STUDIES PUBLICAÇÕES
Studies in Engineering and Exact Sciences
ISSN: 2764-0981

Quantification of water losses and performance analysis of drinking water supply systems in northern Algeria - case study in the Medea region

Quantificação das perdas de água e análise do desempenho dos sistemas de abastecimento de água potável no norte da Argélia - estudo de caso na região de Medeia

DOI: 10.54021/seesv5n1-014

Recebimento dos originais: 28/12/2023
Aceitação para publicação: 30/01/2024

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ABSTRACT
This study was prompted by the observation of the great difficulties that affect the public provision of drinking water in Algeria. The analysis of measurements revealed the performance level of the tested systems as well as the rates of drinking water losses rates in the Medea region (located 60 km southwest of Algiers). The small number of water meters and an intermittent supply make it difficult to quantify water volume losses. This article presents an analysis of the demand for drinking water and the supply systems performance, based on an extrapolation from a sample of consumers on whom data are available. This approach to exploring the current state of the drinking water system, its functioning and behaviour, has made it possible to draw up a report on this system's reliability even in the almost total absence of metering of the consumed volumes. It will also help appreciate the quality of service and contribute to establishing relevant database on the water system and its service.

Keywords: drinking water, networks performance, technical diagnosis, water losses, water supply.

RESUMO
Quantificação das perdas de água e análise do desempenho dos sistemas de abastecimento de água potável no norte da Argélia. Estudo de caso na região de Medeia. Este estudo nasceu da observação das grandes dificuldades que afectam

o abastecimento público de água potável na Argélia. A análise das medições revelou o nível de desempenho dos sistemas testados, bem como as taxas de perdas de água potável na região de Medeia (localizada a 60 km a sudoeste de Argel). O pequeno número de hidrômetros e o abastecimento intermitente dificultam a quantificação das perdas de volume de água. Este artigo apresenta uma análise da procura de água potável e do desempenho dos sistemas de abastecimento, com base numa extrapolação a partir de uma amostra de consumidores sobre os quais existem dados disponíveis. Esta abordagem de exploração do estado actual do sistema de água potável, do seu funcionamento e comportamento, permitiu elaborar um relatório sobre a fiabilidade deste sistema mesmo na quase total ausência de contagem dos volumes consumidos. Também ajudará a avaliar a qualidade do serviço e contribuirá para estabelecer uma base de dados relevante sobre o sistema de água e o seu serviço.

Palavras-chave: água potável, desempenho de redes, diagnóstico técnico, perdas de água, abastecimento de água.

1 INTRODUCTION

In Algeria, the quantities of exploited underground and surface water have increased a lot due to decades of increasingly intensive underground withdrawals and dams construction. However, Algeria is one among the poorest countries in term of water potential. Water availability is below the theoretical scarcity threshold set by the World Bank – at 1000 m^3 per capita per year. In addition, the urban population is growing very fast. 15 to 20 billion m^3 of water is needed per year; however, the annual exploited water volume is barely more than 5 billion m^3 [1, 2]. The unbilled water volume reaches 50% of the distributed volume [3, 4]. Analyzing the demand for drinking water in urban and rural built-up areas might be considered as an endeavor of national interest. The reliability of the drinking water supply and sanitation systems can only be achieved by studying their physical and functional behavior and improving their technical management. In this context, particularly in the northern regions, expert water restrings management and loss minimization are deemed as strategic and operational issues for society and its economy.

2 OBJECTIVES AND METHOD

Many research works have been undertaken to test different approaches to improving drinking water supply systems performance. The International Water Association (IWA) conferences: Leakage 2016 and 2018, Water-loss 2018 and

2020focused their works on examining water losses in supplying systems as well as their performance indexes **[5, 6]**. However, very little work has been carried out on systems with low metering levels, when distribution is discontinuous.

The purpose of this study is to provide technical indicators and performance parameters of distribution systems in four main centers in Medea, located in North Algeria. Consumption and water losses estimates through two different approaches are strongly recommended:

- The first approach consists in evaluating drinking water consumption through a panel of metered subscribers and then extrapolating results to the whole population. Loss rates and performance parameters will be calculated based on results.
- The second method relies on the collected data from distribution systems operator in the four centers tested.

3 RESULTS AND DISCUSSIONS

After briefly describing the context of water supply in Medea, this article quantifies water consumption by domestic, commercial and industrial users. Losses and various performance technical indicators of the analyzed systems will be determined and the two methods results compared.

