International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 12 Dec 2021, pp: 892-904 www.ijaem.net ISSN: 2395-5252

Assessment of a Constructed Wetland Design toTreat the Sewageof University of Lay Adventists of Kigali(UNILAK) - Rwanda

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Submitted: 01-12-2021 Revised: 12-12-2021 Accepted: 15-12-2021

ABSTRACT:
Wastewater treatment will always pose problems if there are no new alternative technologies in place to replace the currently available technologies which are less affordable in developing countries. This paper discussion is about the assessment of Constructed wetland as a tool of wastewater treatment. There are many different wastewater systems which don't meet the Rwanda context in term of their costs. In this context we chose to establish and assess a constructed wetland for measuring its effectiveness and cost effective.

To evaluate the performance of the constructed Wetland, we tested the parameters: Turbidity, TSS, PH, BOD, COD, fecal coliforms and E. coli of the influent and effluent. The tests were repeated each trimester for measuring the trend and comparing to standards. To compare the cost of Conventional Wastewater Treatment Plant and Constructed Wetland, we contacted responsible of different institutions which expressed their need of wastewater treatment Plant and were demotivated by their costs. Then after we compared the cost proposed to the cost of a constructed wetland for calculating the costs ratios.

The laboratory tests highlighted that the constructed wetland effluent has clean water compare to Rwanda Bureau standards (RBS). The cost is affordable because the ratio cost related to implementation, maintenance and operation are respectively 1/5 and 1/10 when compare the construction Wetland and the conventional waste water treatment Plant. As conclusion, we can say that the constructed wetland is the best in the context of developing countries in general and Rwanda in**particular**

KEYWORDS: Constructed wetland, Phytoremediation; Inlet, outlet, Sewage and Wastewater treatment.

I. INTRODUCTION

This paper describes the design of a constructed Particular. Wetland, its performance and its cost comparing to conventional wastewater treatment plants.

The world is facing a global water quality crisis. Continuing population growth and urbanization, rapid industrialization, and intensifying food production are all putting pressure on water resources and increasing the unregulated or illegal discharge of contaminated water within and beyond national borders. This situation presents a global threat to human health and wellbeing, with both immediate and long term consequences. There are many causes driving this crisis, but it is clear that freshwater and coastal ecosystems across the globe, upon which humanity has depended for millennia, are increasingly threatened. It is equally clear that future demands for water cannot be met unless wastewater management is revolutionized.[1]

The statistics are unambiguous: Globally, two million tons of sewage, industrial and agricultural waste is discharged into the world's waterways and at least 1.8 million children under five years-old die every year from water related disease, or one every 20 seconds. (Idem)

The main issues of **a**ccess to improved sanitation systems is that 2.5 billiard people can't access to "improved" hygienic services. Therefore, every year 4 million cases diarrhea kill 1.8 million people; 90% are children less than 5 years old, 133 million people suffer from intestinal infections (helminthes) because oflack of safety and unsafe water use. [2]

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globally, it has been estimated that 2.6 billion people lack improved sanitation. [3], [4] Sanitation is one of the critical and essential infrastructure sectors for well-being, health and Environmentalsustainability[5].

In Sub-Saharan Africa, at least 450 million people lack adequate sanitation. Nevertheless, however, wastewater management has been one of the mainchallenges that faces developing countries due to population growth and the lack of sanitation andwastewatermanagement practices [6,7]. Therefore, 80–90% of the generated wastewaters in developing countries are discharged directly into water bodies [8]. For example, 62% of the urban population in sub-Saharan Africa disposes wastewater directly to water bodies due to the lack of sanitation infrastructures [9].

The case of Rwanda, specifically the city of Kigali, has no centralized public sewerage system while the few semi-centralized wastewater treatment plants (SCWWPs) which do not function properly as initially designed. 81.6% of the improved sanitation in Rwanda used pit latrines with solid slab due to the absence of sewage system/network in the country [10]. Hotels, hospitals, and big commercial buildings are obligatory required to install private SCSSs for the treatment of their wastewater before beingdischarged into the environment. However, due to the poor governmental monitoring the standards for theirrecreation, education, aesthetic/amenity value. [12].

Hypothesis of the research

The UNILAK wastewater treatment Plant is an affordable model tool designed and built in local material for sewage treatment; its physical and biological facilities can remove organic matter and decant at the outlet, the treated wastewater which meets the Rwanda Bureau Standards (RBS) at affordable cost.

