Comparison of the Functional and Dimensional Characteristics of TwoDrinking Water Treatment Plants: Case of Goudel II and Goudel III, Niamey Niger

Abstract

This study compares the functional and dimensional characteristics of the two drinking water treatment systems at Niamey's Goudel I and Goudel II plants. The results of this study show that the Goudel factory produced 36,089,492 m^3 in 2018, corresponding to an annual production yield of 94.98%. The average specific electrical energy consumption of the Goudel factory is 537 Wh/m^3. The average daily production at Goudel is 98,875 m^3 /d for a theoretical nominal capacity of 85,000 m^3 /d, which was increased to 110,000 m^3 /d in 2013 following work to improve the factory's capacity. Production peaks in April with approximately 320,7757 m^3 /month or 106925 m^3 /day on a 30-day operating basis. The production trough was reached in February with approximately 2,725,551 m^3 /month or 97,341 m^3 /day based on 28 operating days. Electricity consumption reached 1,357,861 kWh, corresponding to a specific consumption of 498 Wh/m^3. The plant's annual electricity consumption is 19,014,670 kWh. In 2018, 934,793 litres of diesel were consumed, compared with 1,079,659 litres in 2017, a saving of 144,866 litres equivalent to CFAF 77,937,908. Although sectors II and III use the same processes and the same production capacity, the Goudel 2 sector appears to consume the most energy.

Keywords: Goudel I and Goudel II; Drinking water treatment systems; Dimensional characteristics

Introduction

Water is an acute problem in most countries of the world. In fact, 2.1 billion people, or 30% of the world's population, have no access to domestic drinking water supply services. Significant disparities exist between the relatively "better served" urban areas in terms of access to water and rural regions worldwide. Five years ago, access to water in urban areas was 87% compared with just 35% in rural regions, according to this joint report **[1]**.

As the quality of life improves, people's need for water increases considerably. The optimization problem is significant for water services **[2] [3]**. Water supply pumping stations are an indispensable part of any water supply system. They ensure the water supply to each container, but also the pressure required on the water supply network to fight fires. The operation of a pumping station is very important to accomplishing the station's tasks. The main task is to maintain an appropriate volume of water in the reservoir and to meet demand. Another important task is to reduce operating costs **[4].**Optimized operations planning could remarkably reduce operatingcostin operating costs could be achieved without requiring any changes to physical components, such as pumps and civil infrastructure **[5]**. The cost of energy is one of the most important components of the price of treated water. They include, among other things, the costs of pumping and transporting water **[5] [6] [7]**. Worldwide trends in electricity savings and the constant rise in electricity prices mean that you must to look for savings at every stage.

One of the main problems when designing water distribution networks is to obtain the type of pump that best matches the water demand under specific pressure head requirements. Various algorithms for minimising the total cost of pumping stations (capital and operating costs) have been developed **[8] [9]**. One of the key economic parameters for pumping stations is the cost of the energy required to operate the system **[10]**. Rational and efficient use of energy is essential for sustainable development. In Niger, as in many other countries, pumping stations require a high level of energy consumption, mainly for machinery. These systems allow easy management and automation, as well as appropriate adjustment to changes. Research aimed at increasing the efficient use of electrical energy in pumping stations should be developed.

Niger is experiencing rapid and uncontrolled urbanization. It is now estimated that the urban population of the country as a whole is growing at a rate of 3.9% per year (INS, 2012). Under these conditions, planning essential social services in most towns remains difficult. This is the case of Zinder, a city that is facing a drinking water supply problem **[11]**.

Drinking water supply to the city of Niamey is provided by two (2) drinking water production factories located upstream of the city on the banks of the River Niger **[12]**. These are the Goudel treatment factory, with a nominal capacity of 85,000 m^3 /day (Figure 1), in the Goudel district, and the Yantala factory, with a nominal capacity of 30,000 m^3 /day, in the Yantala-bas district. Water is distributed by fourteen (14) reservoirs spread throughout the city of Niamey. It should be noted that the R4 reservoir has been abandoned and R13 has not yet been commissioned.

The Goudel pumping station, which is the subject of our study, consists of 3 treatment processes: Goudel I, Goudel II and Goudel III. It continuously supplies 70% of Niamey's water needs. It is equipped with a central laboratory that monitors and controls the water quality produced and distributed in Niamey. This laboratory is attached to the quality monitoring department and has a remote management unit.

At the Goudel pumping station, the raw water passes through grids that retain large particles and protect the drainage pumps from abrasion. Eight (8) of these pumps are divided into two groups of four (4) pumps, each with a capacity of 700 and 1,100 m^3 /h respectively. The water is then conveyed via pipes to water retention basins located in the factory. The Goudel I factory, financed by German cooperation, was commissioned in 1978 with a nominal capacity of 25,000 m^3 /d. At this factory, the daily drinking water production is 25,000 m^3 /d. The factory is supplied from the distributor with less overloaded water, which undergoes severaltreatments based on the same principle, eliminating suspended solids and micro-organisms contained in the water in successive stages. For example, aluminium sulphate and AN910 polymerare introduced into the water from the tundishes containing stubborn flocs. The water is then sent to the sludge bed decanter, which has a different property to other decanters. This decanter contains sludge; thanks to the law of gravity, this sludge sinks slowly to the bottom of the decanter, forming a sludge bed. The clear water filling the walls is passed to the sand filters, whose role is to prevent the passage of micro-organisms and certain chemicals. Because the filtered water contains some acid, limewater is added to make it neutral, in compliance with standards, to raise the pH. Once the filtered water has reached a considerable pH, we proceed to the disinfection stage by introducing chlorine with indicative values of between 1 and 2 mg/l **at the** factory outlet. The disinfected water is then transferred to water storage tanks, commonly known as "tanks", with a capacity of 2,000 m^3.

The Goudel II factory, financed by French cooperation, was commissioned in 1994 with 30,000 m^3 /d capacity. The Goudel III factory, financed by Chinese cooperation, was commissioned in 2007 and has 30,000 m^3 /d for capacity. Both factory provide the same treatment and undergo the same procedure, using the same quantity of chemical reagents. The difference is that Goudel I has a sludge bed decanter and Goudel II and III have lamella decanters. The remote management unit is attached to the maintenance department, which comes under the Technical Operations sub-directorate. It is responsible for maintaining SEEN's remote management installations and for designing and implementing remote management projects. Remote management provides a dashboard of data (consumption, flow rates, assessment of losses, leaks, technical faults, etc.) in the form of reports; provides synoptics and alerts of any malfunction or risk to enable an adequateresponse.