3.1 WATER RESOURCES ALLOCATED TO THE POPULATION'S SUPPLY

In fact, the water produced in the Medea region falls into two categories: surface water from two dams – Ghrib and Koudiet-Ecerdoune, as well as that pumped from the Chiffa Wadi; groundwater comes from a number of boreholes and a few captured springs.

A large part of the extracted water is pumped back to storage and distribution reservoirs, while the boreholes located in several localities in the region send their water directly into various distribution networks. Extracted volumes are reserved for different users: domestic, public and industrial ones. However, repeated interruption in the water supply service has been known to happen; and most users suffer from insufficient flows and pressures granted (users resort to their own storage and pumping means to cover their daily drinking water needs). This observation led us to carry out analyses of various parameters series relating to drinking water consumption and distribution systems reliability, as well as investigations on the time-related variations in consumption.

Table 1 summarizes the types and volumes repartition of produced water across the four centers examined over the 2008-2020 period:

Table 1. the types and volumes repartition of produced water across the four centers examined

Center	Year / Water type (10^3 m^3)	2008	2009	…	2016	2017	2018	2019	2020
Medea	Surface water	9 142	9 616	…	10 377	9 426	11 893	14 115	14 287
	Underground water	406	399	…	825	774	794	1 202	1 004
	Total	**9 548**	**10 015**	…	**11 202**	**10 200**	**12 687**	**15 317**	**15 391**
Berrouaghia	Surface water	3 216	3 698	…	7 285	6 019	5 876	5 378	4 628
	Underground water	121	170	…	86	93	49	65	72
	Total	**3 337**	**3 868**	…	**7 371**	**6 112**	**5 925**	**5 443**	**4 700**
Ksar-El-Boukhari	Surface water	14	15	…	6029	5937	7 933	7 212	5 477
	Underground water	3 513	4 238	…	3 567	3 240	3 262	3 968	5 015
	Total	**3 527**	**4 253**	…	**9 596**	**9 177**	**11 195**	**11 180**	**10 492**
Beni-Slimane	Surface water	351	329	…	2 189	4 151	4 304	5 055	5 491
	Underground water	451	369	…	275	288	251	286	310
	Total	**802**	**698**	…	**2 464**	**4 439**	**4 555**	**5 341**	**5 801**
Surface water production Medea region		12 372	13 329	…	23 691	21382	30 006	31 760	29 883
Underground water production Medea region		4 040	4 807	…	4 478	4 107	4 356	5 521	6 401
Total production Medea region		**16 412**	**18 136**	…	**28 169**	**25 489**	**34 362**	**37 281**	**36 284**

over the 2008-2020 period:
Source: Authors

In 2020, it is estimated that the daily pumped volumes in these four main centers in the region are as follows: 42 167 m^3 in Medea, 12 877 m^3 in Berrouaghia, 28 745 m^3 in Ksar-El-Boukhari and 15 893 m^3 in Beni-Slimane. Gross production per capita in 2008 was 141, 114, 129 and 186 l /d/capita respectively in the Medea, Berrouaghia, Ksar-El-Boukhari and Beni-Slimane centers; and it reached 153, 103, 194 and 142 l/d/capita in same centers in 2020. During these years, gross production increased in Medea, Ksar-El-Boukhari as well as in Beni-Slimane and it decreased in Berrouaghia. This could only be explained by a gradual increase in endowments accompanying the evolution of populations in Medea, Ksar-El-Boukhari and Beni-Slimane. The Berrouaghia center did not meet this similarity.

3.2 USERS AND ASSESSMENT OF DRINKING WATER CONSUMPTION

The lack of counting means for most users makes it impossible to accurately estimate the volumes actually consumed. Water volumes estimated from meters can be considered reliable, unlike those taken as a flat rate for subscribers without metering means. To estimate the consumed water quantity, we relied on readings already carried out by the region's water service over the period: 2008-2020.

Table 2 summarizes the drinking water consumption billed during between 2008 and 2020.

