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DRINKING WATER CONSUMPTION AND LOSS IN ALGERIA THE CASE OF NETWORKS WITH LOW LEVEL COUNTING

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Abstract: Demand for drinking domestic water is continuously increasing specially in urban centres which experience high demographic expansion. The decrease of water losses in water supply networks can help preserve such a rare resource. Low number of water meters and intermittent supply make it difficult to quantify the leaking volumes of water. This article presents an analysis of the consumption for drinking water based on an extrapolation from a sample of consumers on whom data are available. Comparison of the volumes of water produced allows a determination of the losses in the water supply system. This analysis is completed by measurements of night flows. The results obtained may be relied on for an evaluation of the needs for drinking water in the South of Algeria, and for future regional development. The study indicates a high rate of water losses in the distribution network, reaching about 40%, and over-consumption due to an insufficient number of water meters and discontinuous supply. It is recommended that water meters come into general use and defective parts of the network are rehabilitated. We will try then to make the necessary recommendations in order to better functioning of the water supply systems in Algeria.

Keywords: Water supply network; drinking water consumption; distribution; losses; distribution system; domestic water demands; Algeria

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INTRODUCTION

In Algeria, to master the water management has always been considered as an objective of the utmost importance in the struggle for national development. Generally speaking, management of water resources is facing now three types of problems:

(a) over-consumption that exceeds the rate of natural renewal of the resource;
(b) diffuse or occasional, often long-lasting, pollution; and
(c) seasonal shortages.

The drought that Algeria has been experiencing for more than two decades has decreased the average annual rainfall and supplies by more than 20% Garadi (2006). An important programme of mobilisation and transfer of surface water resources has started; its medium term objective was to make up for the chronic shortages that affect the supply of water to homes and agriculture in Algeria (Garadi, 2006; Kettab, 2008).

Since the mid-nineties, people in Algeria have become more aware of the severity of the water problem. Such a change in awareness occurred during the 1999 drought that affected seriously Western Algeria, leading to the first set of measures taken against wastage of water. Several years later, there is no choice but to accept that the improvement achieved during that period, and in spite of the increased awareness, had not been considerable. All that consumers still remember from the ORSEC plan was the water cuts as part of the rationing plan. The water reserves of the country are estimated at slightly less than 20 billion m^3, 75% of which are renewable (60% surface water and 15% groundwater) Cefigre (1990). The non-renewable resources are groundwater reservoirs in Northern Sahara that seemed to be exploited like a deposit, thereby causing a continuous lowering of their level.

Furthermore, over the period 1999−2009, there was an increase in the total water production, estimated at 42.5%, while the population increased by 44.0% (the per capita total water production fell from 118 litres/day to 90 litres/day) (CNES, 2010; Margat, 2005).

At present, most Algerian towns are facing at least one water-related problem: either with distribution (network, storage, reservoirs), or with supply, and even with drainage of the sewage. In addition to droughts, unfavourable economic factors and population problems combine to make easy access to drinking water difficult Cefigre (1990).

In this context and particularly in the arid southern areas, efficient management of water resources and minimizing water losses constitute the strategic and operational tasks for the society and the economy.

OBJECTIVES AND METHOD

Many studies have been devoted to the study of losses from water supply distribution networks, such as those presented in the International Water Association (IWA) conferences: Leakage 2005, Waterloss 2007, 2009 and 2012 Pearson *et al.* (2005), Marco *et al.* (2006), Liemberger *et al.* (2007) and Lambert *et al.* (2009). However, very few have dealt with networks with a low level of metering and on which the supply is frequently interrupted.

The aim of this study is to conduct an assessment of drinking water consumption and to provide an estimate of the water losses of the domestic water supply network in the region of Biskra located in the south of Algeria. Two methods were used: The first method consisted of an evaluation of the consumption for drinking water through the study of a sample of consumers on whom relevant data are available, followed by an extrapolation from the results obtained to the whole population. A comparison with the production was then made.

