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Sludge Wastewater Management by Conventional Treatment Process: Case Study - Bujumbura Municipal Sewage

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Abstract: In the period 1990-2012, the percentage for open defecation has dropped by 11% in sub-Saharan Africa which has resulted to substantial progress in access to improved sanitation facilities i.e. pit latrines, VIPs, septages and centralized sewage facilities since 1990 [figure 1]. This therefore put at ease the operations of many municipal's water resource and waste management agencies. Recent investigation confirms that the number of people defecating in the open is currently increasing in 26 of 44 countries of sub-Saharan Africa and this unsustainable practice is predicted to persist as long as there are toilets that are dysfunctional or unhygienic (WRC, 2015) in Africa. Per review conducted, the unhygienic and dysfunctional conditions of public toilets facilities are results of poor sludge management operations of which inconsistent collection of faecal sludge from toilet sites is a major part. Reported cause of inconsistent emptying of faecal sludge at sanitation sites is due to higher cost of faecal sludge management(FSM) services within urban and peri-urban settlements. FSM services comprise of three stages i.e. collection, treatment & re-use, and disposal of which the treatment stage accrue the most cost of the services. Treatment cost depends on treatment techniques applied by sanitation inspectors/operators but there is currently no definite treatment method which is the most suitable as the physico-chemical properties and environmental compliance requirements for disposal of faecal sludge is highly variable and most solutions have not been demonstrated at scale. To be precise on the key scope of study, on-site sanitation & centralized facility faecal sludge treatment techniques and management practices are deemed the core basis of study hereafter. In this paper, anaerobic-aerobic phosphorous removal process (A/O) is selected as an efficient and cost-effective centralized facility sludge treatment technique and its applied to a case study in Bujumbura municipal of Burundi. Also a simple but effective on-site sanitation management plan which is feasible in Africa communities is discussed.

1. INTRODUCTION

Many developing countries are presently experiencing rapid urbanization and human population growth mainly in the urban centers but however the provision of environmental protection measures, including reliable system of wastewater collection, treatment and disposal has not kept step to this development. Pit latrine, full pit and septage on-site sanitation systems which are the most common practiced sanitation system in the informal urban, peri-urban settlements and rural areas of Africa are mostly dysfunctional and unhygienic due poor management operations. The faecal sludge is rarely emptied and the few times they are emptied, it is unsafely disposed to water bodies. It is also estimated that the percentage of open defecation at shores of water bodies and abandoned farms has increased in 26 of 44 countries in sub-Saharan Africa due to dysfunctional and unhygienic condition of shared toilet systems. Due to the above, agencies responsible for the protection of municipal water resources and sanitation in general is now facing difficulties of many sorts including failure to satisfy the need of pure drinking water in communities. Dysfunctional toilet facilities, increased rate of open defecation and unsafe disposal are probable results of poor faecal sludge management(FSM) practices and higher cost of sludge collection & treatment in general. Selection of a proper treatment technique is a good step to optimizing the cost of treatment to a lower rate.

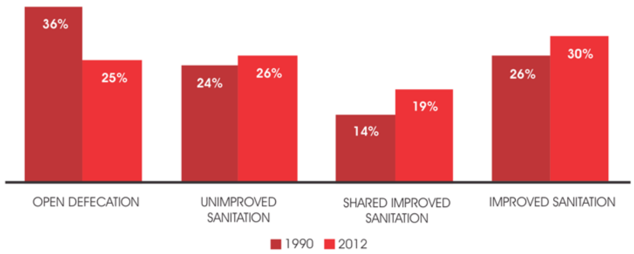

Figure -1: Progress in sanitation in sub-saharan Africa (Source, Slabbert 2015 [1])

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However, there is currently no definite conclusion as to which treatment method is the most suitable as the physico-chemical properties and environmental compliance requirement for the disposal of faecal sludge is highly variable. In this paper, basic and cost-effective treatment techniques for on-site sanitation and centralized sewage facility are briefly discussed.

1.1 Constituents of Faecal Wastewater

The constituents of municipal fecal wastewater discharged into water bodies are a reflection of the community's civilization and of habitant's metabolism and hence it spatially varies. In spite of its spatiality dependent varying constituents, the treatment processes and methods still remains consistent and unchanged. The reactions of wastewater in water bodies if untreated are the production of large quantities of malodorous gases, consumption and depletion of dissolved oxygen which could kill fishes, eutrophication due to quick stimulated growth of aquatic plants and alga blooms, contamination of water body due to presence of numerous disease causing microorganisms and toxic compounds that dwell in the human intestinal tract[2]. Wastewater contains significant amount of bacteria in the form of coliforms which originates from faecal waste of humans and other warm-blooded animals and hence the amount of fecal coliform in stream or water bodies increases with the amount of domestic sewage waste. Wastewater treatment deemed effective if pathogens such as E coli, hepatitis, and salmonella, and fecal coliforms are screened or reduced before discharge.

1.2 Overview of Treatment Methods

These contaminants in wastewater are removed by physical, chemical and biological operations and these operations occur in a variety of combinations in treatment systems[3]. In the past, different methods for this treatment were used and through evolution and advancement of technology, developed methods have been advocated. Treatment methods are aimed at the removal of suspended material, biodegradable organics(BOD), disease-causing pathogenic micro-organisms, and nutrients such as nitrogen and phosphorous[2]. It is necessary to understand their standard operating procedures separately. The physical treatment approach requires physical forces like screening, mixing, flocculation, sedimentation, filtration for operation as chemical treatment approach bases on chemical reactions unlike the biological treatment approach which applies biological activities like settling.

