the number of nodes deficit remaining after the implementation of a chlorination station on driving k. As we can see, the major drawback of dynamic programming is made to perform the implantation test on all lines. This creates unnecessary iterations and therefore a greater computation time. As the water distribution network in peak mode is a directed graph, we found it necessary to improve our optimization tool by associating the techniques of graph theory.

## 2.1.2 Graph theory

Graph theory can efficiently represent and with great simplicity the structure of a large number of situations (Gondran and al, 90). The most common examples are the representations of telecommunication networks, road, railway, electric distribution of drinking water.

### 2.1.2.1 Definitions

A graph G = [X, U] is characterized by the set C of the vertices or nodes and the set U of ordered pairs of vertices called arcs. If u (i, j) is an arc of G, i and j are respectively the initial end and the terminal end of u. graphically, the vertices can be represented by points u and the line (i, j) will be represented by an arrow joining the two points i and j. The number N of vertices (nodes) of a graph G is its order

Figure-2 shows a graph with five vertices (1, 2, 3, 4, 5) and six arcs [u1=(1,2), u2=(1,3), u3=(2,5), u4=(2,4), u5=(3,5), u6=(4,3)].
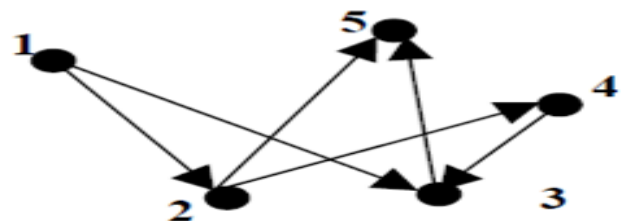


**Figure-2.** Digraph example.

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The node j is the successor of i, if there is an original arc i and j having as terminus. In this case, the node i is the predecessor of node j

Q a path length is defined as a sequence of q arches:

P={u1, u2, …, uq} Avec : u1=($i_0$, $i_1$), u2=($i_1$, $i_2$) …. uq =(iq-1, iq). The top $i_0$ is the initial end (start node) path P; and iq peak is the terminal end (of arrival node) path P.

### a) Ancestor and descendant of a node
All Γ the descendants of i, where :

$$\hat{\Gamma}_i = i \cup \Gamma_i \cup \Gamma_i^{2} \cup \Gamma_i^{3} \cup ... \cup \Gamma_i^{N-1}$$

$\Gamma_i^{k}$ Represents the set of vertices that can be reached from vertex i by paths of exactly k arcs.

All $\Gamma_i^{-1}$ i ancestors is the set of vertices from which one can reach the top through the paths i k arcs (1<k<N-1).

The graph of the Figure-2 has as descendants nodes 1 et 2:

$$\hat{\Gamma}_2 = \{2, 4, 3, 5\}, \quad \hat{\Gamma}_1 = \{1, 2, 3, 4, 5\};$$

and as nodes of ancestors 4 et 5 :

$$\hat{\Gamma}_4^{-1} = \{4, 2, 1\}, \quad \hat{\Gamma}_5^{-1} = \{5, 2, 3, 1, 4\}.$$

### b) Representations of a graph
To describe a graph G, two representations may be used. On the edge by the adjacency matrix or using the node-arc incidence matrix.

#### i. Adjacency matrix
The adjacency matrix (vertices and vertex-incidence matrix) is a matrix with coefficients A 0 or 1: A= (Aij) / i=1, .., N, et j = 1, .., N (N is the number of vertices).

Wherein each row and column corresponds to a vertex of the graph G=[X, U], with: Aij = 1 if and only if: ui,j ∈ U (Aij = 0 if not).

The representation of the graph of Figure-2 using this matrix gives:

|   | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 0 | 0 |
| 2 | 0 | 0 | 0 | 1 | 1 |
| 3 | 0 | 0 | 0 | 0 | 1 |
| 4 | 0 | 0 | 1 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 |

However, this representation has the drawback of only represent one-graphs (oriented). In effect, this representation is inoperable when it exists in the network two nodes which are connected by at least two different lines.

#### ii. Matrice d' incidence sommets-arcs
The node-arc incidence matrix of a graph G=[X, U] is a matrix A = (aij), i = 1, .. N, (N is the number of vertices) and j = 1, .., M (M is the number of edges), with integer coefficients 0, +1, -1 such that each column corresponds to an arc of G, and each line a summit of G; if u(i, j) ∈ u, uj the column has its zero terms, unless: Aiu = + 1 (if i is the initial end of u)
Aju = - 1 (if j is the terminus of u)

**Exemple:** the node-arc incidence matrix of the graph of Figure-2 is:

|   | $U_1$ | $U_2$ | $U_3$ | $U_4$ | $U_5$ | $U_6$ |
|---|---|---|---|---|---|---|
| 1 | +1 | +1 | 0  | 0  | 0  | 0  |
| 2 | -1 | 0  | +1 | +1 | 0  | 0  |
| 3 | 0  | -1 | 0  | 0  | +1 | -1 |
| 4 | 0  | 0  | 0  | -1 | 0  | +1 |
| 5 | 0  | 0  | -1 | 0  | -1 | 0  |

An improvement of this representation is to define two vectors α () and β () of dimension M (M is the number of arcs). For each edge (u = 1, .., M), α (u) represents the initial and end β (u) the terminal end. The example graph of FIG (IV-2), gives:

- α(1, 1, 2, 2, 3, 4).
- α(2, 3, 5, 4, 5, 3).

**Note that**, unlike the adjacency matrix, this representation can describe perfectly any graph. Thus, we adopted this representation to describe the drinking water distribution network.

