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QUANTITATIVE WATER MANAGEMENT IN RABAT, SALE AND TIMISOARA DRINKING WATER SYSTEM

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Abstract

For efficient management of the losses of drinking water distribution networks, it is essential to have a precise knowledge of the system and its infrastructures. In this context, our study focused on describing two drinking water distribution networks, from two different countries: Rabat and Sale, Morocco and Timisoara, Romania, for water losses over a period of four and five years, respectively. The work consists of calculating some performance indicators to establish thematic maps using Geographical Information System (GIS) in order to identify and prioritize the critical sectors by the method Analytical Hierarchy Process (AHP) based on technical criteria. Timisoara, Romania has a huge volume of water losses, inefficient use of resources, scarce data and poor control. Whereas, the Rabat and Sale, Morocco network also has significant water losses, but the great contribution provided by the sectorization network and flow measurements that the data are available for local managers. The technical performance indicators and the results obtained gave us an idea of the reliability of the leak management methods adopted by each manager**.**

Key words: drinking water system, geographic information system (GIS), leaks, multicriteria analysis method

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1. Introduction

Technical management of drinking water supply systems is a national and international issue. Each year, more than 32 billion m^3 of treated water does not reach to subscribers due to numerous failures such as leaks, faulty connections or piping. In some low-income countries, losses account are 50-60% of the water supplied whereas the global average loss is 35 %. Water loss occurs in all distribution systems, only the volume of loss varies. This depends on the characteristics of the pipe network and other local factors. The water utilities operational practices and technological expertise was applied to controlling that water loss (Karathanasia and Papageorgakopoulos, 2016). The basic function of a water distribution system is to satisfy the water user's needs. This water must meet standards of good quality, potability, pressure and enough quantity (Haidar, 2006). This type of management requires precise knowledge about the system, its infrastructures, and hydraulic operation while keeping regular system maintenance. For better management, the use and integration of IT tools will facilitate and help managers to make decisions, develop action plans and interventions. Among these tools, GIS is considered to be as an efficient technology. It plays a vital role in water resources management because this technology is considered as one of the most authentic technologies for integration, analysis, and manipulation of data. Moreover, this

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technology is well known and implemented in many countries of the world and has shown great efficiency in the field of resource management through their performance in georeferencing. This technology offers appropriate tools for spatial data combination as well as models on the same graphic support. Which allow data communication between stakeholders to ensure good coordination of activities.

Numerous research projects have been developed in recent years to facilitate the tasks of managers. When setting up intervention operations; among them, we already mentioned: (Mahmoud and Gan, 2018) (Karathanasia and Papageorgakopoulos, 2016), (Samir et al., 2017). The methodology used to prove its reliability according to Abdelbaki et al. (2016), Blindu (2004), Romocea et al. (2018). They have proved the reliability of the use of GIS in the management of the distribution of drinking water.

Unfortunately, in Morocco and Romania, this technology is not used very much in infrastructure at the national or regional level. In Morocco, the Department of Water and Environment stated that the state of degradation of the networks in the cities had resulted in a loss of 35% of the distributed water. This led to the development of several methods to estimate current and future performance. In this article, the goal is to provide an interactive decision support tool that will help managers to optimize water management and intervention. This decision-support tool is proposed to provide general information (collection, analysis, and prioritization) and to sort out the priority intervention sections taking into account several performance indicators.

Do drinking water system operators in Romania and Morocco have the same network problems? Is their leak management strategy reliable?

2. Case studies presentation and methods

In order to help the drinking water supply network managers successfully accomplish the mission entrusted to it, we propose a structured methodology in several successive and distinct stages to improve the strategy of the detection of the leaks and which will lead to the optimization of the service.

The methodology is based on the collection, processing, and analysis of different data. It aims to develop support for study and management. We chose two cases, belonging to two different countries: Rabat and Sale in Morocco located in North Africa and Timisoara in Romania located in Eastern Europe. We studied each independent case with the data available and provided by the managers. The methodology adopted to do the work is presented as follows in Fig.1.