Concluding, the consequence of poor sanitation practices like improper fecal wastewater disposal is the ill effects of the urban population and the enormous investment of the state to maintain the health of its population. Conversely, effective waste water treatment technologies are available to elude the undesirable consequences but they are expensive and have no direct economic returns and hence many local authorities are not interested in implementing those methods. Therefore, in this paper, a cheap, simple and conventional wastewater treatment process is presented which comprises of the principles, ideas and design.

2. FAECAL SLUDGE MANAGEMENT

2.1. Implementation Phase

In line with SANDEC, faecal sludge management imple- mentation phase comprises of the following items

- Collection
- Treatment
- Re-use and disposal
- Responsibilities, communication and coordination

2.2. Waste-water Collection System

The modes of fecal wastewater collection in African countries are by centralized sewerage network system(CNS) and on-site faecal collection system which includes pit latrine, full pit, septic tanks, etc. In case of on-site collection system, fecal sludge is transported to treatment plants by vacuum trucks or a tank and pump mounted on a flatbed [figure 2 & 3]. Unlike the SNS, septage is directly transported directly through pipe network system into the central treatment plant for final disposal. Densely populated areas operate on FSM services mostly in developing countries due to inaccessible connection to the central sewerage lines. However, FSM in developing cities is informal, unregulated, unhygienic and unsafe and due to this, discharge of untreated sewage into water bodies have become rampant and have resulted in contamination of surface water bodies. For scenarios of pit latrine on-site faecal connection,[4] summarizes few pit emptying technologies to overcome the problem of fecal sludge management, and also presents a framework to assist decision makers in identifying potential pit emptying methods based on local technical conditions.

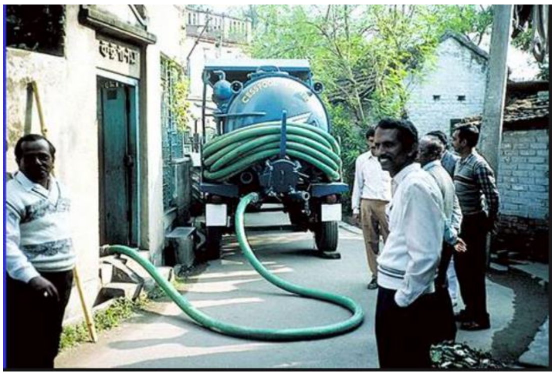

Figure -2: Pit latrine on-site faecal collection

Figure -3: Septage latrine on-site faecal collection

2.3. Faecal Treatment and Re-use

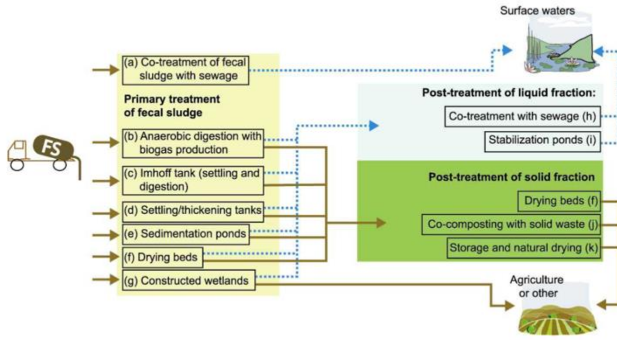

Figure-5: Overview of faecal sludge treatment technologies for on-site sludge. (Source, Strauss 2002[5])

2.3.1 On-site Treatment

On-site treatment process are mostly comprised of only primary treatment techniques. Primary treatment of sewage enables separation of floating material and heavy solids from liquid waste. It reduce BOD by 20% to 30% and suspended solids by up to 60% which retains approximately two-thirds of initial BOD composition in the form of colloids and dissolved organic compounds. Effluent from primary treatment plant can be directly discharged to nearby water bodies so that natural biological decomposition can self-oxidize the remaining waste. Primary treatment compared to secondary treatment has no advantage in the cost of removing certain amounts of organic pollutants and suspended solids. The ratio of operation and maintenance costs of primary and secondary treatments correlates negatively with the treatment scales as reported by Pengfei[6] and therefore, considering the economic levels of developing countries, secondary treatment techniques are more reasonable to remove more pollutants and to eliminate water pollution. According to Klingel et.al [5], the following are commonly used physical on-site treatment techniques. They are applied to on-site faecal sludge as effective treatment techniques and also referred as primary treatment processes sequential to post-settling unit (a clarifier) in a centralized treatment facility.

- Solids-liquid separation
- Settling/thickening tanks or ponds(batch-operated)
- Unplanted drying bed
- Constructed wetlands
- Anaerobic digestion with biogas utilization

A. Solids-liquid separation

To recycle nutrients in human excreta and municipal solid waste for use in agriculture, solids-liquid separation technique is enough. In separating solid and liquid fractions of faecal sludge (FS), drying beds can be used so that the retained solids can be co-composted and the organic matter and part of the nutrients captured will be available for urban agriculture. Sludge influent onto drying beds, percolate effluent, and dewatered sludge (biosolids) were monitored over eight loading cycles in 2002 by O.Coffie et. al [7]. It was observed after an average drying time of 2 weeks that, Biosolids with TS 20% had already been obtained. Also, the drying beds retained 80% of solids and 100% of helminth eggs. The biosolids had average organic matter content of 61%; hence, allowing for co-composting with biodegradable organic solid waste for hygienisation. Many other research studies complies to the efficiency of this technique.

