Journal of Applied Science and Environmental Studies
JASES
http://revues.imist.ma/index.php?journal=jases

Original Paper

IMPROVEMENT OF WASTEWATER TREATMENT FOR AGRICULTURAL REUSE IN THROUGH A SYSTEM CONSISTING OF SEDIMENTATION BASIN AND HORIZONTAL SUBMERGED FLOW CONSTRUCTED WETLAND, IN THE TECHNOPOLE AREA OF DAKAR, SENEGAL

D. BOP[1*], O. GUEYE[1], A. NDOYE[2]

[1]University Cheikh Anta Diop, Dakar;Sciences and technologies Faculty
[2]laboratory and discharge control department. National Sanitation Office of Senegal
* Corresponding author. E-mail address: dame1bop@gmail.com

Received 10 March 2020; Revised 15 August 2021, Accepted 20 September 2021

Keywords
Constructed wetland, pretreatment, septic tank, Technopole.

Abstract
The present research aims to study the improvement in the performance of wastewater treatment within the WWTP of the Technopole area of Dakar through a system consisting of a septic tank and a horizontal submerged flow constructed wetland, planted with reeds. A volume of wastewater equal to 2000 L is treated daily. The pretreatment function performed by the septic tank leads to a removal yield of 48.7% for TSS, 49% for BOD, 31% for COD and 77% for E. coli compared to inlet wastewater. After a stay of 24 hours inside the septic tank, the clarified wastewater passes through a horizontal flow constructed wetland. The removal yields are 91% for TSS, 82% for BOD, 75% for COD and 99.5% for E. coli with respect to inlet wastewater. However, even after the treatment and the storage, some outlet parameters, such as E. coli, did not meet the limits of WHO and FAO guidelines for the reuse of treated water for irrigation nor the Senegalese standard for the discharge of wastewater. Therefore, disinfection through bleach was used to improve the treatment. Results after disinfection reported a complete removal of E. coli, yields of 97% for BOD and 68% for COD.

1. Introduction

In developing countries, the deficit in sanitation infrastructure has contributed to the underestimation of the issue of wastewater discharge in natural environments, exposing them to the risk of pollution and contamination of water resources; that worsens water crisis and reduces the exploitable resources potential. All human activities, whether they are domestic, industrial,

agricultural or artisanal, produce wastewater [1]. Water scarcity creates the need to use unconventional water resources for several possible uses (civil, industrial, agricultural, recreational, etc.) [2]. Wastewater purification is therefore necessary if we want to increase water availability through the recycling for industrial or agricultural purpose, in order to protect marine and living environment [3]. Phytoremediation is a treatment technique that has been tested since the early 1930s and has been widely and positively acknowledged throughout the world [4]. The first experimentations aimed at treating wastewater with plants were undertaken by Käthe Seidel in Germany in the early 1950s at the Max Planck Institute in Plön [5]. Constructed wetlands are treatment units that simulate naturally flooded areas and have mechanisms for removing pollutants similar to the ones of medium-sized microorganisms systems [6].

Many studies have confirmed the considerable benefits of treatment wetlands, such as high purification efficiency, relatively low costs, easy-to-handle technique, CO_2 consumption and O_2 production [7]. This treatment technique is particularly known for being ecological and economical. It is used in several countries belonging to different regions characterized by different climates. Phytoremediation involves technologies based on natural processes involving plants, soil and related microbial association in order to treat wastewater [8]. Wastewater simply flows through one or more open ponds populated by aquatic plants. The reed (also called *Phragmites*) and other aquatic plants belonging to the group of macrophytes have been widely used for this purpose. The rhizosphere is the most reactive portion of soil in which physical, chemical and biological processes of pollutant removal take place [9]. Phragmites Australis and Typha latifolia are two macrophytes most commonly found in natural and artificial wetlands. The roots of these plants interact with a wide range of microorganisms, collectively termed microbiota. Microbiota plays a key role in the natural phytodepuration process, whereby pollutants are removed from contaminated water bodies [10]. Recently, constructed wetlands are starting to be used for wastewater treatment with high concentrations of pollutants, such as sewage sludge with COD greater than 5000 mg/L [7]. The conclusions of the first part of the work that has been done on the study area, entitled "Assessment of water quality (treated wastewater, groundwater and surface water) in the Technopole zone of Dakar, Senegal" (in preparation), revealed that the area surrounding the wastewater treatment plant is the most polluted one inside the Technopole. This is caused in particular by the amount of wastewater coming from the treatment plant which is largely overloaded.

The context in which the problem is inserted has imposed the need to find sustainable solutions adapted to the socio-economic, technical and financial realities of the country to improve the treatment of wastewater that is destined to be reused in market gardening. The choice of treatment technology to be developed must satisfy the needs of the population and depend on the availability of resources and the characteristics of the territory. Hence, we have tested a pilot system consisting of a septic tank, a horizontal flow constructed wetland planted with reeds and a storage tank to collect treated wastewater to be reuse in market gardening.

2. Experimental details

2-1. *Study area: the wastewater treatment plant in Niayes, Pikine (Technopole).*

The experimentation has been done inside the Niayes wastewater treatment plant in Pikine. The plant was commissioned in June 2008 and it processes wastewater through activated sludge. It is located in the Technopole area situated in the Grande Niaye, in the department of Pikine in Dakar. *Niaye* is a local term that refers to interdune depressions where agricultural practices are carried out [11]. The Niayesis the agro-ecological region that occupies the Atlantic region of Senegal from Dakar to St-Louis [12].

The National Sanitation Office of Senegal ONAS is a public institution that oversees the collection, operation and maintenance of sewage and rainwater sanitation facilities. It is the service that deals with the management of the WWTP.