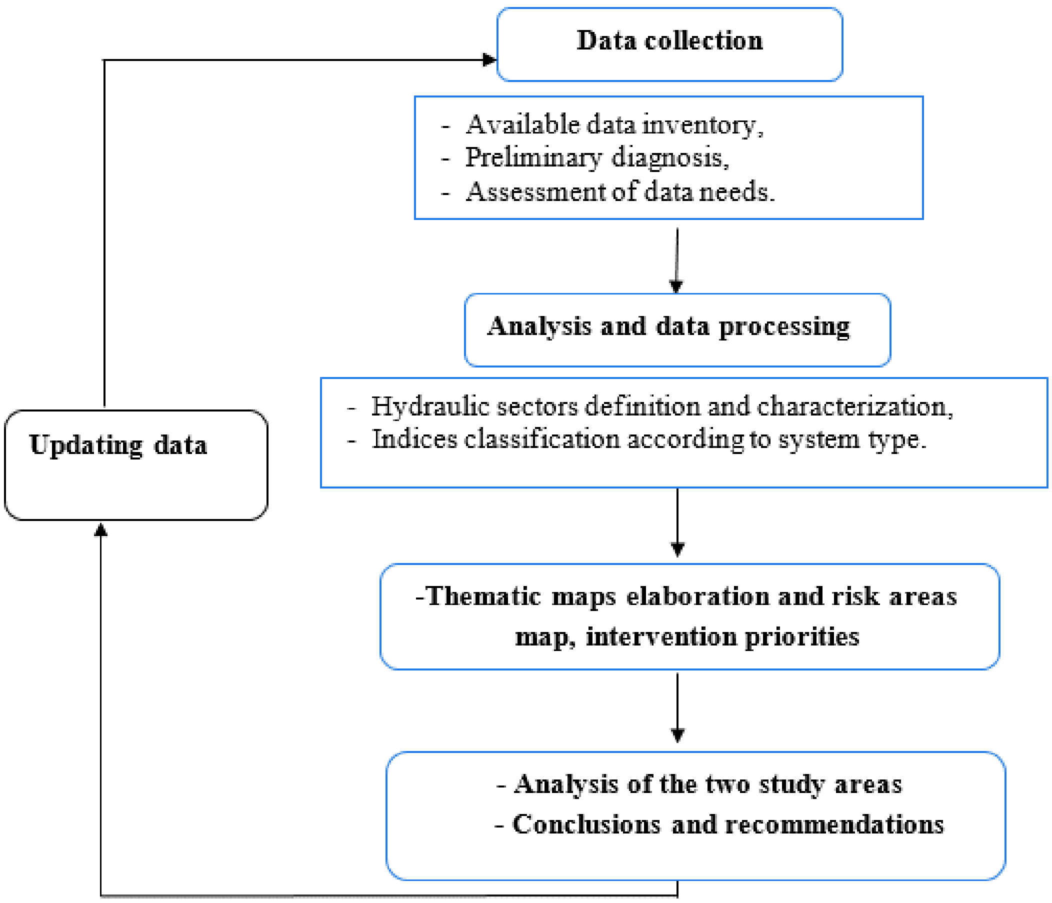


Fig. 1. General organization chart of the intervention plan.

After calculating and analyzing the performance indicators for each drinking water supply system, we used the AHP (Analytical Hierarchy Process) for the Rabat, Sale city, this AHP method is broken down into four stages (Saaty, 1996): ranking of indicators by importance from most important to least important, constructing a matrix based on the comparison of indicators two by two, determination of the weights associated with each indicator using a vector calculation method clean and finally check the consistency of the result.

The first phase consists in structuring the decision problem in a hierarchical structure by identifying the elements (indicators), the second phase, a pairwise comparison matrix was established to evaluate the importance of each of them. Then, the overall weights were calculated. For comparison, the experts determined the relative importance using pairwise assessments, the values being suggested by Saaty, scale from 1 to 9 (Harker, 1987), allowing the decision maker's judgments to be brought closer to reality. The comparison leads to obtaining the decision matrix (Eq.1).

$$A = [a_{IJ}] \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \frac{1}{a_{12}} & 1 & & a_{2n} \\ \vdots & & \ddots & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \cdots & 1 \end{bmatrix} \quad (1)$$

A: is the decision matrix, aij (individual priority) the comparisons between the elements i and j for all i, j ∈ {1, 2... n}.

Then we have to check the consistency of the result. At this point, we have the "weight" of each of the elements. The AHP method then proposed to validate the reliability of the result in calculating the coherence ratio (CR) the consistency ratio is calculated as follows in equation 2. Saaty has shown that a consistency ratio (CR) of 0.10 or less is acceptable to continue the AHP analysis. If the consistency ratio is greater than 0.10, it is necessary to revise the judgments to locate the cause of the inconsistency and correct it (Eq. 2).

$$CR = \frac{CI}{RI} \quad (2)$$

with *CI*-index of coherence and *RI*- index of a random-like matrix.

After the prioritization of the indicators, the criteria are used to build new GIS thematic maps, with high, medium or low risks, which are used to identify critical sectors.

2.1. First study area: Rabat and Sale cities

Rabat-Sale-Kenitra region covers an area of 18,194 km^2 and has 4,581 thousand inhabitants, a density of 251.8 inhabitants per km^2 and an area of 2.56% of national territory. It is limited North by Tangier-Tetouan-Al Hoceima region, East by Fez-Meknes region, and South by Beni Mellal-Khénifra region and Casablanca-Settat region, and West by the Atlantic Ocean. In our study, we will focus on both cities Rabat and Sale.

Data is provided by REDAL (Autonomous Water and Electricity Distribution Authority), which is responsible for delegated management of liquid sanitation and drinking water and electricity distribution services in Rabat-Sale - Zemmour - Zaers Wilaya, and which serves nearly 2 million people inhabitants. Network heritage represents a total linear of 3980 km in drinking water. It is broken down into an infrastructure network and the non-structuring network service that is distinguished by pipes diameter and materials that compose them. Fig. 2 shows the hydraulic sectors of Rabat and Sale.

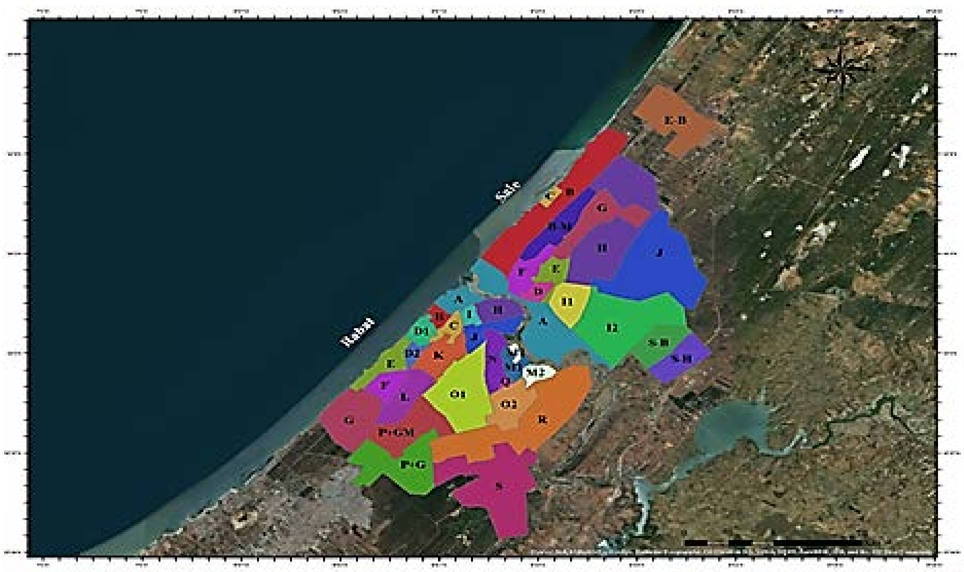


Fig. 2. Hydraulic sectors of the cities Rabat and Sale

2.2. Second study area: Timisoara city

Timisoara is the capital of Timiş Country; situated in the far western part of the country, with a population of 319.272. Within a radius of 600 Kilometers, there are seven major capital cities of Central and South Eastern Europe. (Neumann, 2015).

