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Proposal for a Tariff System for the AEP Service of the Temeye Toucouleur Drinking Water Treatment Plant in the Municipality of Mbane

Cheikh Ahmadou Bamba NDIAYE[1*], Moustapha SY[2], Mallé GUEYE[2], Abdou Lahat DIOP[3]
[1]Department of Agricultural Sciences and Agrobusiness at the ISEP in Thies
[2]Department animal productions of the Higher Institute for Agricultural and Rural Training (ISFAR) of the University Alioune Diop de Bambey Senegal
[2]Iba Der Thiam University of Thies Senegal
[3]National Cell Organization for the Development of the Senegal River (OMVS)/ Organization for the Development of the Gambia River (OMVG)
[1*]Contact: bamba_agro@yahoo.fr

Abstract**—** *The aim of this study is to formulate proposals for improving the operation and management of the drinking water treatment plant at Temeye toucouleur. The analysis of the situation of the drinking water service in the study area shows the appropriation of drinking water installations by the beneficiary populations and their involvement in the management is essential. In addition, with a view to determining the cost of water, it has been shown that the operation of the network generates significant costs. Taking into account the latter, the proposed price is 550 F CFA per m³ for special connections and 15 F CFA per 20 L can at the fountain terminals. Compared to the prices of similar stations in the area, this price for the proposed m3 of water is cheaper than that of the ASUREP of Thiago at its start-up in 2010 (800 F CFA/m³) and slightly higher than the current rates applied to Mbane and Thiago (400 F CFA/m³). Despite this, the beneficiaries are motivated to pay for water because they are well aware of the issue of this drinking water project in Temeye toucouleur. Payment shall be made by invoice based on meter index readings at the level of individual connections and cash at the level of fountain terminals. The revenues generated must be paid into a bank account opened in the name of ASUREP and will be used to cover all operating expenses of the station and the association*.

Keywords**—** *Operation; balance sheet; expenses; cost, pricing*.

I. INTRODUCTION

During the 21st century, the effects of climate change are being felt on water resources, leading to shortages and difficulties in their sustainable management. However, water consumption continues to increase with population growth. According to statistics from the United Nations (UN) in May 2013, 780 million people around the world do not have access to water and about 2.5 billion people or a third of the world's population are without safe drinking water. Safe water is becoming increasingly scarce in poor countries such as Africa where nearly 35% of the population are deprived of it. According to the UN, about 5 million people die each year from infectious or parasitic diseases due to unsafe water. Therefore, many reflections are carried out to find a solution to this vital emergency.

Like developing countries, the lack of drinking water is a crucial problem in Senegal affecting mostly rural people. Thus, for decades, the State has invested in the field of rural hydraulics which remains one of the main priorities for the development of the country.

In particular, in the Senegal River basin, OMVS contributes to the construction of water infrastructures to improve access to drinking water for the population and to combat waterborne diseases. Created on 11 March 1972 by the States bordering the Senegal River, namely Mali, Mauritania and Senegal, OMVS is committed to meeting the challenge of rural hydraulics in its basin.

The OMVS carries out, with funding from the AFD, actions aimed at improving the supply of drinking water (AEP) and sanitation in the pilot villages of Ndombo, Thiago, Temeye toucouleur and Medina Baidy in the department of Dagana.

Among the activities initiated for the AEP part of the project, a drinking water treatment plant is being built in Temeye toucouleur to meet the daily water needs of users and improve public health of local populations.

It is in this context that the present study aims to propose a better mode of operation and sustainable management of the drinking water treatment plant of Temeye toucouleur in order to ensure continuous water service.

II. MATERIALS AND METHODS

2.1 Description of the study area

The study area is located in the region of Saint-Louis, department of Dagana, municipality of Mbane more precisely in the village of Temeye toucouleur. The municipality of Mbane covers an area of 1906 km² and officially polarizes 65 villages and many hamlets.

It is located in latitude between 16°' and 17°' N and longitude between 15°' and 16°' W and limited:

- to the East by the district of Thillé Boubacar (department of Podor);
- to the West by Lake Guiers, Taouey and the rural communities of Gnith and Ronkh;
- to the South by Keur Momar Sarr and Yang Yang Districts;
- and North by the rural community of Bokhol and the commune of Richard Toll (ARD Saint Louis, 2010).