The area where the WWTP is located is made up of three parts:

- the part managed by ONAS, which cares of wastewater treatment, where the WWTP is installed.
- the private part managed by Delvic Sanitation Initiatives (DSI). Delvic Sanitation Initiatives is a Senegalese owned and managed company with the mission of building a profitable and sustainable business providing sanitation solutions adapted to West African market needs. It is the party that manages the collection and transport of wastewater from septic tanks in the nearby neighbourhood (Pikine, Cambéréne, Parcelles Assainies) that do not have collective sanitation system. Sludge is transported by trucks of 8m^3, 10 m^3 and 16 m^3. This part performs the pre-treatment of wastewater (sedimentation) before sending it to the WWTP for treatment. About 500m^3 of wastewater is supplied daily by the Delvic part to the WWTP. One of the reasons why the water treated by the WWTP is of poor quality comes from Delvic: the normal amount of wastewater that Delvic have to supply to the WWTP is 60 m^3 per day. In addition, pre-treatment does not work properly, so wastewater provided by Delvic contains significant amount of sludge. Recently, a flocculation system that uses aluminum sulphate as reagent has been installed to further decant the sludge contained in wastewater.
- Bill & Melinda Gates Foundation Omni-Processor: it is a group of physical, biological or chemical processes to treat faecal sludge. The machine is located in the area in order to receive and treat the sludge produced by the Delvic part. Its role is to transform sludge into energy.

Apart from wastewater supplied by Delvic, the WWTP also receives the wastewater from the Guédiawaye pumping station. This pumping station supplies about 2500 m^3 of wastewater per day. By contract, the normal amount of wastewater to be supplied by the pumping station to the WWTP should be 825 m^3, thus confirming the quantities of wastewater that far exceed the acceptance standards of the WWTP.

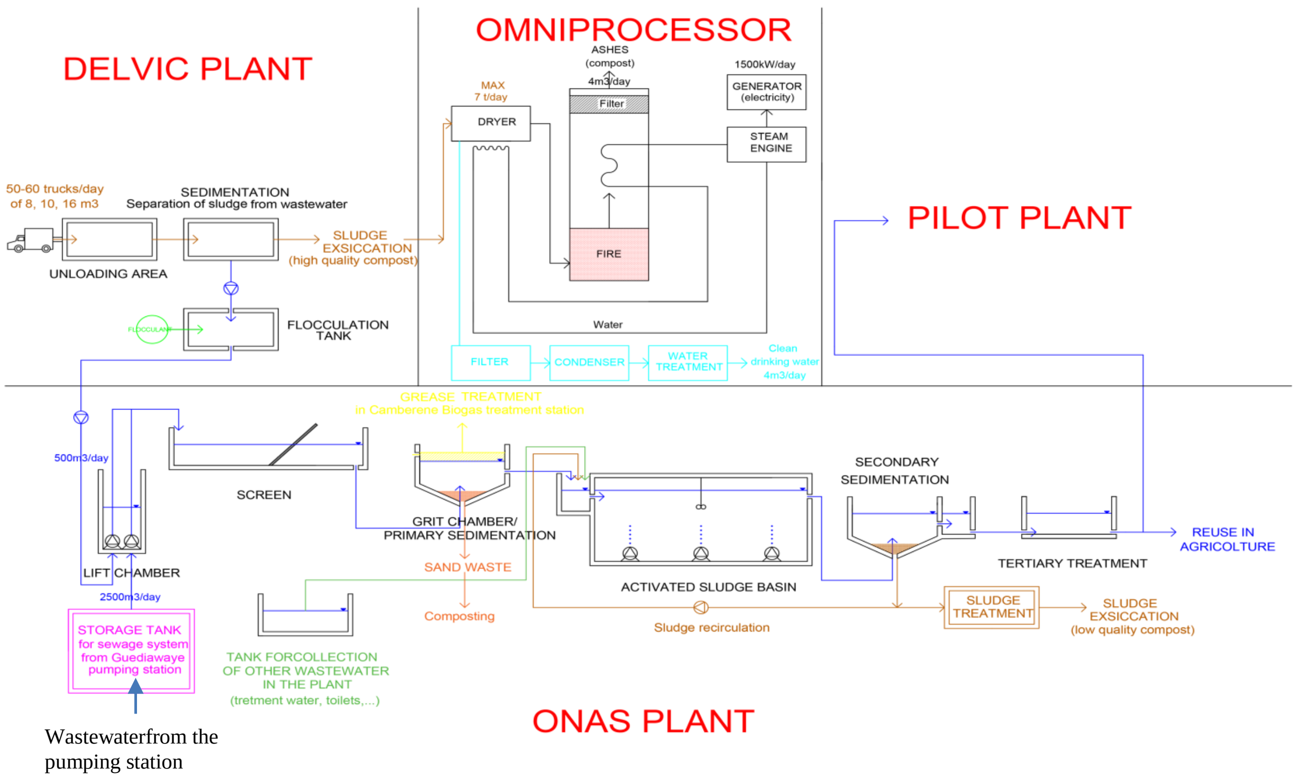

Figure 1: Scheme of the wastewater treatment path of the treatment plant of Technopole.

Tests were carried out by the National Sanitation Office of Senegal, ONAS, on the different wastewaters received and the water treated by the WWTP. The results are in Tables 1 and 2.

