Chapter

Reliability and Problems of Wastewater Treatment Processes in the Algerian Sahara

Rachid Zegait, Saber Kouadri, Samir Kateb and Mohamed Azlaoui

Abstract

This modest chapter deals more particularly with the reliability and the problems of the different processes used at the level of several treatment plants installed in the Algerian Sahara with the aim of eliminating the nuisances and the risks of contamination in the urbanized areas, protecting the receiving environment and water resources, the possibility of reusing treated effluents for irrigation. Through an evaluation of the performance of these stations after years of operation which confronted with climates such as the high temperature and evaporation and the impact of the sand winds on the efficiency of the basin, technical and anthropic problems such as the salinity and mismanagement of the waters on the other hand.

Keywords: westwater, purification, Sahara, Lagoon, problems

1. Introduction

In recent decades, humanity has become more and more aware of the danger threatening the planet as a result of the great demographic growth and the enormous technological advances which generate unsanitary conditions of the environment. Water is a big problem today affecting the whole of the earth. To do this, it must then be preserved by all possible means: reduction of waste; reuse of wastewater and its introduction into special recycling techniques. The reuse of wastewater is a widely used practice in regions of the world affected by water resource shortages. The Mediterranean Basin is one of the regions of the world where the reuse of urban effluents is practiced at a low rate.

In Algeria, this area is not very developed, and the system put in place does not allow the desired prospects to be achieved to deal with the problems emanating from wastewater. Several regions of the Algerian Sahara where wastewater discharged into nature without prior treatment with large and increasing volumes which are sources of pollution. They generate many water-borne diseases and the spread of epidemics [1]. The Algerian authorities have agreed to plan several purification stations, with a view to eliminating pollution and the risks of contamination in urban areas. Protecting the receiving ecosystem and the water supplies of these regions of the Algerian Sahara, in particular the water table, the possibility of reusing filtered effluent for irrigation, becoming an important biodiversity area and a breeding ground [2].

This chapter, aiming to shed light on the wastewater treatment component in the Algerian Sahara, through a description of the different systems used and to discuss their reliability and constraints.

2. The Saharan area in Algeria

The Sahara covers nearly 90% of Algerian territory, it is crossed ergs by sand dunes, regs of stony land, as well as volcanic massifs in the far south.

In the north, the grass of the steppe slowly becomes scarce as the species change to make way for the reg. The erg, the sand desert covers only a fifth of the Sahara. The great eastern erg borders the Wadi Righ, a succession of oases, stretches along the underground wadi. The Saoura valley limits the great western erg to the west. Between these two great ergs, is the M'Zab valley carved into a plateau.

This northern Sahara, still dotted with oases, is opposed to that of the South, dominated by the Hoggar massif at an altitude of more than three thousand meters. Vast monotonous hamadas like the Tademaït plateau between El Goléa and In Salah connect the large geographical areas of the Sahara [3]. **Figure 1** present the localizations of deferent WWTP concerning in this chapter.