Aquatim S.A. Timisoara operates the water supply and sewerage systems in the area of operation starting with 2010, the area of operation at the end of 2015 includes 102 water supply systems in 102 localities including a municipality Timisoara (Aquatim, 2016). In Timisoara city, the sectorization method is still under study, so we will not have data by sector but of the whole city.

3. Results and discussion

3.1. Analysis of drinking water system performance parameters Of Rabat and Sale

3.1.1. Night flow

Regular measurement of night flow sectors makes it possible to locate the important leaks which exist, but also to be informed quickly about the emergence of new leaks in areas where the significant ones are likely to occur. Flow measurements were carried out continuously concerning the four last year's evolutions 2012, 2013, 2014 and 2015 for Rabat and Sale cities in (Figs.3-4).

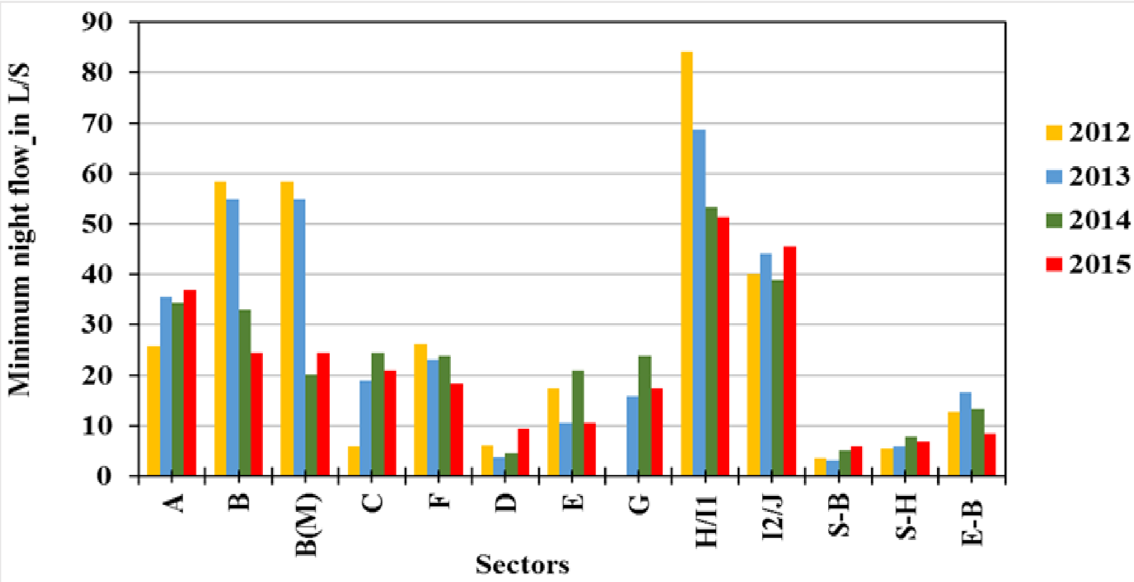


Fig. 3. Evolution of the minimum night flow of Sale

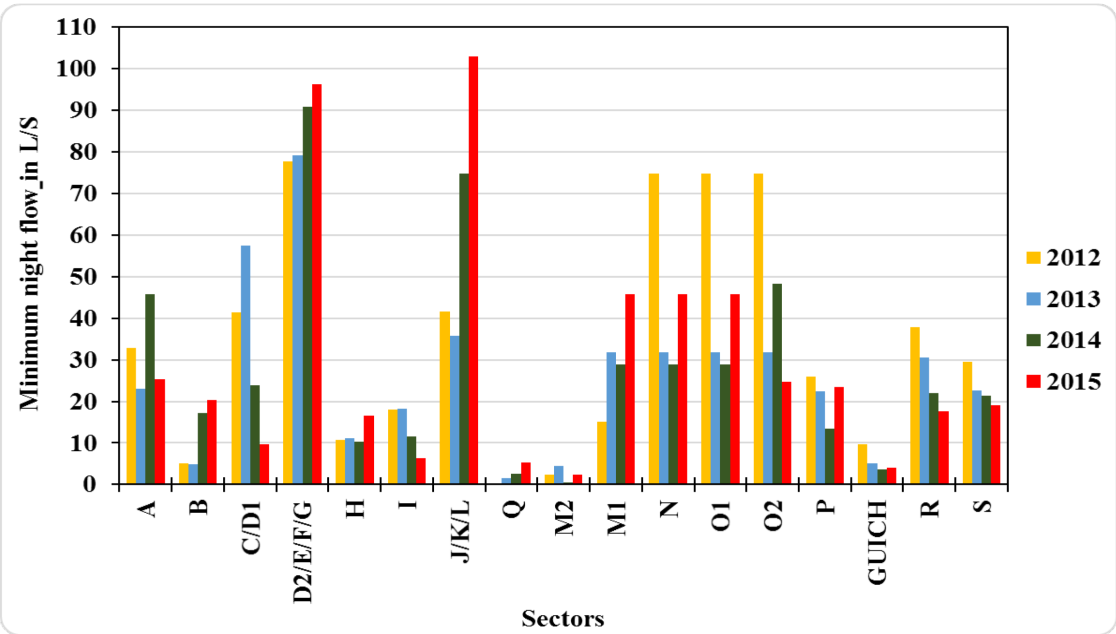


Fig. 4. Evolution of the minimum night flow of Rabat

In 2012 and 2013, the night-flow values were very high, especially in sectors B, H, I1, I2, and J. it should be noted that these sectors are fueled a gravity manner, hence the need to provide an audit of networks and their modulations. For 2014, leakage losses were not negligible in almost all hydraulic sectors except for areas D, E, Sala Al Jadida (S-B, S-H) and E-B (Bouknadel). In contrast to previous years, it is clear that sectors B, H, I1, I2, and J (2015) still require intervention at detection level and leaks repair. It is recommended to check network and water tightness in order to anticipate loss reduction measures such as sectorization and pressures modulation.