Table 1: Results on raw wastewater from the Niâyes WWTP; EB (raw water) (Mixture between wastewater at the outlet of Delvic plant and from the pumping station of Guédiawaye) from 07/08/2018 to 27/11/2018.

pH	Cond (µS/cm)	Salinity (mg/L)	TSS (mg/L)	BOD (mg/L)	COD (mg/L)	TKN (mg/L)	P_{TOT} (mg/L)	Fecal Coliforms (UFC/100mL)
7.54	4150	2100	2340	1100	5430	-	-	$6.3*10^6$
7.52	3110	1500	950	900	2300	-	-	-
7.57	3990	2000	1390	800	2670	-	-	-
7.65	3170	1600	632	700	1604	-	-	$6.5*10^6$
7.68	2510	1200	404	650	1154	-	-	-
7.42	1643	600	1350	800	2248	-	-	-
7.71	4050	2100	700	400	1598	-	-	-
7.33	2420	1100	27940	1800	21840	-	-	-
7.51	3490	1700	868	550	1928	431.3	23.5	-
7.52	2500	1100	360	550	2244	-	-	10^6
7.56	2480	1100	900	750	2112	-	-	-
7.64	2090	900	476	350	1132	-	-	-
8.03	3720	1900	653.3	650	1337	481.4	16.0	-
7.55	3520	1800	720	700	1724	-	-	-
7.52	3080	1500	473.3	900	1436	-	-	-
7.52	2880	1400	524	1200	1481	-	-	-

Table 2: Results on treated wastewater at the outlet of ONAS WWTP: EC (clarified water) from 07/08/2018 to 21/11/2018

pH	Cond (µS/cm)	Salinity (mg/L)	TSS (mg/L)	BOD (mg/L)	COD (mg/L)	TKN (mg/L)	P_{TOT} (mg/L)	Fecal Coliforms (UFC/100mL)
7.81	3310	1600	448	400	956	-	-	$3.7*10^6$
7.75	3180	1600	540	320	1144	-	-	-
7.81	2470	1100	500	320	1020	-	-	-
7.89	2380	1100	212	175	415	-	-	-
7.87	2400	1100	520	200	603	-	-	$1.3*10^5$
7.86	2460	1100	276	180	646	-	-	-
7.93	2470	1100	228	200	627	-	-	-
7.91	2470	1100	324	160	680	-	-	-
7.91	2440	1100	500	220	894	-	-	-
7.79	2470	1100	360	180	892	271	5.8	-
7.85	2430	1100	132	200	768	-	-	$1.6*10^6$
7.82	2460	1100	256	240	618	-	-	-
7.59	3360	1700	236	180	536	-	-	-
8.23	3580	1900	240	200	559	-	-	-
7.90	3450	1700	264	200	33	-	-	-
7.79	2520	1200	220	440	564	-	-	-

2-2. *Materials and Methods :*

This section deals with the sizing and construction methods used for the pilot plant, with a focus on constructed wetland; this technology has been chosen among the most appropriate treatments for the management and depuration of wastewater in the Senegalese context. Furthermore, the methods of analysis of chemical, physical and microbiological parameters are explained, as well as the monitoring plan for experimentation in Senegal.

The configuration of the system presents, from upstream to downstream, a septic tank (with a closing valve) which is at the same time a loading tank, a sedimentation tank and also feeds the filter, a horizontal flow sand filter planted with reeds and a storage tank for treated water where the disinfection phase takes place (Figure 2).The disinfection by bleach was carried out on the filtered water, because after the treatment the values of some parameters (in particular E. coli) did not comply with the guidelines suggested by WHO and FAO on wastewater to be reused for irrigation nor with the Senegalese standards for the discharge of wastewater.For each 150 ml sample of filtered water, 0.05 ml of bleach was added. Orthotolidine test method was used in order to be sure not to exceed the residual chlorine limit for wastewater reuse (FAO).*Phragmites australis* (Common Reed) is the macrophyte used for the constructed wetland. It is by far the most widely used plant in the world for the planting of treatment wetlands with horizontal subsurface flow[13]. Reed has several properties that make this species particularly suitable. The main one is represented by the particularly deep roots and rhizomes which create a large volume of activate rhizosphere per unit surface [14]. Figure 2 shows a simplified scheme of the pilot plant and Figure 3 a picture of the installation inside the wastewater treatment plant.

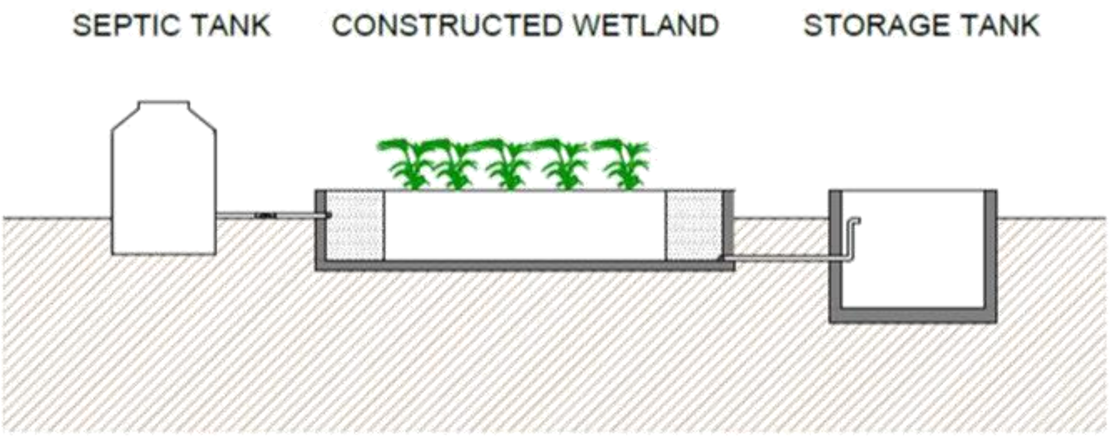

Figure 2: Simplified scheme of the system configuration.

Figure 3: Picture of the installation inside the wastewater treatment plant of Technopole, Dakar.

Figure4: Evolution of the installation a year later.

2-3. *Dimensioning criteria:*

Septic tank: The septic tank used is a 3000 L precast plastic tank. Its role is to store the wastewater to be treated for 24 hours as a pretreatment (sedimentation), and to feed the filter the next day.
The tank is considered to consist of four zones: sedimentation zone, sludge digestion zone, digested sludge storage zone, scum storage zone. The calculations of the volumes of the different parts led to a total volume of the septic tank of 3000L. The supply pipe of the constructed wetland is located at 0.6 m from the bottom of the septic tank: it creates a volume of 1000 L on the bottom of the tank reserved for the digestion and the storage of digested sludge, in order not allow the sludge to pass through the pipe, and the remaining volume (2000 L) is used to supply the filter. The flow that enters the system has been set at 2000 L / day, by design choice, and therefore this configuration allows the system to function even in the absence of a pumping system capable of continuously feeding the septic tank. Table 3 shows the dimensions of the septic tank used.