Materials and methods

Presentation of the study area

The Goudel drinking water treatment factory (named after the district in which it is located) is situated to the north-west of Niamey in Commune I on the banks of the river. The region of Niamey is located in the southwest of Niger between the parallels 13 ° 28 'and 13°35' north latitude and the meridians 02 ° 03 'and 02 ° 12' east longitude. It covers an area of 239 km2. This region is located to the north by the municipalities of Karma and Hamdallaye, to the east by the municipalities of Liboré and Hamdallaye, to the south by the municipalities of Liboré and Bitinkodji and to the west by the municipality of Bitinkodji. The Niger River divides Niamey into two distinct parts (right bank and left bank) and two bridges currently connect the two banks. Most of the population is located on the left bank which totals 4 of the 5 districts of Niamey while the 5th district occupies the right bank. The Goudel treatment factory lies between 2°03' and 2°10' east longitude and between 13°28' and 13°35' north latitude **[13] [14].**

General methodology of the study

The general methodology adopted for the study is based on 3 phases: an initial phase, a data collection and processing phase and an analysis phase, data interpretation and drafting of the document. The preliminary phase will focus on understanding the terms of reference, making contact with the staff of the Niger water company and documentary research. The data collection and processing phase will involve creating an inventory of the active equipment, and processing the operational data.

Materials used

Energy measures

To carry out the energy audits, Fluke 345 multimeter clamp is used (Figure 1) to measure all the electrical parameters (current, active and reactive power, frequency, etc.) required on the electric motors of the submersible pumps in the wet well and the surface pumps in the delivery room.

Hydraulic measures

One (1) pressure gauge (Figure 2) measures the suction pressure of surface pumps.

Figure1 *FLUKE 345 multimeter clamp.*

Figure 2 *Pressure gauge*

Method for analysing the energy consumption of the treatment Station between Goudel II and III

Operational performance monitoring carried out by SEEN on equipment at Niamey's drinking water production stations indicates high energy consumption.

The main aim of the study is to monitor the pumping units on site in order to assess their hydraulic and energy performance and to detect any anomalies by measuring parameters such as upstream pressure (suction pressure), downstream pressure (discharge pressure), discharge flow rate and the active power absorbed by the groups, on each pumping unit, under normal operating conditions, in isolation or groups.

Measurements are taken at one or more operating points (flow rate/HMT pair), with a maximum of 5 points, depending on the feasibility of the measurements and the technical interest.

The calculations resulting from these measurements determine the Wh/m^3 /mCE ratio for each of the pumping units, enabling the value measured on site to be compared with the target/optimal ratio for units identical to those installed on site.

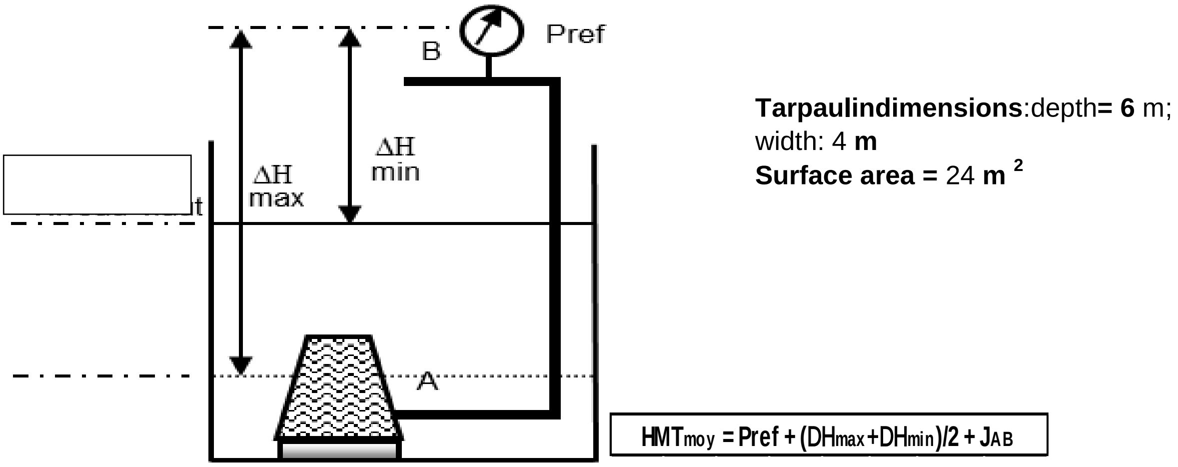
Objective ratios have been established by VEOLIA's Technical and Performance Department (DTP) for each type of unit (surface drinking water and immersed drinking water) depending on the pump flow rate. The difference between the calculated ratio and the target can be used to estimate the annual saving that could be achieved by replacing the existing pumping units with more suitable ones.

There are many reasons why pumps do not work or no longer function optimally, including inappropriate selection. The machine chosen is not (or is no longer) exactly suited to the installations in which it operates, in particular the correspondence between the Q-H operating range of the installation and the Q-H range of optimum efficiency of the machine; changes over time in pumping conditions (often as a result of network modifications); inadequate or poorly performed maintenance; inappropriate choice of technology and cavitation, wear, corrosion, etc. This drop in performance will result in additional energy costs (for the same volume pumped), which can be significant. Checking the performance of electric pumps will enable you to observe any drift and decide whether or not to replace the machine **[15]**.

Methods for Determining Hydraulic Parameters

The hydraulic parameters (figure 3) to be measured and identified with the operating teams when diagnosing the drainage pumps (submersible motor pump unit) are as follows **[16]**:

- ΔH = measurement of the dynamic level of the water table from the Normal Ground Level (NGL) + measurement of the height between the NGL and the horizontal axis of the pump discharge where the pressure measurement is taken;
- Discharge pressure measurement ;
- Measurement of the pump installation depth from the ground level + measurement of the height between point A and the horizontal axis of the tank discharge where the pressure is measured;
- Nominal diameter (DN) of the drainage pipe for calculating linear head losses ;
- The submersible motor pump unit delivers permanent flow.



Tarpaulindimensions:depth**= 6** m; width: 4 **m**
Surface area = 24 **m** ^{2}

$HMT_{moy} = Pref + (DH_{max} + DH_{min})/2 + J_{AB}$

Figure 3 *- Hydraulic parameters for pump diagnostics*

With :

J_{AB} = Pressure drop between points A and B (m)

HMT_{moy} = Total Head (m)

Pref = Discharge pressure (bar)

ΔH_{max} = Maximum dynamic level of the water table from the Normal Ground (m)

ΔH_{mini} = Minimum dynamic level of the water table from the Normal Ground (m)

To maintain the condition of the assets, the following method of operating the drainage unit has been adopted:

- ✓ To prevent flooding of the discharge chamber during periods of high water, the inlet gates of the suction tank, which brings river water into the chamber system, are closed;
- ✓ The discharge valve at the pump outlet is also tiered to limit pump flow and vibrations.