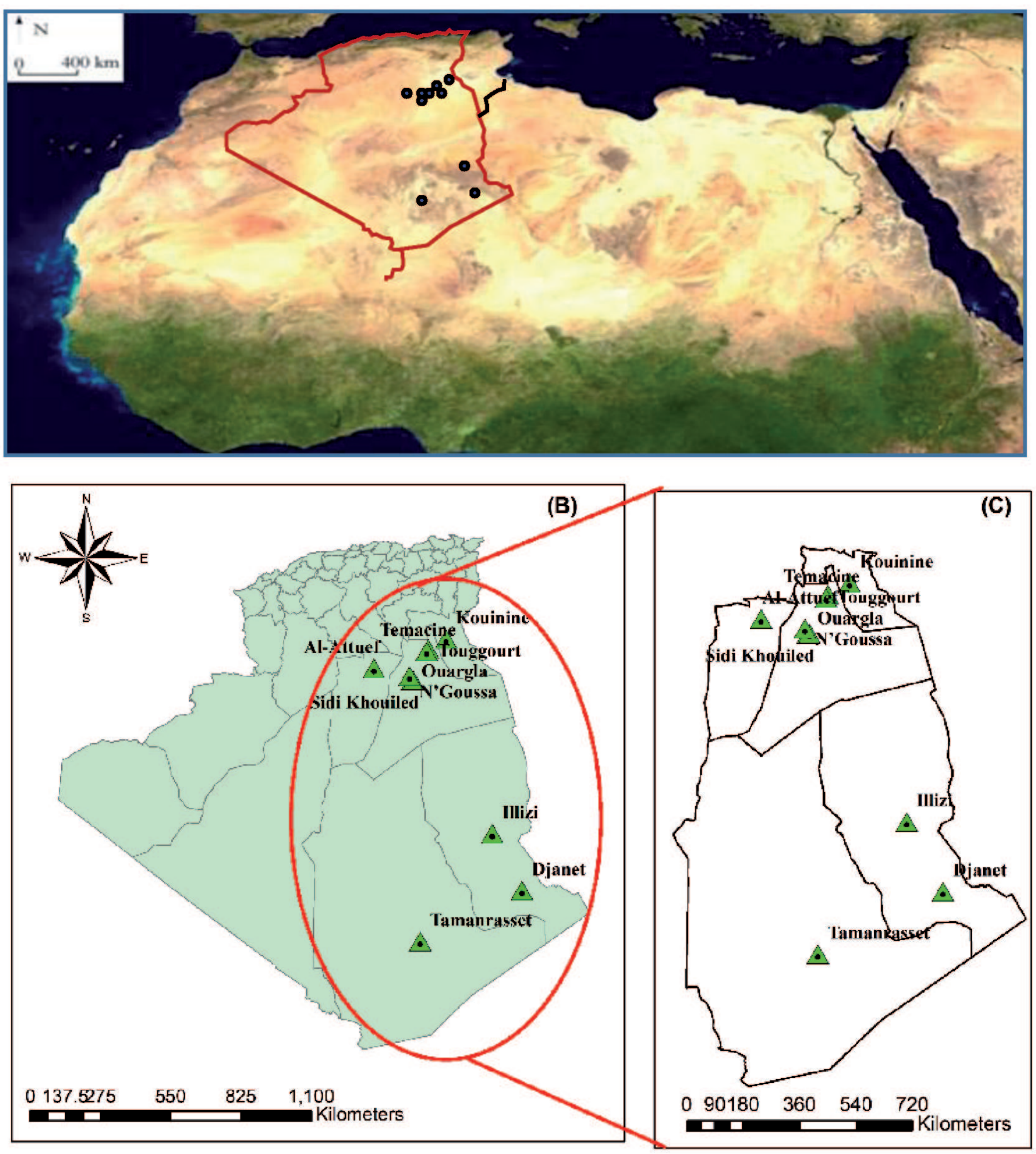

Figure 1.
Situation of the study area. (a) International location map of the study area. (b) Algerian location map of the study area. (c) Regional location map of the study area.

N°	Province	Number municipalities	Area Km^2	Population 2008
01	Ouargla	21	211 980	558 558
02	Ghardaia	13	86 105	363 598
03	El-Oued	25	54 573	647 548
04	Illizi	06	284 618	52 333
05	Tamanrasset	10	557 906	92 635
Total		75	983 202	1 714 672

Table 1.
Administrative breakdown [4].

The Sahara is characterized by low rainfall, recording less than 100 mm per year. It does happen, however, that it snows and floods sometimes revive the wadis that have dried up since prehistoric times. High temperatures can exceed 45 ° C especially in summer, winter is generally mild with average temperatures ranging from 8 to 12 ° C. The subsoil is full of water in the Albian tablecloth which extends under a large part of the Algerian Sahara, a vestige of the steppe climate that the region experienced 10,000 years ago. In 2018, it is home to a population of 3,600,000 inhabitants, or 10.5% of the Algerian population. Our investigation in this document concerns 10 wastewater treatment plants in 5 provinces in southern Algeria (**Table 1**).

3. Extensive processes in the Algerian Sahara

Groundwater is the main source of water in the Algerian Sahara; the preservation of this precious resource from all types of pollution is essential; to this end, the treatment of wastewater in the Algerian Sahara is a requirement and an inescapable social and environmental issue. The extensive process is used in most of the Saharan areas, it is ecological insofar as it does not use any chemical product to treat wastewater and evacuate it safely to the receiving natural environment [5].

We noted more than 90% of the planned purification stations in the Algerian Sahara have extensive processes, the extensive solutions characterized with a large area and totally or partially dependence on natural purification processes in which the concentration of purifying organisms is low [6]. They do not involve recycling of bacterial liquor. Among these processes we note: lagooning and spreading. They bring into play complex natural self-purification phenomena dependent on climatic conditions. These extensive solutions require large footprint areas, implementation is essential and the quality of construction depends in part on the purification performance. They generally require little electromechanical equipment and are known for their hardiness and ability to adapt to variations in organic and hydraulic loads [7].