From 2012 to 2015, it was found that D2, E, F, G, J, K and L sectors have very high night time values. It was noticed that night flow values of sectors D2, E, F, and G are still increasing though these sectors are modulated. Sectors J, K, L, in 2015 experienced a sharp increase, it is recommended to check network of these sectors in order to anticipate loss reduction measures and react with a maintenance plan or pipe renewal for their optimization.

3.1.2. Linear loss index

It is used to monitor network evolution and to evaluate leakage losses on the distribution network. This index helps by providing a comparison to the physical state of two or more networks. Linear water loss index (LLI), expressed in cubic meters per day and per kilometer of the pipeline. LLI is calculated as shown in Eq. (3).

$$LLI = \frac{Q}{L} \tag{3}$$

With Q: Night flow, L: Network length (m^3 / km / d).

After calculating LLI, the analysis of drinking water system category was based on linear loss index of Rabat and Sale cities, obtained from REDAL (Autonomous Water and Electricity Distribution Authority) as shown in Table. 1.

Table 1. Linear loss indices classification according to drinking water system type

Drinking water system category	***Rural***	***Semi-rural***	***Urban***
Good	LLI<1	LLI<3	LLI<7
Acceptable	1≤LLI≤3	3≤LLI≤7	7≤LLI≤12
Bad	LLI>3	LLI>7	LLI>12

Processing results linear loss index data from 2012 to 2015 by ARCGIS software are presented in LLI form evaluation cards by sector of each city below (Fig. 5).

(a) (b) (c) (d)

Fig. 5. Linear loss index (LLI) m^3 / J / Km evaluation in Rabat and Sale cities sectors in 2012, 2013, 2014, and 2015: (a) linear loss index m^3 / d / Km of the Rabat and Sale cities sectors in 2012, (b) linear loss index m3 / d / Km of the Rabat and Sale cities sectors in 2013, (c) linear loss index m^3 / d / Km of the Rabat and Sale cities sectors in 2014, (d) linear loss index m^3 / d / Km of the Rabat and Sale cities sectors in 2015

According to maps analysis of linear losses index presented previously, it has been noted that they present different network categories according to LLI follow:

- Sectors presented in green indicates that the drinking water system was in good condition,
- Sectors shown in yellow indicates that the drinking water system was an unacceptable condition,
- Sectors presented in red indicates that the drinking water system was in poor condition.

Due to the linear losses index, the degradation occurred in the condition of systems belong to Rabat and Sale city. For example in 2012, Rabat sectors H / I / J / K / L and Sale's Bouknadel were in good condition. But in 2013 it was come under the acceptable range, after that in a bad state. This provides us an indication that the strategy for managing and reducing leaks in Rabat and Sale drinking water system was unreliable. It was recommended to check these sector's networks and revise the strategy to solve problems in the drinking water system.

3.1.3. Leakage linear index

It is expressed from the minimum flow of a network that is generally observed. It makes it possible to estimate the share of leakage-related water losses considering that night-time consumption is negligible. The formula is mentioned in Eq. (4). The judgment of network state in leaks terms made on the basis of the ILI data derived from the work experience of detection agents/search for leaks at REDAL (Table 2).

$$ILI = \frac{Total\ Leaks\ Number}{Cumulative\ Swept\ Lines}(Leaks/km \tag{4}$$

Table 2. Linear leakage indices classification by network type

Drinking water system category	
Good	ILI<0.3
Acceptable	0.3<ILI<0.6
Bad	ILI>0.6

3.1.4. Pipes Age

Historical installation data were taken from GIS records. It can be seen from the Fig. 6 that some periods were more favorable to certain materials use.

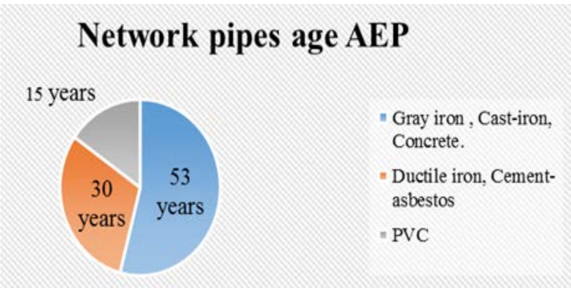


Fig. 6. Drinking water system pipes age by type

3.1.5. Emergency level

At this level that prioritized sectors can be identified which are most deficient in supplying a good drinking water system and optimize decision-making. Performance of a criterion is calculated from indicators performance associated with it (Ellis. et al., 2004).

The AHP (Analytical Hierarchy Process) method was used to study the hierarchy of sectors. This AHP method is broken down into four stages (Saaty, 1996): indicators prioritization by importance from most important to least important, a matrix construction based on a comparison of two by two indicators, weights determination associated with each indicator, and calculating method that finally checked the result consistency.

According to collected data and analysis of the studied area, data management, is one of the most important parameters that have weight when studies carry out on: night flow, linear loss index, linear leakage index, and installation date.

Night flow: weight 5,
Linear loss index (LLI): weight 4,
Linear leakage index (ILI): weight 3,
Pipes Age: weight 2.