B. Settling/thickening tanks (batch-operated)

Thickening tanks are settling tanks that allow faecal sludge to thicken and dewater. The effluent is removed and treated, while the thickened sludge can be further treated in a subsequent technology (e.g. in waste stabilization ponds, planted or unplanted drying beds, short rotation plantations or by composting). This is not very efficient for large volume on-site faecal sludge (e.g. from latrines or unsewered public toilets) because it will require long retention times during which settled sludge will undergo further stabilization by anaerobic digestion. However, settling tanks can be used as first step in fresh faecal sludge treatment to reduce retention time. Pond systems are relatively low cost, as they do not require much maintenance and no energy but depending on the frequency of desludging, emptying, it may become expensive or labour intensive.

C. Unplanted drying beds

This is a low-cost option that can be installed in most hot and temperate climates. An unplanted drying bed is a simple, permeable bed filled with several drainage layers that, when loaded with sludge, collects percolated leachate and allows the sludge to dry by percolation and evaporation [figure 3a,3b]. Approximately 50% to 80% of the sludge volume drains off as liquid or evaporates. The sludge, however, is not effectively stabilized or sanitized. Additional treatment by composting may be foreseen for the dried sludge before it can be safely disposed or used as a nutrient-rich soil amendment in agriculture. Both the incoming and dried sludge are pathogenic; therefore, workers should be equipped with proper protection (boots, gloves, and clothing). Unplanted drying beds need to be desludged before fresh sludge is applied. Drying beds are relatively easy to construct and simple to maintain, although large surface areas and man- or mechanical power is required for regular desludging. Operation costs are low as no energy or complicated equipment is required. However, desludging is laborious.

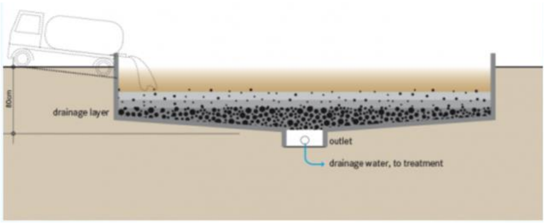

Figure -3a: Unplanted drying beds

Figure -3b: Unplanted drying beds in Ghana
(Source, Tilley 2008[8])

D. Constructed Wetlands

Constructed wetlands have most commonly been used in wastewater treatment to control organic matter, nitrogen, and phosphorus. Constructed wetlands are designed and built similar to natural wetlands to treat wastewater. It is a treatment system that use natural processes involving wetland vegetation, soils, and their associated microbial assemblages to improve water quality [figure 4].Constructed wetlands are most economical as compared to conventional treatment units which needs more energy for its process and this method require cheaper materials. Angular horizontal subsurface flow constructed wetland unit is one kind of efficient wetland unit that treats wastewater effectively based on its quality parameters like pH, EC, TSS, TDS, TS, BOD, COD, Nitrate, Phosphate and Sulphate. Colocasia esculenta vegetation has maximum pollution reduction efficiency of about 70% and its therefore suggested for wetland units. Constructed wetlands can be built to meet the needs of homes with failed septic systems.

Figure -4: Constructed wetland: Plenty Valley Christian College Wetlands (PVCC) Located in Doreen, Victoria
(Source, www.ausecosolutions.com.au)

E. Anaerobic digestion with biogas utilization

Anaerobic digestion is the process of biologically breaking down organic wastes in absence of oxygen. It yields two outputs as follows: an effluent that is highly reduced in organic content and biogas—a mixture of methane (55–70% of total volume makeup) and carbon dioxide (30–45% volume) with trace concentrations of hydrogen sulfide (H2S), hydrogen, and water vapor [9].

2.4. Centralized Sewage Treatment

Collective sewage network that runs into a centralized treatment facility mostly comprises of a secondary treatment section. Secondary treatment is a treatment process further applied on wastewater (or sewage) from primary treatment plant to achieve a certain degree of effluent quality through application of biological treatment processes to remove the residual organics, microorganisms and suspended solids. The composing micro-organisms convert the biodegradable organic matter contained in the wastewater into simple products and additional biomass, thereby producing more microorganisms and inorganic end-products (principally CO2, NH3, and H2O)[10]. Several aerobic biological processes used for secondary treatment differs basically by the way the oxygen is supplied to the microorganisms and the rate of these organisms metabolize the organic matter. Widely used secondary processes includes;

- Adsorption-bio-degradable treatment Process(AB)
- Sequencing batch reactors process (SBR)
- Cast process
- Oxidation ditch process
- Biological Aerated Filter(BAF)
- A/O & A^2O process

2.3. Disposal

There are several approaches to septage treatment and disposal which include private or public ownership. Larger municipalities are capable of managing the whole process from handling and treatment to disposal, while other municipalities opt to use privately owned facilities that alleviate some of the responsibilities of operating a facility[11]. Land disposal of septage after adequate treatment is also a popular option (figure 6). However, untreated disposal is as well commonly practiced (figure 5).

