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Key triggering factors in the clogging process of Nyarutarama hybrid ponds treating municipal wastewater in Kigali

Frodouard Hitimana[1], Elisee Gashugi[1], Vedaste Nyandwi[1], Emmanuel Nkurunziza[1], Christian Sekomo Birame[2]

1.Department of Chemistry, School of Science, College of Science and Technology, University of Rwanda, P.O Box 3900 Kigali, Rwanda

2.National Industrial Research and Development Agency, P.O Box 273 Kigali, Rwanda

*Corresponding Author: Frodouard Hitimana, f.hitimana@ur.ac.rw

Abstract

Constructed wetlands are man man-made wetlands or ponds that use the natural processes involving wetland vegetation, gravel, sand and their associated microbial assemblages to treat and improve the quality of wastewater effluent. The major operational challenge faced by natural wastewater treatment systems including constructed wetlands or hybrid ponds is the clogging process of porous media resulting from the accumulation of various solids types such inorganic solids from chemical precipitation, sludge from sedimentation and biological process like plant detritus and biofilm formation. The present study was carried out to determine the level of clogging process of Nyarutarama natural ponds system treating sewage from neighboring estate. Data were collected through the key informant interview about the key triggering factors in clogging process of that treatment system. This system is made by a combination of three series of constructed ponds that were built in Kigali. The assessment results indicated the clogging level of 78%, 60%, and 75% for primary facultative pond, water lettuce covered pond and free water surface flow pond respectively. Those results indicated that the ponds system clogging was due to the accumulation of solids materials resulting from the lack of operational, monitoring and maintenance plans. The well operated and managed constructed wetlands can effectively be used for environmentally and friendly treatment of wastewater rather than using conventional treatment systems since constructed wetlands are inexpensive. The constructed wetlands and hybrid ponds can easily be operated and maintained. In addition, when they are well designed they can serve as touristic and field study areas.

Keywords: wastewater, Nyarutarama ponds, accumulation, solids materials, clogging process

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1. Introduction

Clogging is progressive obstruction of the filter media in natural treatment wetlands that occurs due to the accumulation of various types of solids and biofilm materials (Knowles, 2012; Kuddus et al., 2017; Torrens Armengol, 2015) associated with wastewater treatment through intentional or external loads and other operational factors or anthropogenic activities that reduce the infiltration capacity of the surface and subsurface of the natural treatment systems (Durán-domínguez-de-bazúa, 2018; Knowles, 2012). Clogging is a complex process that involves biological, chemical and physical processes (Albacar, 2010; Pereira, 2016; Stewart, 2009). It can be the one of the most challenges of using natural wastewater treatment system including constructed wetland, mainly subsurface flow constructed wetland systems, because it results in the gradual blocking of the porous bed medium and therefore, in malfunction of hydraulic conductivity and/or in reduction of the treatment performance of the systems to remove various pollutants (Durán-domínguez-de-bazúa, 2018). Therefore, clogging is a crucial operational and maintenance problem associated with the utilization of the infiltration system and due to the drawbacks that may be arisen from clogging including both treatment efficiency and management costs terms, a pretreatment process is needed to prevent the clogging processes development in order to enhance the natural treatment system performance and lengthen its service life (Albacar, 2010; Zhu et al., 2020). The quantity and composition of accumulated solids material usually referred to as clog matter will vary according to the internal and external loads (Belachew, 2018; Torrens Armengol, 2015; Tse Hung et al., 2012). Clog matter are commonly composed of highly hydrated gels and sludge that are formed of inorganic and organic solids (Knowles, 2012). Clog matters often have high density than its water such that they settled into the bottom of the natural treatment systems and can effectively minimize the pore space in the wetland porous bed media (Durán-domínguez-de-bazúa, 2018; Knowles, 2012). The common components of clog matter including biofilm, plant detritus, chemical precipitates, and wastewater solids are categorized in the Table 1 into intentional or incidental accumulations. The incidental accumulations may include accidental operations and anthropogenic activities (Albacar, 2010; Knowles, 2012).

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Table 1: Categorization of typical non-hydrous components of clog matter in natural treatment wetlands

Component	**Intentional accumulations (external loads)**	**Incidental accumulations (internal loads**
Organic solids	✓ Wastewater solids ✓ Runoff solids from soil erosion	✓ Biomass growth ✓ Plant roots growth and elongation ✓ Biofilm and plant detritus ✓ Solids introduced during construction
Inorganic solids	✓ Wastewater solids ✓ Chemical precipitates ✓ Runoff solids from soil erosion	✓ Solids from chemical erosion of bed porous media material (gravel, sand and soil) ✓ Solids introduced during construction

Plant roots and rhizomes detritus contributes to subsurface clogging while plant leaf litter-fall contributes to surface clogging. Above ground up to half of the standing plant biomass, plant stems may be dead and remain relatively stable due to the presence of esters in the plant tissue that are biodegradation resistant (Knowles, 2012). Thus, it is generally accepted that the better wastewater pre-treatment application is essential for sustainable long-term operation of natural eco-friendly technologies treating various types of wastewater (Durán-domínguez-de-bazúa, 2018; Tse Hung et al., 2012; Varga et al., 2013).