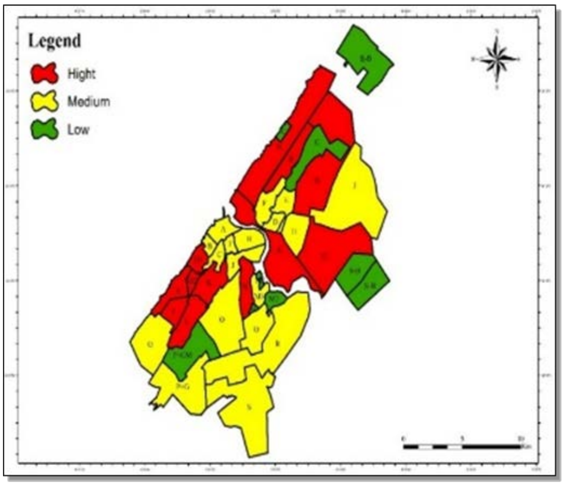
The number of class is set at three for better readability and a good interpretation of resulting maps. This approach will lead to thematic maps production and water leakage risks for years 2012 to 2015, this approach was programmed in ArcGIS in order to automatically determine emergency levels for each sector in map form which will be easily exploited by managers. Criteria classification will lead to thematic maps of three classes that are a risk, high, average and low classes.

This methodology has been applied to identify priority sectors on the drinking water system of Rabat and Sale cities. The implementation of this step has been facilitated by ArcGIS software use. Results obtained by software are automatically presented in maps form below (Fig. 7).

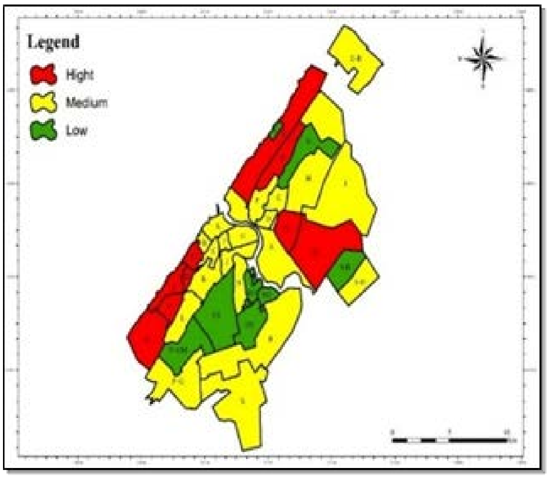
By analyzing water leaks risk maps in Rabat city hydraulic sectors, sector O modulation in 2013 has reduced water leakage risk but network condition was degraded after 2014 which gave us an indication that the methodology used by REDAL was reliable over a short period of time. For sectors D1 / D2 / E / F J / K and L, they are still in a critical state and require urgent intervention.

For Sale city, Sector A, H, I1, are still in critical condition, thus there must be an intervention to reduce water leakage and to innovate in these sectors. This indication makes it possible to establish an action plan for leaks detection and orientation of research for better management of the drinking water system, as well as anticipating emergency program for immediate drinking water system leaks repair.

To confirm our analysis, we will evaluate the reliability of REDAL leakage strategy followed by gain percentage compared to each previous year (Fig. 8).



(a)



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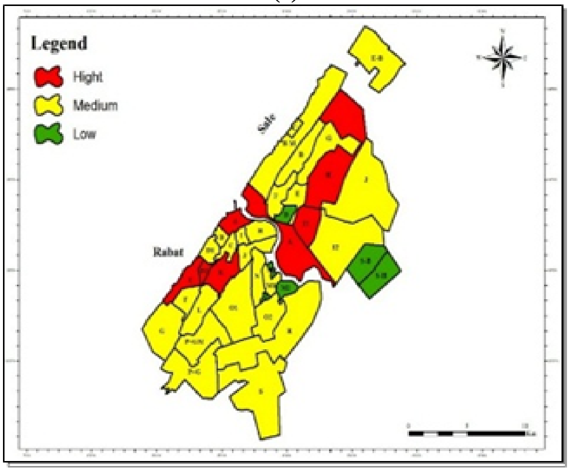
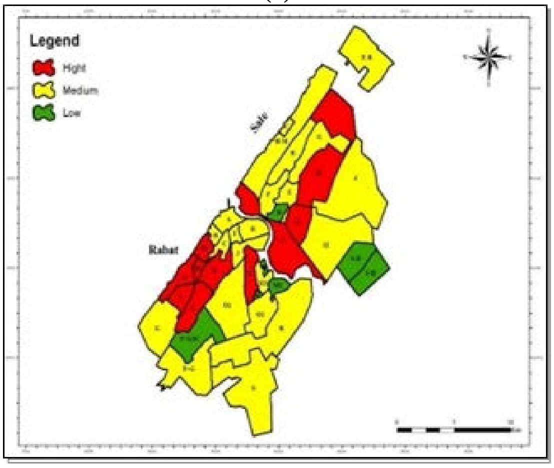
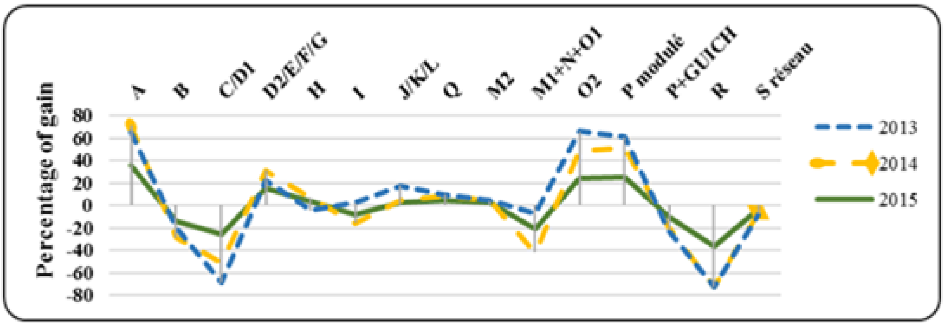