- The second method evaluated the water losses on the water supply distribution networks through measurements of the flow of water supplied to the town of Biskra at night.
- After a brief presentation of the context in which water is distributed in the region of Biskra, an assessment of the domestic, commercial and industrial demands for water is made, followed by an evaluation of the losses, and finally a comparison of the results obtained by the two methods used.

DRINKING WATER SUPPLY IN BISKRA

Resources

Groundwater represents the main drinking water resource in southern region of Algeria, which includes the three towns of Biskra, Ouled-djellal and Eloutaya. About 69 medium and large depth wellfields (between 150 and 850 meters deep) were sunk in order to supply the population with drinking water. The water produced is either pumped to storage reservoirs, or directly injected into the distribution networks. Most of the water produced in 2009 (58 642 m^3/day in Biskra, 5 115 m^3/day in Ouled-djellal and 3 865 m^3/day in Eloutaya) was allocated for the population, while the remaining amounts (600 m^3/day) was allocated to industry ANAT (2010). Most consumers in the three towns still suffer from problems of discontinuous water supply and insufficient flow and pressure.

The total per capita production in 2009 amounted to 293, 200, and 290 L/day in Biskra, Ouled-Djellal and

Eloutaya, respectively, whereas the production was 235, 163 and 181 l/day in 1999; the progress of the overall water production has been as important as the number of users increase. Masmoudi (2009).

Invoices Consumption

The total number of domestic consumers of water in the three main towns of Biskra region increased from 37 452 in 1999 to 50 520 in 2009, about 35% increase in one decade. On average, one thousand four hundred fifty two users are connected to the network every year. Biskra Region Water Board makes a distinction between the consumed annual volumes of water and the invoiced ones, based on the method of determination of each of them. These are: metered consumption (assessed by meters installed), and consumption payed for on an inclusive basis according to the type of house and number of floors contained Masmoudi (2009).

The quarterly variations in domestic consumption during 2004−2009 corresponding to metered consumptions revealed that in Biskra, the consumption reached a peak in the fourth quarter and was less important in the third quarter which corresponds to the hot season. It is very probably because many people left the area in that period of the year Kettab (2009).

Water demand in commercial, public establishments and industrial plants

Like most areas and towns in Algeria, the towns of the region of Biskra are witnessing a rapid and steady growth in trade, industry and agriculture. The number of commercial establishments, small factories and office buildings has been constantly increasing. In addition, there has also been an increase in the public amenities and facilities, whether they are related to cultural activities, sports and education, or to tourism, sanitation and religious practices.

Conducted surveys revealed that the total number of commercial and public consumers had increased from 1 254 in 1999 to 1 978 at the end of 2009. On average, seventy-three establishments are annually connected to the water network as a consequence of the development of their different activities. Nevertheless, there remains the problem of assessment of the quantity of water really consumed, because although consumers of large amounts of water are usually equipped with water meters, many office buildings and other establishments are connected to the water supply network without meters. It has been shown Kettab (2009) that out of the 1 978 consumers, only 587 have meters, with a rate of defectiveness of 30%.

Moreover the industrial infrastructure in the region of Biskra includes two industrial complexes, namely the National Company of Cable Industry (ENICAB) and the Textile Industry Complex (ELATEX), in addition to a few minor oil production units Masmoudi (2009). These production and manufacturing units are supplied with drinking water by the public network and from wells drilled in the location of these factories, accounting for the fact that the overall daily quantity of water tapped from the network is relatively small at about 640m^3/day. As the number of establishments that consume significant amounts of water is limited, the industrial water consumption is relatively better known than the domestic one.

RESULTS AND DISCUSSION

In the absence of reliable water meters in most of the dwellings, it becomes very difficult to determine the quantity of water really consumed with accuracy. Domestic consumers having water meters do not represent more than 40% of all consumers included in the study. Furthermore, the problem of defective water meters, of which the number is unknown, makes any evaluation still more difficult. This problem led us to rely on a sample of metered readings taken during a limited period of the measurement campaign. Such readings enabled us to determine by extrapolation the overall drinking water consumption in the three towns of the region of Biskra.