Figure -5: illegal disposal of faecal waste-water in outskirt of Ouagadougou. (Source, Strauss 2002 [5])

Figure -6: Treated disposal of faecal waste water in Ghana

2.4. Process Selection

According to Sudhir Pillay as reported by WRC [1], there is currently still no definite conclusion as to which treatment method is the most suitable as the physico-chemical properties of faecal sludge is highly variable and most solutions have not been demonstrated at scale. However, by subjective comprehensive assessment and consideration of the below listed criteria, the planning & implementation team can preferably select a suitable treatment technique. In this study, A/O which is termed as "Anaerobic-Aerobic phosphorous removal process" is selected as a conventional technique applied to a case hereafter. P. Rajasulochana & V. Preethy [12] discussed that, the selection of a particular treatment technique primarily depends on a variety of factors, e.g. waste type and concentration, effluent heterogeneity, required level of cleanup, as well as economic factors. However, narrowing this selection criteria, faecal treatment main basis for selection are listed below;

- The ability of process to fight contaminant load
- Efficiency level of contaminant removal regards to the sewage plant's design requirements
- Degradation effect on Organic matter
- Processing power during times of high density/volume sewage

3. CASE STUDY

3.1. Geographic Description

Bujumbura, Burundi's capital city is located in the western part of the country on Lake Tanganyika. The city of Bujumbura is stuck between the lake to the west and the Mumirwa hills to the east [figure 7]. Its altitude is between 800 and 100 meters, well below the rest of the country, whose average altitude is 1500 meters. Its topography is relatively complex, as it is traversed by a series of several parallel, relatively and regularly spaced rivers flowing from east to west (in the lake). The city of Bujumbura with an area of 86.52km^2 is the big city built on the shores of Lake Tanganyika with an estimated population of about 800,000 inhabitants and a density of 4.5%. It is the administrative and economic capital of the country where the majority of the country's industrial activities are concentrated.

Figure -7: Map Geographic Location(Voilet color)

3.2. Current Sanitation Situation

The city of Bujumbura has a collective sewer network of 145 km (primary and secondary), which covers five municipalities out of thirteen municipalities in the city of Bujumbura which includes Ngagara, Nyakabiga, Buyenzi, Bwiza and Rohero as shown in figure 12. From studies conducted, this represents just 30% of the entire city's sanitation demands and out of this, 20% is currently accesed and connected by households and industries which renders it 10\% less under-loaded. Partly, 60% of the 20% successful connection represents households and the remaining portion represents industries. The general overview about the public sewerage connection rate is classified as "low rate" and it exposes the water resources of Lake Tanganyika to eutrophication, which is the natural outlet for domestic wastewater. On the other hand, other households use septic tanks and deep pits which its depth at a time reaches the groundwater level mainly in high water-table(2.0 - 2.5m) formation areas like Kinindo town. This is very unsafe as towns of that lithological formation are closer to the Tanganyika lake.

3.3. Mode of Collection and Treatment

The entire city population operates on three kinds of wastewater collection which include pit-latrine, septage(autonomous mode) and sewerage network system(collective mode). The collective mode represents 30% whiles the autonomous mode represents 70%. Mainly grey water is conveyed by the collective mode but the black-water is transported by collective per to its availability and accessibility as in figure 10 which shows that Ngagara has more wastewater transported by collective mode. Nevertheless, studies showed that greywater exceeds blackwater by volume as in figure 11. However, blackwater is heavily collected from Kinama and Kanyosha(figure 8). Centralised treatment plant is necessary required at Kanyosha due to the fact that it is closely by Lake Tanganyika and it serves as water provision outlet for many neighbouring cities (figure 8). Also Kanyosha has higher existence of septage(figure 10) and therefore its appropriate to practice centralised sewage system.