3.1 Natural lagoon

Natural lagooning is an interesting wastewater treatment process, particularly for small communities, and has been relatively developed since the 1970s [8].

Among the ten stations observed 3 stations (**Table 2**). planned using the natural lagooning process, we are talking about the stations of Djanet, M'Zab, and Illizi (**Figures 2–4**), these stations were abused in 2011; 2012 and 2019 respectively. The largest is that of Ghardaïa, which was built during the period 2008–2012

N°	Province	Station	Zone	UTM coordinates		
				X	Y	Z
01	Ghardaïa	Al-Attuef	31S	575518.34 m E	3589342.52 m N	435
02	Illizi	Illizi	32R	441295.27 m E	2930379.60 m N	554
		Djanet	32R	546961.85 m E	2703766.31 m N	995

Table 2.
Coordinates of natural lagoon stations.

Figure 2.
Ghardaia wastewater treatment plant.

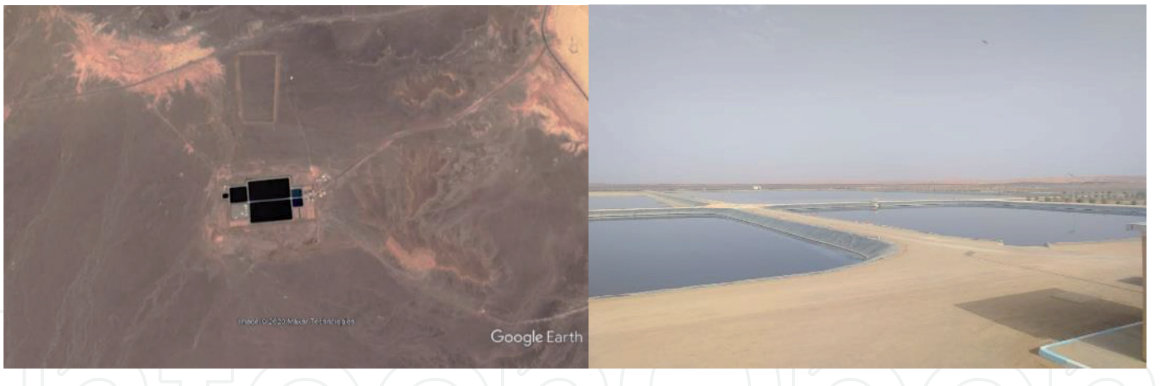

Figure 3.
Illizi wastewater treatment plant.

Figure 4.
Djanet wastewater treatment plant.

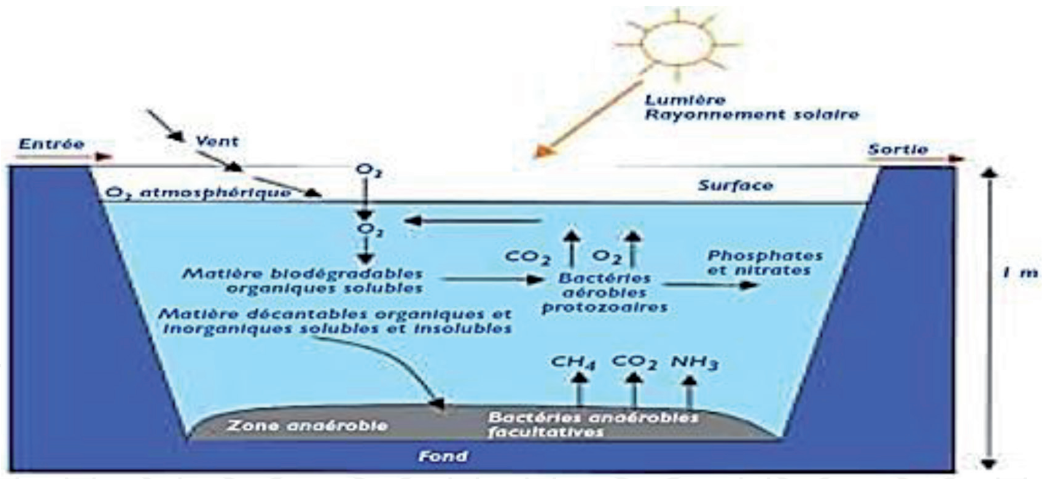

Figure 5.
Mechanisms involved in natural lagoon basins [10].

by the companies AMENHYD SPA as a production company and AQUATECH-AXOR (Canada): a control and monitoring design office; it was commissioned in November 2012 for a maximum capacity of 46,400 m^3/d, corresponding to 331,700 eq/inhab. by 2030. The station spread over 79 ha, has 16 basins divided into 02 floors finalized by 10 drying beds [9].