### 2.1.2.2 Practical implementation
The algorithm based on dynamic programming, testing all possible configurations, simulating a chlorine booster station on each pipe network. These tests enable the selection of the best configurations that minimize the number of loss-nodes on the network. However, it has the drawback, when the network is very dense, have a high response time (Elbelkacemi and al, 992). Indeed, in the following example illustration:
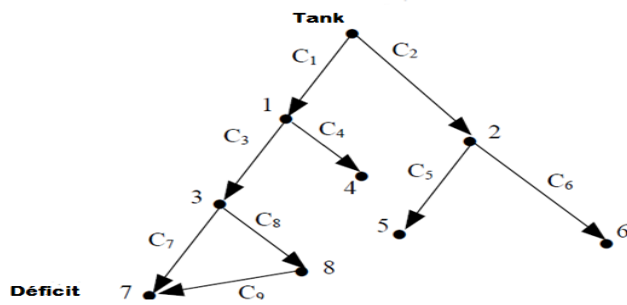
**Figure-3.** Example of a water distribution network.

It is assumed that the node 7 is the only deficient node. Installation tests chlorination station on one of the lines C2, C4, C5 or C6, having regard to the network structure of the preceding figure, has no impact on the chlorine content of the node 7. Therefore, it is always in deficit. However, the implantation of a rechlorination station on one of the lines (C1, C3, C7, C8, C9) corrects the Node chlorine level 7. The tests must be performed only on the lines C1, C3, C7, C8, and C9 and not all network lines (C1, C2, C3, .., C9).

Indeed, this illustrative example shows that 44% of the lines have no impact on improving the content of the deficit node and yet these behaviors are involved in the research process best resorts. Hence a considerable loss in response time of the optimization algorithm based only on dynamic programming techniques. This problem is further complicated when the network density increases. To improve this algorithm, we tried to minimize the number of test configurations based on graph theory.

Knowledge of ancestor's deficit nodes becomes paramount, since it determines the conduits for which the tests should be performed. If therefore refers to the diagram of Figure-1 in the new version of the optimization module, only the decision vector Xi of each stage is changed. Xi becomes:

- all lines including the arrival nodes belong to the set of ancestors deficit nodes present in phase i. As the distribution network is a directed graph without cycle, the search for ancestors of a node is performed by the following module:

```
Beginning
(a)- Initialization
Anc(k) = {k} /* Anc(k) : all k ancestors */
Parent(k) = {k} /* Parent(k) : Set of nodes for
which one must seek their predecessors
to add to the set of k ancestors (Anc(k)).*/
(b)- fundamental step
Repeat
i ← Parent first node (k) ;
pred(i) ← pred(i) − Anc(k) ;
Anc(k) ← Anc(k) ∪ pred(i) ; /* pred(i) : all predecessors
node i.*/
Parent(k) ← (Parent(k)-{i}) ∪ pred(i) ;
Until (Parent(k) = Φ)
End
```

**Note:** all predecessors of a node ipred (ii)) should not contain reservoirs or just downstream nodes to chlorination stations. Indeed, the rise in the graph stops when encountering a tank or station.

**Example:** Consider the example of the Figure-3. The ancestors of the search procedure gives for k = 7.

(a) Anc(7) = {7}, Parent(7) = {7}
(b) i = 7, pred(7) = {3, 8}, Anc(7) = {7, 3, 8}, Parent(7) = {3, 8}
(b) i = 3, pred(3) = {1}, Anc(7) = {7, 3, 8, 1}, Parent(7) = {8, 1}
(b) i = 8, pred(8) = φ, Anc(7) = {7, 3, 8, 1}, Parent(7) = {1}
(b) i = 1, pred(1) = φ, Anc(7) = {7, 3, 8, 1}, Parent(7) = φ.

The optimization algorithm based on graph theory becomes:

```
Beginning
Tclmi; Tclmin
Repeat
Simulation (0); /* Initial distribution of chlorine */
Ancestor ← ∪ Anc(i) /* Anc(i): function that returns all
i: deficit ancestor node of node i */
X ← conduite (Ancestor); /* Conduct (): returns the lines that have
to finish the elements of ancestor nodes */
Repeat
K ← first line of X;
Initialize "nodes" and "conduct";
Simulation (k); /* Chlorination station on driving K */
Cost(K) ← number of remaining nodes deficit;
X ← X-{K};
Until (X = ∅);
Cost ← min (Cost (K));
View optimal locations; /* K the pipes do not cost (that) = cost */
If Cost ≠ 0 Cost /* There are still deficient nodes */
Fix optimal station /* selected from the list of
optimal location published */
Up (cost = 0);
End
```

## 3. RESULTS AND DISCUSSIONS

To test the performance of these two approaches, we grafted onto the distribution of chlorine simulation tool, the optimization module whose execution latch on one of two methods. We conducted these tests on real sites Wilaya's distribution network Rabat-Sale (Redal). For the presentation of results, we have deliberately chosen two floors of different density. The first bit is the dense network of the urban center of the city of Temara; the second is more dense than the on stage 61 of the medina, orange trees and the ocean. The stage 61 is powered by the Agdal tanks.
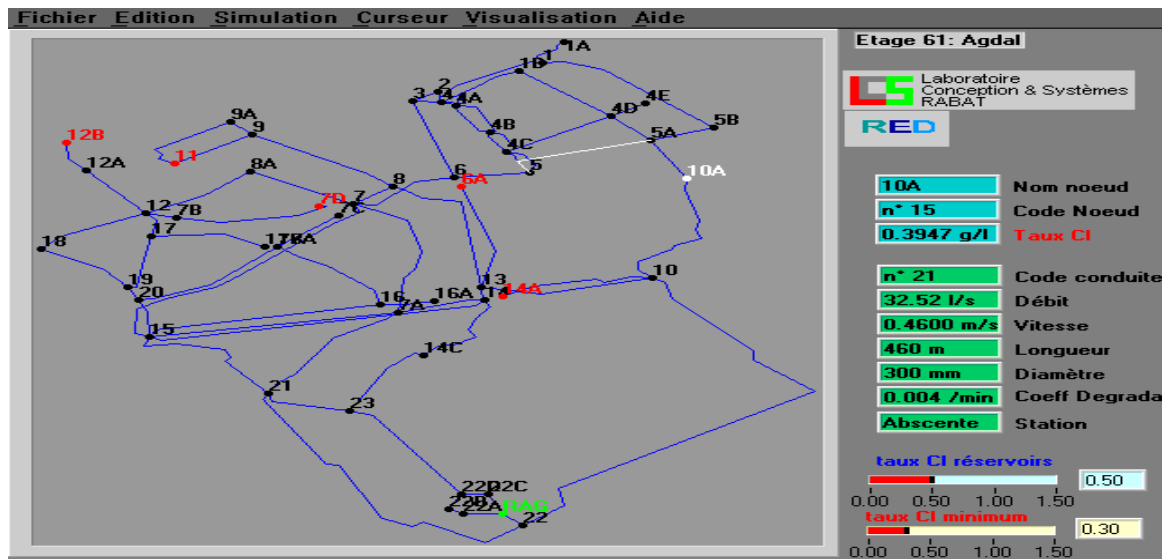
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**Figure-4.** The two stages represented by our Decision Support Tool.