(c)

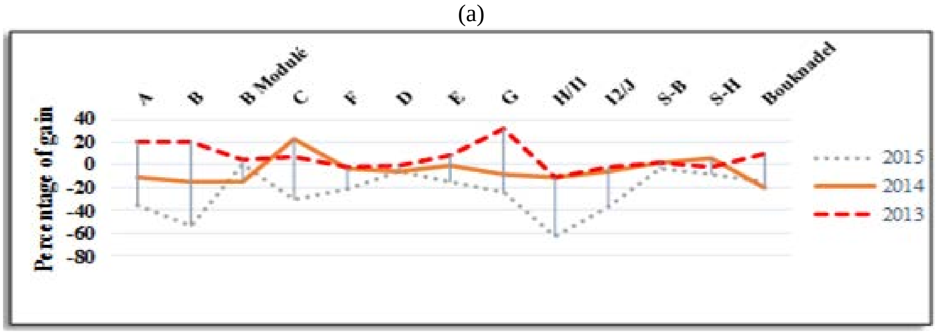


(d)

Fig. 7. Water leaks risk maps in hydraulic sectors for 2012, 2013, 2014, 2015:(a) Water leaks risk maps in hydraulic sectors for 2012, (b) Water leaks risk maps in hydraulic sectors for 2013, (c) Water leaks risk maps in hydraulic sectors for 2014, (d) Water leaks risk maps in hydraulic sectors for 2015



(a)



(b)

Fig. 8. The gain percentage in Rabat and Sale for 2013, 2014, 2015: (a) The gain percentage in Rabat and Sale for 2013, 2014, 2015, (b) The gain percentage *in Rabat and Sale for 2013, 2014, 2015*

After the treatment of Rabat and Sale's data, several sectors have priority over other sectors. Hence establishing interest in an action plan for leaks detection and team's orientation for drinking water system's better management, as long as regular and anticipated verification of an emergency program for repairing network leaks. Water leakage risk thematic maps of the pipeline sector obtained at the end of this work for both cities were consistent with the distributor's perspective. This proves geo-computer system reliability that was created during this work and offers the opportunity to exploit this system on a larger scale, save time, and manage resources. The thing which is altarpiece for this latter, not forgetting its characteristic and its capacity in coupling with a large and medium software range, stimulation systems, and management and programming.

Monitoring, under good conditions, should lead to reduce water losses, especially follow-up and results to identify performance indicators at a good level. The objective is to preserve these assets and monitor network evolution so as to ensure as quickly as possible any slippage in water consumption to ensure its reliability and performance.

According to the obtained results, the objective was to detect and identify areas risk zones to reduce and control leaks in Rabat and Sale drinking water system. It is mandatory to move towards a pressure modeling for high linear index percentage compared to each previous year.
sectors ILI and LLI since excess reduction pressure makes it possible to reduce the continuation flow rate of one part, and continuation frequency of another part. Monitoring network is an essential step in ensuring sustainable management of distribution from which monitoring of night consumption (night flow).

It should also be noted that repair details or leakage repairs, for example, can be found in diagnostics sheets of drinking water connections and pipes, which contain all information needed for future monitoring and diagnosis (failure nature, installation conditions, equipment condition, environment condition, etc.). To ensure this task, tools and means are varied and will depend, in particular, on methods implemented to carry out the diagnosis.

3.2. Analysis of drinking water system performance parameters of Timisoara city

The most common method of determining water loss is water balance calculation by IWA methodology (International Water Association). Table. 3 below shows the volume of water entering the system and the loss of water for each system within the operating area over the last five years in Timisoara:

3.2.1. Performance indicators

Based on IWA specifications which facilitate continuous analysis and benchmarking. The objective is to describe the resources spent (e.g. repair cost/km) or conditions (e.g. a number of failures/km), to compare sub areas or entire networks and to estimate the benefits of a rehabilitation or pressure management program. The IWA water performance indicators for water loss are:

- Specific water losses (QSL)
- Non-revenue water
- Current Annual Real Losses (CARL)
- Unavoidable Annual Real Losses (UARL)
- Infrastructure Leakage Index (ILI)
- Customer leakage index (CLI)

In Table 4 are presented the main performance indicators for several water supply systems.

After calculating the ILI for the water supply system, it has been found that all the values are greater than 8, which indicates an inefficient use of resources, poor maintenance of system condition. An initial assessment of its condition and immediate description of water loss management performance can be obtained by using the World Bank Institute's banding system shown in Table 5.

Table 3. Water volume entering the system and the loss of water for Timisoara city

Water supply system	***Year***	***System input volume***	***Water losses***			
			Apparent losses		***Real losses***	
		m³	***m³***	***%***	***m³***	***%***
Timisoara water supply system	2011	36.558.840	1.853.574	5.1	12.946.587	35.4
	2012	36.396.596	1.837.377	5.0	13.099.069	36
	2013	33.671.343	1.726.054	5.1	11.178.339	33.2
	2014	31.239.729	1.627.274	5.2	9.583.773	30.7
	2015	31.274.780	1.637.259	5.2	9.361.064	29.9

Table 4. The volume of water entering the system and the loss of water for each system within the operating area over the last five years

Water supply system	***Year***	***Performance indicators***					
		QSL	***CARL***	***UARL***	***ILI***	***Non-revenue water***	
		m³/km/day	***m³/day***	***m³/day***		***m³***	***%***
Timisoara Water supply system	2011	54.65	35.470	907	39	14.891.558	40.7
	2012	55.30	35.790	921	39	15.027.458	41.3
	2013	47.19	30.626	993	31	12.988.571	38.6
	2014	40.46	26.257	1.001	26	11.289.146	36.1
	2015	39.51	25.647	1.100	23	11.076.510	35.4

Table 5. World Bank Institute's banding system for developed and developing countries