Table 3 : Septic tank dimensions.

	height (m)	diameter (m)	volume (L)	Q (L/d)	HRT (d)
Septic tank	2.15	1.42	3000	2000	1

Horizontal filter: The data used to determine the dimensions of the filter were obtained in the first part of the work, "Assessment of water quality (treated wastewater, groundwater and surface water) in the Technopole zone of Dakar, Senegal". This work allowed us to evaluate the parameters of the pollutants of water treated by the WWTP. In particular, the mathematical model used to determine the dimensions of the filter is the one proposed by the US Environmental Protection Agency (EPA), which suggests the calculation of the area needed to remove major pollutants [15].

$$A = L * W = \frac{Q*(lnCi - lnCe)}{n*Kt*0.95*d}$$

where 0.95 is a required safety factor, n = porosity of bed = 0.35 for sand, L = bed length, W = width of the bed, d = depth of the bed, Q =average flow that pass through the filter [m^3/d], A = surface area [m^2]. Table 4 provides the dimensions of the filter.

Table 4: Horizontal filter dimensions.

	length (m)	width (m)	depth (m)	A (m^2)	Q (L/d)	HRT (d)
Horizontal filter	5.5	1.5	0.8	8.25	2000	1

Sampling site:

We decided to take the sample to be analysed in 5 different positions of the pilot plant, in order to verify the yields of all the parts (Figure 4):

• IN Septic tank: the bottle for the sample has been filled directly from the pipe at the inlet of the septic tank and at the outlet of ONAS plant; we were able to study the characteristics of the input wastewater of our treatment system;

• IN Constructed wetland: the bottle for the sample has been filled from a tap in the septic tank at the same level as the filter supply pipe; we were able to measure the the performance of the septic tank;

• IN Storage tank: the bottle for the sample has been filled from the pipe entering the storage tank; we were able to compute the efficiency of filtration and phytoremediation and check whether the filter is working or not and how fast water is passing;

• OUT Storage Tank: the bottle for the sample has been filled from the tank; it was possible to calculate the worsening or the improvement of water characteristics due to long exposition to open air;

• OUT Disinfection: the bottle for the sample has been filled from the tank and then, in the laboratory, the amount of disinfectant corresponding to a given sample volume has been added; it was possible to know the disinfection yields and, at the same time, the actual characteristics of water at the outlet of the system to be used in agriculture.

For each sampling site, in situ analysis were performed for the following parameters: dissolved oxygen, temperature, conductivity, pH, total dissolved solids.

3. Results and discussion

The wastewater whose treatment must be improved are the effluent from the Niayes wastewater treatment plant from Pikine to the Technopole.

The parameters of the wastewater to be improved are variable because the wastewater at the outlet of the treatment plant is not constant in terms of volume nor level of pollution. The characteristics of these waters have been mentioned in Table 2.

In order to determine the performance and to increase the yields of our treatment system (septic tank and constructed wetland), the following pollution parameters were analyzed through measurements in situ and at the laboratory: temperature, dissolved oxygen, pH, conductivity, chemical oxygen demand COD, biological oxygen demand BOD, total suspended solids TSS, total nitrogen, total phosphorus, nitrates, nitrites, residual chlorine, sodium absorption ratio SAR, Escherichia coli.

Septic tank:

It is installed as a pre-treatment and to feed the filter; it removes part of the pollution of the water destined for filtration, reducing parameters such as total suspended solids TSS, chemical oxygen demand COD, biological oxygen demand BOD and Escherichia coli.

The septic tank plays an important role in improving water quality. Pollution parameters such as pH, conductivity, salinity and temperature are not affected by the 24-hour stay in the septic tank. The average values of these parameters at the inlet and at the outlet of the septic tank are generally not very different. The septic tank has virtually no effect on these parameters. pH is the most constant parameter after pre-treatment, which is justified by the buffer capacity of wastewater; the results of other works, such as [16], have confirmed that. Instead, total suspended solids TSS, biological oxygen demand BOD, chemical oxygen demand COD, Escherichia coli of pre-treated water are improved. The retention time in the septic tank is 24 hours, therefore consistent with literature that suggests one to three days of detention [17].

Table 5: Water quality parameters at the inlet and outlet of the Septic Tank, removal yields.

Water quality parameters	Dates	pH	Cond (mS/cm)	D.O (mg/L)	Temp (°C)	Salinity (g/L)	TSS (mg/L)	BOD_5 (mg/L)	COD (mg/L)	E. Coli (UFC/100 mL)
IN septic tank – IN constructed wetland	22/10 - 23/11	7.96 - 7.98	3.68 - 3.73	-	30.0-29.9	1.1-1.1	468 - 207	300 - 140	1078 - 527	5250000 - 1050000
	06/11 - 07/11	7.97 - 8.32	4.37 - 3.21	0.010-0.008	28.3-28.0	1.1-1.4	56-166	160 - 260	562 - 515	-
	12/11 - 13/11	7.96 - 7.93	2.84 - 2.87	0.009-0.015	27.9-25.9	1.3- 1.2	436 - 138	380 - 140	759 - 510	3590000 - 900000
	14/11 - 15/11	7.94 - 7.94	3.39 - 3.22	0.010-0.014	25.7-25.3	1.7-1.6	330 - 52	440 - 300	407 - 209	1200000 - 200000
	27/11 - 28/11	7.87 - 7.88	2.53 - 2.54	0.013-0.000	25.6-26.6	1.2-1.2	266 - 182	-	642 - 647	5900000 - 1200000
	03/12 - 04/12	7.93 - 7.82	2.49 - 2.91	0.015-0.014	31.2-30.0	-	380 - 248	760-200	515 - 345	1400000 - 670000
Average IN ST-IN CW		7.94 - 7.98	3.22 - 3.08	0.011-0.010	28.1 - 27.6	1.28- 1.3	323 – 165.5	408- 208	661 - 459	3468000 - 804000
Yields							48.7%	49 %	31%	77%