The Figure 1 shows some of the clog matter components mentioned in Table 1 and visualize how they accumulate within the natural treatment wetlands especially in horizontal subsurface flow constructed wetlands at the macroscopic system-level and at the microscopic pore-level (Knowles, 2012). Clog matter accumulations can be resulted from a single phase such as biofilm on surfaces of bed media or from a combination of phases, like biofilm forming around entrapped wastewater solids (Dotro & Chazarenc, 2014; Pereira, 2016). The accumulations that take place into pore spaces decrease the subsurface hydraulic conductivity while the accumulations that occur onto the bed surface decrease the surface infiltration rates. The combination of the two types of clogging processes will determine if the hydraulic issues occur at the macroscopic scale or not (Knowles, 2012).

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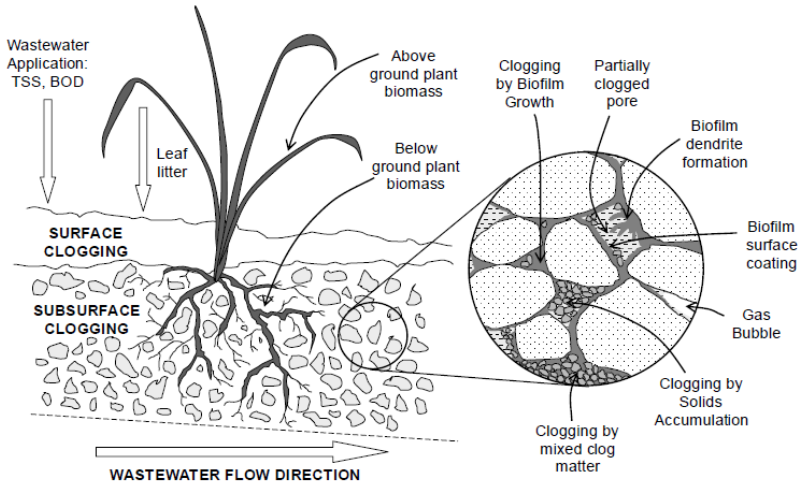

Figure 1: Clogging processes that occur at the surface and in the subsurface of Horizontal Subsurface Flow natural Treatment Wetlands. Adapted from Kadlec and Knight (1996), Knowles, (2012.

2. Key factors causing clogging in natural wastewater treatment systems

Clogging is a great operational and maintenance challenge associated with the utilization of the natural infiltration system in domestic, municipal and industrial wastewater treatment (Sexauer & Karn, 2013; Roberts, 2011; Zhu et al., 2020). Chemical (precipitation), biological (biofilm and vegetal debris) and physical (settling and filtration) processes can contribute in the key triggering factors in clogging process (Albacar, 2010; Dotro & Chazarenc, 2014). Some of most important factors promoting the clogging process are solids accumulation within porous bed media, inappropriate design, excessive loading of organic matter and suspended solids (Cha et al., 1999; Varga et al., 2013). The solids accumulation might result from the entrapment of inorganic and organic wastewater influent solids, biofilm growth, plant detritus, development of plant roots and rhizomes and chemical precipitates accumulation (Albacar, 2010; Pereira, 2016). Clogging reduces the lifespan of the treatment systems and show negative effects on treatment efficiency (Albacar, 2010). Many different publications suggested that most of the accumulated solid materials are inorganic particles since only 20-25% is organic solids fractions and thus the higher inorganic fraction could be associated with the wear of the support material (Pereira, 2016; Matos et al., 2017). The solids entrapment in constructed wetland takes place mainly in the inlet zone where the wastewater has a higher content of settleable solid materials (Dotro & Chazarenc, 2014; Stewart, 2009). The settlement of suspended solids at the inlet zone is resulted from the low speed of the

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wastewater flow. As the pores volume is highly decreased, the hydraulic conductivity will also be lowered (Pereira, 2016). Caselles-Osorio and García (2006) showed that the biofilm development could be an important factor for clogging but it is not continuous even if the clogging phenomenon takes place progressively throughout the treatment system operation time (Matos et al., 2017). Chemical precipitations take place inside the porous bed medium where the formed precipitates are associated with sulfides, carbonates, silicates, hydroxides and phosphates of iron, calcium, magnesium, aluminum and heavy metals. The involvement of the wetland plants in the clogging process is controversial (Pereira, 2016; Matos et al., 2017). The total suspended solids influent are retained by the network of roots and rhizomes occupying the bed porous space and became a crucial and significant triggering factor causing clogging in natural treatment systems including constructed wetlands and hybrid ponds (Dotro & Chazarenc, 2014; Matos et al., 2017; Varga et al., 2013). Others factors are the plant detritus resulting from plant parts senescence and death which could contribute to accelerated clogging (Knowles, 2012; Matos et al., 2017). The rates of the plant detritus (dead plant parts matter) accumulation and decomposition will vary geographically and will provide a net contribution to clog matter within time if the plant detritus accumulation rates of exceeds the plant detritus decomposition rates (Dotro & Chazarenc, 2014; Knowles, 2012; Matos et al., 2017).