### 3.1 Influence des paramètres d'entrée sur les résultats d'optimisation

The distribution of chlorine and therefore the number of nodes in a network loss of the edge depends on the concentration of chlorine injected into storage tanks (set) and then the concentration threshold below which a node is said deficit. We studied, in both stages, the impact of these two factors on the evolution of the number of nodes deficit. The results obtained using the simulation tool, are shown in Figures 5 and 6:
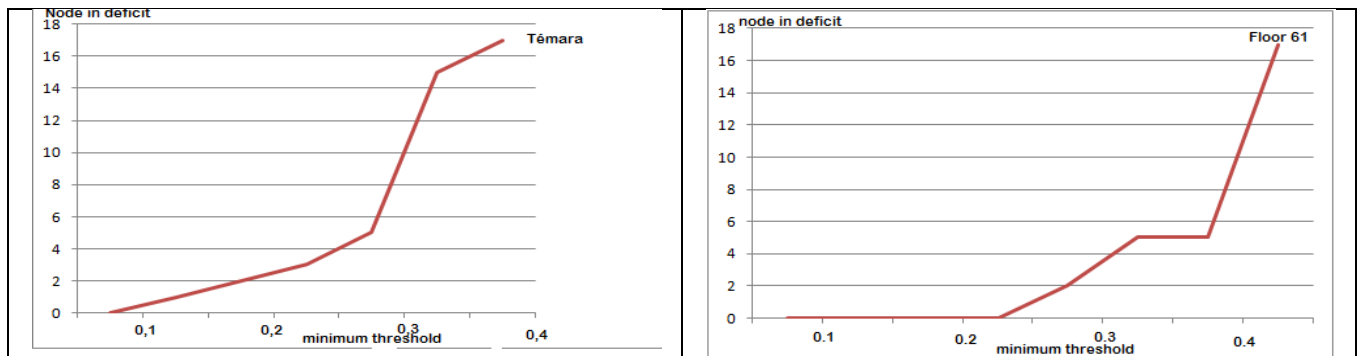


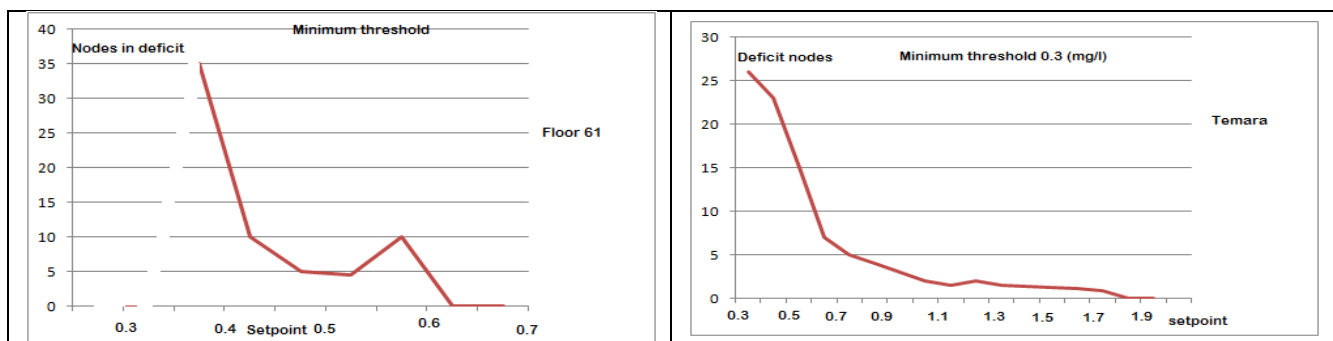**Figure-5.** Number of nodes deficit based on the minimum threshold.



**Figure-6.** Number of nodes in loss function of the set.

It is clear from these curves:
- the number of nodes increases loss when on the one hand the minimum threshold is increased and on the other hand when the value of the set decreases.

The analysis of these results the first idea that comes to mind to reduce the number of nodes deficit is to increase the setpoint at the storage tanks.

This simplistic solution is to spread because as we can see in the case of the floor of Temara, this

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deficiency disappears only when the value of the deposit is three times higher than normal. This heavily affects the taste and flavor of the water in the vicinity of the injection points. Now the installation of intermediate stations chlorination is the best solution to this critical problem. Optimal search results using the two approaches show that the method based on the techniques of graph theory, greatly enhances the optimization module response time. Indeed, Figure-7 shows that the algorithm response time based on dynamic programming is independent of the number of nodes deficit and the gap widens when this number becomes less and less important. The density of a network also influences the difference in response times of the two approaches, as shown in Figure-8.
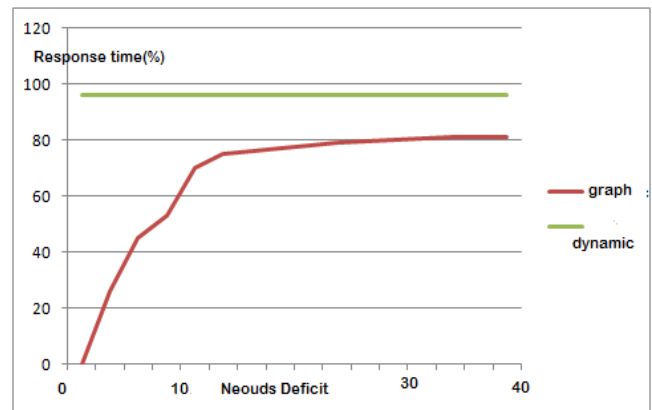