Table 2. The various drinking water consumption billed during between 2008 and 2020.

center	Invoiced Consump. (m^3/d) / Year	2008	2009	…	2016	2017	2018	2019	2020
Medea	Domestic	7 542	7 830		11 655	11 723	13 162	14 074	15 255
	Commercial and Public	4 414	4 362	…	3 370	2 592	3 118	2 685	2 447
	Industrial	1 049	1 022		1 033	962	866	904	940
	Total	13 005	13 214	…	16 058	15 277	17 146	17 663	18 642
Berrouaghia	Domestic	2 200	2 405		6 025	5 389	5 337	5 767	6 006
	Commercial and Public	611	827	…	2 236	2 090	2 129	1 786	2 326
	Industrial	38	38		389	271	321	304	200
	Total	2 849	3 270	…	8 650	7 050	7 787	7 857	8 532
Ksar-El-Boukhari	Domestic	2 186	2 518		5 978	6 512	6 616	7 203	7 534
	Commercial and Public	1 101	1 249	…	1 605	1 570	1 562	1 721	1 663
	Industrial	93	192		847	964	814	877	743
	Total	3 380	3 959	…	8 430	9 046	8 992	9 801	9 940
Beni-Slimane	Domestic	551	545		3 178	3 449	3 658	4 030	4 584
	Commercial and Public	584	85	…	1 882	1 641	1 625	2 203	2 244
	Industrial	0	0		33	38	69	66	25
	Total	1 135	630	…	5 093	5 128	5 352	6 299	6 853
Total invoiced consumptions Medea region (m^3/d)	**Domestic**	***11 928***	***12 753***		***23 658***	***23 624***	***28 773***	***31 074***	***33 379***
	Commercial and Public	***6 126***	***6 438***	…	***7 211***	***6 252***	***8 434***	***8 395***	***8 680***
	Industrial	***1 180***	***1 252***		***2 269***	***2 197***	***2 070***	***2 151***	***1 908***
	Total	***19 234***	***20 443***	**…**	***33 138***	***32 073***	***39 277***	***41 620***	***967***

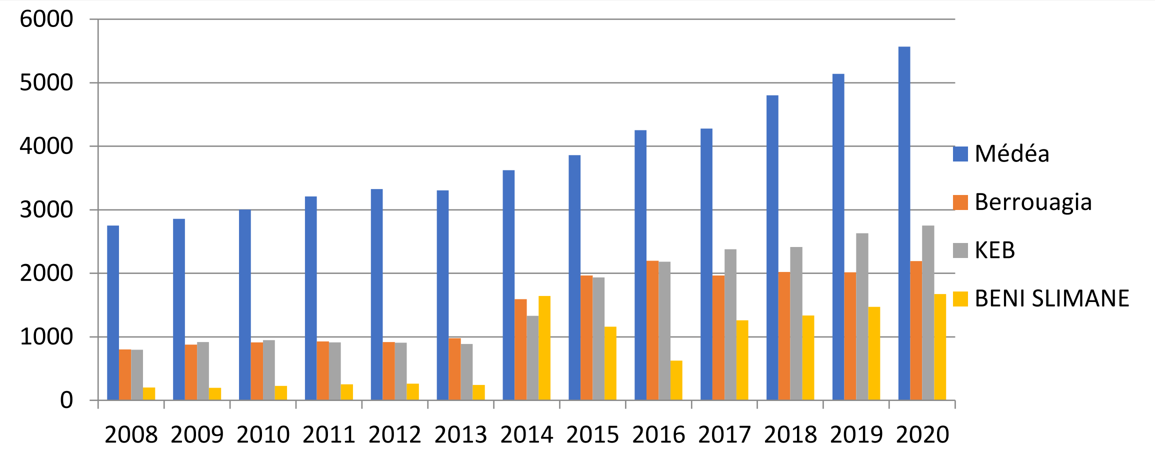
Source: Authors

3.2.1 Domestic Consumption

The steady evolution of domestic users in the region has led to an increase in consumed water volumes. From 48 028 domestic subscribers in 2008 to 100 060 subscribers in 2020, new connections being 4 000 per year on average.

The quantification of consumed volumes is carried out by the operator in two different ways: directly from the metering system already set up; and a flat estimate depending on the building's type and the number of floors **[7, 8]**. Annual invoiced domestic consumption volumes provided by operator ADE (Algérienne des eaux de Medea) are shown in Figure 1:

Figure 1. Evolution of annual domestic consumption volumes by center



Source: Authors

3.2.2 Public, Commercial and Industrial Consumption

The development of various activities registered in Medea resulted in100 new connections per year on average. However, quantifying actually consumed volumes is still a problem. Although large water consumers are generally equipped with water meters, many other consumers do not have one, including administrations and a number of other establishments. Actually, out of 4 538 consumers registered in 2020, 4 311 have meters with a high failure rate. This explains the high rate of water losses in the region.