The measurements were carried out with the discharge valve held in the escutcheon in normal operating mode, and with the discharge valve fully open.

Results and discussions

Monthly trend in electricity generation and consumption

The Goudel station produced 36,089,492 m^3 in 2018 (for the three sectors), corresponding to an annual production efficiency of 94.98%. Considering 90% of yearly production under normal conditions with a NIGELEC power supply, the average specific electrical energy consumption of the Goudel plant is 537 Wh/m^3. The daily average at Goudel is 98,875 m^3 /d for a theoretical nominal capacity of 85,000 m^3 /d which increased to 110,000 m^3 /d in 2013 following work to increase the factory's capacity. The graph in **Figure 4**was based on 2018 operating data shows the seasonal variation in production for 2018.

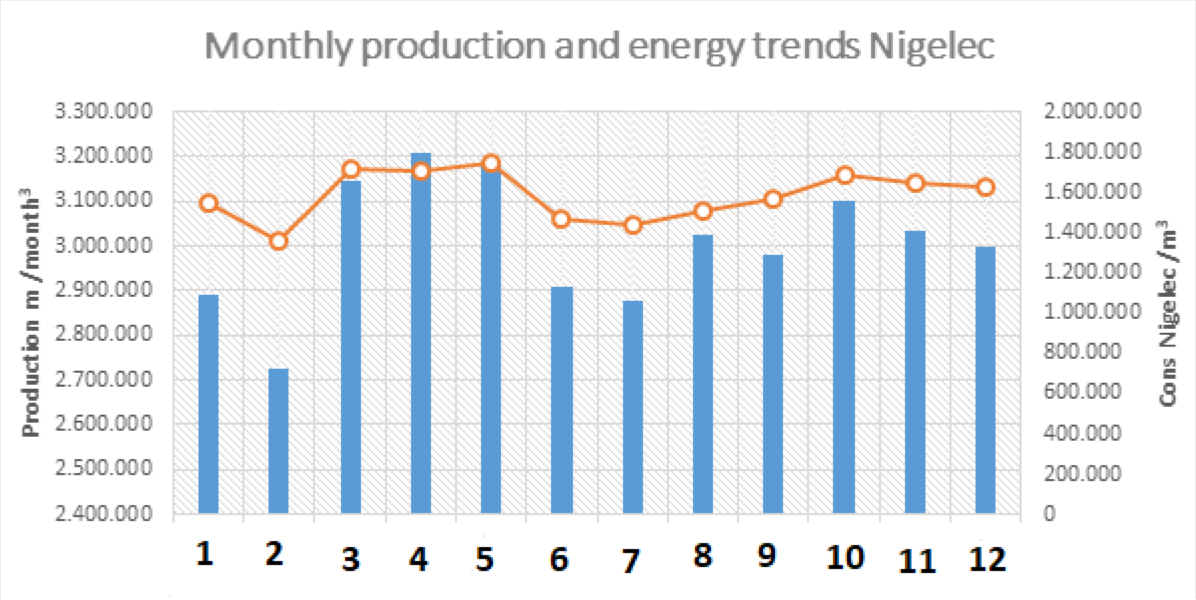


Figure 4 *Monthly trend in electricity generation and consumption.*

The seasonal variations in the operation of the water supply system for the city of Niamey in 2018 are as follows:

Peak production is reached in April with approximately 3,207,757 m^3 /month or 106,925 m^3 /day based on 30 days of operation. This corresponds to an average operating time of 22 hours per day. NIGELEC consumption reached 1,704,959 kWh, corresponding to a specific consumption of 548 Wh/m^3 ;

Production peaks in February, with approximately 2,725,551 m^3 /month or 97,341 m^3 /day based on 28 days of operation. This corresponds to an average operating time of 20 hours per day. NIGELEC consumption reached 1,357,861 kWh, corresponding to a specific consumption of 498 Wh/m^3 .

In Niamey, for example, the total number of stoppages due to NIGELEC power cuts was 648 hours in 2018, i.e. 27 days of generator use, which corresponds to diesel consumption equivalent to 236,520 litres at a total cost of 127,247,760 CFA francs.

These power cuts caused losses in volumes not produced or sold, estimated at 1,405,100 m^3 at a cost of 229,070,051 FCFA.

The factory's annual NIGELEC consumption is 19,014,670 kWh/year.

Specific energy consumption

In order to optimise and monitor the proper operation of drinking water production facilities, three (3) ratios are monitored: average specific consumption of electrical energy, specific consumption of petroleum products and average electrical consumption (Wh/m^3). This specific consumption ratio corresponds to the electrical energy consumed to produce one (1) m^3 of water. It is used to assess the performance of electromechanical equipment (**Figure 5**). The results used to produce this figure are taken from Table 1.

It should be noted that the energy supplied by the emergency generators has been taken into account in the consumption figures. We based our calculations on 1 litre of diesel = 2 kWh, corresponding to the average obtained for generators fitted with energy metering devices. The average specific consumption in 2018 is 0.53 kWh/m³.

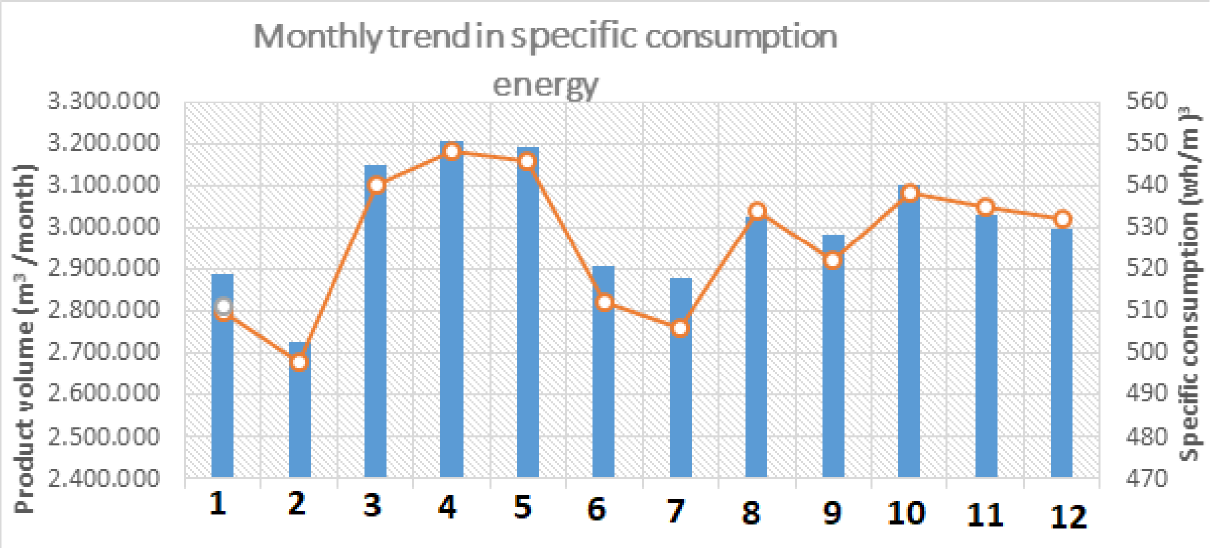


Figure 5 *Trends in specific energy consumption (Wh/m^3).*

Specific diesel consumption (l/m^3 and l/h)