Suspended solids from wastewaters pass from an average of 323 mg/L to 165.5 mg/L with a removal efficiency of 48.7 %; it allows the clarification of water. Settleable organic matter is rapidly removed in the treatment system in quiet conditions by sedimentation (septic tanks) and subsequently by filtration (constructed wetland).
Biological oxygen demand passes from an average value of 408 mg/L to 208 mg/L with a removal efficiency of 49%; this value falls within the range of removal efficiency of 35 to 60% in anaerobic treatment systems for domestic wastewater suggested by [18].
Chemical oxygen demand passes from an average value of 661 mg/L to 459 mg/L with a removal efficiency of 31%; Escherichia Coli pass from an average value of 3468000 UFC/100 mL to 804000 UFC/100 mL with a removal efficiency of 77%.

Constructed wetland:

Constructed wetland system reduces many contaminants, including organic matter (BOD, COD), suspended solids, nitrogen, phosphorus, trace metals and pathogens [19].
After pretreatment by the septic tank, the filter monitoring reported a significant elimination of Escherichia coli, biological oxygen demand BOD, chemical oxygen demand COD and total suspended solids Tsps. increases slightly and becomes a little more basic from 7.95 to 8.02; however, pH is within the acceptable range of 6.5-8.5 according to WHO guidelines for wastewater reuse in agriculture (Guidelines for the safe use of wastewater, excreta and greywater - Excreta and greywater use in agriculture, WHO, 2006).Electrical conductivity decreases from 3.08 mS/cm to 2.70 mS/cm; therefore, it complies with the maximum limit of 3 mS/cm (WHO, 2006).
Dissolved oxygen (DO) improved a little from 0.01 mg/L to 1 mg/L. Knowing that the concentration of dissolved oxygen in water varies with temperature, dissolved salts, and biological activity [20], then aeration of water inside the constructed wetland and the formation of an algae layer may be some causes.
The average value of total suspended solids at the inlet of our constructed wetland is 132 mg/L, while at the outlet is 31 mg/L, with a removal efficiency of 76%. TSS removal in treatment wetlands is mainly due to physical processes, such as sedimentation and filtration, which are not temperature-dependent processes [20]. The TSS concentration of 31 mg/L in filtered water intended for irrigation complies with Senegalese wastewater discharge standards NS 05-061 July 2001, in which the maximum is 50 mg/L.
The growth and the decomposition of algae present in stagnant water for a long period inside the storage tank cause recontamination of the filtered water. Similar results have already been observed by other authors [21]. As a result, suspended solids in filtered and subsequently stored water are sometimes higher than those at the outlet of the constructed wetland.
The average value of biological oxygen demand BOD at the inlet of constructed wetland is 211 mg/L, while at the outlet is 87 mg/L, with a removal efficiency of 59 %. This outlet value is slightly higher than the limit in Senegalese wastewater discharge standard [22], which is 80 mg/L in the case the maximum daily flow does not exceed 30 kg/day. Removal of organic matter from wastewater in constructed wetlands can be achieved either by absorption by the roots of macrophytes or by aerobic degradation. Aerobic degradation of soluble organic matter is governed by the following reaction by means of aerobic heterotrophic bacteria [19]:

$$Organic\ matter + O_2 \rightarrow CO_2 + H_2O$$

The aerobic zones in the constructed wetland occur around roots and rhizomes, thanks to Aerenchyma, a spongy tissue that forms air channels in the roots of some aquatic plants; it allows exchange of oxygen with the part of the plant above the water and create oxidized zones in the rhizosphere. During the passage of the wastewater through the rhizosphere, the wastewater is cleaned by microbiological degradation and by physical/chemical processes. In these zones most of the organic content in the wastewater is decomposed into carbon dioxide and water using oxygen as terminal electron acceptor [14].

The average value of chemical oxygen demand COD at the inlet of constructed wetland is 520 mg/L, while at the outlet is 178 mg/L, with a removal efficiency of 66%. This outlet value complies with the maximum limit for Senegalese wastewater discharge standards [22], which is 200 mg/L in the case the maximum daily flow does not exceed 100 kg/day.

Escherichia coli are bacteria that indicate recent fecal contamination [23]. The average value of Escherichia coli at the inlet of constructed wetland is 846250 UFC/100 mL, while at the outlet is 17975 UFC/100 mL, with a removal efficiency of 98%. The efficiency of the filter for the removal of Escherichia Coli being high, however, the E. coli limit of 1000 / 100ml of wastewater discharge in Senegal, NS 05-061, July 2001, nor the FAO / WHO standards reuse of wastewater in irrigation are not respected. Despite the removal efficiency of Escherichia Coli is high, neither the limit of E. coli for the discharge of wastewater in Senegal [22], equal to 1000 UFC/100 mL, nor the one suggested by WHO guidelines for the reuse of waste water in irrigation (WHO,2006), equal to 1000 UFC/100 mL, are not respected.

Table 6: Water quality parameters at the inlet and outlet of the Constructed Wetland, removal yields.