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According to the ANSD, the population of Temeye toucouleur is estimated in 2023 at 623 people with 343 men and 280 women. Economic activities are mainly based on agriculture, fishing and livestock.

The town of Mbane is located mainly on deck-dior and dior floors. However, the shores of Lake Guiers have hydromorphic soils similar to those of Walo (PNIR 2002). The climate of the area is semi-arid tropical type marked by the alternation of two seasons: a dry season of nine months (November to June) and a rainy season of three months (July to October).

At the same time, the municipality of Mbane has important surface water resources, including the lake of Guiers which makes it a highly coveted area. The lake is fed by the Senegal River through the Taouey canal. There are also water bowls in the area.

According to the DGPRE, most of the department of Dagana, consisting of the municipalities of Ross-Béthio, Ronkh and Gaé, is covered by salt water units while the municipality of Mbane is located in the Maastrichtian.

2.2 Methodology

The methodological approach adopted can be summarised as follows:

2.2.1 Bibliographical review

It took place at the ENSA library in Thiès, at the OMVS/OMVG National Cell, at the Etudes Travaux Ingénierie Conseils (ETIC) office, at the documentation centre of the OMVS in Saint-Louis, at the SAED, more precisely at the Dagana delegation, the Regional Directorate of Hydraulics and Sanitation in Saint-Louis, the General Directorate of Senegalese Water (SDE) in Dakar, the Hydraulic Directorate in Dakar, the Operations and Maintenance Directorate (DEM). Thus, studies already carried out in this direction are revisited and interviews conducted with resource persons.

The literature review provided a better understanding of the study's problem and thus contributed to the development of the tools necessary for data collection.

2.2.2 Development of data collection tools

Data collection tools are developed in the form of questionnaires for users and maintenance guides addressed to stakeholders involved in the management of similar drinking water treatment plants.

2.2.3 Field work

This includes socio-economic surveys, field visits and technical interviews. Surveys are carried out in the village of Temeye toucouleur and around using questionnaires already developed. Forty households were surveyed and collected users' opinions and assessments of the drinking water service in the area, their willingness to pay for water. A diagnosis of the AEP situation of similar stations in the area is thus made.

At the same time, interviews are conducted with stakeholders involved in the project, including OMVS the project manager, the Construction of Works and Networks (ECORE) responsible for the work on the Temeye toucouleur station, the Mauritanian Consulting Group (MCG), the ETIC firm responsible for monitoring and the Hydraulic and Sanitation Directorate of Saint-Louis responsible for monitoring. Subsequently, other structures and resource persons are consulted: the SDE of Saint Louis, the Direction de l'Hydraulique (DH), the DEM, the SAED, the ARD of Saint-Louis, the Office national des Lacs et Cours d'eau (OLAC) etc.

III. Results And Discussions

3.1 Diagnosis of similar stations in the area

Financial management is based on water pricing, recovery and operating costs.

3.1.1 Pricing applied

Mbane and Thiago rates are set arbitrarily and do not really reflect the cost of water. Mbane water rates set by ASUREP are as follows:

- 10 F CFA per 20L can at the fountain;
- 400 F CFA per m^3 at the level of private connections.

These rates are underestimated and therefore fail to cover the station's operating expenses, despite regular payment of their bills.

Today, with the expansion of the Mbane network, the situation is becoming critical, particularly with the increase in operating expenses that are far greater than the revenues from the sale of water. ASUREP is no longer able to cover the costs of purchasing inputs for drinking water and its very salty electricity bills (2 250 000 F CFA in June 2013).

The extension of the Mbane network has thus greatly facilitated this situation. The station is even overused: the pumps and equipment of the Mbane station are constantly operating almost 24 h/ 24h resulting in a high energy consumption.

To deal with this situation, the ASUREP of Mbane is considering an increase in the price of water so that the cost-revenue balance can be restored.

Unlike Mbane, Thiago's pricing manages to cover the operating expenses of the Thiago station, despite the fact that it has fallen from 15 to 10 F CFA per bottle of 20 litres at the water supply and from 800 to 400 FCFA per m^3 at the private connections. Since the Thiago network has not been extended, the supply adequately meets demand.