Measured consumption

The campaigns of measurements launched in the three towns aimed at evaluating the quantity of water consumed, and determining the rate of temporal variations in consumption. The approach adopted consisted of measuring the quantity of water consumed every 24 hours and during a week using a sample of 147 consumers in Biskra, 39 in Ouled-Djellal and 27 in Eloutaya.

The campaigns were conducted in the period from September to November, and involved consumers having an uninterrupted supply of drinking water and equipped with perfectly working water meters. These two conditions which are indispensable for the achievement of reliable results were not easy to fulfil as they restricted our choice of the size and dispersion of the sample, particularly because of the frequent interruptions of water supply to most consumers. For a better representativeness of the samples, we took into consideration the types of houses in the area (**Table1).**

It is important to notice that most of the flats have three main rooms. Analysis of the measurements made showed that the range of daily demand for water per

Table 1. Sizes and compositions of the samples of consumers

Types of houses making up the sample				
Town	Size of sample	Single-floor house	Two-floor house	Flat
Biskra	147	41	16	90
O.Djellal	39	18	09	12
Eloutaya	27	13	04	10

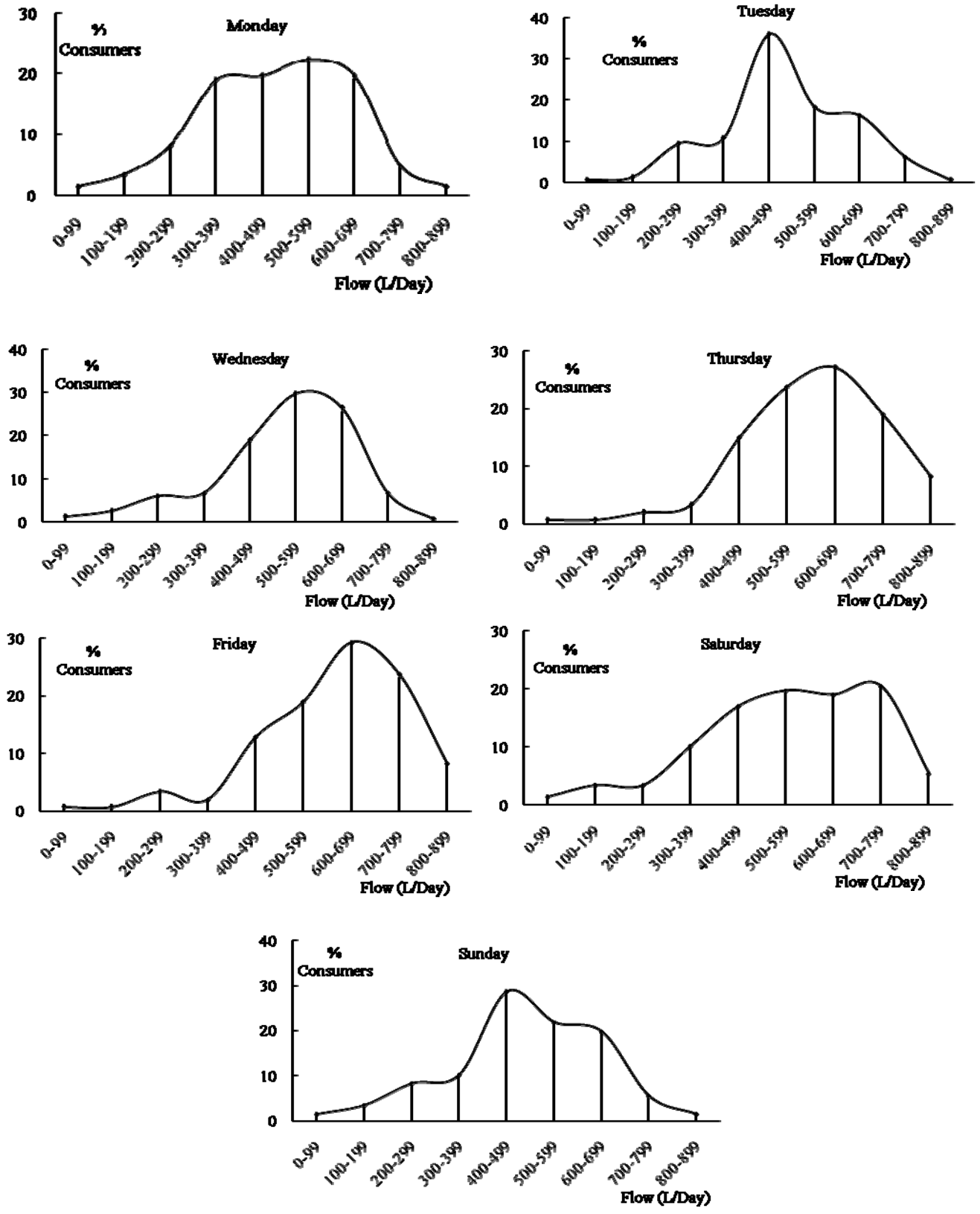

Fig. 1 Coefficients of daily variations in water consumption.

consumer in this area is very wide, from less than 45 liters to more than 859 L/day.

The diagram representing daily consumption during seven days of the week (**Fig. 1**) shows the wide range of daily water consumption in the town of Biskra.

Mean daily consumption per consumer, measured during a week (**Table 2**) was between 383 and 668 L/day/consumer in Biskra, 351- 558 L/Day/consumer in Eloutaya and 231 – 389 L/Day/consumer in Ouled-Djellal. Mean hourly consumption per consumer, measured during 24 hours in three towns (**Fig. 2**) was

Table 2. Daily consumption per type of house

	Domestic consumption per consumer (L /day/consumer)		
Town	Single-floor house	Two-floor house	Flat
Biskra	668	383	496
O.Djellal	231	254	389
Eloutaya	382	351	558

Table 3. Coefficients of hourly variations in water consumption

Town	00h – 07h	07h – 10h	10h – 13h	13h – 20h	20h – 00h
Biskra	0.40	1.40	2.10	1.30	0.40
O.Djellal	0.25	1.60	2.28	0.65	0.25
Eloutaya	0.28	1.97	2.74	0.97	0.28

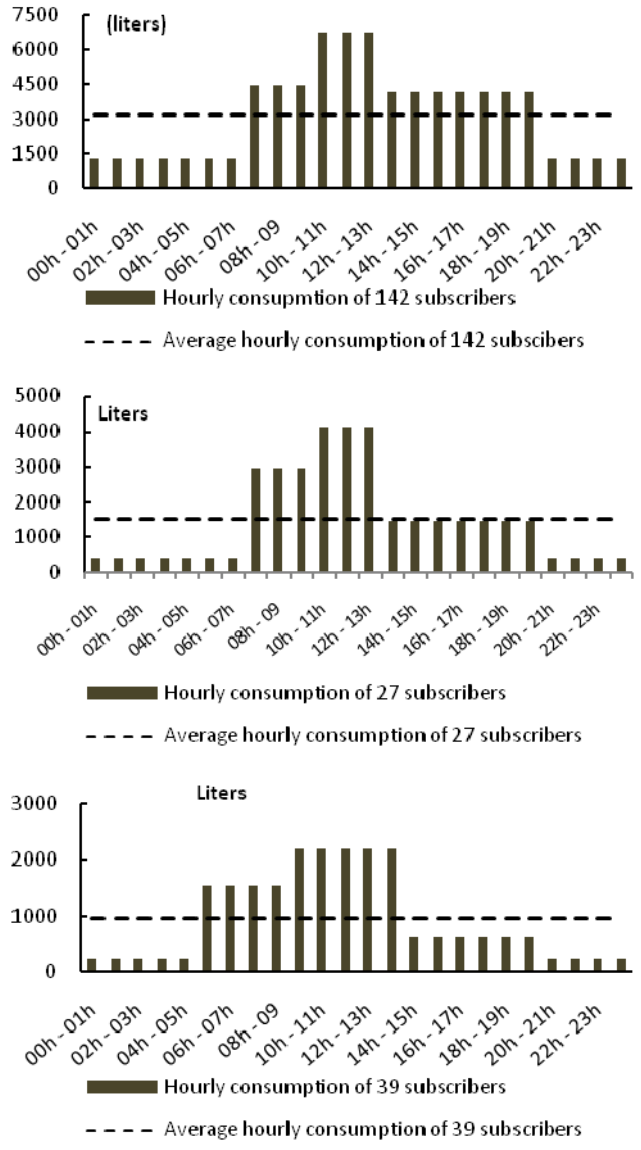

Fig. 2 Variations of the hourly consumption in three towns.