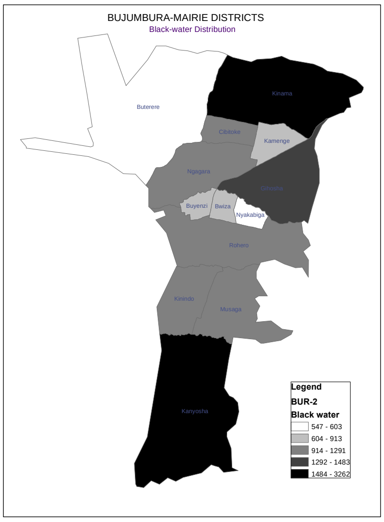

Figure -8: Black water distribution map for Bujumbura

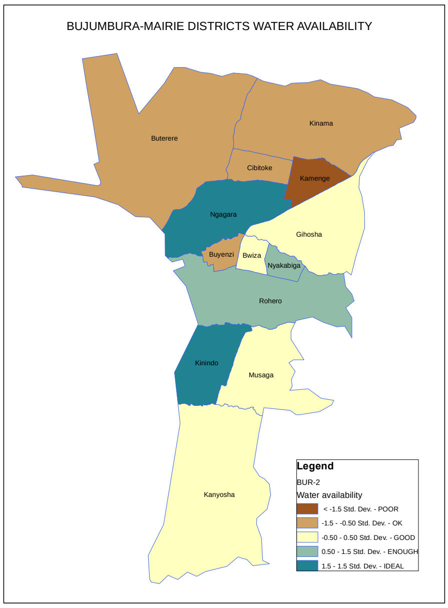

Figure -9: Water availability map for Bujumbura

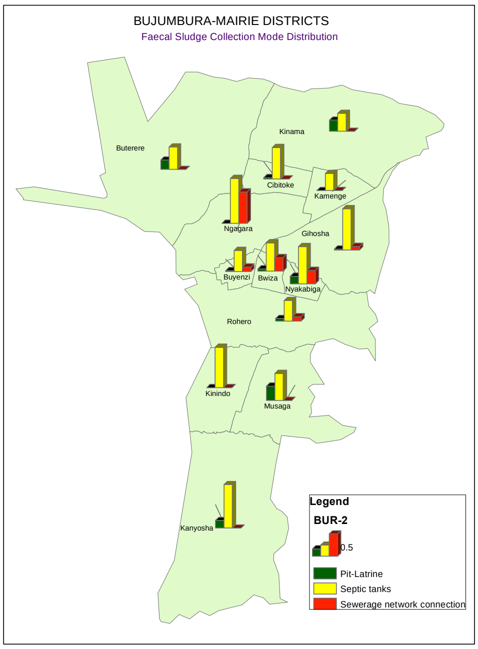

Figure -10: Sources for faecal sludge collection for Bujumbura

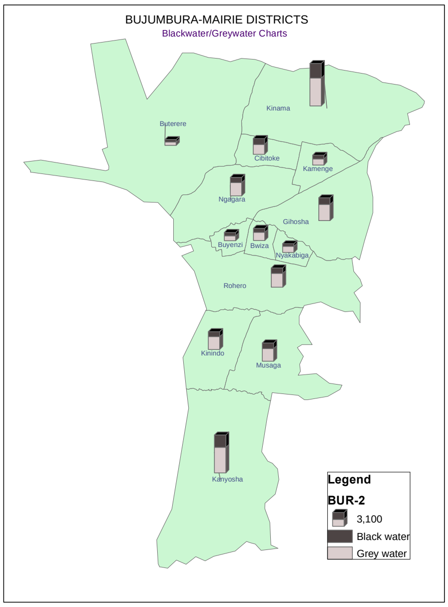

Figure -11: Black water/Graywater proportion map for Bujumbura

3.3.1. Centralised Sewage Network System (Collective Mode)

This refers to transportation mode by which the households' wastewater reaches the treatment plant for final disposal through central sewerage system. In this mode, the black and grey water runs through the public sewerage connection which is authorized by SETEMU(official authorization office for sanitation). Technically, connections are made to a secondary network by two types namely; via tertiary pipes (PVC 160) which reaches the secondary level through a sewer hole and PVC(110) that directly joins a single household to the secondary network at the level of a sewer hole. To avoid unnecessary treatment cost and volumes, less concentrated grey-water from households is diverted to run through the road side drains, meanwhile others take this opportunity to discharge sorts of heavily polluted wastewater to open-side drains through clandestine connection and this compromise the safety.

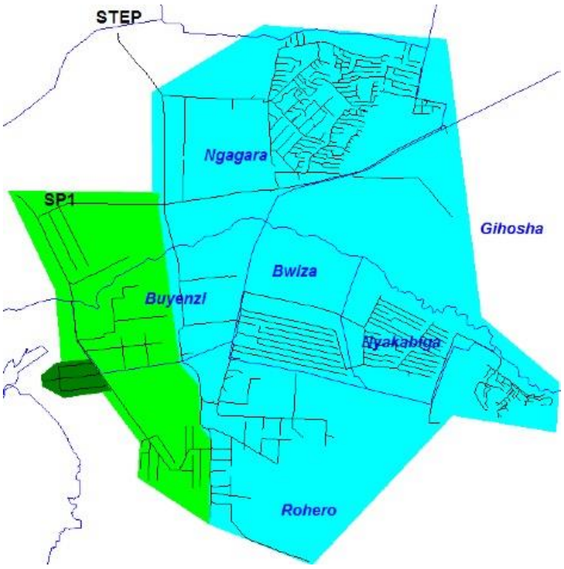

Figure -12: Central sewage network map

3.3.2. On-site Collection (Autonomous Mode)

A large part of the city (70%) is not served by the sewer network and uses autonomous treatment. Estimatedly, 70% of their households are equipped with mechanical flush latrines with septic tanks while 30\% of the other households use a ventilated toilet with a sump, also others use simple unconstructed ditches stabilized with the placement of tires as rings. This system of faecal collection relies mostly on suction trucks for evacuation and transportation to treatment plant sites. Autonomous mode which also known is mostly informal, unregulated and untreats the wastewater prior to discharge to streams.

3.4. Organic Composition of Sewage

The sewage to be treated has relatively good biodegradability and its mainly composed of organic pollutants with low levels of slowly biodegradable pollutants and metals. Furthermore the major pollution indicators of the sewage include BOD, COD, and SS and a consideration of NH4 levels in the effluent discharge because of their relatively high requirement (figure 13). Therefore, there is need for a simultaneous efficiency of nitrogen and phosphorus removal. The sewage treatment capacity of this study is relatively large; hence the discharge compliance of sewage must be met as in table 10. Special attention of the area of the project and the economic costs of sewage treatment should be paid.

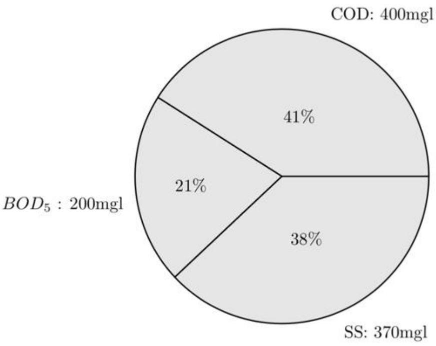

Figure -13: Organic Composition of sewage water

3.5. Centralized Sewage Treatment Process Selected

After a comprehensive analysis and a consideration of several of the above centralized sewage treatment process, It is decided to select Anaerobic - Anoxic - Aerobic biological treatment as the core processes. The main reasons are; the process has a strong ability to fight contaminant load, and the removal efficiency is high, for the design requirements of the city sewage plant to meet the required emission standards. Simultaneously, A^2/O process (figure 14) has a significant effect on the degradation of organic matter in sewage, and also can do well when it comes to Nitrogen and Phosphorus removal.