WBI band	*ILI range*		*Guideline description of real loss management performance categories*
	Developed countries	*Developing countries*	
D	8.0 or more	16.0 or more	Very inefficient use of resources, poor maintenance of system condition, leakage reduction programs are important with high priority

3.2.2. Customer leakage index

A reference system of the linear leakage index adjusted proportionally to the customer's density that has been adopted by SMERGREG. The customer leakage index (CLI) has shown in Eq. (5) and Fig. 9(Renaud, 2010).

$$CLI = \frac{CAWL}{365 \times N} \quad (5)$$

CLI: Customer leakage index in m^3/customer/day; *CAWL*: Current Annual Water Losses in m^3; *N*: Number of customers

3.2.3. The material used for distribution networks execution

During the historical development of the water distribution networks, the materials used were gray cast iron, asbestos, steel, precast concrete, polyvinyl chloride (PVC), high-density polyethylene (HDPE), ductile iron and composite materials (HOBAS-fiberglass).

Over the years, it has been found that old water networks made of gray cast iron or asbestos pipes are sensitive to external factors (traffic, laying bed and improper filing) that lead to the occurrence of transverse cracks. (Aquatim SA database). In which HDPE was the most used. According to some performance parameters calculation of Timisoara city drinking water supply network. The price of a cubic meter of water was calculated as shown in Eq. (6) and presented in Table. 7.

$$Water\ price/cubic\ meter = 3.11\ LEI = 0.66\ EUR \quad (6)$$

Unexamined water must be equal to or lesser than 40% according to standards. Timisoara city results according to Aquatim from 2011 until 2015 is not up to the mark, which explained the progressive efforts made by the company for drinking water network management. But these good efforts were made at very high cost, for example in 2015, the cost of water loss was 7310496, 6 euros. So urgent intervention is mandatory and it has been recommended to switch towards sectorization, integration, and application of ArcGIS geographic information system. This computer tool is one of the best-known technologies in data integration field analysis and processing. Thus, network monitoring can ensure sustainable management of the distribution network with the help of regular monitoring of interest for night consumption (night flow).

It should also be noted that details of leaks repair can be found on diagnostics sheets for drinking water connections and pipelines containing all information needed for future monitoring and diagnosis. To ensure this task, tools, and resources are varied and depend on particular methods used to carry out the diagnosis. On the basis of methodology adopted, a comparison with some recent work is provided in the table given below.

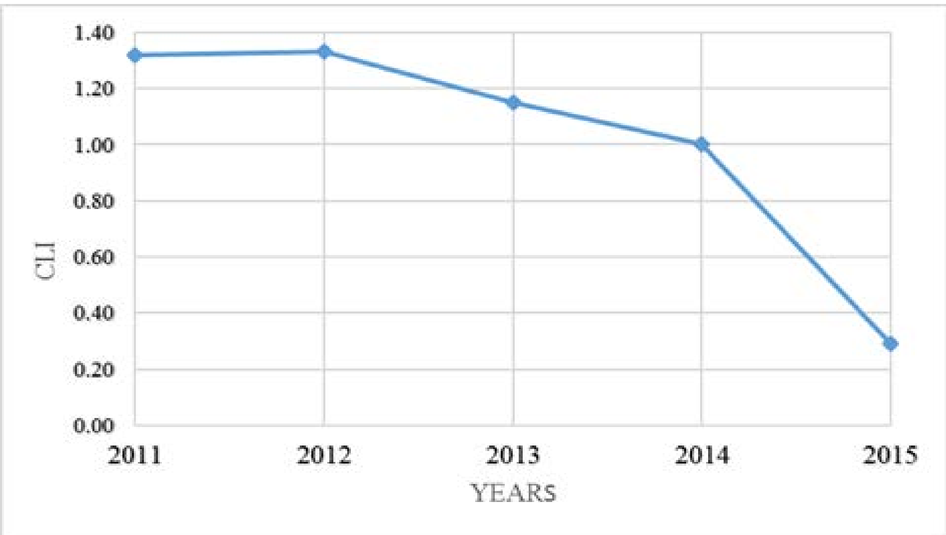


Fig. 9. Customer leakage index in 2011, 2012, 2013, 2014, and 2015 (m^3/customer/day) for Timisoara city

Table 7. Non-revenue water prize of Timisoara city from 2011 until 2015 in lei and euro

Water supply system	***Year***	***Performance indicators***		***Cost of loss***	
		Non-revenue water		***LEI***	***Euro***
		m^3	***%***		
Timisoara Water supply system	2011	14.891.558	40.7	46312745.38	9828428.28
	2012	15.027.458	41.3	46735394.38	9918122.28
	2013	12.988.571	38.6	40394455.81	8572456.86
	2014	11.289.146	36.1	35109244.06	7450836.36
	2015	11.076.510	35.4	34447946.1	7310496.6