The purification is ensured through to a long residence time, in several watertight basins arranged in series. The most commonly encountered number of basins is 3. However, using a configuration with 4 or even 6 basins allows more thorough disinfection. The basic mechanism on which natural lagooning is based is photosynthesis. The upper water section of the basins is exposed to light. This allows the existence of algae which produce the oxygen necessary for the development and maintenance of aerobic bacteria (**Figure 5**). These bacteria are responsible for the degradation of organic matter [10].

The carbon dioxide formed by bacteria, as well as the mineral salts contained in wastewater, allow algae to multiply. There is thus a proliferation of two interdependent populations: bacteria and planktonic algae, also called "microphytes". This cycle is self-sustaining as long as the system receives solar energy and organic matter.

At the bottom of the pool, where light does not penetrate, it is anaerobic bacteria which degrade the sediments resulting from the settling of organic matter. A release of carbon dioxide and methane occurs at this level [10].

This type of process was chosen in these regions for various reasons, such as the low energy use or almost non-existent, especially if the difference in level is favorable; good elimination of nutrients phosphorus, nitrogen and pathogenic germs especially in summer when the high temperature. It adapts well to strong variations in hydraulic head which can favor the presence of the water table close to the surface. We also noted in these stations an absence of noise pollution with stable sludge and good integration into the landscape.

On the other hand; these stations encountered several obstacles during the design and operation, such as the large footprint (10 to 15 m^2/pe); investment cost very dependent on the nature of the subsoil. In the Saharan regions, where the terrain is sandy and unstable, this type of process is not recommended; which remains a contradiction with the location of these stations.

For the technical aspect, we noted that the purification performance is lower than intensive processes on organic matter. However, the release of organic matter takes place in the form of algae, which is less harmful than dissolved organic matter for the oxygenation of the environment downstream; and the control of the biological balance and the purification process remains limited. With a variable quality of

Figure 6.
Ouargla wastewater treatment plant.

Figure 7.
Tamanrasset wastewater treatment plant.

Figure 8.
Sidi khouild wastewater treatment plant.

Figure 9.
Kouinin wastewater treatment plant.

N°	Province	Station	Zone	UTM coordinates		
				X	Y	Z
01	Ouargla	Ouargla	31R	723557.44 m E	3542455.78 m N	129
		Sidi Khouiled	31R	729649.40 m E	3542586.63 m N	135
02	El-Oued	Kouinine	32S	300095.71 m E	3699943.49 m N	69
03	Tamanrasset	Tamanrasset	31Q	756780.31 m E	2519993.29 m N	1360

Table 3.
Coordinates of aerated lagoon stations.

Station	Year	Capacity Eq/inhab	Treated flow (m^3/d)	Receiving medium
Ouargla	2008	260.000	13986	Sebkhat Sefioune
Sidi khouiled	2010	7.156	995	Oum Raneb
Kouinine	2009	246.300	33251	Chott Haloufa
Tamanrasset	2011	228667	18000	Oued Tagrambait

Table 4.
Characteristics of aerated lagoon stations.

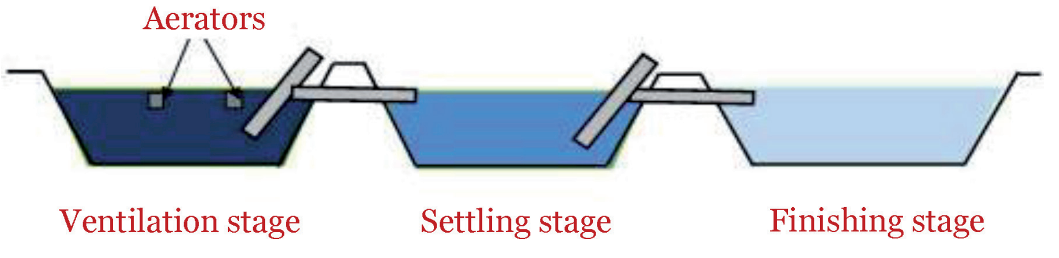

Figure 10.
Principle of aerated lagooning [12].

discharge depending on the season, especially in summer when the temperature is very high, which causes very strong evaporation, which influences the concentration of water in the lagoons and the formation of algae due to the long insolation period.