Although public and commercial consumption in the region remained relatively constant during the 2008-2012 period, it experienced a significant increase over the 2013-2020 period: (from 1 919 000 m^3 in 2013 to 5 201 000 m^3 in 2020).

Absence of autonomous resources has led water-consuming industries to extract all of their needs from the public network, and withdrawn flow reached an average of 2 300 m^3/day in 2016.

3.3 ASSESSMENT OF WATER LOSSES

Water volumes and loss rates will be calculated based, among other things, on the consumed volumes determined through two different approaches: The first approach quantifies the total consumed volume in each center, based on billed domestic, commercial-public and industrial consumptions (Table 2); the second method assesses losses by introducing the domestic consumption billed to the metered subscribers and extrapolating it to the whole population’s domestic consumption in calculating overall consumed volume (Tables 3 and 5).

Use of two different approaches helps compare obtained results.

Table 3. Volumes and loss rates by balance sheet A: Production-Invoiced domestic consumption

Year	Center	Invoiced consumptions (m^3/d)			Production Vp (m^3/d)	Losses L_A (m^3/d)	Loss rates Rl_A (%)
		Domestic Vd (with compt. + without comp)	Com. and public Vcp	Industrial Vi			
2008	Medea	7542	4414	1049	26159	13154	**50**
	Berrouaghia	2200	611	38	9142	6293	**69**
	Ksar-El-Boukhari	2186	1101	93	9663	6283	**65**
	Beni-Slimane	551	584	0	2 197	1 062	**48**
2009	Medea	7830	4362	1022	27438	14224	**52**
	Berrouaghia	2405	827	38	10597	7327	**69**
	Ksar-El-Boukhari	2518	1249	192	11652	7693	**66**
	Beni-Slimane	545	85	0	1 912	1 282	**67**
…	**…**	**…**	**…**	**…**	**…**	**…**	**…**
2016	Medea	11655	3370	1033	30690	14632	**48**
	Berrouaghia	6025	2236	389	20195	11545	**57**
	Ksar-El-Boukhari	5978	1605	847	26290	17860	**68**
	Beni-Slimane	1 715	1 882	33	6 751	3 121	**46**
2017	Medea	11723	2592	962	27945	12668	**45**
	Berrouaghia	5389	2090	271	16745	8995	**54**
	Ksar-El-Boukhari	6512	1570	964	25142	16096	**64**
	Beni-Slimane	3 449	1 641	38	12 162	7 034	**58**
2018	Medea	13 162	3 118	866	34 759	17 613	**51**
	Berrouaghia	5 537	2 129	321	16 233	8 246	**51**
	Ksar-El-Boukhari	6 616	1 562	814	30 671	21 679	**71**
	Beni-Slimane	3 658	1 625	69	12 479	7 127	**57**
2019	Medea	14 074	2 685	904	41 964	24 297	**58**
	Berrouaghia	5 767	1 786	304	14 912	7 055	**47**
	Ksar-El-Boukhari	7 203	1 721	877	30 630	20 829	**68**
	Beni-Slimane	4 030	2 203	66	14 633	8 334	**57**
2020	Medea	15 255	2 447	940	42 167	23 525	**56**
	Berrouaghia	6 005	2 326	200	12 877	4 346	**34**
	Ksar-El-Boukhari	7 534	1 663	743	28 745	18 805	**65**
	Beni-Slimane	4 584	2 244	25	15 893	9 040	**57**

Source: Authors

Table 4. Extrapolation of metering domestic consumption to the whole domestic population