3. Materials and Methods

3.1 Description of the study area

Nyarutarama natural hybrid constructed ponds system is situated in Nyarutarama cell, Remera Sector, Gasabo District in City of Kigali. The Nyarutarama constructed Ponds are consolidated treatment systems that receive and treat municipal wastewater from septic tanks of Juru Estate and Green Hills Academy in Kigali (Figure 2). The system consists a set of three constructed ponds in series with different layouts; a primary facultative pond which has a length of 101 m, a width of 66 m and a depth of 1.5 m (with sections or layers of aerobic and anaerobic zones). The second or maturation pond is covered by water lettuce (*Pistia stratiotes*) which has a length of 73 m, a width of 42 m and a depth of 1.2 m. The third pond is a free water surface CWs planted with wetland vegetation and has a length of 67 m, a width of 43 m and a depth of 0.9 m. The ponds layout and dimensions are shown in Figure 3. The figure 3 shows also the sampling points from which the sludge samples have been collected for further determination of solid density and estimation of the mass of clogging solids materials.

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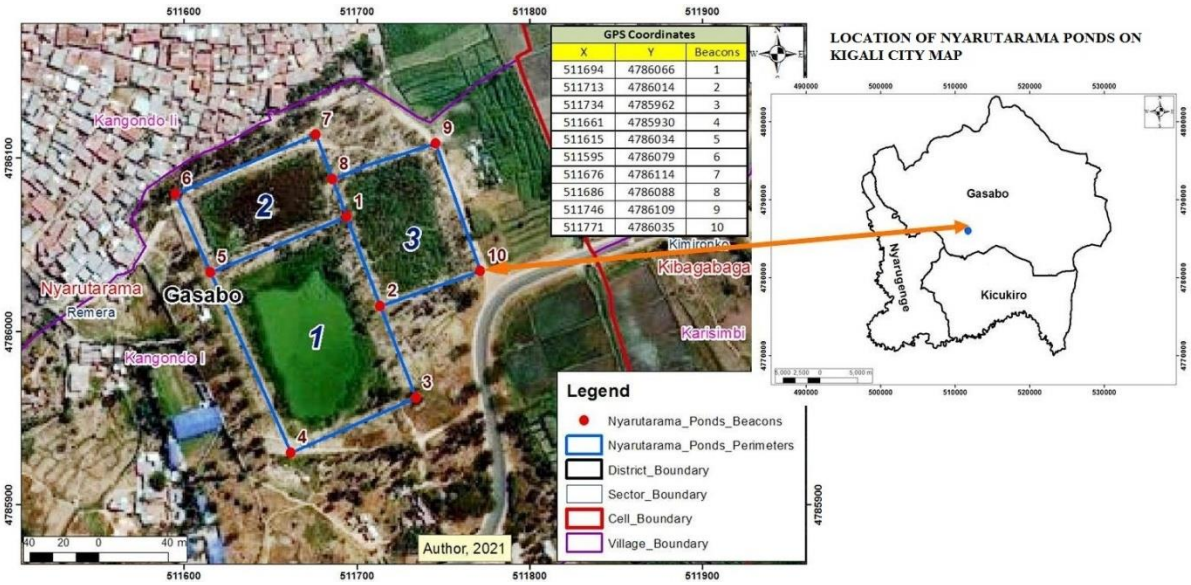

Figure 2: Location of the Nyarutarama constructed Ponds system

1: Primary Facultative Pond, **2:** Water Lettuce Covered Pond and **3:** Constructed wetland pond

(Source: Google map)

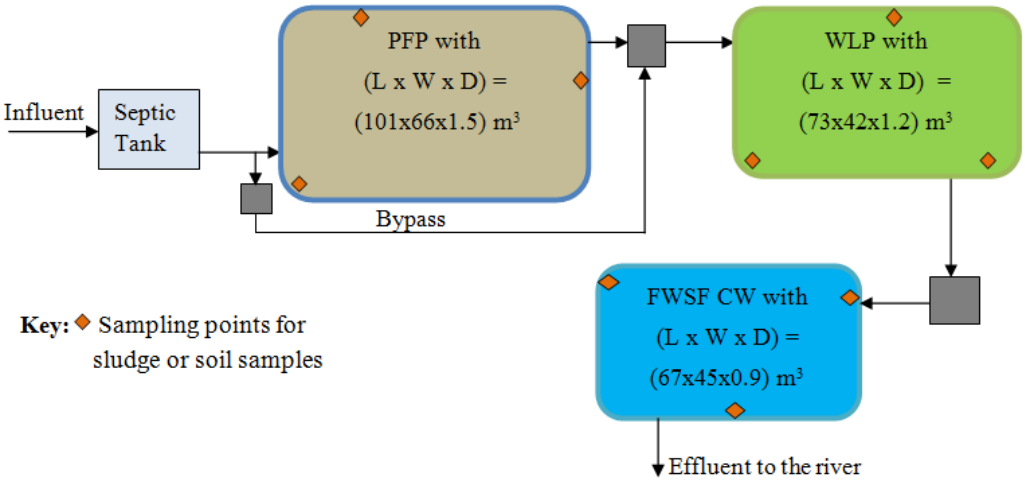

Figure 3:, Layouts and sampling points (red shape) on schematic diagram of Nyarutarama Ponds