General objective of the study

The purpose of the present study is to establish a constructed wetland and assess its performance and its affordability in wastewater treatment. **Specific objectives**

- ❖ To establish an experimental constructed wetland plant (CWP) for treating the wastewater;
- ❖ To assess the UNILAK/CWP performance by measuring and comparing the influent and the effluent wastewater quality trend;
- ❖ To compare the cost of UNILAK/CWP to cost of alternative conventional wastewater treatment Plants (CWWTP).

Significance of the study

This study report targets decision-makers on natural resources, at ministerial and municipal levels, consultants and NGOs for providing a technical tool able to facilitate the sanitation promotion by treating the wastewater and cleaning the environment at affordable cost.

II. MATERIAL AND METHODS

This experimental essay focused on three steps which can be summarized in: description of the design of the Constructed Wetland Plant (CWP), the assessment of its performance in wastewater treatment and the comparison of its cost to the cost of the alternative Conventional Wastewater Treatment Plant (CWWTP).

2.1 Design of a Constructed Wetland (CW)

A pilot CWP was established for wastewater treatment. It has components such as tanks to receive the sewage, channels as networks to bring the wastewater in the CWP, river stones, gravel, wetland soil and specific plants. Other component like microorganisms and invertebrates were developed naturally. It is important that the plant species identified should have high tolerance level towards the contaminants present in wastewater. To identify and select the suitable Phytoremediation species for the wastewater treatment should be considered. For the experimentation Eichhorniacrassipes, Typha specie and vetiver were used after species suitability assessment. The INILAK/CWP was well designed for facilitate the water flow by gravity through the plant for avoiding the usage of pomp and electricity.

The CWP has a calculated capacity of treating the sewage discharge by UNILAK community equivalent to 2000 people (Students and staff). The sewage goes through sewer to a sedimentation pond composed by six-chambers; from there, the sewage is discharged through the open channel to Horizontal Subsurface Flow/Constructed wetland (HSSF/CW).

It is an appropriate structure which allows the physic, chemical and biological operations which facilitate the removing of pollutants. The cleaning continues by in a channel where it will benefit from a filtration processes. After this step the wastewater passes in outlet to be tested before being discharged to the environment (Fig. 1).

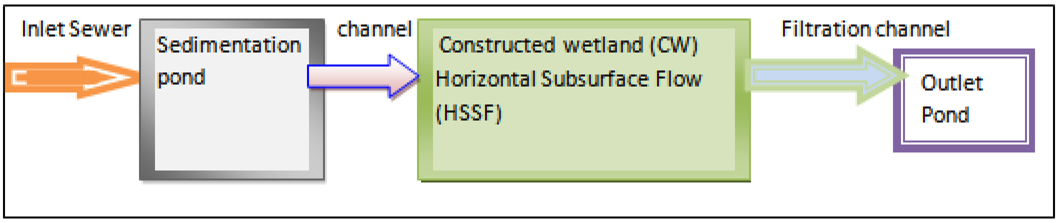


Figure 1: Process schema of constructed wetland

2.2 Performance assessment of Constructed Wetland Plant in wastewater treatment

Considering the mechanism of wastewater treatment using the wetland technology as summarized in the table 1, two samples were collected once each trimester, one from inlet and another from outlet of the CWS. The study was performed both in dry seasons and rain seasons from 2014 to 2017. The samples were collected 15 times as it is demonstrated in the table 2. Both dry and rain seasons helped to know the influence of climate change on the variability of the UNILAK/CWP performance. Considering that rain can cause two opposing effects, in one hand the dilution by rain water which reduces the organic concentrations in wastewater, in other hand increased the speed of flow of wastewater water and decrease in that way the water retention time within a wetland. [13]

Table 1: Mechanisms of wastewater treatment using wetland technology [14]

Wastewater constituent	Removal mechanism
Suspended solids	✓ Sedimentation ✓ Filtration
Soluble organics	✓ Aerobic microbial degradation ✓ Anaerobic microbial degradation
Phosphorus	✓ Matrix sorption ✓ Plant uptake
Nitrogen	✓ Ammonification followed by microbial Nitrification ✓ Denitrification ✓ Plant uptake ✓ Matrix sorption ✓ Ammonia volatilization
Metals	✓ Adsorption and cation exchange ✓ Complexation ✓ Plant uptake ✓ Precipitation ✓ Microbial oxidation/reduction
Pathogens	✓ Sedimentation ✓ Filtration ✓ Natural die-off ✓ Predation ✓ UV irradiation ✓ Excretion of antibiotics from macrophytes

Table 2: Guideline of the samples collection according to seasons and years

Period	**Dry season**	**Rain season**	**Dry season**	**Rain season**	**Total**
	Dec- Feb.	**March-May**	**June–Aug**	**Sept –Nov**	
2014	1	1	1	1	4times
2015	1	1	1	1	4times
2016	1	1	1	1	4times
2017	1	1	1		3times
Total	**4**	**4**	**4**	**3**	**15times**