3.1.2 Recovery and operating costs

Recovery from users occurs at two levels:

- At the fountain terminals, water is paid for in cash;
- For private connections, beneficiaries pay monthly according to the water bill consumed.

The revenues thus collected are paid into the ASUREP account opened at Credit Mutuel of Senegal (CMS). These revenues will be used to cover the station's operating costs and the maintenance of the network.

A financial statement is prepared monthly and at the end of each year. However, the AUSREP of Mbane does not respect this rule, which nevertheless allows to assess the management of the Association. Only monthly financial statements from August to December 2012 are available and are as follows:

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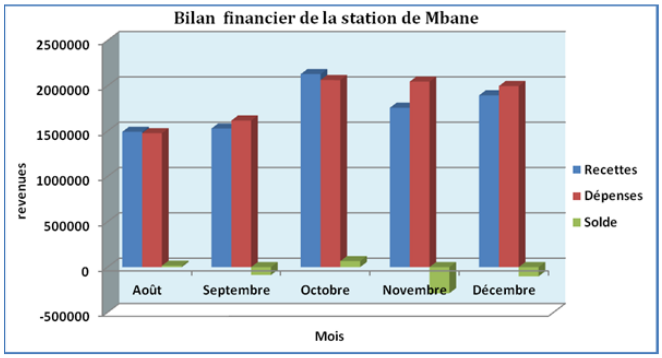

Figure 1: Mbane Station Financial Statement from August to December 2012

The analysis of the financial balance sheet shows two statements: a positive, but not significant, balance in August and October and a negative balance over the other 3 months (September, November and December). This proves the precarious situation of the treasury of ASUREP Mbane who can no longer adequately ensure the management of the station.

In Thiago, we were able to obtain the following four (4) financial statements:

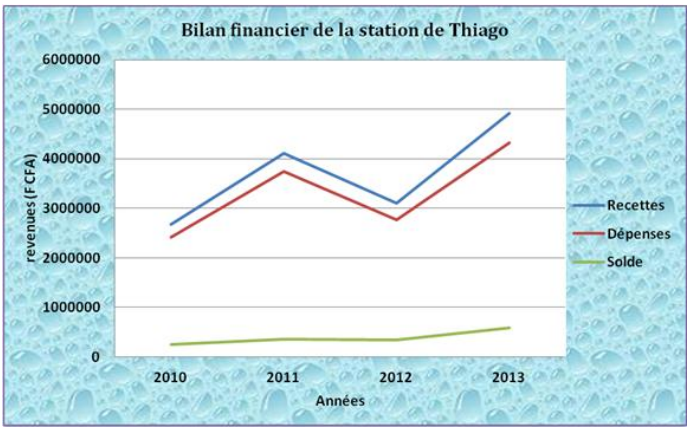

Figure 2: Thiago Station Financial Statement from 2010 to 2013

In contrast to Mbane, the financial balance of the station of Thiago shows a positive balance during the last four years (from 2010 to 2013). Revenues always exceed expenditures. But both vary proportionately from year to year. Indeed, the increase in water production tends to favour more operating costs. Variable charges such as input purchase, electricity bills vary according to water production.

3.1.3 Diagnostic assessment of similar stations

The balance - diagnosis of the operation and management of the stations reveals that the drinking water service seems more guaranteed in Thiago. Mbane station faces huge problems, the most pressing of which are:

high operating expenses accentuated by overpriced electricity bills and;

the application of a water tariff schedule that does not take account of the balance between charges and revenues, etc.

3.2 Operation of the Temeye toucouleur station

In the case of a drinking water treatment plant, operation can be defined as all activities to ensure the production and distribution of drinking water.

The proper functioning of the drinking water service is a function of the operating system set up. To do this, the operation made on the network must meet water needs.

3.2.1 Determination of water requirements

Water demand is the supply that the operator will have to make available to meet user demand. Water requirements are determined at each stage of the system taking into account users' water demand, their behaviour and the performance of the installations concerned. Daily water requirements are given by the following formula:

$$Q_j = \frac{D_{jm} \times C_{pj}}{\eta_t \times \eta_d}$$

With:

- Q_j: daily water requirements (m^3/d);
- D_{jm}: average daily water demand (m^3/d);
- C_{pj}: daily attachment coefficient with C_{pj} = 1.10;
- η_t: yield on processing losses with η_t=95%;
- η_d: distribution loss yield with η_d = 85%.