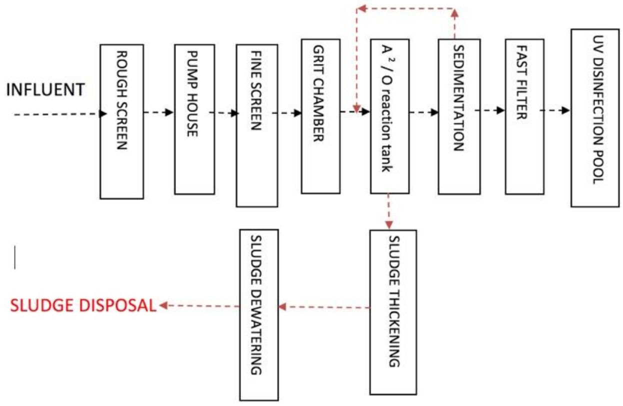

Figure -14: Influent treatment process

3.5. Treatment Facility Structures

According to existing plants across the globe and survey analysis of the operation of large and medium-sized sewage treatment plants, A^2/O activated sludge process has been selected as the core of this project design. The treatment facility structures are schematically represented in a plan(figure 15).

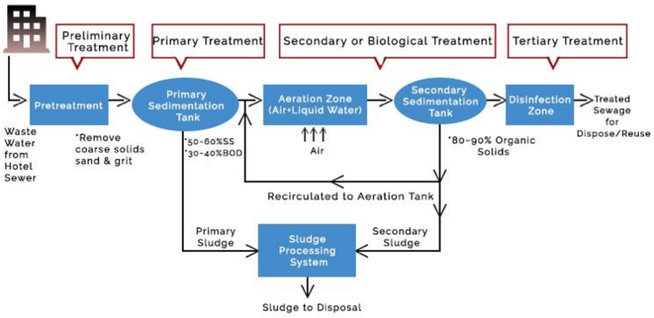

Figure -15: Schematic plan of facility structures arrangement.

3.5.1. Screen

Screen is often placed in the forefront of the wastewater process and is made of a set of parallel metal gratings. Screen is typically mounted at the inlet pumping station, primarily to intercept large floating or suspended solids materials, such as cellulose, tissue, hair, etc.

A. Coarse Screen

The role of the coarse screen is to intercept the larger suspended solids or floats which will protect the pump unit. The water velocity passing through the metal gridlines is generally around 0.6 ~ 1.0m / s. This is because if the flow rate of the sewage is too large, not only will it increase the head loss, but also part of the suspended solids may be taken to the next structure, lowering the removal efficiency. On the other hand, if the flow rate is too small, precipitation may occur in the screens and the removal efficiency of the suspended solids will be reduced.

B. Fine Screen

The fine screen is used to intercept the suspended matter/floats unrestrained by the coarse screen. The speed of the water through the fine screen is the same as in the coarse screen, around 0.6 ~ 1.0m / s and the head loss through the fine screen is generally 0.3 ~ 0.4m.

3.5.2. Grit Chamber

The working principle of the grit chamber is to remove the inorganic particulate matter in the sewage, which includes sediment and so on. The types of grit chamber include: advection grit chamber, vertical flow grit chamber, aeration grit chamber, cyclone grit chamber. In this design, the choice of grit chamber is swirling grit chamber. The swirling grit chamber is controlled by the mixing force to control the flow rate of the water stream, thereby accelerating the sedimentation of the sand and allowing the water to take away part of the organic matter. The grit chamber can achieve the best sanding efficiency by changing the rotational speed of the impeller. A sand bucket is available for the discharge of sand, you can choose to enhance the air, sand pump sand and other parameters, and finally through the sand and water separation function to achieve the standard sand.

3.5.3. A^2/O Reaction Tank

A^2/O is a reaction cell belonging to the activated sludge treatment process, the process is the use of activated sludge to achieve the degradation process of organic matter contained in the wastewater. The sewage, after pre-treatment and primary treatment, flows into the anaerobic tank where phosphorus release and organic intake occurs. It then flows into the anoxic tank where denitrification process is completed after internal reflux and mixing. Finally, the mixture flows into the aerobic tank, for the removal of BOD, nitrification and phosphorus suction process(figure 16). The advantage of this process is that no dosing is required and in anaerobic and anoxic tanks, only gentle stirring and mixing is required which make the operating costs low.

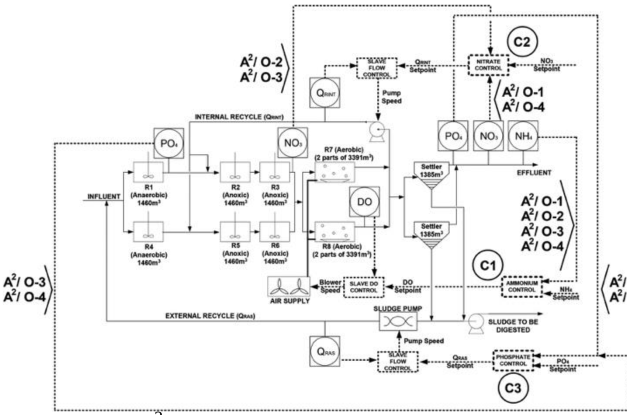

Figure -16: A^2/O reaction tank components

3.5.4. Sedimentation Tank

The role of the secondary sedimentation tank is to separate the sludge and water (figure 17), and the mixture can be clarified and the separated sludge is returned to the biological reaction stage. The characteristics of the secondary sedimentation tank are; the high concentration of sewage treatment, mud sedimentation speed is relatively slow, and the quality of light and so on. Advection secondary sedimentation tank, Flow secondary sedimentation tank and Inclined Plate secondary sedimentation tank are various types of secondary sedimentation tanks, Flow secondary sedimentation tank is the choice made for this design. The reasons include the simple management of this method, the overall operation is relatively good and it is applicable to large and medium-sized sewage treatment plants.