Table 8. Comparison with some recent work in this domain

Tittle	***Methodology***	***Observations***	***References***
Management of water losses in water supply and distribution networks in Turkey	This work was based on calculating the water balance for one year, then network division in to metered area and finally monitoring and assessment, that reduced the physical water losses.	The only performance indicator (PI) for water losses in the Turkish regulation was the percentage value only However, which is not enough since the work did not take into consideration all the other technical parameters. Hence the need to add and calculate other performance indicators such as the Infrastructure Leakage Index (ILI) and GIS.	Ayşe et al. (2018)
Management of a water distribution network by coupling GIS and hydraulic modeling: a case study of Chetouane in Algeria	Map info GIS (8.0) software was coupled with a hydraulic model (EPANET2.0) and applied to a case study region.	The results showed that a combination of GIS and modeling permit network operators to better analyze malfunctions with a rapid response as well as facilitating in an improved understanding of the work performed on the network.	Abdelbaki et al., (2016)
Pressure control for minimizing leakage in water distribution systems	Modeling leakage as a function of pressure and pipe length, calibrating leakage coefficient, using fixed pressure reducing valves (PRVs) to develop pressure fluctuation and developing water CAD scenarios to minimize leakage through the most effective settings of PRVs.	This research work applied Infrastructure leakage index (ILI) only, which provided a network evaluation.	Samir et al. (2017)
Development of a leakage control system at the water supply network of the city of Patras	This work included hydraulically discrete sectors (DMAs), pressure management, GIS based support system, and aggregation of various operational databases through development of an intelligent reporting software.	The methodology was good for reliability and pressure management, but they lack the analysis of the minimum night flow and the estimate of the level of physical losses in each DMA.	Karathanasi and Papageorgakopoulos (2016)
Quantitative water management in Rabat, Sale, and Timisoara drinking water system	GIS-integrated AHP method, which aims to facilitate decision making, to identify and prioritize critical areas. Finally, this research work analyzed the financial score to quantify the cost of water losses in each system.	The quantitative study of the drinking water distribution system of two cases by integrating the GIS and AHP was carried out. This detailed study is reported on the basis of the analysis of several performance indicators such as minimum flow night, linear loss index, linear leakage index, age of the pipeline. This combination has proven its reliability to give a clear picture of the network situation to the managers. This analysis can identify certain dysfunctions resulting in an improved management systems.	Present work

3.3. Analysis of the two study areas

The study on drinking water in Rabat, Sale and Timisoara cities were made on the available data. The comparison cannot be made since the work data of each manager are different, and they did not use the same performance indicators, but our work focused on the quantitative water loss and recognizing the efficiency of networks for water supply. This analysis allowed to identify certain malfunctions by which the improvements to a management system can be done. According to the analysis of the data that have been collected from the managers, it can be noticed that the attempts were made by the managers in each country. But there are still some weak points which need a sufficient workout. Table 9 given below summarizes the analysis between the two systems.

Table 9. The difference between the two systems Rabat, Sale, and Timisoara

	Rabat and Sale	***Timisoara***
Sectorization	X	-
Using the geographical information system (GIS)	X	-
Emergency Intervention Method	X	X
Calculation and monitoring of indicators	X	X
Renewal and rehabilitation of facilities	-	-
Updated information and data base	X	-

4. Conclusions

A brief discussion was given for the two water distribution networks, from different countries (Morocco and Romania) on the basis of water loss over a duration of four/five years. From the available data, it has been concluded that the city of Romania has inefficient resources with a lack of data and poor control. On the other hand, the Rabat and Sale (Morocco) network presented a great level of water losses, because of network sectorization and flow measurements more data is available to the local managers.

Thematic maps on GIS as well as AHP based on night flow, linear loss index, linear leakage index, pipe age was used to recognize the poor performance of the sectors in Rabat and Sale only because in Timisoara enough data was not available at that moment. For future development, it is necessary to adopt a structured and adaptive methodology, which would lay the foundations for a management tool.

The challenge is to create a decision support tool that provides managers with a quantitative means to implement driving renewal programs in different areas of the city, at different horizons. Taking into account all the parameters characterizing the drinking water networks.

References

Abdelbaki C., Benchaib M., Benziada S., Mahmoudi H., (2016), Management of a water distribution network by coupling GIS and hydraulic modeling: a case study of Chetouane in Algeria, *Applied Water Science*, **7**, 1561-1567.

Aquatim, (2016), Expertise on the water losses from water supply systems operated by Aquatic SA, Aquatim SA, Project 169/AP/2016, Timisoara, Romania.

Ayşe M., Habib M, Alev A ., Özlem İ., Yakup K., (2018), Management of water losses in water supply and distribution networks in Turkey, *Turkish Journal of Water Science and Management*, **2**, 58-75.

Blindu I., (2004), *Diagnostic aid tool for the drinking water network for the city of Chisinau by spatial and temporal analysis of dysfunctions hydraulic*, PhD Thesis, Saint-Étienne School of Mines, France.

Ellis J. B., Deutsch J.-C., Mouchel J.-M., Scholes L., Revitt D, (2004), Multicriteria Decision Approaches to Support Sustainable Drainage Options for the Treatment of Highway and Urban Runoff, *Science of the Total Environment*, **334–335**, 251-260.

Haidar H., (2006), *Drinking water networks rehabilitation, Methodology for multicriteria heritage analysis and rehabilitation programs*, PhD Thesis, National Institute of Applied Sciences of Lyon, France.

Harker P., (1987), Alternative Modes of Questioning in the Analytic Hierarchy Process, *Mathematical Modeling*, **9**, 353-360.

Karathanasi I., Papageorgakopoulos C., (2016), Development of a leakage control system at the water supply network of the city of Patras, *Procedia Engineering*, **162**, 553-558.

Mahmoud H.S., Gan T.Y., (2018), Urbanization and climate change implications in flood risk management: Developing an efficient decision support system for flood susceptibility mapping, *Science of the Total Environment*, **636**, 152-167.

Neumann S., (2015), First Monitoring Meeting, Report by the panel of independent experts, Candidate City, On line at: https://ec.europa.eu/programmes/creative-europe/sites/creative-europe/files/files/ecoc2021-timisoara-monitoring_en.pdf.

Romocea T., Onet A., Sabau N.C., Onet C., Herman G.V., Pantea E., (2018), Change of the groundwater quality from industrial area Oradea, Romania, using Geographic Information Systems (GIS), *Environmental Engineering and Management Journal*, **17**, 2189-2199.

Saaty T., (1996), *Decision Making with Dependence and Feedback: The Analytic Network Process*, WS publications, University of Pittsburgh Berlin Heidelberg, 4922 Ellsworth Avenue Pittsburg, 15213.

Samir N., Kansoh R., Elbarki W., Fleifle A., (2017), Pressure control for minimizing leakage in water distribution systems, *Alexandria Engineering Journal*, **56**, 601-612.