Specific diesel consumption quantifies the volume of diesel consumed by generators to produce one (1) m³ of water. During 2018, 934,793 litres of diesel were consumed compared with 1,079,659 litres in 2017, a gain of 144,866 litres equivalent to 77,937,908 FCFA.

Comparison of specific energy consumption between the Goudel II and Goudel III treatment processes

The calculated values of the energy ratios are presented in Table 1. These ratios make it possible to compare the various surface water treatment processes and to choose the least costly process in terms of energy, which should be recommended to operators and departments in charge of managing the urban water sub-sector.

Table 1 - Monthly trend in Specific Consumption by treatment method.

Months	**Annual volume dewatered by sector (m^3)**		**Annual volume processed by sector (m^3)**		**Total energy consumed by sector (kWh)**		**Specific consumption by sector (wh/m^3)**	
	Goudel 2	Goudel 3	Goudel 2	Goudel 3	Goudel 2	Goudel 3	Goudel 2	Goudel 3
January	1.117.367	1.113.479	1.020.013	1.092.730	6.571	5.204	6	5
February	1.059.856	1.077.492	989.436	1.065.552	6.545	4.121	7	4
March	1.200.815	1.246.309	1.120.170	1.225.812	7.308	5.271	7	4
April	1.269.243	1.278.407	1.146.741	1.268.076	8.322	5.066	7	4
May	1.269.513	1.307.006	1.121.037	1.293.179	7.777	6.075	7	5
June	1.024.709	1.233.632	897.694	1.196.885	7.116	4.731	8	4
July	984.196	1.269.080	821.383	1.198.104	6.102	5.338	7	4
August	996.060	1.275.818	881.853	1.216.602	6.571	6.008	7	5
September	1.033.729	1.110.416	988.965	1.102.616	8.322	5.740	8	5
October	1.102.590	1.141.406	1.068.309	1.126.206	7.308	5.405	7	5
November	1.122.094	1.187.907	1.072.377	1.174.507	8.255	5.807	8	5
Décember	1.161.524	1.112.438	1.099.100	1.111.005	7.576	5.271	7	5
Total	**13.341.696**	**14.353.390**	**12.227.078**	**14.071.274**	**87.774**	**64.033**	**7**	**5**

A comparison of specific electrical energy consumption between the two treatment processes for the same monthly volume of wastewater to be treated has produced an initial series of energy ratios per cubic metre of water treated (**Figure 6**). This graph clearly shows that processes II and III use the same processes and the same production capacity, with the Goudel 2 process appearing to consume the most energy.

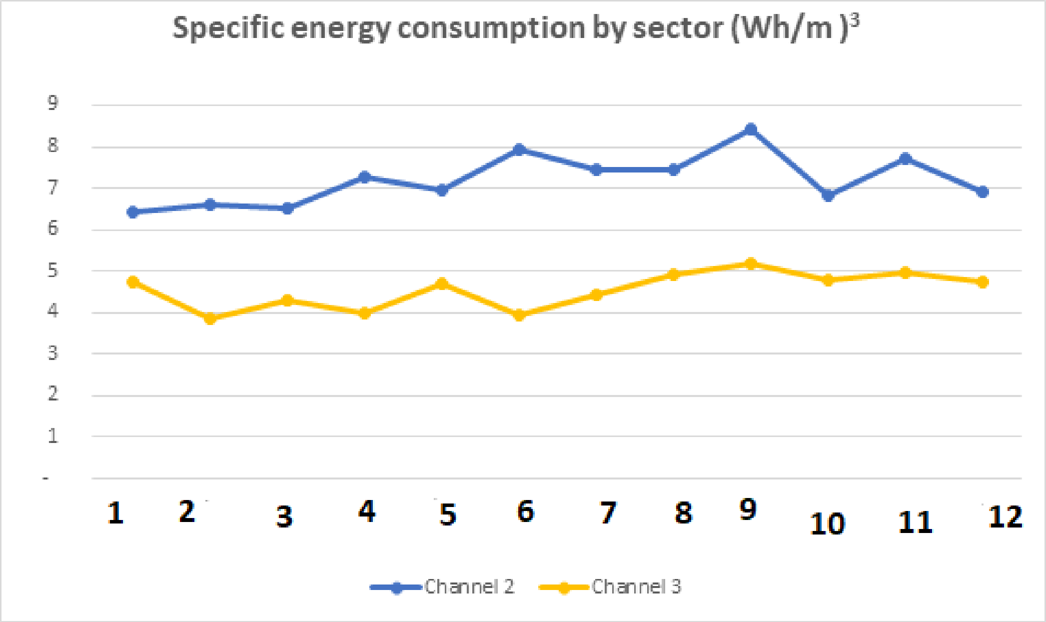
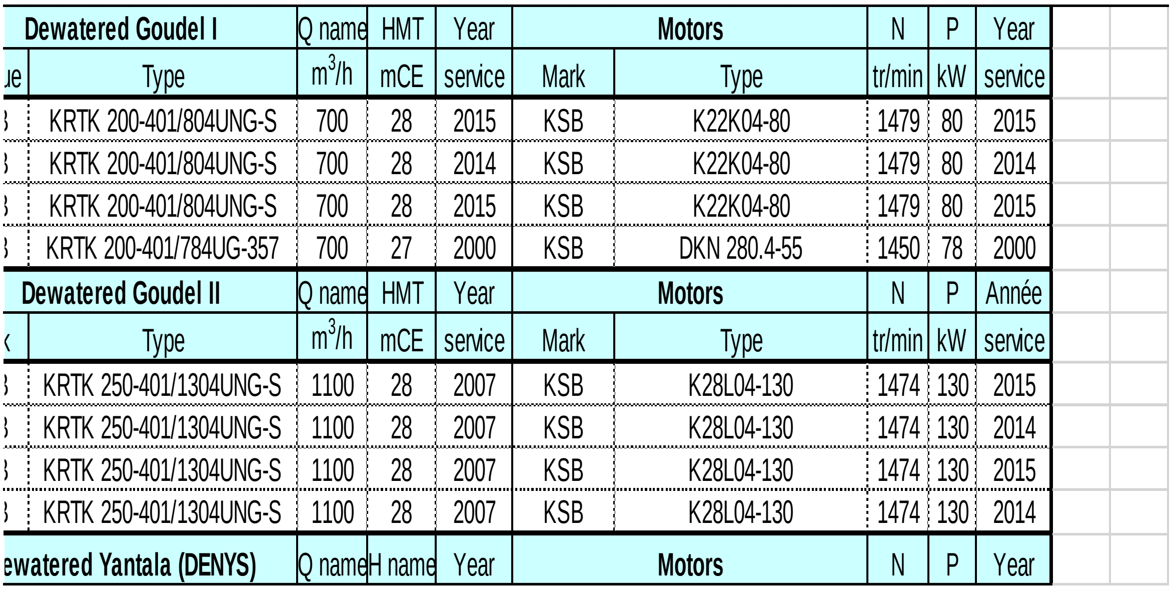