TABLE 1: Daily water requirements (2013 to 2030)

Years	2013	2015	2020	2025	2030
Population	2140	2270	2632	3051	3537
Request	**53.5**	**56.76**	**65.8**	**76.3**	**88.4**
Daily water requirements (m^3/day)	**72.88**	**77.31**	**89.63**	**103.9**	**120.46**

3.2.2 Organization of the farm

The organization of the operation is the key to the smooth running of drinking water production and distribution. It must conform to the water demands expressed by users.

a) Water pumping

The production of drinking water takes place under the supervision of a pump operator who ensures the entire process of potabilization. For the station of Temeye toucouleur, it is better to have two pump men who take care of it. Their task will be to ensure the production of drinking water in compliance with the standards for drinking water (quantity and quality). They must first be trained by the water services. Indeed, the operation of such a station requires a high level of technicality in order to properly comply with dosages of inputs for potabilization and also to ensure the quality of the water produced. As a result, their work is difficult and requires the regular availability of technical staff. The pump operators can thus carry out relays of 4 to 5 working days. Nevertheless, the station must have a guard and support staff in case of absence.

For the operation of the system, raw water pumping must meet the beneficiaries' water needs. At Temeye toucouleur, it is carried out automatically, the submerged pump is equipped with a floating tank. Once the water tower is full, the system stops pumping.

b) Distribution organization

Temeye toucouleur's network consists of five (05) fountain terminals, two (02) community connections and two (02) water points (taps). For a better AEP on the Temeye toucouleur

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network, it would be necessary to set up distribution schedules to facilitate and organize service.

- Calculation of hourly distribution rate:

The distribution network is dimensioned based on the hourly peak flow defined by the following formula

$$Q_{dis} = \frac{D_{jm} \times C_{ps} \times C_{ph} \times C_{pj}}{(\eta_d \times 24)}$$

With a daily water demand: D_{mpj}= 88,4 m^3 (in 2030)

$Q_{dis} = 12,7\ m^3/h$

$Q_{dis} = 3,53\ l/s$

- *Calculation of daily water service time:*

Given that the distribution flow rate Qdis=12.7 m^3/h and the daily water demand D_mpj= 88.4 m^3 (in 2030), we will therefore determine the daily water service time as follows:

$$T_d = \frac{D_{mpj}}{Q_{dis}} = T_d = 7\ h$$

In order to better organize distribution, the schedules recorded in table 2 are proposed.

TABLE 2 : Distribution schedules

Hours of distribution	
Morning	**Evening**
7h -12h	16 h -18h

3.3 Temye Toucouleur Station Tariff System

3.3.1 Temeye toucouleur ASUREP operating loads

The expenses required for the operation of ASUREP include:

a) Employee compensation

In terms of remuneration, we propose to harmonize with Thiago, given the management of its station and its financial balance sheet that are considered satisfactory. For this purpose, ASUREP employees may be paid monthly as follows:

- 50000 CFA francs for each pump operator;
- For the meter reading, the station keeper 25000 F CFA each.

The monthly salary for fountain attendants is also 25000 F CFA francs per fountain attendant. However, these salaries may change over time. For better results-based management, we could even consider paying water fountain attendants according to the volume of water sold.

b) Office Supplies

Office supplies, as the name suggests, are office equipment (notebooks, logbooks, pens...) and can be estimated at 5000 F CFA per month.

c) Transportation and communication costs

Listed in the expenses of the ASUREP, these expenses include communication and travel expenses made by the ASUREP of Temeye toucouleur. Like the stations in the area, they are estimated at 15000 F CFA per month.

d) Electricity bills and input purchases

In the area, the electricity bills recorded by the stations weigh heavily on their operating expenses. They have caused serious financial problems to the Mbane station, which is struggling to pay for them.

To overcome this situation in Temeye toucouleur, it is important to take into account the electricity costs. Indeed, the energy consumed depends mainly on the power of the pumps and their operating time.