**Figure-7.** Response time depending Du number number of lines.
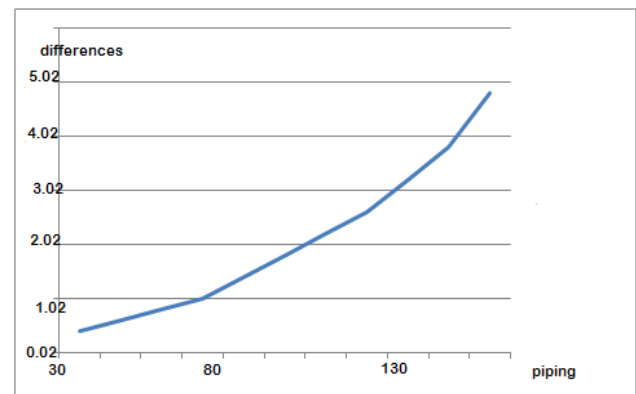


**Figure-8.** Deviation of the response time based on the of nodes deficit.

The test results for these two stages are grouped in the following tables:

| iteration | Setpoint (mg/l) | threshold min (mg/l) | Number deficit | Number deficit remaining | Correction (i,i-1) | Correction (i,i-0) | dynamic programming (min) | Teorie graphs (min) | Difference (min) | Amelioration time (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.5 | 0.35 | 18 | 10 | 44.4 | 44.4 | 1.52 | 1.39 | 0.13 | 9 |
| 2 | 0.5 | 0.35 | 10 | 6 | 40.0 | 66.7 | 1.52 | 1.16 | 0.36 | 24 |
| 3 | 0.5 | 0.35 | 6 | 4 | 33.3 | 77.8 | 1.52 | 0.85 | 0.67 | 44 |
| 4 | 0.5 | 0.35 | 4 | 3 | 25.0 | 83.3 | 1.52 | 0.65 | 0.87 | 57 |
| 5 | 0.5 | 0.35 | 3 | 2 | 33.3 | 88.9 | 1.52 | 0.18 | 1.34 | 88 |
| 6 | 0.5 | 0.35 | 2 | 1 | 50.0 | 94.4 | 1.52 | 0.07 | 1.45 | 95 |
| 7 | 0.5 | 0.35 | 1 | 0 | 100.0 | 100.0 | 1.52 | 0.03 | 1.49 | 98 |

Optimization cost: 7

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.5 | 0.3 | 5 | 3 | 40.0 | 440.0 | 1.52 | 0.84 | 0.68 | 45 |
| 2 | 0.5 | 0.3 | 3 | 1 | 66.7 | 80.0 | 1.52 | 0.62 | 0.9 | 59 |
| 3 | 0.5 | 0.3 | 1 | 0 | 100.0 | 100.0 | 1.52 | 0.06 | 1.46 | 96 |

Optimization cost: 3

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| 1 | 0.45 | 0.3 | 8 | 6 | 25.0 | 25.0 | 1.52 | 1.11 | 0.41 | 27 |
| 2 | 0.45 | 0.3 | 6 | 4 | 33.3 | 50.0 | 1.52 | 0.78 | 0.74 | 49 |
| 3 | 0.45 | 0.3 | 4 | 3 | 25.0 | 62.5 | 1.52 | 0.40 | 1.12 | 74 |
| 4 | 0.45 | 0.3 | 3 | 2 | 33.3 | 75.0 | 1.52 | 0.19 | 1.33 | 88 |
| 5 | 0.45 | 0.3 | 2 | 1 | 50.0 | 87.5 | 1.52 | 0.09 | 1.43 | 94 |
| 6 | 0.45 | 0.3 | 1 | 0 | 100.0 | 100.0 | 1.52 | 0.05 | 1.47 | 97 |

Optimization cost: 6

**Table-2.** Floor 61.

| 1 | 0.4 | 0.3 | 28 | 16 | 42.9 | 42.9 | 1.52 | 1.45 | 0.07 | 5 |
| 2 | 0.4 | 0.3 | 16 | 9 | 43.8 | 67.9 | 1.52 | 1.17 | 0.35 | 23 |
| 3 | 0.4 | 0.3 | 9 | 6 | 33.3 | 78.6 | 1.52 | 0.69 | 0.83 | 55 |
| 4 | 0.4 | 0.3 | 6 | 5 | 16.7 | 82.1 | 1.52 | 0.35 | 1.17 | 77 |
| 5 | 0.4 | 0.3 | 5 | 4 | 20.0 | 85.7 | 1.52 | 0.29 | 1.23 | 81 |
| 6 | 0.4 | 0.3 | 4 | 3 | 25.0 | 89.3 | 1.52 | 0.25 | 1.27 | 84 |
| 7 | 0.4 | 0.3 | 3 | 2 | 33.3 | 92.9 | 1.52 | 0.10 | 1.42 | 93 |
| 8 | 0.4 | 0.3 | 2 | 1 | 50.0 | 96.4 | 1.52 | 0.07 | 1.45 | 95 |
| 9 | | | 1 | 0 | 100.0 | 100.0 | 1.52 | 0.03 | 1.49 | 98 |

Optimization cost: 9

| Iteration | Setpoint (mg/l) | threshold min (mg/l) | Number deficit | Number deficit Remaining | Correction (i,i-1) | Correction (i,i-0) | dynamic programming (min) | Teorie graphs (min) | Difference (min) | Amelioration time (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.6 | 0.2 | 2 | 1 | 50 | 50 | 0.13 | 0.1 | 0.03 | 23 |
| 2 | 0.6 | 0.2 | 1 | 0 | 100 | 100 | 0.13 | 0.02 | 0.11 | 85 |