Figure 6 Comparison of specific energy consumption by sector.

Diagnostics of the Goudel drainage pumps

The eight (8) dewatering pumps at Goudel draw raw water from the River Niger to supply the two treatment stations at Goudel. The detailed characteristics of these eight (8) pumps are given in table 2.

Table 2 Nominal characteristics of Goudel dewatering pumps.



Dewatered Goudel I		Q name	HMT	Year	Motors		N	P	Year
ue	Type	m^3/h	mCE	service	Mark	Type	tr/min	kW	service
	KRTK 200-401/804UNG-S	700	28	2015	KSB	K22K04-80	1479	80	2015
	KRTK 200-401/804UNG-S	700	28	2014	KSB	K22K04-80	1479	80	2014
	KRTK 200-401/804UNG-S	700	28	2015	KSB	K22K04-80	1479	80	2015
	KRTK 200-401/784UG-357	700	27	2000	KSB	DKN 280.4-55	1450	78	2000
Dewatered Goudel II		Q name	HMT	Year	Motors		N	P	Année
	Type	m^3/h	mCE	service	Mark	Type	tr/min	kW	service
	KRTK 250-401/1304UNG-S	1100	28	2007	KSB	K28L04-130	1474	130	2015
	KRTK 250-401/1304UNG-S	1100	28	2007	KSB	K28L04-130	1474	130	2014
	KRTK 250-401/1304UNG-S	1100	28	2007	KSB	K28L04-130	1474	130	2015
	KRTK 250-401/1304UNG-S	1100	28	2007	KSB	K28L04-130	1474	130	2014
ewatered Yantala (DENYS)		Q name	H name	Year	Motors		N	P	Year

A detailed view of the Goudel drainage system is shown in Figure 7.

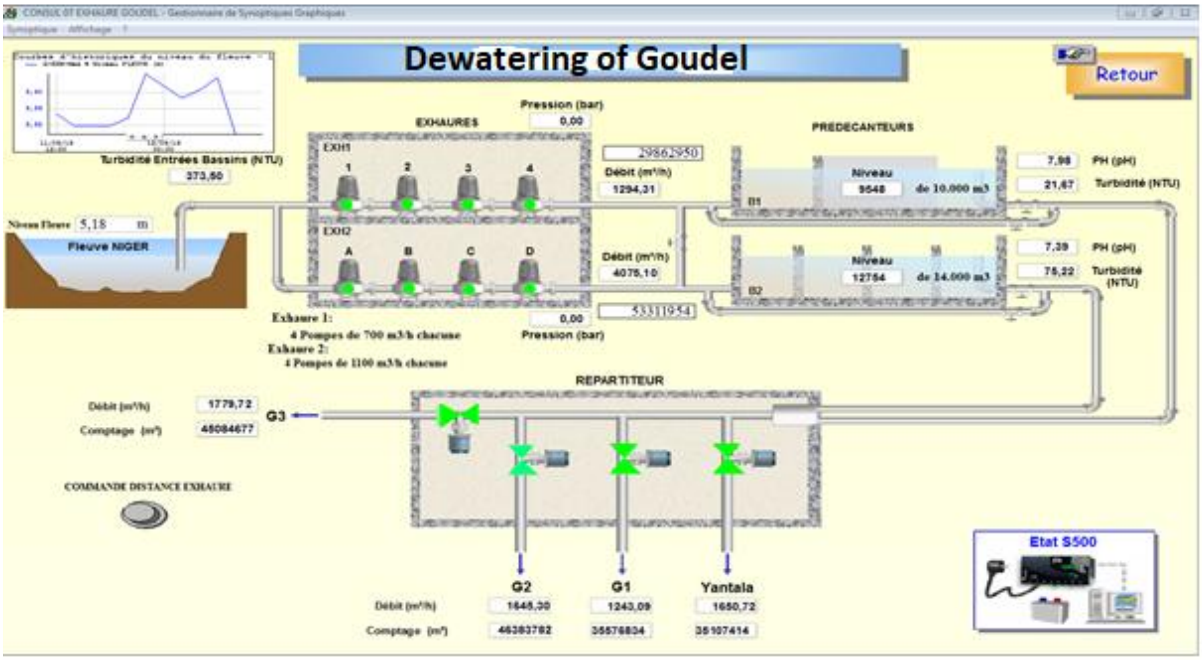


Figure 7.*Schematic diagram of the Goudel drainage system.*

Hydraulic parameters

Measurements with discharge valve fully open and tiered

Table 3 below shows the hydraulic parameters required to diagnose dewatering pumps. These parameters are determined with the discharge valve fully open.

Table 3 - Hydraulic parameters for the diagnosis of dewatering pumps.

Grouping	Pressures measurement					Debit
	Pref (B)		ΔH min	ΔH max	J_{AB} (*)	
	bar	mce	m	m	mce	m^3/h
(A+B)	1,95	19,9	2,3	2,3	1	2275
(A+C)	1,95	19,9	2,3	2,3	1	2275
(A+D)	1,85	18,9	2,3	2,3	1	2275
(A+B+C)	2,08	21,2	2,3	2,3	1	3150
(A+B+D)	2,08	21,2	2,3	2,3	1	3150
(A+B+C+D)	2,08	21,2	2,3	2,3	1	4400

Here J_{AB} *corresponds to the calculated pressure drop between points A and B shown in the schematic diagram (Figure 7).*

Δ H is the vertical distance between the discharge pressure gauge and the suction pressure gauge (or the dynamic level of the water table).