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 12 Dec 2021, pp: 892-904 www.ijaem.net ISSN: 2395-5252

For the wastewater quality analysis, 30 samples, in 15times were collected by laboratory staff using sterilized bottles previously. 2 samples were collected once for each season 1from influent and 1 effluent of the CWS. Wastewater samples were tested for pH, total suspended solids (TSS), 5 days Biochemical Oxygen Demand (BOD5) at 20°C, Chemical Oxygen Demand (COD), total coliforms, fecal coliforms and E. coli. All samples were analyzed by certified waterand wastewater qualities laboratories.For assessing the UNILAK/CWS performance, the samples of inlet and outlet were tested and repeated 15 times, one sample for each consecutive season. In one hand, the pollutants remove rate were calculate using the formula: $\frac{\textbf{Influent average} - \textbf{Effluent average}}{\textbf{Influent average}} X100$.
In another hand the outlet pollutants concentration at outlet were compared to standards in the table 3. Based on these data the recommendations were made.

Table 3: Tolerance limits for discharged domestic wastewater

Parameter	Limits	Methods of test	RBS Limit
Turbidity	<15	ISO 7393	<15
TSS mg/l	<50	ISO 11923:1997	<50
pH	5-9	ISO 10523:1994	6.5- 8.5
Temperature variation of treated water	<3	Thermometer[1]	13-25
BOD5 mg/l	<50	ISO 5815-2:2003	<30
COD mg/l	<250	ISO 6060:1989	<250
Total coliforms/100ml	<1000	ISO 7887	<1000
Faecal Coliforms /100ml	<400	ISO 4831:2006	<400
E. Coli	<10	ISO 22743	<10

2.3 Cost evaluation CWP

One supplier was contacted for discussing his proposition cost of CWWTP for five institutions supposed to be in urgent need of WWTP.Considering the number of permanents people in respective institutions. The suppler presented the setting cost, eventual operational cost and the maintenance cost separately. In the same way the set up area cost, and the set up plan cost were calculated and the maintenance cost was calculated. The CWP cost and the CWWTP were compared for getting the ration.

III. RESULTS AND DISCUSSION

This study is a trial applied for wastewater treatment. The design and the performance assessment were done for determining the effect of that experimental tool. This experimental sewage treatment was done from UNILAK/Kigali campus site.

3.1 UNILAK overview

UNILAK is a University with three campuses; the main campus is located at Kigali city/Gasabo District/Remera Sector. Among the programs of studies organized at UNILAK, the environment conservation management is more interested by this experimental attempt. UNILAK/Kigali Campus has around 4,000 students in 2 cohorts (Day and evening),

thus it was considered that UNILAK has 2000 permanents peoples (Staff and students). The campus is established on a slop place, where the pipes (sewers) of all toilettes of UNILAK buildings convey sewage in downstream where the sedimentation pond is establish for gathering all UNILAK sewage.

3.2 Description of the UNILAK/CWP

The sedimentation pond is used as a pretreatment step. The sludge is deposit on bottom for continuing its degradation.

As the wastewater enterscontinuouslyin the first chamber of the sedimentation pond, the speed of the flow is reduced and the heavy solids settle, forming sludge. The wastewater with less sludge pass in the next chamber, this exercise is repeated six times. By this way the wastewater becomes progressively clean. This exercise is the pre-treatment phase.The next phase called primary treatment consist of a channel settled for transferring the wastewater in an open and aerated pond before getting in the CWP. The key element of UNILAK/CWP is the horizontal subsurface flow recognized as secondary phase of wastewater treatment. This kind of system was chosen because it has less obstruction risks. The cell design consists of a rectangular bed, bordered with

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 12 Dec 2021, pp: 892-904 www.ijaem.net ISSN: 2395-5252

masonry work of 0.25m wall and concrete based floor to protect seepage of wastewater. The cell is 0.6m of depth, so no external water enters into the cell from the natural ground surface.