Optimization cost 2

**Table-3.** Floor Témara Bas.

| **1** | **0.56** | **0.2** | **3** | **1** | **67** | **67** | **0.13** | **0.12** | **0.01** | **8** |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 0.56 | 0.2 | 1 | 0 | 100 | 100 | 0.13 | 0.02 | 0.11 | 85 |

Optimization cost: 2

An iteration corresponds to the execution of the optimization module. Each iteration involves the implantation of intermediate station chlorination. The latter generates a new distribution of chlorine in the network which is a function of the set point, the minimum threshold of chlorine, and the number of stations in the network. Each iteration takes into account the result of the preceding iteration and therefore takes into account the stations already established in the network. It is clear that the number of nodes loss decreases as the number of iterations of the optimization module. Indeed, each rechlorination station located in the network increases the chlorine content, and therefore a reduction of the deficit nodes (Figure (9), (a) and (b)). The implementation of the optimization module is repeated until there have more deficit nodes in the network. Thus, the number of implanted stations is defined as the cost optimization stage, for a couple (Storage, Threshold) gave.

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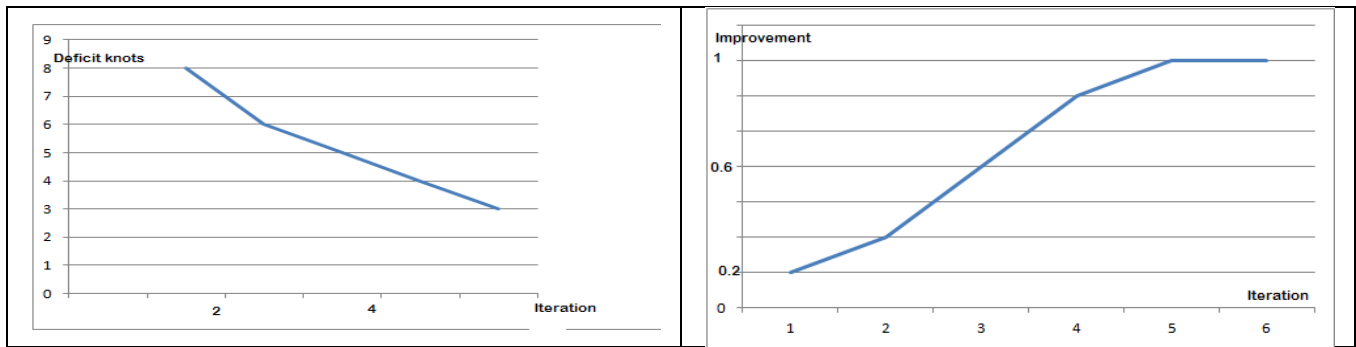


**Figure-9.** (a) Number of nodes deficit (b) The improvement in function of iterations.

Each station has a chlorination degree of effectiveness. Degree is the change in the number of loss-knots before and after the establishment of the facility.
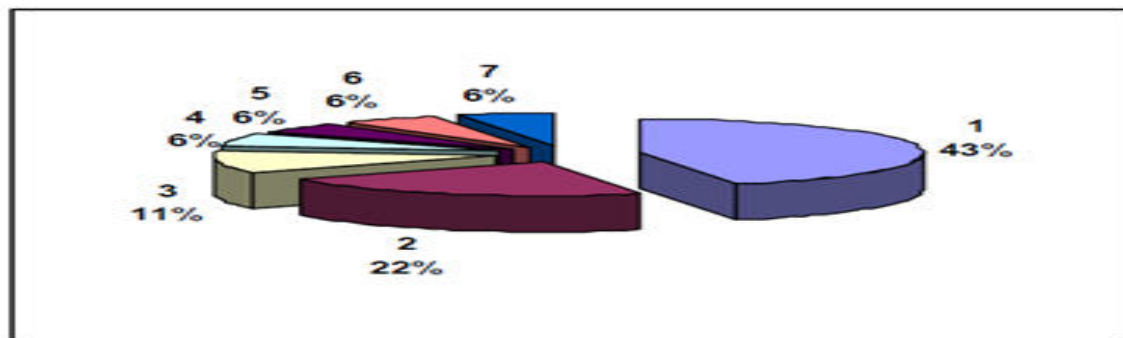


**Figure-10.** How effective each station (Stage 61 (0.5mg / l and 0.35mg / l)).

The location optimization chlorination stations within the distribution network mainly aims at reducing the number of loss-making nodes with minimal chlorine stations to be set (minimum cost optimization).

Il It is clear from comparing optimization results obtained by approaches, dynamic programming and graph theory, that the contribution of graph theory in the optimization module is better than that of dynamic programming SINCE it greatly accelerates the search speed optimization tool.

**3.2 Criticism of the existing**

The network REDAL account a set of already implanted stations (8 to Rabat and in Sale) impact of these stations, the chlorine distribution in the network is reduced because of the choice of their locations. Yes, this choice is made intuitively, which often brings the problem that a local solution.

**3.2.1 Pressure stage 61**

The stage 61 is a distribution network served by two reservoirs Agdal storage capacity 3000 m3 each. It is so called because the invert of these tanks has a vertical side in the order of 61.23 m. It allows the drinking water supply of the Medina, the ocean, and Orange. This floor has 50 nodes and 73 arcs.

Table-4 contains the results of optimization made relative to two values of the initial chlorine content (set at the output of the tank).

**Table-4.** number of deficit node on stage 61.

| Proposed stations | Tcl-ini=0.6mg/l | | Tcl-ini=0.7mg/l | |
|---|---|---|---|---|
| | Tcl min=0.25 | Tcl min=0.3 | Tcl min=0.25 | Tcl min=0.3 |
| Any | 2 | 5 | 0 | 0 |
| (9A611) exist | 1 | 4 | 0 | 0 |

It appears from the above table that:

The station carried by the arc (9A-11) has no great influence; therefore, it is desirable to move it to another pipe. It should be noted that it is entirely at the end of stage 61 (the Ocean). Therefore, the degree of influence is small.