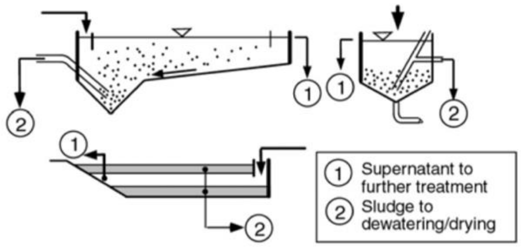

Figure -17: Schematic diagram of sedimentation treatment.

3.5.5. Filter

For this design to be able to discharge an effluent according to the standards, three levels of treatment need to be effected. An ordinary fast filter is used to remove suspended solids in the water to get water turbidity drop. In the presence of fine-grained quartz sand, the speed of filter is around 4.8 ~ 20m/h and 3.8 ~ 37m/h in a coarse grained quartz sand filter. Fine-grained quartz sand is suitable for relatively clean water.

3.5.6. UV Disinfection Pool

In order to remove some of the microbes in the treatment of water, such as bacteria, algae, zooplankton, viruses, parasites, etc., a disinfection method has to be applied to the water to eliminate the biological activity of these microorganisms and therefore, to achieve a pollution-free and non-hazardous effluent discharge according to the respective standards. This design uses UV disinfection to be able to meet the water quality standards.

3.5.7. Sludge Thickening

The main purpose of sludge thickening is to reduce the volume of sludge in the wastewater from the secondary settling tank. Sludge thickening optimizes the subsequent processing structures such as digestion, dehydration, drying and incineration, even though the sludge released from the sludge thickening stage is still in fluid form. The methods used for sludge thickening are mainly, gravity, air flotation and the centrifugal method and are specially designed for sludge with high moisture content like the one produced in the activated sludge process which have moisture content that can go up to about 99%.

3.5.8. Sewage Pumping Station

During times the urban water consumption is uneven, the sewage flow into the pipeline is also uneven. The sewage needs to be coming in a small but continuous flow. When the content of debris in the water is high, the pollution of the surrounding environment is also large. Pump station design must meet the requirements of the surrounding environment, noise levels for example, and also regular monitoring of the sewage pump, its cleaning and protection.

3.5.9. Sludge Dewatering

In the activated sludge sewage treatment process, the resulting sludge has a moisture content of about 97% ~ 99.6% which is, in nature, a loose and bulky structure of a granular or flocculent material in a flowing state that is difficult to treat by digestion. Hence, sludge dewatering must be initialized before any other sludge treatment process [14]. The sludge dewatering methods generally include the natural drying method, sludge drying, mechanical dehydration and incineration.

3.6. Compliant Analysis

An analysis was made to assess the removal efficiency of the main treatment units in this design. The tables 1, 2, 3 below portray the estimated removal percentage of the Grit chamber, A^2/O tank and the settling tank respectively;

Table -1: Grit chamber treatment efficiency

Item	COD(Mg/L)	BOD_5(Mg/L)	SS(Mg/L)
1. Influent	400	200	370
2. Treatment efficiency	15%	15%	25%
3. Effluent	340	170	277.5

Table -2: A^2/O Treatment efficiency

Item	COD(Mg/L)	BOD_5(Mg/L)	SS(Mg/L)
1. Influent	340	170	277.5
2. Treatment efficiency	82%	88%	86%
3. Effluent	61.2	20.4	38.85

Table -3: Secondary settling tank treatment efficiency

Item	COD(Mg/L)	BOD_5(Mg/L)	SS(Mg/L)
1. Influent	61.2	20.4	38.85
2. Treatment efficiency	15%	15%	80%
3. Effluent	52.02	17.34	7.77

3.6.1. Coarse Screen

The coarse screen is designed according to the influent composition and effluent expected quality. Table 4 shows the dimensioning results of coarse screen. Figure 18 shows a schematic diagram of the coarse screen.

Table -4: Coarse screen treatment efficiency

Item	Safe Range	Chosen
1. Entry influent flow rate	0.4 0.9ms	0.5ms
2. Intermidiary screen flow rate	0.6 1.0m/s	1.0ms
3. Angle of inclination	70° - 90°	60°
4. Width of aisle	$\geq 1.5m$	1.5m
5. Pool to grill distance	-	0.5m
6.Gap width	-	0.025m
7. Screen groove width	-	2.72m
8. Head loss	-	0.095m
9. Total length of groove	-	6.16m
10. Amt. of sediment intercepted by screen per day	-	$0.3m^3/d$

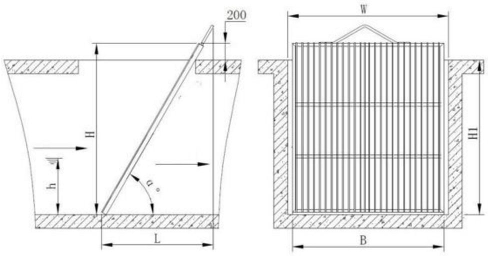

Figure -18: Diagram of Coarse screen

3.6.2. Fine Screen

The fine screen is designed according to the outflow volume from coarse screen. Table 5 shows the dimensioning results of fine screen. Figure 19 shows a schematic diagram of the fine screen.