Table 4: Parameters and characteristics ofUNILAK constructed wetland design

Parameters	Unit	Value
Length	meter	20
Width	meter	10
Height	meter	0.6
Surface area	Square meter	200
Characteristics	Unit	Value
Hydraulic retention	Days	4
Flow	Cubic meter per day	16
Vegetation	Per square meter	4 plants

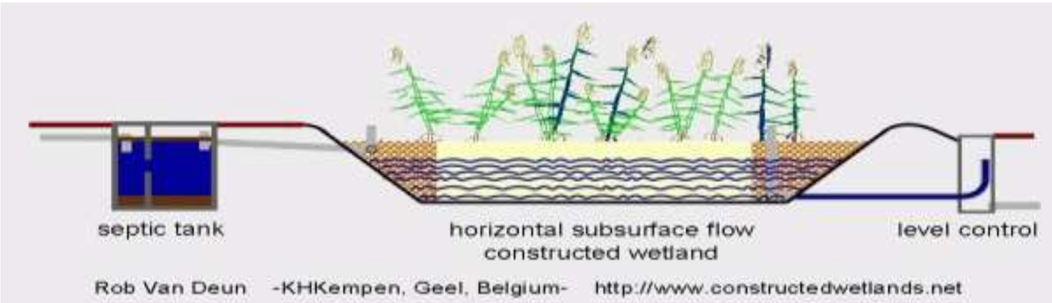


Figure 2: Horizontal subsurface flow constructed wetland

According to the flow of wastewater, there are three models of construction wetlands: Surface flow,Horizontal subsurface flow and Vertical subsurface flow. Each one has advantages and disadvantages; this is why the analysis of the context of each institution orients the decision. For example the surface flow requires space, it smells bad, it needs to be far from buildings, and thus, it was not appropriate for UNILAK. The horizontal subsurface flow as shown in the figure 2 can be set up near the buildings, because it doesn't smell, the available space of UNILAK was sufficient and was in downstream of all buildings for allow to sewers to gather the sewage by gravitation. It has another advantage of not obstruct easily as it is the case of the vertical subsurface flow.

		
Step1: Sedimentation tank with six chambers as pre-treatment tank	**Step2: Inlet from Sedimentation tank**	**Step 3: Aeration channel as primary treatment**

Step 4: Constructed Wetland as secondary treatment chamber	Step 5: Maturation Pond	

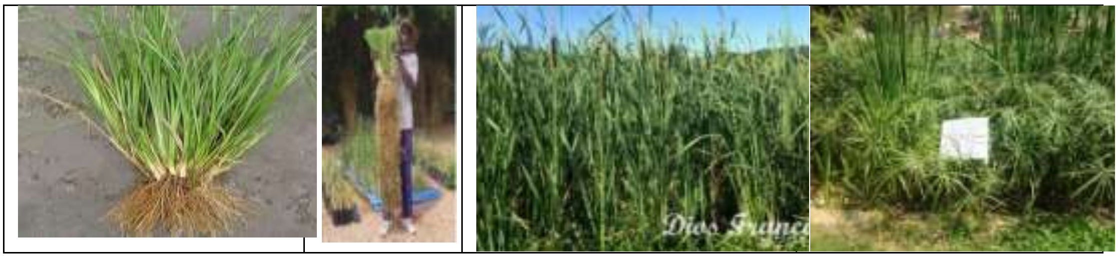
Figure 4: 4steps of wastewater treatment in the Constructed wetland plant

Vegetation in CWP
The wetland is planted with emergent macrophytes. The planting density is 4 to 6 plants per m². The vegetation should be planted randomly. A wide variety of aquatic plants have been used in wetland systems and the native plants were preferred: Phragmitesaustralis, Typhalatifolia, Sparganiumerectum, Scirpuslacustris, Iris pseudacorus, Carex sp., Phalarisarundinacea

Role and types of wetland vegetation:

- The root system increases the surface area available to bacterial colonization;
- Transfer of oxygen to provide an aerobic/oxidized environment by oxygen leakage from the rhizomes;
- Nutrient assimilation (N, P and heavy metal);
- Maintaining hydraulic pathways in the substrate;
- Plant litter provides substrate to the microorganisms;
- Accumulated litter serves as thermal insulation;

Aesthetics of the constructed wetland



The Vetiver grass tolerates and removes at high level the nitrates, phosphates, heavy metals, and agricultural chemicals. It can be used for treating wastewater, rehabilitating mine tailings, stabilizing landfills and general rubbish dumps. The plants takes up the toxic materials and confines contaminates to the affected area.