As its effectiveness is equal 1, this means that the station only corrects the deficiency of single node directly upstream of the station. Having regard to the cost of

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implementing an intermediate station of chlorination, it is clear that increasing the setpoint 0.6mg / l to 0.7mg / l is the best solution, in this particular case, for irradiating the deficiency of the Room 61.

### 3.2.2 Pressure stage 86-reduced

The pressure stage 86 reduced results from sharing the stage 61 into two zones. It is served by four transfer lines, three of which are from the 86 floor and the floor 126. These transfers are made Ibn Rushd through pressure reducers 1 and 2, the gear of Oncology floor 86 and end the pressure reducer Riyadh upstairs 126. the neighborhoods served by this floor are Akkari, Yacoub El Mansour and El Fath Hay.

### a.   Initial concentration is 0.6 mg/l

To a concentration setpoint 0.6mg/l, Table-5 shows the results of chlorine deficit for three values of the minimum threshold chlorine.

**Table-5.** deficit node number of 86 reduced, Tclini = 0.6mg /l.

| Proposed stations | Tcl-ini=0.2mg/l | Tcl-ini=0.25mg/l | Tcl-ini=0.3mg/l |
|---|---|---|---|
| Any | 15 | 32 | 67 |
| (33-30B) | 14 | 31 | 66 |
| (60_60A) | 14 | 31 | 64 |
| (RP.IB.ROCHD1839A)Any | 14 | 30 | 63 |
| (RP.ONCO58)Any | 12 | 20 | 42 |

It appears from these results that:

- Chlorine deficiency is very large compared to other floors. This is due to the remoteness of the tanks that serve this floor.

- Tree of stations already operating in this stage have no great influence on the distribution of chlorine. This is due to the position of closed valves to the station (33-30A) and the direction of water flow which limits the influence of the implanted on the driving station (60 - 60A), and the opposite station of the sheet of Avicene is small. However, the station "Oncology" (implanted after the pressure reducer oncology) has a relatively large effect in the correction of the chlorine content in the network.

Ultimately, it is proposed to move the two stations placed on the pipes (33 - 30B) and (60 - 60A) on the two arcs proposed below. Indeed, Table-6 gives the results of optimization of locations regardless of the first stations already established:

**Table-6.** Node number of 86 reduced, Tclini = 0.6mg /l.

| Proposed stations | Tcl-ini=0.2mg/l | Tcl-ini=0.25mg/l | Tcl-ini=0.3mg/l |
|---|---|---|---|
| Any | 15 | 32 | 67 |
| (RP_Ryad-58)optimal | 12 | 22 | 47 |
| (RP.ONC-58)existe | 10 | 12 | 26 |
| (RP.IB.Rochd2-40)optimal | 8 | 11 | 16 |

We see that with three stations, we achieve significantly better results.

To further reduce the number of loss-nodes, two possible solutions:

▪ Add other intermediate chlorination stations; this solution only depends on the cost and budget allocated to this operation.

▪ Increase the value of the setpoint at the storage tanks, the solution depends on the tolerance of the taste and flavor of chlorine in the water.

We considered the study of the impact of the correction of the set level the chlorination stations. With chlorine concentration of about 0.8 mg / l. Table-7, gives proposals for new optimal locations:

**Table**-7. node number of 86 reduced, Tclini = 0.8mg/l.

| Proposed stations | Tcl-ini=0.2mg/l | Tcl-ini=0.25mg/l | Tcl-ini=0.3mg/l |
|---|---|---|---|
| Any | 15 | 32 | 67 |
| (70_89)optimal | 12 | 22 | 47 |
| (RP.ONC-58)existe | 10 | 12 | 26 |
| (RP.IB.Rochd2-40)optimal | 8 | 11 | 16 |

This further confirms that the stations located on arcs (33-30B), (60-60A) and (RP.IB.Rochd1-39A), have no significant influence on the distribution of chlorine in this stage.

This economic solution also depends on the distance of the reservoirs that feed the floor. Indeed, when these tanks are away from their garden area, the initial concentration of chlorine diminishes per stay effect from pipes. However, in the case of this floor deficit ease this solution must be rejected, since as shown in Figure below the deficit is not irradiated when the target becomes greater than 5.3 (mg / l).
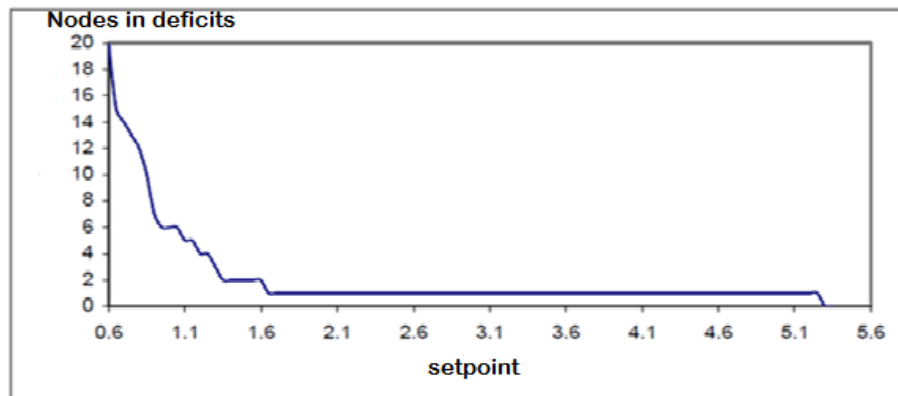


**Figure-11.** Impact of the set on the evolution of the deficit: the case (86 floor reduced).

The best way to eradicate the deficit, in this case, then be an adequate combination between the two solutions.

**3.3 Results**

The main objectives of the decision support tool is the calculation of the chlorine content anywhere in the drinking water distribution network, and the search for optimal locations of intermediate chlorination stations that minimize the number of nodes chlorine deficit in the same network.