- ΔH > 0 when the discharge pressure gauge is above the suction pressure gauge or above the dynamic water level ;
- ΔH < 0 otherwise.

Table 4 below shows the hydraulic parameters required to diagnose dewatering pumps. These parameters are determined in the case of a third-party discharge valve.

Table 4 Electrical parameters for dewatering pump diagnostics.

Grouping	**Electric measurement**					
	V	**A**	**kW**	**cos ϕ**	**kVA**	**Hz**
(A+B)	377	191	108	0,84	129	50,1
(A+C)	376	190	105	0,85	124	50,3
(A+D)	375	182	99	0,84	118	50,2
(A+B+C)	383	190	105	0,84	125	50,3
(A+B+D)	383	193	99	0,85	116	50,6
(A+B+C+D)	391	192	110	0,85	129	50,5

The hydraulic and electrical measurements are then cross-referenced to calculate the performance indicators for the pump sets audited, as summarised in Table 5.

Table 5 - Performance indicators for Goudel dewatering pumps.

Groupemnts	HMT	Debit	Power	Specific energy		Yield η		SEEN indicator
				Calculated	Objective	Calculated	Objective	
	mCE	m^3/h	Kw	$Wh/m^3/mCE$	$Wh/m^3/mCE$	%	%	Wh/m^3
(A+B)	23,2	1138	108	4,1	3,4	66,50%	80%	95
(A+C)	23,2	1138	105	4,0	3,4	68,40%	80%	92
(A+D)	22,2	1138	99	3,9	3,4	69,36%	80%	87
(A+B+C)	24,5	1050	105	4,1	3,4	66,75%	80%	100
(A+B+D)	24,5	1050	99	3,8	3,4	70,79%	80%	94
(A+B+C+D)	24,5	1100	110	4,1	3,4	66,75%	80%	100

Tables 6 and 7 illustrate the hydraulic parameters for dewatering pump diagnostics and the electrical parameters for dewatering pump diagnostics respectively.

Table 6 Hydraulic parameters for the diagnosis of dewatering pumps.

Grouping	**Pressures measurement**					
	Pref (B)		**ΔH min**	**ΔH max**	**J_{AB} (*)**	**Débit**
	bar	**mce**	**m**	**m**	**mce**	**m^3/h**
(A+B)	1,90	19,4	2,3	2,3	3,3	2640
(A+C)	1,90	19,4	2,3	2,3	3,3	2640
(A+D)	1,90	19,4	2,3	2,3	3,3	2640
(A+B+C)	1,85	18,9	2,3	2,3	3,3	1823
(A+B+D)	1,85	18,9	2,3	2,3	3,3	1823
(A+B+C+D)	1,95	19,9	2,3	2,3	3,3	2715

Table 7 Electrical parameters for dewatering pump diagnostics.

Grouping	**Electric Measurement**					
	V	**A**	**kW**	**cos ϕ**	**kVA**	**Hz**
(A+B)	398	192	112	0,85	132	50,1
(A+C)	398	194	113	0,85	133	50,2
(A+D)	394	192	110	0,85	129	50,2
(A+B+C)	394	190	113	0,85	133	50,3
(A+B+D)	396	199	109	0,85	128	50,3
(A+B+C+D)	398	201	116	0,85	136	50,4

The hydraulic and electrical measurements are then cross-referenced to calculate the performance indicators for the pump sets audited, as summarised in Table 8.

Table 8. Performance indicators for Goudel dewatering pumps.

Grouping	HMT	Debit	Power	Specific energy		Yield η		dicator
				Calculated	Objective	Calculated	Objective	
	mCE	m^3/h	Kw	$Wh/m^3/mCE$	$Wh/m^3/mCE$	%	%	Wh/m^3
(A+B)	25,0	912	112	4,9	3,4	55,42%	80%	123
(A+C)	24,5	912	113	5,1	3,4	53,81%	80%	124
(A+D)	25,0	912	110	4,8	3,4	56,42%	80%	121
(A+B+C)	25,0	880	113	5,1	3,4	53,03%	80%	128
(A+B+D)	25,5	880	109	4,9	3,4	56,09%	80%	124
(A+B+C+D)	26,0	880	116	5,1	3,4	53,75%	80%	132

When the pumps operate with the discharge valve fully open, hydraulic performance is good, although the nominal HMT is not reached for the nominal flow rate (Q_{nomin}). The efficiency per electric pump unit, depending on the configuration adopted (Table 6), is then between 66.50 and 70.79% (i.e. between 3.8 and 4.1 Wh/m^3 /mCE against a target of 3.4 Wh/m^3 /mCE or 80% efficiency for each new unit).

When the discharge valve is kept in the tiered position, which is the mode chosen by the operator, vibration and noise are less, although still noticeable. Although recommended in the current situation, this configuration leads to a more degraded energy efficiency of each electric pump unit (table 9) than in the open valve configuration (between 53.03 and 56.42%, i.e. almost 1Wh/m^3 /mCE more than the open valve configuration).

The graphs of Figures 8, 9 and 10 illustrate the variations in operating point for different types of given configuration.