3.3 Performance of the CWP

For assessing the performance, 9 parameters were tested 15times equivalent to 8dry seasons and 7 rain seasons during the period 2014-2017. The results presented in the table 3 are the mean of each parameter. For calculating the performance of the UNILAK/CWP, the pollutants remove rate was calculated using this formula:

$$\frac{\text{Influentaverage} - \text{Effluentaverage}}{\text{Influentaverage}} X100$$

Table 5: Average of inlet and outlet of wastewater test parameters and RBS standards

parameters	Unities	Influent	Effluent	CWP Performance	RBS standards
Temperature	°C	21	20.5	Remove %	13-25
Turbidity	NTU	235	12	94.9	15
TSS	mg/L	207	14.1	95.2	50

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pH		7.4	7.5		6.5- 8.5
BOD_5	Mg/l	225	18	92	<30
COD	Mg/l	317.2	48	84.9	<250
Total coliform	Cfu/100ml	2.10^9	254	99,9	<1000
Fecal Coliform	Cfu/100ml	$2. 10^6$	68	99.9	<400
E. Coli	Cfu/100ml	10^6	5	99.9	<10

Source: Primary data, 2014-2017

The table 5 highlights that it exist a big difference of wastewater quality when compare its inlet and outlet. In one hand, the average of pollutants remove are respectively 94.9% for turbidity, 95.2% for TSS, 92% for BOD_5, 84.9% for COD, 99.9% for total coliform, fecal coliform and E.coli. In other hand all parameters tests are better comparing to RBS standards

Table 6: Performance trend according to parameters and seasons

Season	**T^0**	**Turbidity**	**TSS**	**pH**	**COD**	**BOD_5**	**T. colif**	**Fec. colif**	**E. coli**
Cold	19.7	13.8	18.6	7.6	50.4	24	326	168	6
Warm	20.3	8.6	9.8	7.4	46	13	197	15	4.4
C-W	-0.6	5.2	8.8	0.2	4.4	11	129	153	1.6
mean	20	12.7	14.2	7.5	48.2	18.5	261.5	91.5	5.2
Stand	13-25	14	50	6.8-8.5	<250	<50	<1000	<400	<10
Unities	^{0}c	NTU	mg/L		Mg/l	Mg/l	Cfu/100ml	Cfu/100ml	Cfu/100ml

The table 6 makes clear that the CWP performs well because all parameters mean meet the RBS standards in warm seasons as cold seasons. It is revealed again that in the warm seasons the CWP performs better the wastewater treatment than it performs in the cold season because the table 6 confirms that the difference between cold average tests and dry average tests are respectively 2 for turbidity, 8.8 for TSS, 0.2 for pH, 4.4 for COD, 11 for BOD_5, 129 for T. coliform, 153 for fecal coliform and 1.6 for E. coli.The figures bellows clarify better the performance of wastewater treatment during the warm season than its performance in the cold season.

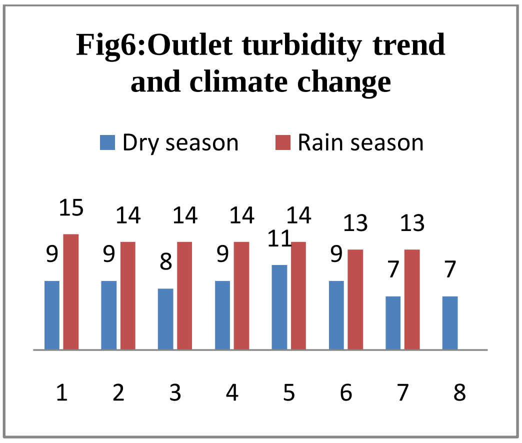

Fig6:Outlet turbidity trend and climate change

The figure 6 highlights that the trend of turbidity is positive because it is reducingprogressively and meet the RBS standards. It is observed again that the climate change has a high impact on the turbidity reduction, thus the performance in dry season is high comparing to rain season.

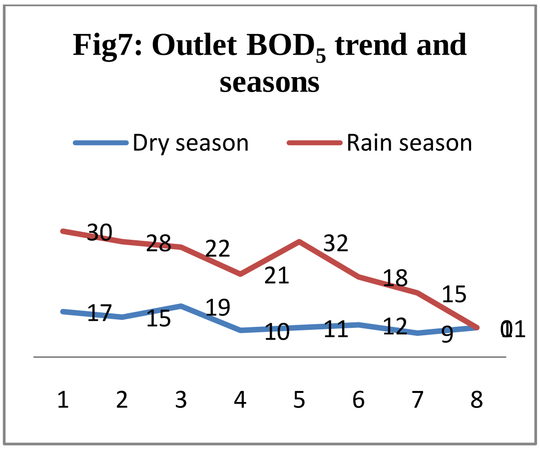

Fig7: Outlet BOD_5 trend and seasons

The figure 7 highlights that the trend of the BOD5 is positive because it is reducing progressively and meet the RBS standards. It is observed again that the climate change has a high impact on the turbidity reduction, thus the performance in dry season is high comparing to rain season.