3.2. Assessment of the clogging level and key triggering factors in the clogging process

Key informant interviews questions were prepared and interviews were organized and proceeded randomly to evaluate the major causes of the clogging and malfunctioning of Nyarutarama natural hybrid ponds treating municipal wastewater in Kigali. In this study the clogging process was also assessed by measuring the depth of the pond from the surface of each of the Nyarutarama hybrid natural wastewater treatment ponds where six sites were randomly measured from each of the

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ponds to determine the level of clogging in each of the ponds. The settled sludge samples were also collected from three different sites in each of the ponds layout to make a composite sample and transported to the Chemistry laboratory of University of Rwanda, College of Science and Technology to determine the bulk soil density and thereafter the mass of the clogging materials in each pond were deduced (Baird et al., 2017).

3.3. Measurement of bulk soil density

- **Laboratory Analysis Equipment**

The bulk soil density was determined by using the aforementioned equipment: Volumetric flask, Analytical balance sensitive to 0.01g, Vacuum pump, Distilled water, Funnel, Spatula and Drying oven (Baird et al., 2017; Knowles, 2012; Sekomo Birame, 2012).

- **Analysis procedure**

The density of the sludge or soil particles collected from Nyarutarama ponds was determined by applying the following procedure (Baird et al., 2017):

The empty cleaned and dried volumetric flask was weighed and recorded as $\mathbf{W_1}$. The weighed flask was filled with distilled water up to its graduation mark. The inside and outer parts of the flask above the water level were cleaned and it was weighed again to be recorded as $\mathbf{W_2}$. The flask was emptied and dried and 50 grams of soil sample were weighed and carefully placed into the dried flask by using funnel and then weighed it with being recorded as $\mathbf{W_3}$. The 2/3 of the flask was filled with distilled water and a vacuum pump was gradually applied to remove the entrapped air by rotating the flask in order to remove the all air bubbles. This step can take place within 10-15 minutes. The vacuum was removed and the flask was cleaned, dried and completed with distilled water up to the graduation mark. Then it was weighed and recorded as $\mathbf{W_4}$. Thereafter, the temperature of the used distilled water was derived by using the thermometer.

Based on the recorded temperature for distilled water in the last step, its density ($\boldsymbol{\rho_w}$) can be then derived from the specific tables (i.e., ρ_w=998.23 kg/m^{3}at$T$=20 ℃) and therefore, the density of the soil particles ($\boldsymbol{\rho_S}$) was calculated by using the equation below:

$$\rho_s = \frac{(W_3 - W_1) * \rho_w}{(W_2 - W_1) - (W_4 - W_3)}$$

The specific gravity of soils usually ranges between 2.65-2.80 in which the finer soils having higher values compared to the coarser ones.

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4. Results and discussion

In this section it was attempted to understand the key factors that are responsible of the clogging leading the poor performance of Nyarutarama hybrid natural system treating the municipal wastewater from Juru estate and Green hills academy. In order to achieve this objective, the clogged volume and the quantity of the accumulated soils in each of the ponds layout of the studied system were examined and estimated. Thereafter, the key informant interviews were conducted in order to collect the information from the neighboring and beneficiary people as well as the local authorities and experts in natural wastewater treatment ponds system.

4.1. Examination of the clogged volume and the quantity of accumulated soils

The Table 2 presents the estimated results from the determination of the clogged volume in each of the ponds as well as the estimated soils amount accumulated in the respective mentioned ponds layout. The clogged volume was determined by measuring the remained depth above the accumulated solids matter surface and this was done in different six points in each pond and the average values were computed as represented in the mentioned table. While the quantity of the accumulated solids was determined by calculating the bulk soil density from the composite samples collected from each of the ponds system layout.

Table 2: Estimated values of clogged volume and accumulated solids mass in Nyarutarama ponds

Pond Layout	Clogged Volume				Quantity of accumulated solids		Clogging rate (%)
	Average Clogged Depth (m)	Length (m)	Width (m)	Volume (m3)	Bulk Soil Density (Kg/m3)	Mass of solids matter (Kg)	
PFP	1.172	97	63	7163.111	2.69	19268.767	78±10
WLP	0.894	71	41	2600.979	2.71	7048.652	60±8
CWP	0.676	64	43	1860.352	2.67	4967.140	75±6

PFP: Primary Facultative Pond, WLP: Water Lettuce covered Pond, CWP: Constructed Wetland Pond

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The results in Table 2 indicated that Nyarutarama ponds system was significantly clogged due the large quantity of accumulated solids that have deposited into the ponds bed surface and reducing the pond's depth which also affect the performance of the ponds system to remove pollutants such as organic matter from the influent sewage or municipal waste water (Matos et al., 2017).