between 9 and 47 L/h/consumer in Biskra, 6 - 60 L/h/consumer in Eloutaya and 6 – 56 L/h/consumer in Ouled-Djellal. Houry variations, around the mean inter-hourly consumptions were rather high. Deduced coefficients of the variations are indicated in **Table 3**. Variations in hourly consumption were high; modulations in relation to the average were between 2.10 and 2.74. Recorded values for hourly consumption per domestic consumer are displayed in **Table 3**.

Measurements extrapolation

Since the campaign took place in the third quarter, extrapolation of measurements based on the sample was made without considering a temporal modulation due to the noted annual variation. (cf Measured consumption paragraph). Furthermore, the extrapolation was based on noted averages shown in **Table 1**, taking into consideration the distribution of the types of houses in the sample (**Table 2**) and in all towns of the area (**Table 4**). This method led to the estimated consumptions displayed in **Table 5**.

Evaluation of water losses

Production-consumption assessment

The campaigns conducted in September – November 2009 in the region of Biskra permitted an evaluation of the water consumed for domestic use by the three towns' populations. As for water consumption for commercial, public and industrial purposes, they were deduced from the bills issued by the Water Board. By comparing the amounts of water consumed with the amounts produced to supply this region with drinking water, we obtained the results shown in **Table 6**. This method of evaluation of the volume of water lost showed that this volume was at 36 805 m^3/day in the town of Biskra, corresponding to a rate of 63%.

By night water flow measurements

Night measurements of water flow were taken at the water wellfield of Biskra in October 2009 during five days. Three wells equipped with water meters and supplying the town of Biskra by injecting water directly into the distribution network, were concerned with these measurements. The choice of this source of water can be

Table 4. Consumer distribution according to the type of houses in the three towns

	Number of consumers			
Town	Single-floor house	Two-floor house	Flat	Total
Biskra	5 537	16 252	11 562	33 351
O.Djellal	1 833	1 421	998	4 252
Eloutaya	862	798	558	2 218

Table 5. Extrapolated values of domestic consumption in the three towns

Town	Number of consumers	Domestic consumption (m^3/day)
Biskra	33 351	14 852
O.Djellal	4 252	1 580
Eloutaya	2 218	875

Table 6. Volume and rate of water loss by production – consumption assessment

Towns	Consumptions (m^3/day)				Production (m^3/day)	Loss (m^3/day)	
	Domestic	Commercial & public	Industrial	Total			rate %
Biskra	14852	6345	640	21837	58642	36805	63%
O.Djellal	1580	462	-	2042	5115	3073	60%
Eloutaya	875	417	-	1292	3865	2573	67%

justified by the availability of the personnel in charge of taking measurements at night, by the possibility of isolating the supplied area with water as well as by the absence of any farming and industrial activities in the town. This area is usually supplied with drinking water through three water mains. The first one carries water from the water wellfield of Oued el Haï, while the other two mains connect the network of this area to that of the rest of the town Kettab *et al*. (2012). Turning off the water supplies provided by these two mains at night, makes it possible to isolate the tested area so that water is supplied starting from the wellfield of Biskra only.

The flow was measured with newly installed meters at the mains coming from the wellfield and supplying the town centre area. There were 8420 consumers in the isolated area. Measurements were taken between 11.00 pm and 3.00 am during five successive nights from October 25 through October 29, 2009. **Table** 7 displays the results obtained for the amounts of water flowing from the wells of Oued el Haï in Biskra. Since the tested area does not have any farming or manufacturing activity and the water supply was measured late at night, water consumption at night is considered very low as it is probably limited to filling up reservoirs as it may have happened during the first two nights. Among the figures noted, the lowest figure of 244 m^3/hour was used, corresponding to 5856 m^3/day. Proportional extrapolation from the number of consumers involved, that is 8420 out of 33 351 consumers in the whole town, led to a volume of the water lost, estimated at 23 195 m^3/day, corresponding, in comparison to an average daily output, to 40%. Proportional extrapolation from the length of the network (97 km out of 378 km in the whole town) indicated a water loss estimated at 22 820 m^3/day corresponding to an average daily output of 39 %.