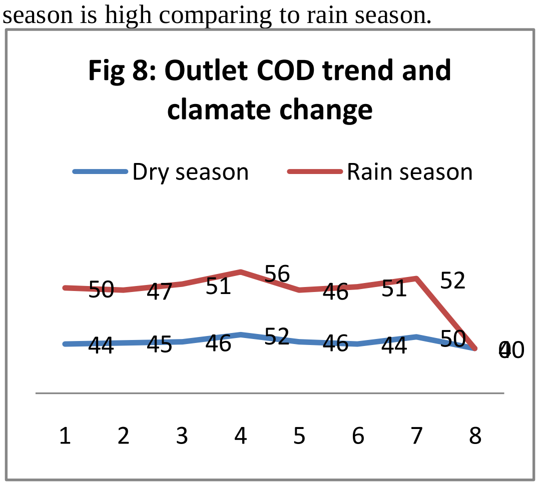

Fig 8: Outlet COD trend and clamate change

The figure 8 elucidates that the trend of COD is positive because its concentration is low comparing to RBS standards. It is observed again that the climate change has a high impact on the COD concentration because its trend is low in dry

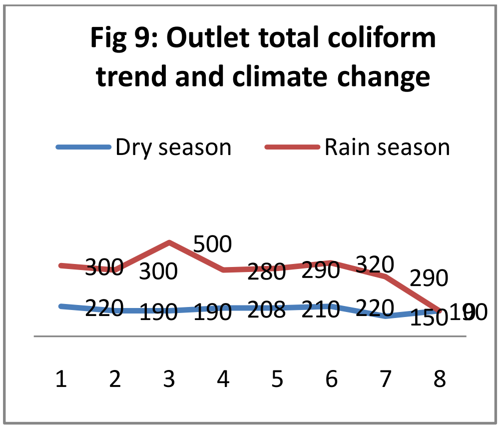

Fig 9: Outlet total coliform trend and climate change

The figure 9 clarifies that the trend of total coliform is positive because it is reducing progressively and meet the RBS standards. We can observe again that the climate change has a high impact on the total coliform concentration because in dry season the trend of total coliform is low comparing to rain season.

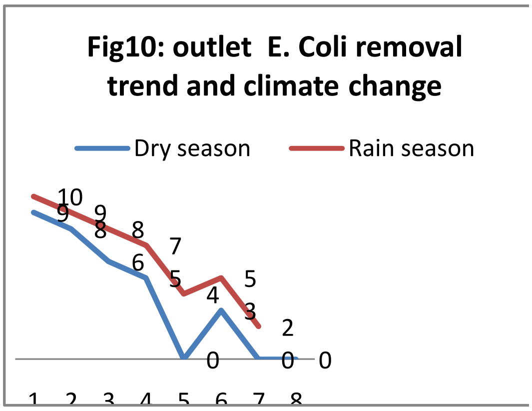

Fig10: outlet E. Coli removal trend and climate change

The figure 10reveals that the trend of E. coli is positive because it is reducing with time and meets the RBS standards. It is observed again that the climate change has a high impact on the E. coli remove, because in dry season comparing to rain season.

3.4 Constructed Wetland Costs

For comparing the constructed wetlands plant (CWP) cost and the Conventional Wastewater Treatment Plant (CWWTP), it requires to identify the major activities and their costs, for finally compare the total costs of CWP and

- A more accurate measure is the quantity of wastewater which is measured in number of gallons of wastewater to treat.
- In place of the quantity of wastewater, another alternative can be to

season, the E. coli concentration become low comparing to E. coli concentration in rain season.

CWWTP.

- The main cost is land or area where to set up the CWP, which varies greatly according to location;
- Cost per acre is based on land cost and how many scale meters are require totreat the wastewater.

appreciate the cost considering the average number of people who use the toilets of the interested institution. For getting data we contacted the suppler of CWWTP who implanted some in some Kigali buildings and then we get the data as presented in the table 7 bellow.

Table 7: CWP cost compare to CWWTP cost

Institution	people to serve	Implement ation Cost of CWTP	Implement ation of CWWTP	Proportion of CWP/CWWTP	Maintenance and reparation cost
University A	4,000	$352,941	$70,588	1/5	1/10
University B	2000	$235,294	$47058	1/5	1/10
Secondary school	1200	$176470	$41,176	1/4	1/10
Hotel	200	$141,176	35,294	1/4	1/10

Source: Primary data, 2014-2017

The table 7 reveals the significant difference between the implementation cost of CWP and CWWTP where the minimum costs ration CWP/CWWTP is equal to 1/4. The maintenance cost is estimated to ration equal to 1/10. The maintenance of CWP is the harvesting of plants one time for 6months and the regular cleaning, where the maintenance for the CWWTP is the regular cleaning and repairing when the plant does not running properly. The monitoring of operation, maintenance and repairing in case of need, requires an expert engineer accompanied by a high salary. The operation cost linked to the electricity used as operation energy cost more than $1000 each month.