According to the obtained results, the measured clogged depths for the first pond were ranged between 1.312 m down to 0.982 m with the average value of 1.172 ± 0.144 m, those of the lettuce covered pond were ranged from 0.987 m to 0.779 m with the mean value of 0.894 ± 0.091 m while the constructed wetland's depth was clogged at the range from 0.743 m down to 0.608 m with the mean value of 0.676 ± 0.055 m. It was observed in this study that, the clogging rate in each of the pond was 78% for primary facultative pond, 60% for water lettuce covered pond and 75% for constructed wetland pond. However, these results shows that the volume occupied by the accumulated solids was larger, and those were the important contributors to the clogging process of Nyarutarama ponds system (Matos et al., 2017).

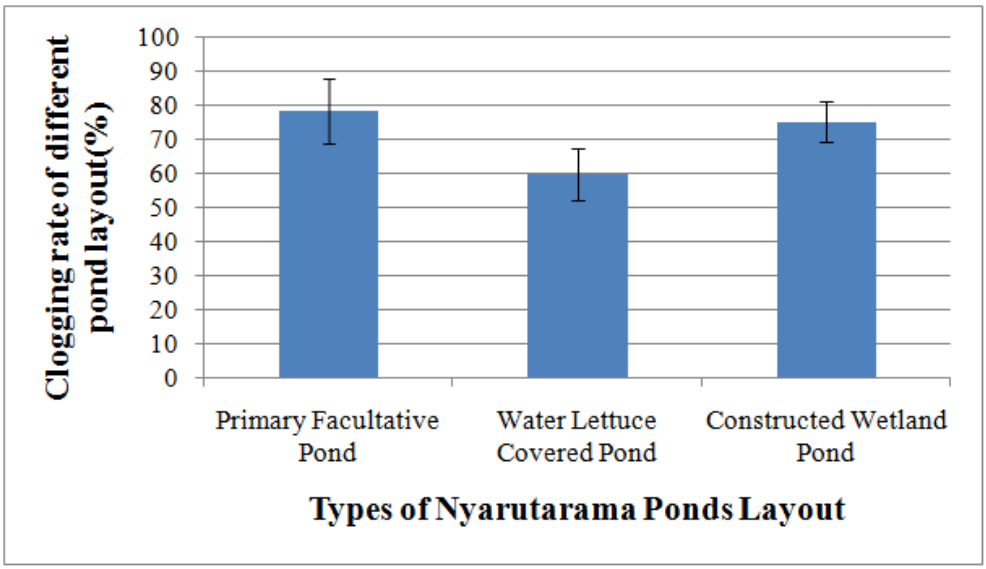

Figure 4: Clogging rate in Nyarutarama different natural hybrid ponds layout

The observation in figure 4 showed that the primary facultative pond and constructed wetland pond are highly clogged than water lettuce pond. This was due to the desludging of the first pond where the sedimentation process should take place at highest level and the constructed wetland pond is highly clogged due to the lack of macrophytes harvesting that has been started in this latest pond

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but becoming common for all three ponds due to the absence of monitoring, maintenance and management of the Nyarutarama constructed ponds system.

Clogging processes in Nyarutarama hybrid ponds appear mostly as a consequence of inappropriate operating, maintaining and management conditions including the poor harvesting of macrophytes that creates the plant debris, biofilm growth as well as the roots and rhizomes development, lack of desludging process, frequent agricultural activities done in wetland buffering zones resulted from the absence of the proper fence and security guard or watchman for Nyarutarama treatment plant (Dotro & Chazarenc, 2014; Nhapi et al., 2013; Sekomo Birame, 2012). The proper fencing of the treatment plant and the availability of means to pay for regularly maintenance by a private company or an individual will prevent or minimize the accumulation of solids in the ponds system, this is because at the period of study it was found that there was no responsible for that treatment system (Nhapi et al., 2013).

4.2. Assessment of the key triggering factors in clogging process

In this section, it was important to identify and understand the key triggering factors in clogging process of Nyarutarama ponds system as well as to suggest the solutions to them by conducting the key informant interviews in the nearest estates and surrounding areas where different activities such as agriculture, horticulture, schools, hotels, snake bars and restaurants, car wash, and small businesses are being conducted. The key informant interviews were conducted within the last two weeks of October 2021. During this study, a total of 24 respondents were interviewed. The highest proportion of key informants were from farmers and gardeners working to the nearest places of the study area (45%), interviewed local authorities were 12%, the experts in natural wastewater treatment systems were also 12% working in civil society, 20% of interviewed peopled were beneficiaries from Juru estate and the rest 11% of interviewed are people who performs small businesses near the Nyarutarama hybrid ponds system. The average age of the respondents was 48 ± 9.85 years that ranged between 30–67 years. 54% of the respondents were male while 46% were female.