Water quality parameters	IN constructed wetland – IN storage tank								Average	Yields
Dates	31/10	02/11	05/11	07/11	13/11	15/11	22/11	28/11		
pH	7.87- 7.17	7.94- 7.96	7.83- 7.74	8.32- 8.71	7.93- 8.17	7.94- 8.23	7.82- 8.16	-	7.95 - 8.02	
Cond (mS/cm)	3.73- 2.86	3.32- 2.89	2.87- 2.94	3.21- 2.27	2.87- 2.58	3.22- 2.48	2.91- 3.06	2.54- 2.53	3.08- 2.70	
D.O (mg/L)	0.012-1.17	0.01-1.08	0.01- 1.81	0.01- 0.8	0.015- 1.21	0.01- 0.188	0.01- 0.128	-	0.01–1.00	
Temp (°C)	28.9- 28.8	30- 29	-	28- 29	25.9- 26.4	25.3- 24.8	25.7- 28.7	-	27.3 – 28	
Salinity (g/L)	1.0- 1.1	1.1- 1.0	1.2- 1.0	1.7- 1.2	1.2- 1.2	1.6- 1.1	1.4- 1.5	1.2- 1.2	1.3 – 1.2	
TSS (mg/L)	164- 36	150- 24	78- 27	166- 29	138- 30	52- 41	182- 35	125- 27	132–31	76 %
BOD5 (mg/L)	180 - 90	-	160 - 100	260 - 85	140 - 95	200 - 55	240 – 60	300-125	211 - 87	59 %
COD (mg/L)	260- 188	324- 171	421- 149	1136- 165	510- 168	345 - 164	-	647- 241	520-178	66 %
E. Coli (UFC/100mL)	1200000 - 14500	500000 - 59500	20000 -6300	670000 -14600	1800000- 10700	600000 -14200	900000 -5300	1200000 -8200	846250 - 17975	98%

The system has encountered problems with the removal of total nitrogen and a little bit with total phosphorus contained in large quantities in the wastewater to be treated. The average total nitrogen concentration of the water at the inlet of the system is approximately 318 mg/L. At the outlet of the septic tank, the total nitrogen concentration is on average 306 mg/L, corresponding to a nitrogen removal percentage equal to 4%. At the outlet of the constructed wetland, the total nitrogen concentration is on average 224 mg/L, corresponding to a 26% removal efficiency from the wetland and 29% from the total system (septic tank and constructed wetland).

For total phosphorus, the total removal rate is 39% (septic tank and constructed wetland). The average total input phosphorus concentration at the inlet of 10.86 mg / L passes to 6.6 mg / l at the outlet of the system, which respect the Senegalese wastewater discharge standards of 10 mg / l of total phosphorus.

According to Senegalese standards [22], the total nitrogen limit for the discharge of wastewater is 30 mg/L in monthly average concentration when the maximum daily flow is equal to or greater than 50 kg/day; on the other hand, the maximum limit according to WHO guidelines for the use of waste water for irrigation (WHO, 2006) is 15 mg/L. Therefore, the nitrogen concentration of water at the outlet of the treatment wetland equal to 257 mg/L is well above the acceptable limit. This confirms the literature regarding the low removal of nitrogen and phosphorus by a horizontal submerged flow constructed wetland.

The quality of the effluent at the outlet of the constructed wetland has proved to be unsuitable for agricultural use, in particular regarding to E. coli and total nitrogen as they do not meet the requirements for irrigation reuse (WHO, 2006) nor Senegalese standards for the discharge of wastewater [22]. Non-compliance concerning E. coli is expected in most of decentralized systems and therefore tertiary treatment (e.g. UV, hypochlorite or chlorine disinfection) is usually suggested whenever reuse is needed[24]. Therefore, after treating and storing the filtered water in the tank, bleach is used as a disinfectant to eliminate E. coli and possibly to reduce the concentration of biological oxygen demand and total nitrogen.

Disinfection eliminates completely E. coli in all the disinfected samples the number of E. coli is zero. The concentration of biological oxygen demand decreases significantly from an average of 78 mg/L in the water at the outlet of the constructed wetland to 11 mg/L after disinfection with bleach. However, unlike to BOD_5 and E. coli, disinfection did not contribute to improved COD removal. BOD and E. coli values of the disinfected water are in line with Senegal's wastewater discharge standards and FAO / WHO for wastewater reuse standards for irrigation.

Disinfection also reduced the total nitrogen concentration from an average of 224mg / L to 168mg / L, with a 25% removal rate. In total, the system after disinfection eliminated 47% of the concentration of total nitrogen of the water entering our system. However, nitrogen is still a problem because the finale concentration 168mg/L does not meet with Senegal's wastewater discharge standards and FAO / WHO for wastewater reuse standards for irrigation.

Sodium absorption ratio (SAR) has been determined at the inlet and at the outlet of the system. Sodium adsorption ratio (SAR) is a water quality parameter used in the management of sodium-affected soils. The formula for calculating SAR is:

$$SAR=\frac{Na^{+}}{\sqrt{\frac{1}{2}\left(Ca^{2+}+\ Mg^{2+}\right)}}$$

The results of the SAR calculation yielded: SAR (outlet) = 0.65 <3, therefore no restriction is required for reuse in irrigation according to the guidelines relating to water quality for irrigation (FAO, 1985). SAR (inlet) = 6.31, this value is between 3 and 9, so there are moderate restrictions regarding the reuse of wastewater in irrigation (FAO, 1985). As a result, the system has eliminated toxic elements such as sodium, which is a harmful element of the soil and undesirable in irrigation water. The amount of residual chlorine is 0.32 mg / L after bleach disinfection.