3.2 Aerated lagoon

In the Algerian Sahara, the aerated lagoon system is used frequently; we have identified four stations (**Figures 6–9**) among ten (Ouargla, Sidi Khouiled, Kouinin, Tamanrasset), where the largest nominal capacity is that of Kouinin with a flow of 33,251 m^3/d (**Tables 3** and **4**).

In this type of process, oxygenation is provided mechanically by a surface aerator or air blowing (**Figure 10**). This principle differs from activated sludge only by the absence of a sludge recycling system or continuous sludge extraction. The energy consumption of the two sectors is, at equivalent capacity, comparable (1.8 to 2 kW/kg BOD5 eliminated) [11].

The Algerian authorities often orient themselves towards this system since this system is very tolerant to variations in significant hydraulic and organic load as in the case of the regions mentioned above as well as their tolerance to effluents imbalanced in nutrients.

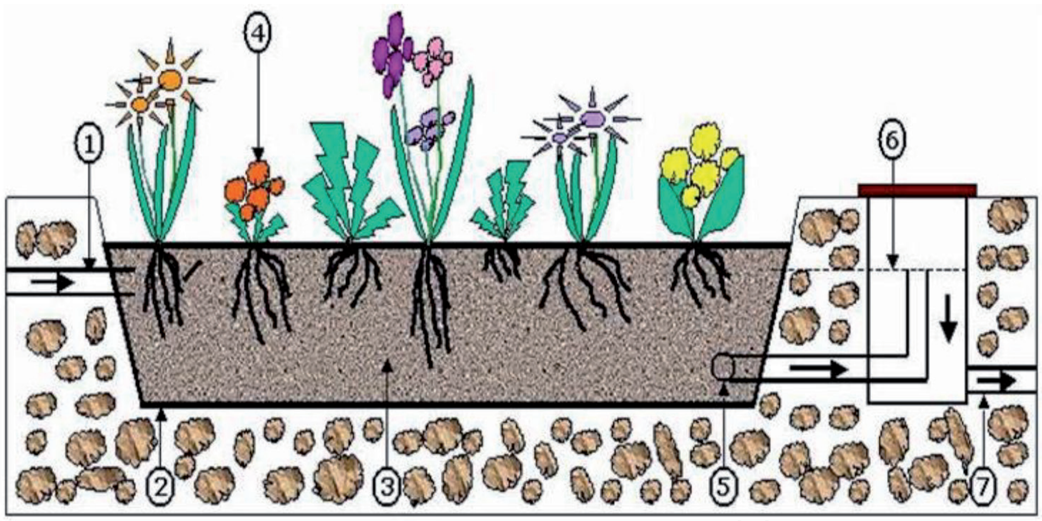

Figure 11.
Principle of wastewater gardens system [12].

According to our investigations, in addition to the average quality of rejection on all parameters and noise pollution, the station managers have some problems such as high energy consumption, and the presence of electromechanical equipment requiring maintenance by a specialized agent; which sometimes takes a considerable amount of time with a non-operating station.

Among the most apparent problems in the region is the inflow of water from the water table and the excess parasitic irrigation in the sewerage network which can influence the performance of the station in two due to the high salinity of the water who can wait 13000 μ/cm, and the rapid change in raw sewage concentration.

3.3 Wastewater gardens system (WWG)

The Wastewater Gardens unit is an eco-technology that uses ecologically based wastewater treatment principles [11].

Is a waterproofed basin, filled with gravel and plants whose roots are tolerant of water saturated conditions (**Figure 11**). There may be one or more compartments, depending on the size of the system and the area available for construction. The efficiency of a Waste Water Gardens pond is based on the time the wastewater residences within it before they flow into the drain area.

We have identified two stations in our region using this system.

3.3.1 Horizontal flow planted filters

The Temacine pilot station (**Figure 12**) is located in the city of Temacine next to old Ksar (**Table 5**), it was mainly created with the aim of treating 15 m^3/d of wastewater by the production of 100 people and at a reasonable rate. of 150 l/inhabitant/day. The surface of the WWG basin is 400 m2, and the total volume is 260 m^3. The water level in the basin is 0.5 m, covered by a layer of gravel ranging from 10 to 15 cm (gravel is a physical filter). The WWG basin is also filled with plants that can live in an environment saturated with wastewater (plants collect their nutrients and water through their roots).