The Nyarutarama natural hybrid ponds system was designed and constructed to treat municipal or domestic wastewater from neighboring estates in Kigali where it was used to treat the sewage from Juru estate and Green Hills Academy in Juru village, Nyarutarama cell, Remera sector, Gasabo District from 2000 up today. It was designed for receiving and treating the sewage from 483 houses

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in its neighboring estates (Nhapi et al., 2013). The successful operation of Nyarutarama ponds systems requires regular monitoring and maintenance to ensure it remains functional and in a 'healthy' condition. The operational and maintenance should consider the requirements for safety, water management, cleanout of sediments, maintenance of structures, embankments and wetland vegetation control and harvesting during maintenance operations.

The key informant interview results on the key triggering factors in clogging process during operation of existing natural wastewater treatment systems which was carried out during this research study indicated that the major problems experienced was poor even lack of management system since 90 % of the interviewees were mentioned it. Other challenges during the operational phase are fluctuation of flows and inadequate performance monitoring of the constructed wetland systems. This is due to lack of operation, maintenance and monitoring by the skilled personnel specialized in CWs services.

4.2.1. Origins of municipal wastewater treated in Nyarutarama Hybrid Natural Ponds

According to the total number of interviewees, 79% have mentioned that the municipal wastewater treated in Nyarutarama ponds systems are originated from Juru estate and Green Hills Academy while 21% have responded that the ponds treat the sewage from only Juru estate. These results indicated that the huge volume of wastewater loaded and treated in the Nyarutarama hybrid ponds is originated in both Juru estate and Green Hills Academy.

4.2.2. Main benefits of Nyarutarama hybrid natural ponds to the society

Most of the interviewed people have said that the existing treatment system has many benefits to the society when they work properly but as it was destroyed and clogged in these days it does not work properly and there are no benefits to the society and surrounding people (72%) while others they have mentioned that as the fence has been removed, it seems to be better because we have found the land for cultivation while before it was not allowed to enter (12%). According to the responses from interviewees, the following benefits are highlighted for Nyarutarama natural ponds system to the society especially to the neighboring population. It provides the treated wastewater to be used in car washing, in agricultural and horticultural activities for irrigation (96%), it treats sewage from the estate (68%), it provides different jobs when working and managed properly (42%) and it facilitates the life of wildlife habitats and animals including birds and fishes (3%).

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4.2.3. Main problems associated with Nyarutarama hybrid natural ponds to the society

The surrounding population and the general public can suffer the following problems associate to the Nyarutarama natural hybrid ponds treating wastewater in Kigali. Nyarutarama ponds occupies a larger surface that should be used for agricultural activities when it was designed to occupy a shorter space (79%), as it is located nearest the houses, it may cause malaria and others communicate and no-communicate diseases as it is a best area for the grow of mosquitoes and other wild animals such as snakes and fogs (42%). When unfenced, Nyarutarama ponds can be a good area for suicide since it easier for everybody to access the ponds (54%). It generates a bad odor when it wrongly operated (92%). All the above mentioned problems should be solved by putting in place the good managerial plan of the Nyarutarama natural hybrid ponds.

4.2.4. Status of Nyarutarama Hybrid Ponds before the destruction of its buffering zone

According to the total number of interviewees, the majority of them (83%) have responded that the ponds was presentable with a very attractive appearance from which the university students from different institutions come here for educational field trips but from 2016 when the fence was removed and the surrounded people got easier access into the system buffer zone, the appearance of the ponds system was changed and become non presentable as you see it today (Figures 5-8). Others have responded that they do not know the appearance of the ponds before the removal of fence followed by the destruction of its buffer zone (17%). The lack of management plan of the ponds after the departure of NPD COTRACO ltd as the managerial company is the main cause of the clogging and wrong operational problems faced by the system that leads to current unsuitable appearance (96%).

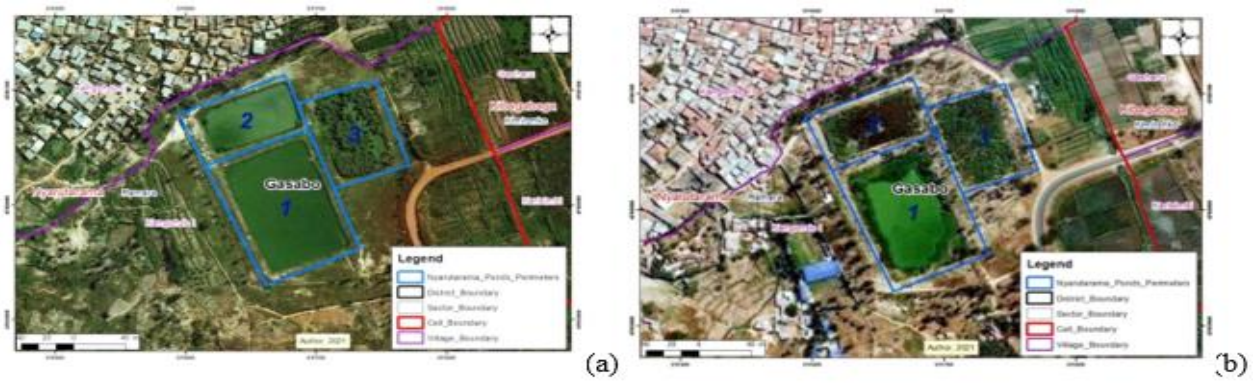

Figure 5: Nyarutarama hybrid ponds appearance (a) before and (b) after clogging process and destruction

(Source: Google map)

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The interviewees have suggested that the ponds should be rehabilitated and restored for its further performance in treatment of sewage from neighboring houses in the way of restoring its suitable appearance and enhancing the environmental pollution reduction by improving the safety population healthy.