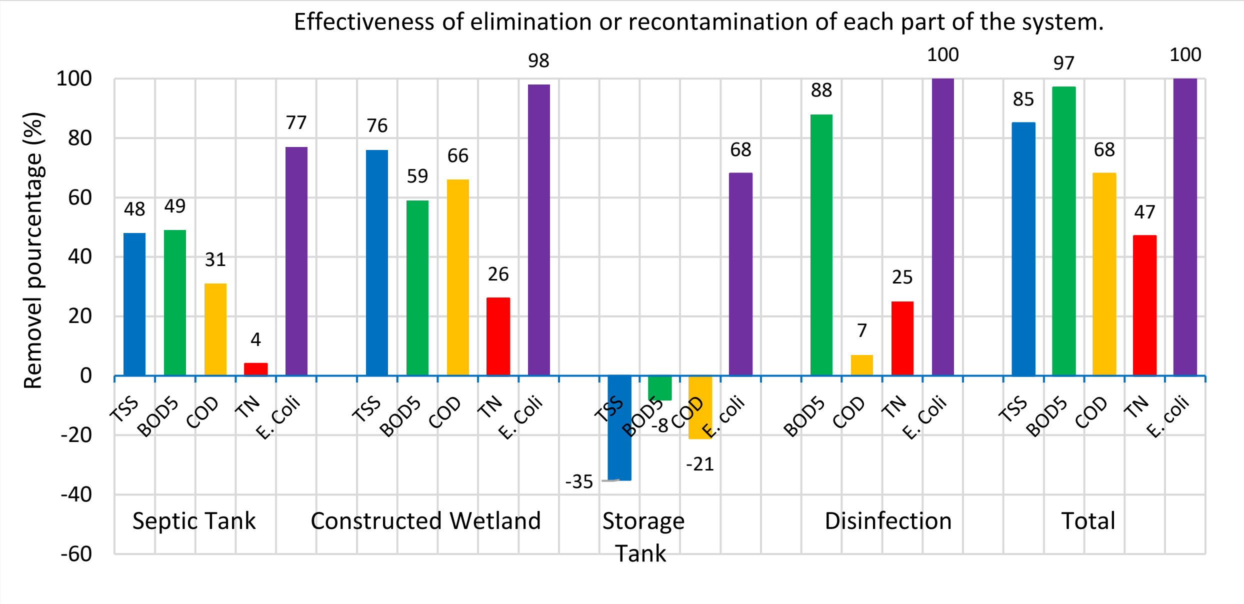

Figure 5: Effectiveness of elimination or recontamination of parameters by the different parts of the system.

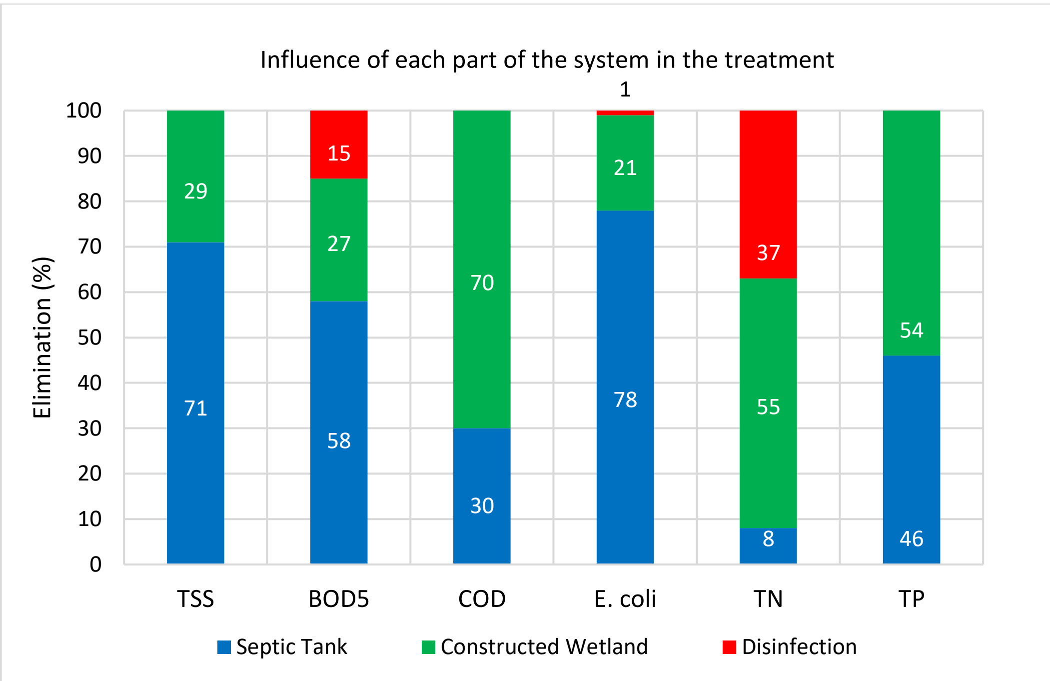

Figure 6: Percentage of influence of each part of the treatment during the elimination of each parameter.

Conclusion

Despite the difficulties we had at the beginning in starting the system, the results finally obtained are satisfactory. The septic tank playes an important role in wastewater pretreatment and filter feeding. The reeds machrophyte plants widely available in the Technopole area were used in the horizontal filter. From pre-treatment to disinfection with bleach, the system eliminates 85% of total suspended solids, 97% of biological oxygen demand, 68% of chemical oxygen demand, 47% of total nitrogen, 39% of total phosphorus and 100% of Escherichia coli present in the received wastewater (Total system figure 4). Recontamination of suspended solids, BOD_5, and COD due to long exposure of the treated water in the storage basin has reduced the removal efficiencies of these parameters. The septic tank contributed to the elimination of all the parameters, especially E. Coli (78%) and suspended matter (71%) (Figure 5). The constructed wetland was more efficience in the removal of COD by contributing to 70% in the removal.

There are no significant variations in terms of pH, conductivity, temperature and salinity between the inlet and the outlet of the system. However, the system has encountered problems in the removal of total nitrogen. Total nitrogen concentrations at the outlet of the constructed wetland are approximately 168 mg/L. Therefore, a study to experiment a different system (such as a hybrid constructed wetland, that combines vertical filter and horizontal filter stages) could be started to make the water perfectly compliant with the WHO wastewater reuse guidelines and Senegalese wastewater discharge standards [22].