To accomplish its tasks, the tool uses data on the one hand, the geometry of the studied network, such as information relating to nodes (name, code, history) and pipes (code starting node, node arrival, length, diameter, coefficient of degradation of chlorine in driving). And secondly, the data representing its state as the hydraulic flow distribution at the nodes, and the water flow rate in each pipe. The tool also uses two essential parameters to the simulation of the distribution of chlorine in the network that are: the setpoint, the value of the chlorine content in the injection point (reservoirs, wells and pipes having a rechlorination station) and the minimum threshold below which chlorine node is declared deficit. Based on these data, the decision support tool developed chlorine distribution anywhere on the network and offers the best locations intermediate chlorination stations.
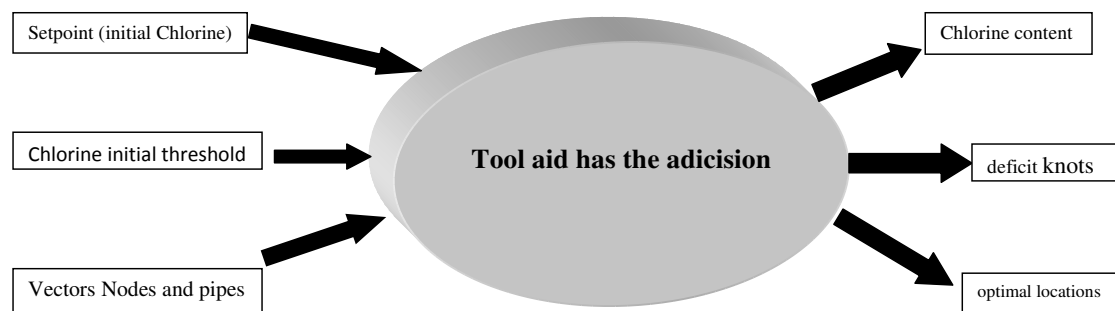


**Figure-12.** Data flow.

### 3.3.1 Architecture générale

The system consists of several modules each of which performs a specific processing. These modules cooperate together to achieve the overall objective of the tool. This decomposition into modules facilitates the development, maintenance and scalability of our system. The overall architecture of this tool is built around da the database on different floors of the network. At this core, are integrated processing and query objects? Figure-13 shows the overall organization of the tool.
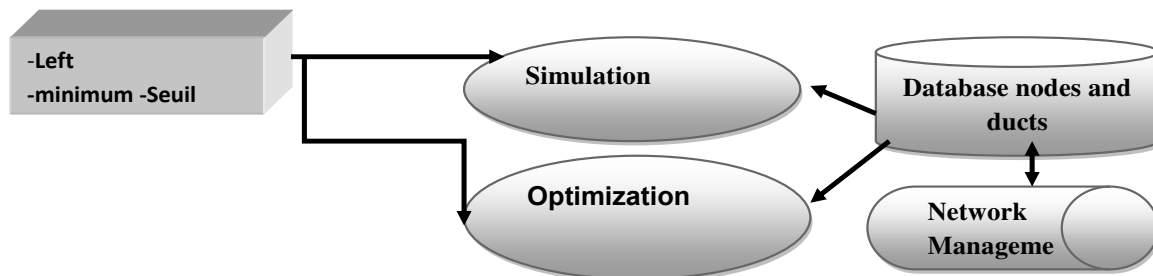


**Figure-13.** Modules of the Decision Support Tool.

The decision support tool implemented is actually an integration of algorithms described in the previous chapters. Indeed it comprises two modules, simulation and optimization, using these algorithms. To allow the card management module is further developed.

#### 3.3.1.1 Simulation module

At the base of mathematical modeling developed in the previous chapter, this module calculates the distribution of chlorine in the network studied, compared with a definite hydraulic regime (distribution of applications in each node and residence times at each conduct). It also offers the opportunity to study the evolution of the distribution of the concentration of chlorine in the network according to the variation of the setpoint injected at reservoir.

#### 3.3.1.2 Optimization Module

We ask this module to optimize chlorine booster station sites within the network studied. There are two variants of this module. The optimization approach integrates the first algorithm based on dynamic programming, while the second is based on techniques of graph theory.

The possible chlorination stations proposals are ranked in descending order of their degree of influence. Indeed, in practice, the priority of installation of a station is given as the pipe which has the widest service area possible. The degree of influence of a node represents the number of descendant nodes.

When a station is selected by the operator, the system recalculates the new distribution of chlorine in the network and the number of remaining deficit nodes before continuing the next iteration.

This process of calculating the number of remaining nodes deficit for each iteration can be repeated until there are no more nodes to deficit or interrupted voluntarily by the operator. The system provides the user the optimization results in a table of the following form:



**Figure-14.** Interface optimization module.

a)  List of proposed pipelines and ranked in descending order of degree of influence

b)  List of proposed pipelines and ranked in descending order of degree of influence.

c)  Number of loss-detected nodes before optimization.

d)  Number of remaining deficit nodes after installing a chlorination station on the line chosen from those available.

e)  Continue optimization, so an additional iteration.

f)  Code of Conduct selected.

g) The number of the current iteration.

h) Stop the optimization process. Network Management

When a station is selected by the operator, the system recalculates the new distribution of chlorine in the network and the numbers of remaining nodes deficit avantde continue the next iteration.