Table 7. Night water flow measurements

Day	Between	Measured flow (m^3)	Measured hourly flow (m^3/hour)
First	11 pm and 1 am	496	248
Second	12 pm and 2 am	488	244
Third	1 am and 3 am	575	287.5
Fourth	11 pm and 1 am	558	279
Fifth	12 pm and 2 am	502	251

Analysis of the results provided by both methods

The results yielded by the two methods used show that a great amount of drinking water is lost from the distribution network. This water loss rate is estimated at 63% in the principal town of the region, by a comparison between demand and production, and at 39−40% by measurements of the night flow. The results show nevertheless that the distribution system is not fully reliable.

The production-consumption assessment approach leads to a less favourable estimation, for it takes into account not only the amount of water lost in the distribution network, but also the over-consumption by consumers unequipped with water meters. There may be uncertainties about the results yielded by this approach: extrapolation from a sample of consumers and, above all, poor knowledge of the commercial and public consumptions which represent 23% of the overall consumption.

Night water measurements lead to a more reliable assessment of the amount of water lost from the distribution network. Evaluation of the over-consumption by consumers without water meters or through fraudulent consumption can be deduced from the two evaluations by considering the difference between both approaches. The volume of over-consumed water determined in this way represented 21 to 28% the amount of water running in the network.

Whatever the method of evaluation used, it is obvious that significant amount of water is being lost. The approach by night (nocturnal) water flow measurements indicated a loss rate of about 40%. It is difficult though, to attribute all the losses to the network, for it is possible that part of the output is used for filling up reservoirs. Use of the lowest value noted during the three days of night water flow measurements would probably minimizes the impact of uncertainty.

CONCLUSIONS AND RECOMMENDATIONS

The present study enabled us to show and stress the importance of having full knowledge and mastery of the way the network of water supply works in the region of Biskra. Data based on the bills issued by the Water Board present too many uncertainties, and thus there is a risk that they do not reflect the reality of the distribution system. Therefore, for an evaluation of the demand for water and of the losses two methods were used. The

first one consisted of taking measurements of water consumption relative to a sample of domestic consumers before extrapolating from the findings obtained to the whole population. The second one was based on measurements of water flow taken at night in the town of Biskra. The results obtained showed that:

(a) Mean water consumption per domestic consumer varied between 370 and 445 L/day; the coefficients of hourly variations were low (0.25 and 2.74).
(b) Water losses from the network were estimated at about 40%.
(c) Over-consumption due to a shortage of meters was estimated at about 20%, but this estimation was not fully reliable for it was associated with uncertainties about the public and industrial consumptions.
(d) Night water measurements lead to a more reliable assessment of the amount of water lost from the distribution network.

However, the results obtained may be relied on for an evaluation of the needs for drinking water in the South of Algeria, and for future regional development.

The study indicates a high rate of water losses in the distribution network and over-consumption due to an insufficient number of water meters and discontinuous supply. Therefore, it is essential that water meters come into general use and that defective parts of the network be rehabilitated. These requirements necessitate further investigations to locate the most important leaks on the network.

Concerning this matter, we would like to point out that it seems inevitable, in the short term that new meters will have to be installed with priority given to large water consumers. It would also be important to install general water meters and divide the network into a number of sectors in order to better locate the defective sections. This action on behalf of the officials should be followed by a new strategy of managing and operating the network aiming at providing the consumers with the best service possible and at ensuring regular meter readings. It would also be necessary to develop new approaches that should help in the choice of the techniques of rehabilitation to be adopted, e.g., replacement and modernization. The effectiveness of the suggested measures can be demonstrated by updating totally or partially the present study after taking the corrective measures.

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