Figure 6: Photo (A) Primary Facultative Pond before clogging (2013) (Nhapi et al., 2013) and Photo (B) Primary Facultative Pond after clogging (2021)

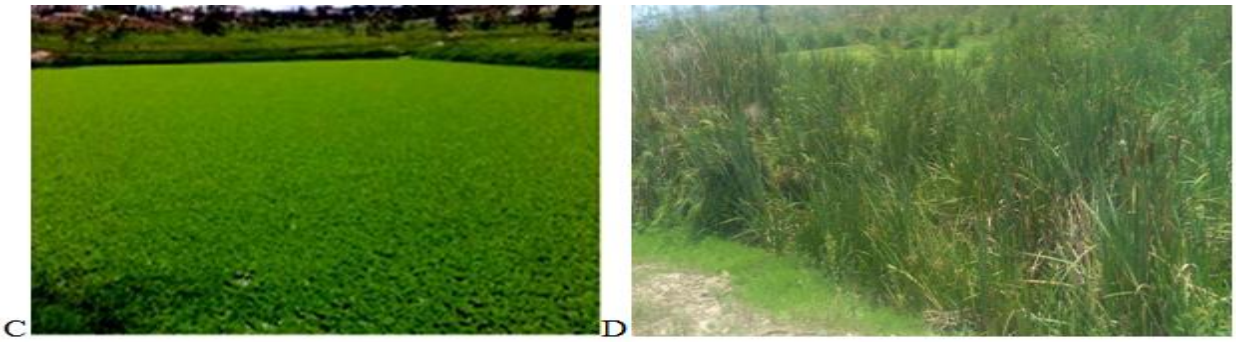

Figure 7: Photo (C) Water Lettuce Covered Pond before clogging (2013) (Nhapi et al., 2013) and Photo (D) Water Lettuce Covered Pond after clogging (2021)

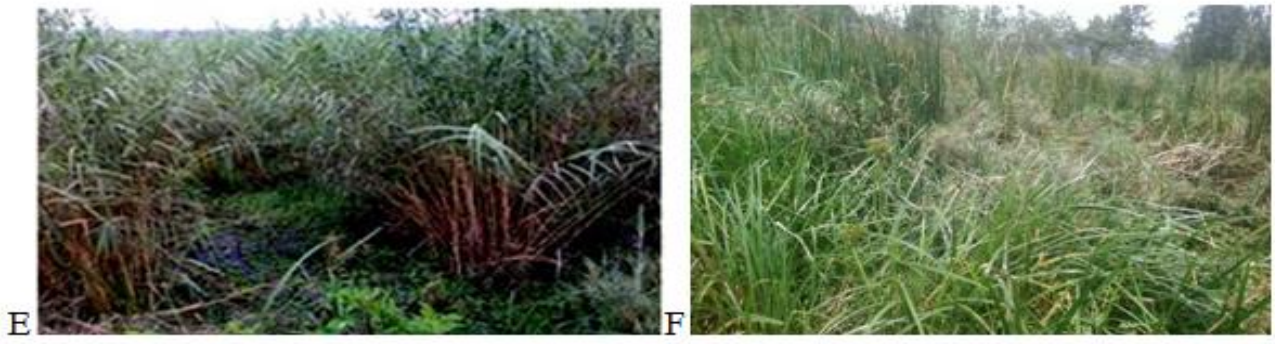

Figure 8: Photo (E) Constructed Wetland Pond before clogging (2013) (Nhapi et al., 2013) and Photo (F) Constructed Wetland Pond after clogging (2021)

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4.2.5. Main driver for the degradation of Nyarutarama hybrid ponds system from the last 5-10 years before 2021.