Year	Center	Number of domestic suscribers		Invoiced domestic consumption		
		With metering	Total	With metering Vdm		Extrapolated Vde (m^3/day)
				(10^3 m^3)	(m^3/day)	
2008	Medea	22 579	24 679	2 465	6 753	7 381
	Berrouaghia	9 268	9 684	745	2 041	2 133
	Ksar-El-Boukhari	9 732	10 802	636	1 742	1 934
	Beni-Slimane	2 828	2 863	199	545	552
2009	Medea	24 095	25 253	2 647	7 252	7 601
	Berrouaghia	9 500	9 887	835	2 288	2 381
	Ksar-El-Boukhari	10 348	11 264	783	2 145	2 335
	Beni-Slimane	2 954	3 026	194	532	545
…	…	…	…	…	…	…
2016	Medea	35 123	36 485	3 944	10 805	11 224
	Berrouaghia	17 168	17 857	2 081	5 701	5 930
	Ksar-El-Boukhari	19 981	21 361	1 979	5 422	5 796
	Beni-Slimane	6 032	6 207	584	1 600	1 646
2017	Medea	37 112	38 467	3 999	10 956	11 356
	Berrouaghia	18 035	18 958	1 882	5 156	5 420
	Ksar-El-Boukhari	20 311	21 917	2 198	6 022	6 498
	Beni-Slimane	9 529	9 872	1 212	3 321	3 441
2018	Medea	37 995	40 105	4 438	12 159	12 834
	Berrouaghia	15 513	16 081	1 914	5 244	5 436
	Ksar-El-Boukhari	20 453	22 195	2 207	6 047	6 562
	Beni-Slimane	10 896	11 230	1 286	3 523	3 631
2019	Medea	39 905	42 740	4 702	12 882	13 797
	Berrouaghia	16 181	18 068	1 905	5 219	5 828
	Ksar-El-Boukhari	21 355	23 548	2 384	6 532	7 203
	Beni-Slimane	11 461	11 872	1 412	3 868	4 007
2020	Medea	41 562	44 948	5 037	13 800	14 924
	Berrouaghia	16 925	18 322	2 003	5 488	5 941
	Ksar-El-Boukhari	21 487	23 952	2 468	6 762	7 538
	Beni-Slimane	11 748	12 838	1 600	4 384	4 791

Source: Authors

Table 5. Volumes and loss rates by balance-sheet B: Production- extrapolated domestic consumption

Year	**Center**	**Invoiced consumptions (m³/d)**			**Production Vp (m³/d)**	**Losses L_B (m³/d)**	**Loss rates by center Rl_B (%)**	**Loss rates-Medea region (%)**
		²Domestic extrapolated Vde	**Com. and public Vcp**	**Industrial Vi**				
2008	Medea	7381	4414	1049	26159	13315	**51**	**58**
	Berrouaghia	2133	611	38	9142	6360	**70**	
	Ksar-El-Boukhari	1934	1101	93	9663	6535	**68**	
	Beni-Slimane	552	584	0	2 197	1 061	**48**	
2009	Medea	7601	4362	1022	27438	14453	**53**	**60**
	Berrouaghia	2381	827	38	10597	7351	**69**	
	Ksar-El-Boukhari	2335	1249	192	11652	7876	**68**	
	Beni-Slimane	545	85	0	1 912	1 282	**67**	
...	...	...	...	...	...	...	...	...
2016	Medea	11224	3370	1033	30690	15063	**49**	**57**
	Berrouaghia	5930	2236	389	20195	11640	**58**	
	Ksar-El-Boukhari	5796	1605	847	26290	18042	**69**	
	Beni-Slimane	1 646	1 882	33	6 751	3 190	**47**	
2017	Medea	11356	2592	962	27945	13035	**47**	**55**
	Berrouaghia	5420	2090	271	16745	8964	**54**	
	Ksar-El-Boukhari	6498	1570	964	25142	16110	**64**	
	Beni-Slimane	3 441	1 641	38	12 162	7 042	**58**	
2018	Medea	12 834	3 118	866	34 759	17 941	**52**	**59**
	Berrouaghia	5 436	2 129	321	16 233	8 347	**51**	
	Ksar-El-Boukhari	6 562	1 562	814	30 671	21 733	**71**	
	Beni-Slimane	3 631	1 625	69	12 479	7 154	**57**	
2019	Medea	13 797	2 685	904	41 964	24 578	**59**	**59**
	Berrouaghia	5 828	1 786	304	14 912	6 994	**47**	
	Ksar-El-Boukhari	7 203	1 721	877	30 630	20 829	**68**	
	Beni-Slimane	4 007	2 203	66	14 633	8 357	**57**	
2020	Medea	14 924	2 447	940	42 167	23 856	**57**	**56**
	Berrouaghia	5 941	2 326	200	12 877	4 410	**34**	
	Ksar-El-Boukhari	7 538	1 663	743	28 745	18 801	**65**	
	Beni-Slimane	4 791	2 244	25	15 893	8 833	**56**	

Source: Authors

It was noted that loss rates in the Ksar-El-Boukhari center were quite high: 72% in 2011,reaching the minimum value of 61% in 2014.In the Berrouaghia center, water loss rates decreased as of 2014, with a value of 46%, reaching 34% in 2020;the lowest values of this parameter reached 34% in Berrouaghia (2020), 42% in Beni-Slimane (2010) and 45% in Medea (2017).The average loss rate in the region –in the order of 55 to 60% – was recorded during the entire period studied.