References

1. M. Touria, 2014, Etude, Conception et dimensionnement d'une STEP par filtres plantés de roseaux des eaux usées des zones éparses de la commune de Terny. Mémoire de fin d'étude. Université Abou Bekr Belkaid-Tlemen, Algérie.
2. B. M. Plaza, F. Fusai, G.Carmassi, S.Jiménez,A. Pardossi, and M. TLao, 2013, Effects of Treated and Untreated Wastewater from Municipal Solid Waste (MSW) Leachates on the Nutritional State of Viola spp.: Sodium, Potassium, Calcium, and Magnesium. Communications in Soil Science and Plant Analysis, 44:1-4, 480-491. DOI: 10.1080/00103624.2013.744148.
3. C. Abdelhamid,2013, Étude et conception d'une station d'épuration des eaux usées domestiques par lits de roseaux pour de petites agglomérations : Cas de Fraouna (Commune de Terny). Mater en Hydraulique Option : Technologie et Traitement des Eaux, Université Abou BekrBelkaid, Algérie.
4. Z. Saad, B. A.Abdelhafid, and L. S. Eddine, 2016, Chemistry Wastewater Treatment of El-Oued City (South-east of Algeria) by Utilization of Typha Latifolia. Oriental Journal of Chemistry, ISSN: 0970-020 X CODEN: OJCHEG 2016, Vol. 32, No. (6): Pg. 3043-3052. DOI: 10.13005/ojc/320625.
5. J. Vymazal, 2010, Constructed Wetlands for Wastewater Treatment. Water 2010, 2, 530-549. DOI: 10.3390/w2030530.

6. M. P. De Matos,M.Von Sperling, and A. T. de Matos, 2018, Clogging in horizontal subsurface flow constructed wetlands: influencing factors, research methods and remediation techniques. Rev. Environ Science and Biotechnology (2018) 17:87–107. DOI: 10.1007/s11157-018-9458-1.
7. R. Wang, N. Korboulewsky, P. Prudent, V. Baldy, G. Bonin, 2009, Can vertical-flow wetland systems treat high concentrated sludge from a food industry? A mesocosm experiment testing three plant species. Ecological Engineering 35, 230–237.
8. J. Vymazal, M. Greenway, K.Tonderski, H. Brix, and Ü. Mander, 2006, Constructed wetlands for wastewater treatment. In: Wetlands and Natural Resource Management, pp. 347, 69–96. https://www.researchgate.net/publication/226366766.
9. R. Wang, V. Baldy, C. Périssol, and KN. orboulewsky, 2012, Influence of plants on microbial activity in a vertical-downflow wetland system treating waste activated sludge with high organic matter concentrations. Journal of Environmental Management 95 (2012) S158eS164.3
10. L. Pietrangelo, A. Bucci, L. Maiuro, D. Bulgarelli, and G. Naclerio, 2018, Unraveling the Composition of the Root-Associated Bacterial Microbiota of Phragmites australis and Typha latifolia. Original Research, published: 02 August 2018. DOI: 10.3389/fmicb.2018.01650.
11. S. C. Faye, S.Faye, S. Wohnlich, C. B. Gaye, 2003, An assessment of the risk associated with urban development in the Thiaroye area (Senegal). Environmental Geology (2004) 45 :312–322.
12. I. Kane, and L. E. Akpo, 2015, Croissance et production de matières de Typha australis (SCHUM et THON.) soumis à différents niveaux d’immersion. Journal of Applied Biosciences 86 :7928– 7939.
13. J.De Anda, A. López-López, E. Villegas-García, and K. Valdivia-Aviña, 2018, High-Strength Domestic Wastewater Treatment and Reuse with Onsite Passive Methods. Water 2018, 10, 99. DOI: 10.3390/w10020099. www.mdpi.com/journal/water.
14. H.Brix, 1987, Treatment of Wastewater in the Rhizosphere of Wetland Plants – The Root – Zone Method. Water Science & Technology ,19, 107-118. DOI: 10.2166/wst.1987.0193.
15. U.S. E.P.A. (United State Environmental Protection Agency), 1993. Subsurface flow constructed wetlands for wastewater treatment – A Technology Assessment. Office of Research and Development Washington, DC 20460.
16. B. E. Abbassi, R. Abuharb, B. Ammary, N. Almanaseer, and C. Kinsley 2018, Modified Septic Tank: Innovative Onsite Wastewater Treatment System. Water 2018, 10, 578. DOI :10.3390/w10050578.
17. F.A. Nasr, and B. Mikhaeil, 2014, Treatment of domestic wastewater using modified septic tank. Desalination Water Treat. 2014, 56, 2073–2081. DOI: 10.1080/19443994.2014.961174.
18. C.A.L. Chernicharo, 2006 Post-treatment options for the anaerobic treatment of domestic wastewater. Rev. Environ. Sci. Bio/Technol. 2006, 5, 73–92.
19. J. Vymazal, H. Brix, R. Perfler, P. F. Cooper , R. Haberl, and J.Laber, 1998, Removal mechanisms and types of constructed wetlands. Backhuys Publisher, Leiden, The Netherlands. pp 17-66.

20. R. H. Kadlec,andS. D. Wallace, 2009, Treatment wetlands. Second edition. ISBN: 978-1-56670-526-4 (alk. paper).
21. M. Von Sperling, and J. G. B. Andrada, 2006, Simple wastewater treatment (UASB reactor, shallow polishing ponds, coarse rock filter) allowing compliance with different reuse criteria. Water Sci. Technol. 54, 199–205.
22. NORME SENEGALAISE NS 05-061 Juillet 2001 :EAUX USEES : NORMES DE REJET. Direction de l'Environnement et des Etablissements Classés.
23. D. Byamukama, R.L. Mach, F. Kansiime, M. Manafi, A.H. Farnleitner, 2005, Discrimination efficacy of fecal pollution detection in different aquatic habitats of a high-altitude tropical country, using presumptive coliforms, Escherichia coli, and Clostridium perfringens spores. Appl. Environ. Microbiol. 71, 65–71.
24. S. Agidi, S. Vedachalam, K. Mancl, and J. Lee, 2013 Effectiveness of onsite wastewater reuse system in reducing bacterial contaminants measured with human-specific IMS/ATP and qPCR. Journal of Environmental Management 115 (2013) 167e174. DOI: 10.1016/j.jenvman.2012.11.021.