Discussion

Design of UNILAK/CWP

In near future, a number of small-scale wastewater treatment plants may gradually increase and a large demand for information on appropriate procedures and technologies have to be developed. The technical alternatives ranging from mechanical and simple biological low rate systems such as ponds, sand filters and

This design is very significant in decentralization strategy because it reduces the need for sewage transportation system, allows the use of the treated water in-situ, it is a smaller system technically and it insures the treatment where it is needed.

The CWP approach of wastewater treatment plant has many advantages, among others: it is affordable, Cost-effective, its operation and maintenance expenses are insignificant; it is any electricity requirement, facilitates recycle and reuse of water, it is no foul odor and no mosquito nuisance, and it tolerates fluctuations in operating conditions such as flow, temperature and pH .

This assay is intended to serve as a technical guide for the design of small wastewater treatment facilities in Rwanda. The small treatment facilities are defined as those with a sewage flow of between 10,000 and 150,000 gallons per day (gpd). UNILAK sewage is approximately 15,840 liters equal to792 gallons of sewage per day, equivalent to $\simeq$ 16m^3 per day. Its design was based on some parameters as land area perimeter, the length reed beds to complex high-rate suspended and fixed film biomass reactors have to be evaluated according to their plant size, operation safety, reliability, demand for skilled personnel, investment and,operation costs [14]

Performance of constructed wetland

The performance of UNILAK/CWP as pilot assay was revealed by the results of the continuous laboratory test. The outlet samples were tested according to parameters like temperature which was between 21-19^{0}c against the standard of 15-25^{0}C, the turbidity was between 15-7 NTU against the standard of 14 NTU, the max 15NTU was tested in the first test (1st trimester) where the plants of the wetland were not mature, from the second tests the measures were 14 NTU or less as reveal the figure 6. The TSS was between 25- 8 where the standard is <50mg/l. The pH was between 7.3-7.7, where the interval standard is 6.5-8.5. The BOD tested from the outlet samples were between 32-10mg/l, where the standard was 50mg/l. The COD tested from the outlet sample were between 56-40mg/l where the standard is 250mg/l. Regarding the bacteriological tests, it was shown that the results are better than standards because the total coliform test from the outlet sample was between 500-90 Cfu/100ml against <1000 as standards, the fecal coliform test from the outlet sample was between 185-10 Cfu/100ml against <4000 as standards. The E. coli test from the outlet sample was between 10-0 Cfu/100ml against <10 as standards. Previous studies have shown high treatment efficiency of constructed wetlands.[15] Regular monitoring of the systems had shown high pollutant removal efficiency achieving close to 100% removal of total coliforms and organic pollutants [16]. Although average removal efficiency of nitrogen and phosphate has been reported, significant difference in removal efficiency is observed among plant species as well as among different type of wetland configuration [17] The main mechanisms leading to contaminant removal in wetlands are microbial of the phytorid bed. Les length, the depth and the wtdth gives the dimension equal to: Depth x length x width which has to allow the retention time of at least for 6days.However plants also have a huge role in contaminant removal in wastewater. They take up nutrients and incorporate them into plant tissue and thus increase in plant biomass [18]

Various types of wastewater are also treated with varying degree efficiencies. [19] have used subsurface flow constructed wetland systems to treat wastewater from municipal sewage, agriculture, industry and from landfill leachate. From 400 constructed wetlands in 36 countries it was found that municipal wastewater had, in overall, the highest contaminant removal efficiencies while the lowest removal efficiency were observed from landfill leachates. Theseobservations suggest that most systems have been designed to treat municipal sewage and also the fact that most municipal wastewater contains predominantly labile organics while landfill leachates often contain recalcitrant organics which are difficult to degrade. Constructed wetlands are low maintenance systems. Poor maintenance may result in poor performance due to simple problems such as clogging of pipes [20] Therefore, all systems need to be regularly monitored and proper systems for operation and maintenance should be established in order to achieve maximum treatment efficiency.

Why constructed wetlands are better alternative and why should they be recommended for wastewater treatment?

The environment is one of the important aspects in our lives. Recently air pollution is becoming a progressive constrain due to emission of greenhouse gases to the atmosphere. Emissions of greenhouse gases have negatively influenced the quality of air and increase the greenhouse effect. They have direct influence on the environment; causing extreme weather changes, global temperature increases, the loss of ecosystem and potentially hazardous health to people.