By both methods, it was demonstrated that, throughout 2008-2020, values of water loss rates in the studied regions' distribution systems are significantly close and abnormally high.

3.4 PERFORMANCE PARAMETERS OF DISTRIBUTION SYSTEMS

Technical yields provide further appreciation of the reliability and efficiency of distribution system. Determining these technical indicators strongly depends on the quantity and quality of the distribution system's operating parameters values **[8]**. The available data and measurements carried out as well as the results obtained as to water losses and leaks help assess the reliability and performance degree of the studied systems by calculating the primary technical yield as well as losses and consumption linear indexes.

3.4.1 Primary Technical Yields

It is the ratio between the volume accounted for and the distributed volume. In the first assessment, the counted volume is considered as the sum of invoiced volumes: domestic (with and without metering), public and industrial. Primary yield values are shown in Table 6:

Table 6. Primary technical yields of drinking water systems-Medea region in 2020

Center	**Volumes (m^3/d)**			**Primary yield Yp (%)**
	Counted Vd+Vcp+Vi	**Distributed**	**Vp**	
Medea	18 642	42 167		**44**
Berrouaghia	8 532	12 877		**66**
Ksar-El-Boukhari	9 940	28 745		**35**
Beni-Slimane	6 853	15 893		**43**

Source: Authors

In second evaluation, the volume accounted for is the sum of volumes: domestic billed, with extrapolated metering, public and industrial. The evolution of the primary yield from 2015 to 2020 is given in Table 7.

Table 7. Primary technical yields of Medea region networks during between 2016 and 2020

Year	Center	Volumes (m³/d)		Primary yield Yp (%)
		Counted Vde+Vcp+Vi	Distributed Vp	
2016	Medea	15 627	30690	**51**
	Berrouaghia	8 555	20195	**42**
	Ksar-El-Boukhari	8 248	26290	**31**
	Beni-Slimane	3 561	6 751	**53**
2017	Medea	14 910	27945	**53**
	Berrouaghia	7 781	16745	**46**
	Ksar-El-Boukhari	9 032	25142	**36**
	Beni-Slimane	5 120	12 162	**42**
2018	Medea	16 818	34 759	**48**
	Berrouaghia	7 886	16 233	**49**
	Ksar-El-Boukhari	8 938	30 671	**29**
	Beni-Slimane	5 325	12 479	**43**
2019	Medea	17 386	41 964	**41**
	Berrouaghia	7 918	14 912	**53**
	Ksar-El-Boukhari	9 801	30 630	**32**
	Beni-Slimane	6 276	14 633	**43**
2020	Medea	18 311	42 167	**43**
	Berrouaghia	8 467	12 877	**66**
	Ksar-El-Boukhari	9 944	28 745	**35**
	Beni-Slimane	7 060	15 893	**44**

Source: Authors

Whatever the method used, all networks 'technical yields are low. Yields from both methods vary between 29 to 66%, indicating, once again, the lack of performance and reliability of the analyzed distribution systems.

3.4.2 Linear Losses and Consumption Indexes

3.4.2.1 Linear losses indexes

The calculation of the linear loss indexes in the four centers was carried out based on two different methods: "A" represents the balance sheet: production – billed domestic consumption (metered and unmetered), "B" is the balance sheet: production –metered domestic consumption extrapolated to the entire population. This calculation led to the following values (Table 8).

Table 8. Linear loss indexes of drinking water systems – Medea region in 2020.