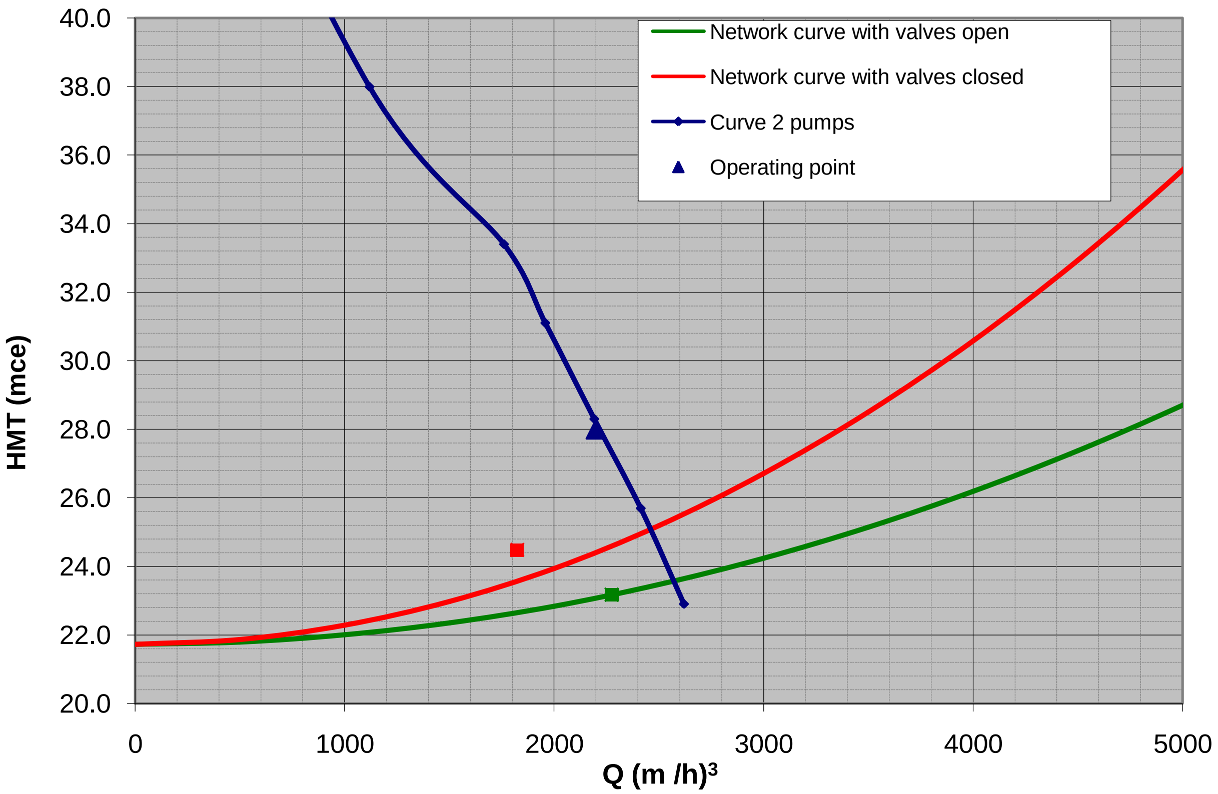


Figure 8 *Operating point with 2 pumps in parallel.*

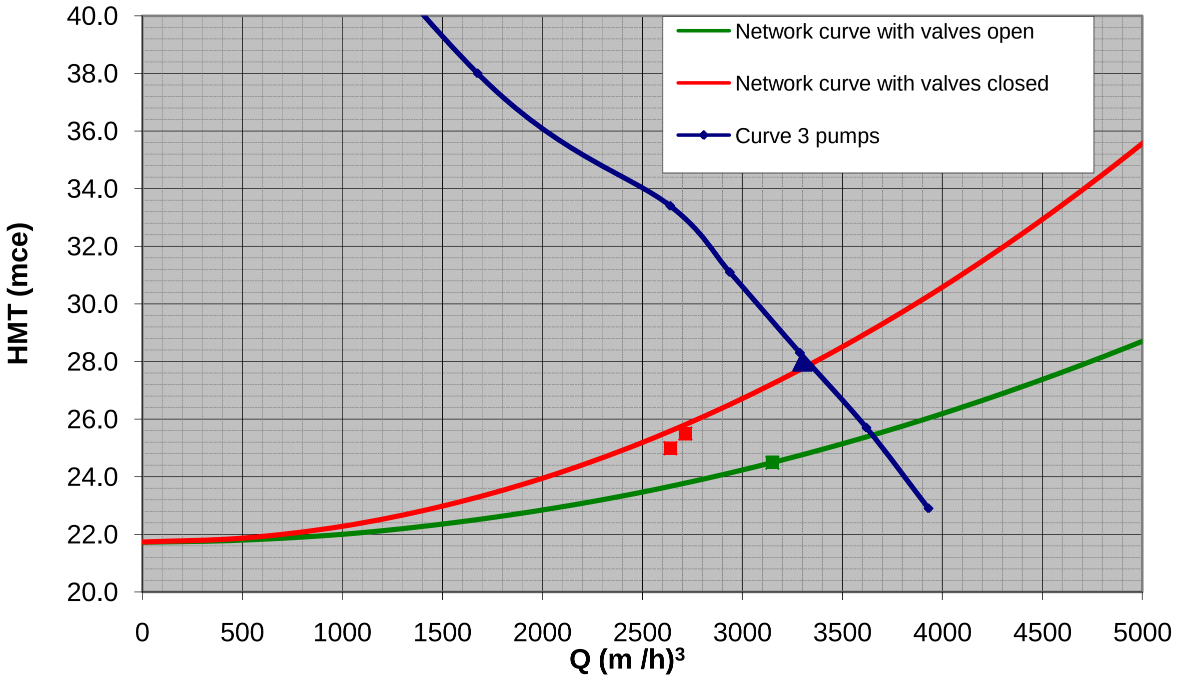


Figure 9 *Operating point with 3 pumps in parallel.*

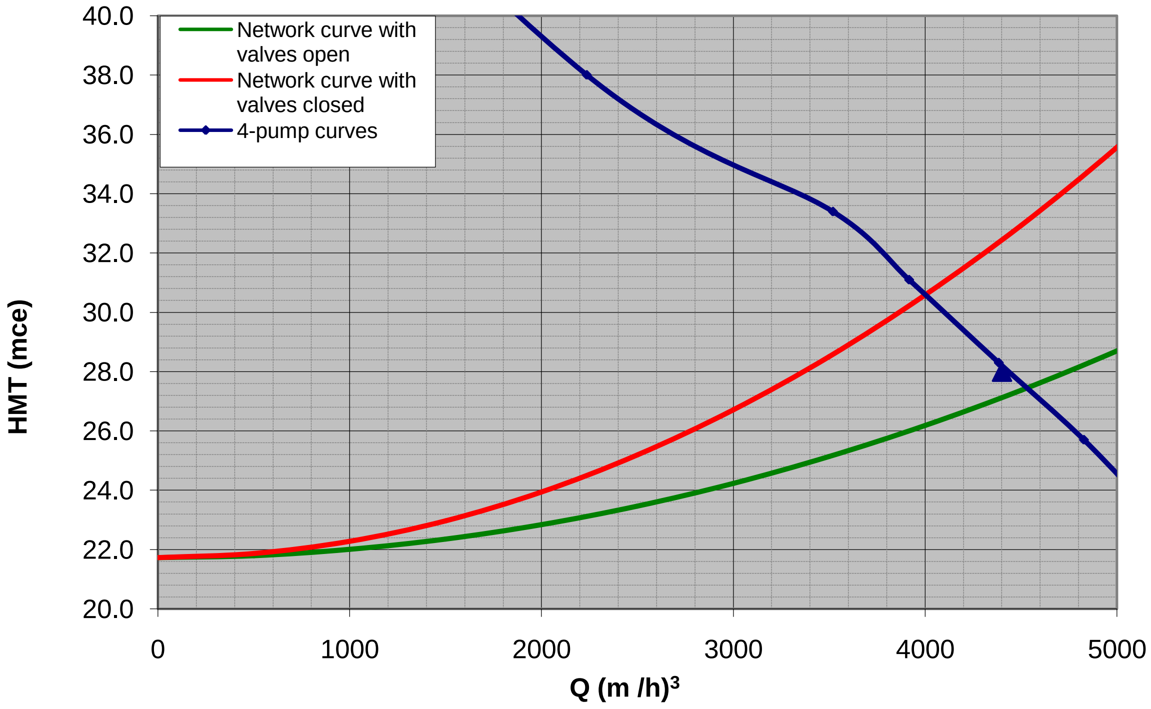


Figure 10. *Operating point with 4 pumps in parallel.*

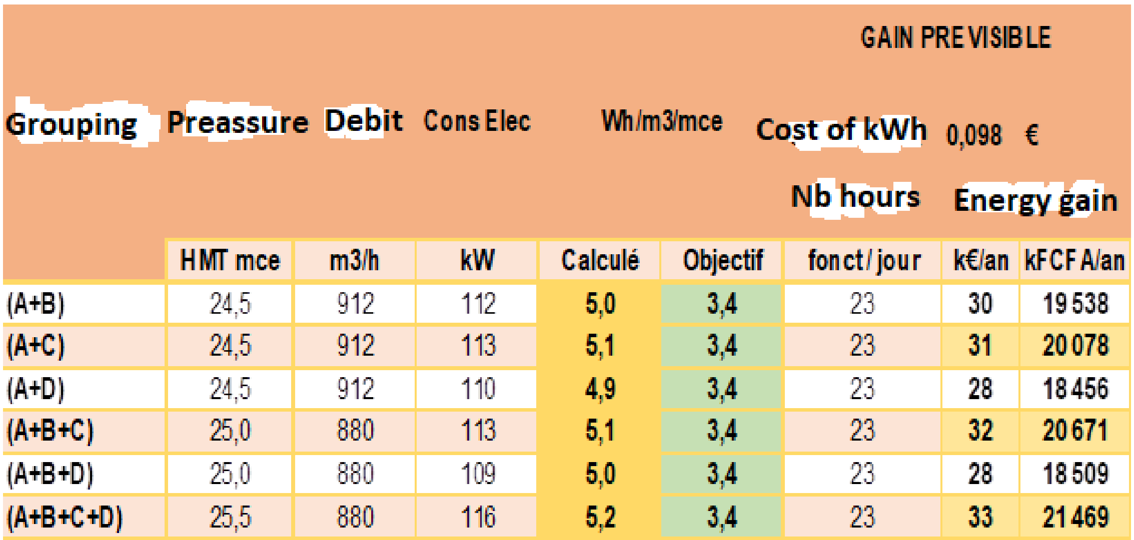
Technical and economic analysis of drainage pumps

An assessment of the energy operating gains (Tables 9 and 10) can then be carried out by targeting the efficiency guaranteed by the manufacturer (minimum and reasonable objective in Niger's operating conditions) for the current operation of the Goudel station.

Table 9. Energy savings for Goudel dewatering pumps (with valve fully open)

Grouping	Preassure	Debit	Cons Elec	Wh/m3/mce		Prediictable gain Cost kWh :	0,098 €	
						Nb hours	energy gain	
	HMT mce	m3/h	kW	Calculated	Objective	fonct / jour	k€/year	FCFA/yea
(A+B)	23,2	1138	108	4,1	3,4	23	15	9.941
(A+C)	23,2	1138	105	4,0	3,4	23	13	8.319
(A+D)	22,2	1138	99	3,9	3,4	23	11	7.206
(A+B+C)	24,5	1050	105	4,1	3,4	23	14	9.489
(A+B+D)	24,5	1050	99	3,8	3,4	23	10	6.246
(A+B+C+D)	24,5	1100	110	4,1	3,4	23	15	9.941

Table 10 - Energy operating savings for Goudel dewatering pumps (with tiered valve at the discharge of each pump)



						GAIN PREVISIBLE		
Grouping	Preassure	Debit	Cons Elec	Wh/m3/mce		Cost of kWh	0,098	€
						Nb hours	Energy gain	
	HMT mce	m3/h	kW	Calculé	Objectif	fonct/jour	k€/an	kFCFA/an
(A+B)	24,5	912	112	5,0	3,4	23	30	19 538
(A+C)	24,5	912	113	5,1	3,4	23	31	20 078
(A+D)	24,5	912	110	4,9	3,4	23	28	18 456
(A+B+C)	25,0	880	113	5,1	3,4	23	32	20 671
(A+B+D)	25,0	880	109	5,0	3,4	23	28	18 509
(A+B+C+D)	25,5	880	116	5,2	3,4	23	33	21 469

The following assumptions have been made for this valuation:

- ❖ Average daily running time of drainage pumps at Goudel :
- 20 hours per day (based on 2018) with a balanced rotation of individual pump operating times and a projected increase to 21 and 23 hours per day (increase in average demand in Niamey);