The inputs are intended for drinking water use and relate to alumina sulphate used for coagulation and chlorine used as a disinfectant. Water intended for human consumption must first be treated with these products. The quantities of inputs required depend on the water quality of Lake Guiers. Since the turbidity values obtained at Mbane meet WHO standards (turbidity value below 5 NTU), field data are used to estimate input quantities. On average, the doses of inputs used are estimated at:

- 86.67g/m^3 during the three (3) winter months and 66.67g/m^3 during the dry season for alumina sulphate;
- 10g/m^3 for chlorine throughout the year.

TABLE 3: Projected Electricity and Input Purchase Charges

Year	Quantity of alumina sulphate (Kg)	Purchase alumina sulphate (F CFA)	Amount of chlorine (Kg)	Purchase chlorine (F CFA)	Energy consumption (KWH)	Energy costs (F CFA)	Total (F CFA)
2014	1964,81	884 164	273.99	465 782	29097.69	3 433 528	**4 783 474**
2015	2023.75	910 689	282.21	479 756	29970.62	3 536 533	**4 926 978**
2016	2089.78	940 399	291.47	495 502	30954.32	3 652 609	**5 088 511**
2017	2147.00	966 150	299.40	508 973	31795.83	3 751 908	**5 227 031**
2018	2211.41	995 135	308.38	524 242	32749.71	3 864 466	**5 383 842**
2019	2277.75	1 024 989	317.63	539 969	33732.20	3 980 400	**5 545 357**
2020	2352.06	1 058 427	328.05	557 692	34839.36	4 111 044	**5 727 163**
2021	2416.47	1 087 410	336.97	572 853	35786.49	4 222 806	**5 883 070**
2022	2488.96	1120033	347.08	590 039	36860.09	4 349 490	**6 059 562**
2023	2563.63	1153634	357.49	607 740	3796589	4479975	**6 241 349**
2024	2647.27	1191269	369.23	627 687	39212.00	4627016	**6 445 973**
2025	2719.76	1223890	379.27	644 752	40278.01	4752805	**6 621 447**
2026	2801.35	1 260 607	390.64	664094	41486.35	4 895 389	**6 820 090**
2027	2885.39	1 298 425	402.36	684 017	42730.94	5 042 251	**7 024 693**
2028	2979.52	1 340 784	415.57	706 468	44133.45	5 207 747	**7 254 999**
2029	3061.11	1 377 499	426.87	725 674	45333.26	5 349 324	**7 452 497**
2030	3152.94	1 418 824	439.67	747 444	46693.25	5 509 804	**7 676 072**

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e) Maintenance and maintenance costs

The determination of maintenance and servicing costs is based on the estimation standards which provide for the following:

TABLE 4: Maintenance costs of equipment and works at the Temeye toucouleur station

Works and equipment	Percentage of annual maintenance costs [1]	Annual maintenance costs (F CFA)
PVC pipe	1%	35 000
Civil Engineering	1%	413 400
Control cabinet	5%	61 588
Pumping equipment	5%	304 793
Miscellaneous materials	5%	197 390
Total (F CFA)		**1 012 171**

f) Equipment and works renewal costs

As regards equipment renewal, it is a function of the depreciation made. Since each equipment has a life span, it is necessary to plan in advance its renewal.

According to the DEM, the ASUREP is responsible for ensuring the renewal of pumping equipment, station equipment and various accessories. However, the renewal of large works (discharge pipe, water tower and accessories, civil engineering of the fountains) is the responsibility of the State through the services of the Ministry in charge of hydraulics.

TABLE 5 : Equipment depreciation costs

Equipment	Depreciation period	Monthly depreciation costs (CFA)
Control cabinet	8 years	153 968
Pumping equipment	9 years	677 317
Miscellaneous materials	10 years	394 780
Total (F CFA)		**1 226 065**

3.3.2 Proposal for a tariff system for the AEP service of Temeye toucouleur

a) Pricing basis

Drinking water pricing is the price to pay for service. It takes into account the notion of balance between charges and revenues. Thus, its determination must be based on the cost of water given as follows:

$$\text{Cost of water} = \frac{\text{Total Charges}}{\text{Water Demand}}$$

TABLE 6: Cost per cubic metre of water by year

Year	Total annual charges (F CFA)	Annual water demand (m^3)	Cost of m^3 of water (F CFA)
2014	10 561 710	20113.33	**525**
2015	10 705 214	20716.72	**517**
2016	10 866 747	21396.69	**508**
2017	11 005 267	21978.37	**501**
2018	11 162 078	22637.72	**493**
2019	11 323 593	23316.86	**486**
2020	11 505 399	24082.16	**478**
2021	11 661 306	24736.85	**471**
2022	11 837 798	25478.96	**465**
2023	12 019 585	26243.33	**458**
2024	12 224 209	27104.68	**451**
2025	12 399 683	27841.55	**445**
2026	12 598 326	28676.79	**439**
2027	12 802 929	29537.1	**433**
2028	13 033 235	30506.56	**427**
2029	13 230 733	31335.9	**422**
2030	13 454 308	32275.98	**417**