This system offers low energy consumption; no need for advanced qualification for maintenance; and good reaction to load variations. On the other hand; this system has not been developed in the region because of their strong footprint, including the surrounding area, this is of the order of 10 m^2/pe (equivalent to the footprint of a natural lagoon).

Figure 12.
Temacine wastewater treatment plant.

N°	Province	Station	Zone	UTM coordinates		
				X	Y	Z
1	Ouargla	Temacine	32S	221565.67 m E	3657276.93 m N	80

Table 5.
Coordinates of horizontal flow planted filters stations.

3.3.2 Planted vertical flow filters

The wastewater treatment plant by vegetation located in the commune of N'goussa (**Figure 13**). The station is located at the lowest point of the sewage network (**Table 6**). Installed in 2010 and has been in operation since 2011. Use of solar energy pilot project of the WWTP. The characteristics of the releases are typically those of a domestic release. The treatment plant with filters planted with vertical flow reeds is made up of four parallel basins planted with reeds, each basin is divided into three equal parts operating alternately. Each basin is made up

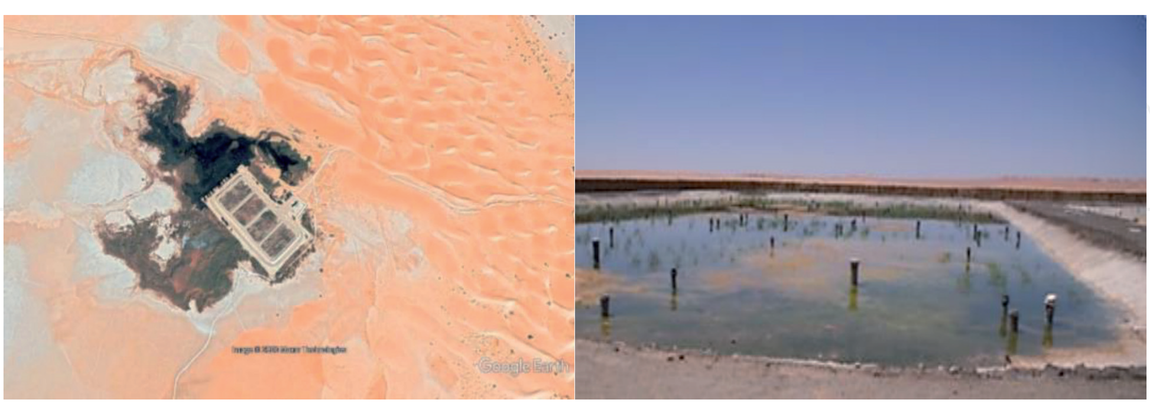

Figure 13.
N'Goussa wastewater treatment plant.

N°	Province	Station	Zone	UTM coordinates		
				X	Y	Z
1	Ouargla	N'Goussa	31R	715432.22 m E	3558668.84 m N	118

Table 6.
Coordinates of vertical flow planted filters stations.

of three main inlets evenly distributed along the basin (one entry to each part), where each inlet fork tubes intended for supply by tarpaulins. The treated water collects in front of the second basin for reuse in watering the trees of the station and the rest is thrown towards the Sebkha of N'Goussa. The station has a capacity of 11000 Eq/hab and a nominal flow of 1743 m^3/d for a residence time of 3 days for each basin.

This system offers ease and low operating cost with reduced management to a minimum of organic deposits retained on the filters of the 1st stage; and good adaptation to seasonal population variations [13].

Besides the risk of the presence of insects or rodents, managers talk about the constraints of regular exploitation, annual mowing of the aerial part of the reeds, manual weeding before the predominance of reeds.

Using this sector for capacities greater than 2000 pe remains very delicate for questions of control of hydraulics and cost compared to conventional sectors.

4. Intensive processes in the Algerian Sahara

4.1 Activated sludge

The Touggourt wastewater treatment plant (**Figure 14**) is located in Ben Yassoued (**Table 7**), in the municipality of Tebesbest. It covers an area of 5 hectares. It was commissioned on 20/11/1993 and rehabilitated in 2004 currently managed by the national sanitation office (ONA), planned for 62,500 population equivalents and a daily flow of 9360 m^3/d.