According to Nhapi, et al. (2013), in the last 5 to 10 years the ponds system was successful work to remove pollutants such as TSS, BOD_5, COD and nutrients as well as microbiological pollutants from sewage but the following important factors have been contributed to its clogging process and its failure to work successful up today as have been mentioned by our interviewees. Among the factors, the lack of management system which may setting the rules and regulations governing the operation, monitoring and maintenance activities including the wetland plants harvesting and desludging processes, 78%, have been highly contributed to the clogging and destruction of the ponds system. The easier access of the population to the pond system is the second significant cause of its clogging (58%). This is because of the agricultural and horticultural activities that were exercised in the buffering zones of Nyarutarama ponds system and they contributed to the solids accumulation into the ponds. Other interviewees, 56%, have mentioned the development of infrastructure from which the pits are designed and constructed to receive the sewage and the inflow rate to the treating ponds system have been considerably reduced. The changing land use also contribute to the current degradation of the Nyarutarama pond system, 48%, because the buffer zone was reserved to be uncultivated for preventing the runoff to reach the system which may allow the entering of solid materials that can contribute to the system clogging. In other important driver there are lack of specialized personnel and the guardians for system monitoring and security saving, 72%, that may inhibit the throwing of the solids waste into the system because these solids waste will be accumulated into the system to allow its clogging process.

4.2.6. Measures for curbing clogging and degradation process and promoting sustainable management of Nyarutarama ponds

The following measures were suggested by the interviewees for the better and sustainable management of the restored Nyarutarama ponds system to prevent its further clogging and degradation processes. The development of the rules and regulations that governing the proper operation and maintenance of Nyarutarama ponds system, (72%), by showing fines for those who will be involved in malpractice of the restored system. Other interviewees, 83%, have responded that all the houses in Juru village should be obliged to throw their sewage into the ponds and they should contribute in terms of money for its operational, monitoring and maintenance activities as it is done for the collection of solids waste. The use of pits and septic tanks to receive municipal

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waste or sewage should be prohibited for all neighboring houses, 100%, and fines should be applied to those who will refuse to direct their home sewage into the ponds, 87%. The ponds system should be fenced to avoid the easier access of people into its buffering zones but only the allowed people may access it, 48%. The indicating signs should be placed near each pond to indicate its depth and this will prevent any accident that may happen, 21%.

4.2.7. Systems for the sustainable management of Nyarutarama hybrid natural wastewater treatment ponds

According to the total number of interviewees, 96% have responded that Nyarutarama ponds systems should have the permanent staff specialized in the matter of constructed wetlands or natural wastewater treatment systems and the permanent guardian from the recognized security company. Among the respondents, 48% of interviewees have mentioned that the private company should be appointed to monitor and maintain the ponds system to enhance its performance and prevent its further destruction and clogging. The people mobilization should be done to increase the beneficiary awareness for contributing in good operational and management of Nyarutarama ponds systems, 72%. The buffering zones should be fenced, mapped and designed into an attractive touristic area for recreation activities and the insecticides should be sprayed permanently to kill the illness vector insects, 46%.

4.2.8. The benefits of Nyarutarama ponds system restoration to the surrounding community

The rehabilitation and restoration of Nyarutarama ponds system have many interests to the surrounding community including availability of treated wastewater for carwash and irrigation, 96%, availability of jobs for its cleaning out and macrophytes harvesting, 72%, educational field trips for people from different areas and cultures, 54%, having the unpolluted environment that will contribute to the safety health of surrounded people, 46%. The restoration of Nyarutarama ponds system will also reduce the borne diseases vectors, 48%.

5. Conclusion and recommendations

It was experienced in this study that the clogging threats that faced by the Nyarutarama constructed ponds system have contributed to its performance lowering. This system clogging process is resulted from the accumulation of various solids materials such inorganic solids from chemical precipitation, sludge from physical sedimentation and biological process like plant detritus and biofilm formation. The quantity of solids accumulates in each ponds was determined and the level

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of clogging was examined and expressed in percentage where the primary facultative pond and free water surface flow CWs due to the desludging process and lack of harvesting process respectively. Nyarutarama natural hybrid ponds system was destroyed and clogged following the lack of management plan to ensure its regular operation, monitoring and maintenance activities. This lack of management plan was leading to the easier access of the surrounding people and they practice the agricultural and horticultural activities in the buffering zones in the system which have been significantly contribute to system clogging process.

To ensure a trusty and sustainable management of Nyarutarama natural hybrid Ponds, the following actions are highly recommended:

1) The ponds system could be rehabilited and restored for improving its actual performance in order to treat generated wastewater in Kigali to prevent the discharge of untreated or partial treated wastewater into the environment to threaten the health of nearest population.
2) A private company or an individual could be assigned to carry out regular monitoring and maintenance of the ponds. At the time of the study there was hardly anyone responsible for this
3) The management of the ponds system could be contracted out to ensure proper monitoring, maintenance and operation of the ponds and their surroundings.
4) Installation of a system for screening and grit removal at the inlet from the pretreatment municipal wastewater in order to reduce the quantity of sludge accumulated in the primary facultative pond and to protect the environment against pollution.
5) Regular desludging and proper management of wetland vegetation coverage, including an optimal wetland plants harvesting plan, is required to ensure their optimal growth and improved pollutant removal efficiency.
6) Checking effluent quality regularly by routine analysis of key parameters, which are harmful to environment especially fecal coliforms, nutrients, chemical and biochemical oxygen demand.
7) Social mobilization could be organized to increase the people awareness on the benefits of well operated ponds systems and the problems associated to the worth operated system. They are also requested to contribute to the budget of the management activities of the ponds system

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