This process of calculating the number of remaining deficit nodes for each iteration can be repeated until there are no more nodes to deficit or interrupted voluntarily by the operator. The system provides the user the optimization results in a Table of the following form:

**Table-8.** Simulation results on the floor of TEMARA low.

| Results optimization | | | | | | |
|---|---|---|---|---|---|---|
| Network Name: Floor 61(Ocean ,Les rangers, and la medina) setpoint (g/l):0.40 Chlorine minimum threshold (g/l):0.30 | | | | | | |
| **Iteration** | proposed pipelines | | | | **Deficit knots before optimization** | **Deficit remaining nodes** |
| | **Code** | **Starting node** | **Node arrives** | **Debit** | | |
| 1 | 44 | 44 | 33 | 188.50 | 28 | 16 |
| 2 | 27 | 35 | 36 | 75.04 | 16 | 9 |
| | 28 | 18 | 36 | 4.95 | | |
| | 35 | 37 | 35 | 186.53 | | |
| | 54 | 34 | 36 | 6.54 | | |
| | 58 | 37 | 36 | 145.77 | | |
| 3 | 4 | 4 | 3 | 12.57 | 9 | 6 |
| | 5 | 6 | 3 | 4.95 | | |
| | 6 | 4 | 6 | 6.19 | | |
| | 7 | 16 | 4 | 39.76 | | |
| | 9 | 7 | 6 | 6.89 | | |
| | 10 | 7 | 6 | 4.91 | | |
| | 22 | 14 | 6 | 3.53 | | |
| | 24 | 18 | 16 | 47.36 | | |
| | 26 | 35 | 18 | 95.50 | | |
| | 30 | 17 | 18 | 0.49 | | |
| | 35 | 37 | 35 | 186.53 | | |

**3.3.1.3 Network management**

This module has a set of editing utilities, graphics manipulation cards (display, selection, zoom ...), and update databases (add, delete, modify and consultation). These management operations concern for files for nodes and ducts.

**a) Gestion graphique**

o **Create new map:** This option sets:

▪ Firstly the geometric characteristics of the network are: the length, diameter pipes

▪ As node coordinates. And secondly, the hydraulic quantities such as flow rates, the deterioration coefficient, and the flow of each pipe.

o **Updated maps:** This function allows you to change the structure or characteristics of network components (node or pipe). The change became necessary following:

▪ Adding or removing a node or conduct.

▪ changing the specifications relating to a node (name, code, address, ...) or to a driving (speed, length, end, breaks, ...).

o **Consulting the map:** it is to graphically display the map of the selected stage and list the information associated with it. It allows changing the display of dimensions (the zoom effect), and edit the attributes of the node and conduct selected.

**b) Updating the database**

The management of the database is done through editing forms and updating of driving and nodes (Figure 15).

▪ **Piping**

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**Figure-15.** Update form the base of the pipes.

a)  List of pipe upstairs study.

b)  The selected driving.

c)  Input fields parameters of driving.

d)  Definition of a pipe breaks.

e)  Sort the list of lines according to the selected criterion.

f)  Monitoring the integrity and consistency of information entered.

g)  Remove the selected driving.

h)  Data validation and Adding driving in the database.

i)  Exit the update module.

▪ **Nodes**



**Figure-16.** Update form of the base nodes.

a.  List the nodes of the floor studying.

b.  The selected node.

c.  Fields entered the node settings.

d.  Add the node entered in the database.

e.  Check the integrity and consistency of data entered.

f.  Sort the list of nodes according to the selected criteria.

g.  Delete the selected node.

h.  Exit the form.

To safeguard consistency and integrity of the database data, daily update modules have watchdogs. They ensure compliance with a set of rules, and thus control the data entry. These rules:

o  two nodes must not have:
▪  the same code,
▪  the same name,
▪  the same coordinates.
o  two different lines can not have :
▪  le the same code,

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- the same path (same starting node, arrival and even breaks).
- speed, diameter, length and the coefficient of degradation must be nonzero.

## 4. CONCLUSIONS

The location optimization chlorination stations within the distribution network mainly aims at reducing the number of loss-making nodes with minimal chlorine stations to be set (minimum cost optimization). To achieve this goal, we used two approaches dynamic programming and graph theory.

The optimization results obtained by these two approaches show that intake of graph theory in the optimization module significantly accelerates the optimization tool search speed. It also follows from the results obtained with the optimization module that the locations of intermediate stations chlorination depends on the chlorine concentration of the injection points (tanks, wells or other chlorine injection points), the rate chlorine threshold below which a node is running a deficit, and the hydraulic system of the network. The study of the influence of the deposit on the distribution of chlorine in the entire floor has shown that it may, in individual cases, opt for a solution that can be tolerated when the set point does not exceed 10% of the standard value.

This greatly reduces the cost of optimization. Criticism of the location of stations already operating in the network has helped to move some to other locations more significant yield.

For a more ergonomic and user-friendly operation of this decision support tool we used for its development, new Windows programming techniques.

## REFERENCES

A.Alj R. Faure. 1990. Guide de la Recherche Opérationnelle, 2 tomes, Masson.

Bellman R. 1954. Some applications of the Theory of dynamic programming - a review. Journal of the Operational Research Society of America. 2(3): 275-288.

Bremond B., Pillier O. et Koubska P. 1998. Modelization of the behaviour of chlorine dioxide in a drinking water supply. First IWSA international conference on master plans for water utilities. Praha, Czech Republic, 17-18 June 1998, Compte rendu.

Brion L. M. et Mays L. W. 1991. Methodology for optimal operation of pumping stations in water distribution systems. J. Hydraul. Eng.-ASCE. 117: 1551-1569.

M. Hafsi, A. Khaoua, S. Ben Abdellah, M. El Mghari Tabib () Effects of the chemical injection points in pre-treatmenton reverse osmosis (RO) plant performance.

Sadic R. et Rodriguez M. J. 2004. Fuzzy synthetic evaluation of disinfection by-products - a risk-based indexing system. J. Environ. Manage. 73: 1-13.

Wable 0.N, Dumoutier j, p. Duguet P, A. jarrige G. Gelas and Depierre J.F. 1991. Modeling Chlorine Concentrations in a Network and Application to paris Distribution.

Wigle D T. 2001. Une eau potable saine: un défi pour la santé publique. Maladies chroniques au Canada, 19, 3.

Elbelkacemi M., Lachhab A., Limouri M., Dahhou B. and Essaid A. 2000. Adaptive control of a water distribution system. Control Engineering Practice. 9: 343-349.