Among the ten stations treated in this document, we noted that the only station with an intensive process is that of Touggourt by activated sludge, its principle resides in an intensification of the self-purification processes that are encountered in natural environments [14]. The bacteria float in flakes in the wastewater and the purification process takes place under intense aeration (**Figure 15**). Aerobic and anaerobic (oxygen poor) conditions can be altered in space and time so that nutrients too (such as nitrogen and phosphorus) can be removed [15].

Figure 14.
Touggourt wastewater treatment plant.

N°	Province	Station	Zone	UTM coordinates		
				X	Y	Z
1	Ouargla	Ben Yassoud	32S	228323.38 m E	3666543.82 m N	64

Table 7.
Coordinates of activated sludge station.

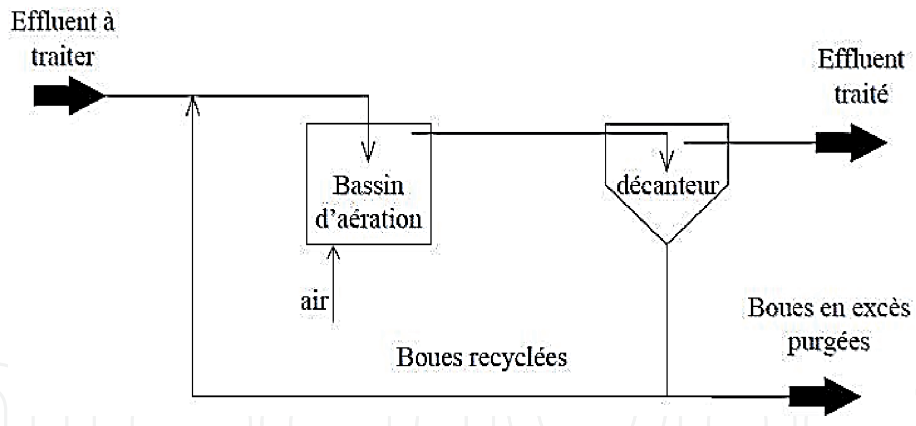

Figure 15.
Basic diagram of the activated sludge process [14].

We have noted that this system offers good elimination of all the pollution parameters (COD, BOD5, MES, N) by nitrification and denitrification; plus an easier implementation of dephosphorization. It is a system suitable for the protection of sensitive receiving environments such as that of Oued Righ.

On the other hand, in addition to the investment cost and energy consumption of this type of stations are quite high, the station encountered several technical and managerial problems such as the need for qualified personnel and regular monitoring; sensitivity to hydraulic overload and difficulty in controlling sludge production.

As the situation of the station in the middle of an area of palm groves, among the most apparent problems in the region is the inflow of water from the water table and the surplus of parasitic irrigation in the sanitation network which can affect the performance of the two stations by the high salinity of the water that can be expected, and the rapid variation in the concentration of raw sewage.

5. Conclusion

Through this chapter, we tried to shed light on the wastewater treatment component in the Algerian Sahara through a description of the different systems used and to discuss their reliability and constraints.

The purification techniques adopted in the Algerian Sahara are limited to three processes: lagooning process, plant filter and activated sludge. Furthermore, the cost of installing and maintaining these sectors requires significant human and financial resources which are difficult to bear in our region.

We noted that the main objective of these stations in the Sahara is the protection of the environment and the almost non-existent tertiary treatment, for this the practice of reuse of purified wastewater remains very limited to the time that these regions have a subsoil. of the largest freshwater table in the world (Intercalary Continental).

The document clearly explained that 70% of stations in the Algerian Sahara using lagooning where 40% are stations by aerated lagooning, which remains a choice which has been subject to constraints such as high energy consumption, and the presence of electromechanical equipment. Requiring periodic maintenance by specialists. Only two pilot stations using plant purification; this system has not been developed in the region because of their strong footprint, the use of this system remains very delicate for issues of hydraulic control and cost compared to conventional channels.

Due to investment costs there are almost no active mud stations and the energy consumption of this type of station is quite high.

The improvement of these wastewater treatment techniques has resulted in an increase in by-products, these by-products, and particularly the sludge which represents the largest volumes, must be conditioned and disposed of in the most appropriate way, this which adds additional equipment to the wastewater treatment plants.

Therefore, it is necessary to explore new wastewater treatment technologies, reliable loads and adapted to the realities of our country Algeria.

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