- Weighted average unit cost of NIGELEC kWh between peak and off-peak hours: 64.4 FCFA/kWh (current tariff used for calculation: 56.12 FCFA for off-peak hours 00h-10h and 16h-00h, and 89.19 FCFA for peak hours 10h-16h).

The energy saving is the amount of energy saved if the current pump unit is replaced by another with better performance. It depends on the specific energy expected for the new pump unit. It is calculated from supplier data and is highly dependent on the nominal flow rate. Each gain also depends on parameters such as the annual average daily operating hours of the pumps and the cost per kilowatt-hour (kWh).

Conclusion

The study shows that the Goudel station produced 36,089,492 m^3 in 2018, corresponding to an annual production efficiency of 94.98%. The average specific electrical energy consumption of the Goudel station is 537 Wh/m^3 . The average daily production at Goudel is 98,875 m^3 /d for a theoretical nominal capacity of 85,000 m^3 /d, which was increased to 110,000 m^3 /d in 2013 following work to increase the factory's capacity. Production peaks in April with approximately 320,7757 m^3 /month or 106925 m^3 /day on a 30-day operating basis. The production trough is reached in February with approximately 2,725,551 m^3 /month or 97,341 m^3 /day based on 28 operating days. Electricity consumption reached 1,357,861 kWh, corresponding to a specific consumption of 498 Wh/m^3 . The factory's annual electricity consumption is 19,014,670 kWh. In 2018, 934,793 litres of diesel were consumed, compared with 1,079,659 litres in 2017, a saving of 144,866 litres equivalent to CFAF 77,937,908. Although sectors II and III use the same processes and the same production capacity, the Goudel 2 sector appears to consume the most energy. When the pumps operate with the discharge valve fully open, hydraulic performance is good, although the nominal HMT is not reached for the nominal flow rate (Q_{nomin}). When the discharge valve is kept in the tiered position, which is the mode chosen by the operator, vibration and noise are less, although still noticeable.

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