Center	Network length (Km)	Losses volume (m³/d)		Linear loss index LLI (m³/d/km)	
		By balance-sheet A	by balance-sheet B	A	B
Medea	250	23 525	23 856	94	95
Berrouaghia	167	4 346	4 410	26	26
Ksar-El-Boukhari	218	18 805	18 801	86	86
Beni-Slimane	64	9 040	8 833	141	138

Source: Authors

The values of the linear loss indexes of tested networks greatly exceed guide values. In the Medea center, for example, calculated LLI is around 95 m^3/d/km, while the corresponding guide value is 20 m^3/d/km. This great discrepancy between the calculated values and reference values of this index confirm, once again, that the Medea region's drinking water systems are not reliable.

3.4.2.2 Linear Consumptions Indexes

In the same way, the linear consumption index (LCI) expresses the ratio between consumed volumes and total pipes length adduction and distribution.

Calculations led to the following results (Table 9):

Table 9. linear consumption index of drinking water networks-Medea region in 2020

Center	Network length (Km)	total consumed volume (m^3/d)		Linear consumption index LCI (m^3/d/km)	
		By balance-sheet A Vc = Vd+Vcp+Vi	By balance-sheet A Vc = Vde+Vcp+Vi	A	B
Medea	250	18 642	18 311	75	73
Berrouaghia	167	8532	8 467	51	51
Ksar-El-Boukhari	218	9 940	9 944	46	46
Beni-Slimane	64	6 853	7 060	107	110

Source: Authors

In addition, and in order to provide further appreciation of the distribution networks performance in the region, we have used the urban and rural character of service, based on the ILC value. This method, adopted by water distributors in France, is based on the referential from annual drinking water distribution system management reports (Table 10).

Table 10. Lyonnaise des eaux Referential (LDE), 2004

Type	Rural	Intermediary	Urban
Criteria	LCI ≤ 10	10 <LCI ≤ 30	LCI > 30
Satisfactory	LLI < 2	LLI < 6	LLI < 10
Quite satisfactory	2 ≤ LLI < 3	6 ≤ LLI < 8	10 ≤ LLI < 13
Mediocre	3 ≤ LLI ≤ 5	8 ≤ LLI ≤ 11	13 ≤ LLI ≤ 16
Worrying	LLI > 5	LLI > 11	LLI > 16

Source: Authors

According to the reference values presented in the Tables 9 and 10 (LCI > 30 and LLI > 16), all urban distribution systems in the Medea region give cause for concern.

4 CONCLUSION

The results obtained in this analysis represent an evaluation basis for drinking water needs in north Algerian built-up areas to be taken into account for future developments.

Loss rates in networks are abnormally high, which requires additional investigations to quantify and locate leaks. Therefore, in the very short term, it seems important to generalize the use of meters and undertake networks rehabilitation. The values of loss linear indexes do not pass muster when compared with reference values: this evidence therefore obligates the operator to undertake reducing loss rates and to improve drinking water systems tightness by taking action:

- Installation of individual meters
- Installation of general and sector meters
- Knowledge of water assets and fight against losses.
- Detection and repair of leaks on networks, in the short term.
- Networks rehabilitation and renovation
- Training of maintenance and intervention staff
- Raising users' awareness against wasting water

These actions must be backed through implementing an operating strategy aimed at optimizing the service provided to users and ensuring regularly meter readings. It is also necessary to develop sustaining approaches to assist in the choice of technical options for systems rehabilitation: renewal, renovation.

The effectiveness of these measures can be demonstrated by immediately renewing all or part of this study, after implementing corrective measures.

In the long term, it is imperative to design master plans and implement recollection plans highlighting the new operations carried out to better schedule and prioritize networks renewal operations as well as plan future investments.

All these considerations must converge towards optimizing the use of the resource to preserve it, and delay or avoid spending money on new investments.

Regardless of the approaches considered, it is strongly recommended to implement a system that can provide users with water that is satisfactory both in quantity and quality, and it is strongly recommended to use water resources that are closely linked to user demand. This can be reached when water providers study water demand parameters precisely, and eventually involve users in demand control operations, should a quantitative water shortage arise.

Drinking water supply systems in the country are generally experiencing serious disruptions causing inconvenience to the population. The application of the corrective measures provided by this study will ensure, in addition to effective supply coverage for citizens, a possible revision of water pricing in favor of users.

In order to assess the state of drinking water supply networks, this analysis considers a limited number of performance indicators. For a more precise assessment, it is desirable that future researches carry out more in-depth diagnostics using all available data.

Studies in Engineering and Exact Sciences
ISSN: 2764-0981

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