The cost of water gradually decreases as demand for water increases.

b) Proposed pricing

Given that the maximum cost per cubic metre is equal to 525 F CFA, it is proposed that the cubic metre of water be increased to 550 F CFA. In the fountain terminals, pricing is given as follows:

TABLE 7: Water prices by volume

Volume of water	15 liter bucket	20 liter can	40 litre tank
Rate	10 F CFA	15 F CFA	25 F CFA

With this tariff system, the ASUREP of Temeye toucouleur will be able to set up its own fund that can be used to finance possible extensions of the network.

3.3.3 Analysis of users' willingness to pay for water

This analysis is very important as it allows to assess the level of willingness of the population to pay for water. To this end, surveys were carried out among the beneficiaries of the project to obtain their opinion not only on the price of water but also on their willingness to pay for it. The results of these surveys first show a sense of relief from having benefited from this project to improve their AEP because they had long suffered from difficulties related to the lack of drinking water. To this end, they have almost unanimously expressed their willingness to pay for water, despite the fact that some populations find the price of water a little expensive. The following figure shows the recipients' views on the proposed rate.

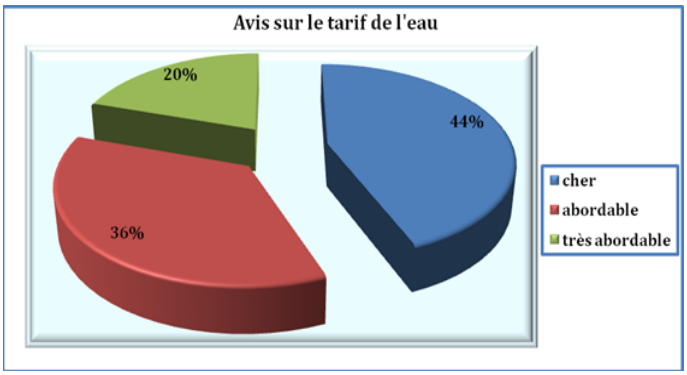

Figure 3: User Feedback on the Proposed Rate

According to Figure 3, 44% of the populations surveyed considered that the price of 550 FCFA proposed is expensive and therefore would like to maintain Mbane's tariffs of 400 F

[1] Maintenance course for hydraulic structures, 2013

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CFA/m^3 for special connections and 10 F CFA per 20L can at the level of the fountains.

On the other hand, 36% of respondents said that the price is affordable. For others, 20%, they like the price range which they find very affordable.

In general, the beneficiary populations, aware of the project's stakes and the burdens to bear, have expressed their willingness to pay the price of water to accompany the said project.

Regarding the payment terms for water, 94% of the surveyed populations want to pay for the volume consumed, compared with 6% who suggest a lump sum payment.

IV. Conclusion

In Senegal, the management of rural water infrastructure poses a serious organizational, financial and technical problem. At the end of the study, it appears that the proper functioning of the water service of the Temeye toucouleur station requires a suitable tariff system taking into account all operating costs to ensure a continuous and sustainable water service. The proposed grid corresponds to 550 F CFA per cubic meter of water for special connections and 15 F CFA per 20 L can at the fountain terminals. This tariff system considered affordable to very affordable by 56% of the respondents, allows to obtain revenues that can cover operating expenses and guarantee maintenance and renewal of equipment in the Temeye toucouleur network. ASUREP will thus be able to have its own funds for its operation.

In addition, the proper functioning of the Temeye toucouleur station contributes to the improvement of living conditions of populations by providing them with enormous benefits including:

- the availability of drinking water and adequate coverage of population needs;
- the reduction of water-borne diseases by reducing the frequence of surface waters;
- the reduction of the water-related time spent by women and children etc.

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