There are some recent fatal events about the effect of greenhouse gas emission. One of the events is heavy rains that took place on the 20th to the 21st of October 2012 at Eastern Cape, in South Africa, where major roads collapsed, houses were washed away and hundreds of

wetlands in treatment of wastewater in tropical regions when compared to modern sewage treatment methods, wetland systems are inexpensive with little or no energy requirements and equipment needs are minimal, which adds to its low-construction people were cut off. Fears were raised that more than R1-billion damages caused within a week of a heavy rains and flooding in Eastern Cape were dwarfed by even bigger economic losses. On the 31st October 2012 Sandy, the storm that caused multiple fatalities, halted mass transit and cut power to more than six million homes and businesses. FEMA reported that Sandy dispensed close to $200 million in emergency housing assistance and has put 34,000 people in New York and New Jersey up in hotels and motels. According to World Health Organization report. [3] About 150,000 annual deaths worldwide have been tied to climate change. Climate related deaths are expected to double in the next 25 years.

Another case occurred on the 22nd of May 2012 whereby a massive earthquake took place 327 miles away from Durban North. All these cases occur as the result of carbon footprint in our environment. Using technologies that will have less footprint in our ecosystem can greatly reduce these consequences. The use of constructed wetlands in wastewater treatment may have answers in terms of footprint reduction and thus protecting the environment as opposed to convectional wastewater treatment systems. Apart from their environmental friendliness, constructed wetlands are also proposed as better alternatives in wastewater or industrial wastewater treatments for their significant advantages, including provision of high wastewater treatment levels. Contaminants in wastewater have been demonstrated to be reduced to acceptable levels using this technology.

that it uses local materials and plant species and no electricity is required. Thus it also contributes to conservation of energy. The only disadvantage is that it requires regular maintenance, certain space and its construction cost.They must be effectively managed if they are to continue to improve water quality.

The present work will help in reaching the Rwanda quality of wastewater to be discharged in the environment or reuse. This practice will protect the community against the waterborne diseases and other diseases related to the polluted environment. This strategy can be implemented cost. This technology need full establishment before it can be considered for full or maximal contaminant removal.

IV. CONCLUSION AND RECOMMENDATIONS

Constructed wetlands are sustainable and cost effective of wastewater treatment because it has a number of advantages compared to conventional technical systems.

They maintain a high performance; use less energy; and require less operation/maintenance and are better able to cope with the impacts of climate change.

Overall the results demonstrate the potential of 'green technologies' are more appropriate for water cleanup because they are responsible for decomposing organic pollutants to non-toxic low molecular substances which can easily be degraded by microorganisms. This technology does not introduce any additional chemical substances into the environment (solvents, alkali, PEG). They are relatively easy to manage and they can be easily adapted to the local needs. The best application is that they are able to remove several pollutants which are in combination.The constructed wetlands (CWs) are considered as low cost alternatives for treating the wastewater. The decentralized treatment system has a great potential for wastewater treatment and resource recovery.

Therefore they are used for nutrient removal from water bodies. The plant species which are native can be used for recycling of water in the water bodies. The concentration of contaminants should not be in excess to ensure that they do not affect the growth rate of the plant species as excess may cause toxicity.

The basic advantage is that it uses a natural process, simple in construction, improves water quality as well as recycling of water. Apart from

Recommendations

- Recognising that the CWP is efficacy and cost effective and that it can be affordable to the Rwanda population, It is recommended to decision makers of the Government in partnership with local governments, institutions and NGOs to reinforce regulation and promote the wastewater treatment as systematic requirement before being discharged in environment or reuse. This regulation concern particularly all public and private institutions as markets, hospitals, bus in Towns and villages. Therefore, such systems will operate with reasonable input of resources, as they represent microcosms that stabilize themselves. Plant harvest, maintenance, and de-clogging are low input activities that require no specifically educated personnel. Public acceptance of green technologies is generally higher than that of industrial processes. The expected, excellentwater quality will lead to additional consumer satisfaction, sustainability for future generations contribute to recreation and eco-esthetics.

The constructed wetland plants (CWPs) are considered as low cost alternatives for treating municipal, industrial and agricultural wastewater. The decentralized treatment system has a great potential for wastewater treatment and resource recovery.

stations, schools, hotels, prisons, etc. In brief, the place where meat more people.

➢ It seems that a number of problems of wastewater from different sources can be treated by constructed wetland because it was demonstrated its potential ability to remove ammonia, metal ions, heavy metals, pesticides, phosphorus compounds, and removal of pathogens, uptake of toxic substances as well as decomposition of biodegradable organic matter and toxic organic compounds, but this requires more trials. Test the CWP efficiency for industries and landfill, where the concentration of heavy metals is high and theirremoval requires more attention.

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International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 12 Dec 2021, pp: 892-904 www.ijaem.net ISSN: 2395-5252

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