Table -5: Fine screen dimensioning data

Item	Value
1. Entry influent flow rate	1.0ms
2. Intermidiary screen flow rate	1.0ms
3. Angle of inclination	60°
4. Width of aisle	1.5m
5. Pool to grill distance	0.5m
6.Gap width	0.005mm
7. Screen groove height	1.508m
8. Total length of groove	12.479m
9. Head loss	0.808m
10. Amt. of sediment intercepted by screen per day	$0.3m^3/d$

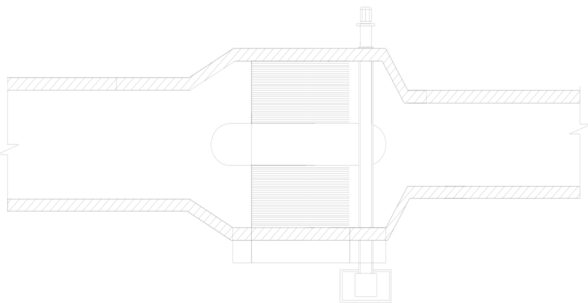

Figure -19: Diagram of Fine screen

3.6.3. Grit Chamber

- The grit chamber must be able to remove particles of 0.02mm and above while the relative density must be 2.65 above sand design.
- The maximum residence time of sewage flow should not be less than 30s
- The hydraulic surface loading is 150m3 ~ 200/ (m2 .h)
- Pool diameter and pool depth should be 2.0 ~ 2.5 and the effective depth, 1.0m ~ 2.0m
- A cyclone type separator blade should be established in the middle of the Grit chamber
- Calculations estimates are according to an amount of grit of 0.03L/ m3.
- The capacity of the bucket cone cannot exceed a grit amount of 2 days of time. When draining the sand by gravity, the angle of the water level and the wall of the bucket should not be less than 55°

- The best method for grit removal is the mechanical method after it has separated from the water and stored. When using manual discharge of the grit, the discharge pipe diameter should not be less than 200mm and anti-clogging measures should be taken for the pipe. [15]

See Table 6 for grit chamber dimensioning and figure 20 & 21 for schematic plans.

Table -6: Grit chamber dimensioning proportioning

Item	Value
1. Design Flow(L/s)	880
2. Grit chamber?s diameterA/(mm)	4870
3. Grit reservoir?s diameterB/(mm)	1500
4. Outlet pipe widthD/(mm)	2000
5. Bucket cone diameterE/(mm)	400
6.Grit reservoir?s depth F/(mm)	2200
7. Grit?s bottom area gradientG/(mm)	1000
8. Inlet pipe In-waterdepth H/(mm)	510
9. Grit?s In-water depth J/(mm)	600
10. Grit zone depthL/(mm)	1850

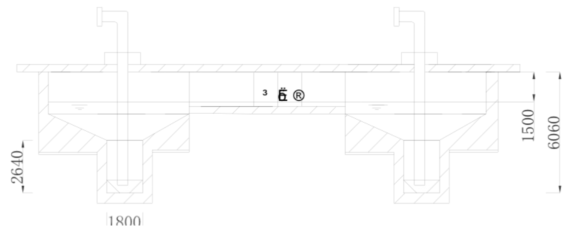

Figure -20: Schematic profile of the swirling grit chamber

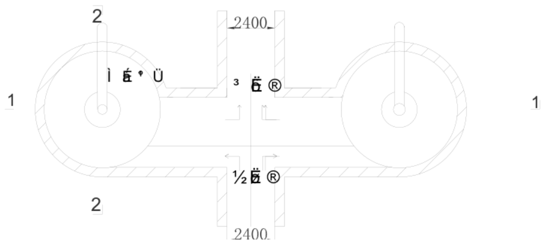

Figure -21: Schematic plan of the swirling grit chamber

3.6.4. Biological Reactor

The biological reactor screen is designed according return sludge concentration and composition. Table 7 shows the dimensioning results. Figure 22 shows a schematic diagram.

Table -7: Parametric data and design of biological reactor

Item	Value
1.Return sludge concentration(mg/l)	6600
2. BOD5 load in sludge(kgBOD_5 /kgMLSSd)	0.13
3. Sludge return ratio (%)	100
4. Mixed liquor suspended solids (MLSS)[mg/l]	3300
5. TNremoval rate(%)	59
6. Concentration of suspended solids(%)	1.439
7. COD/TN $\geq$8 & TP/BOD_5 $\leq$ 0.6	A^2O meets the requirements
8. Reaction tank Volume(m^3)	56587.41
9. Total water retention time of reaction pool (h)	9.51
10. Anaerobic tank Volume(m^3)	11317.48
11. Anoxic tank Volume(m^3)	11317.48
12. Oxygen demand for nitrification(kgO_2/d)	11531.62
13. Total Oxygen demand(kgO_2/h)	1112.55

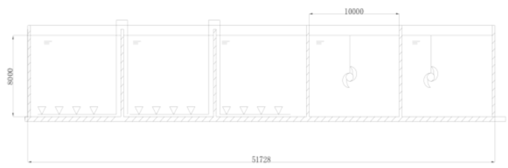

Figure -22: Schematic plan of biological reactor

3.6.4. Sedimentation Tank

The design parameters and output is shown in table 8 and schematic plan is shown in figure 23.

Table -8: Parametric data and design of sedimentation tank.

Item	Value
1.No. of sedimentation tanks	4
2. Hydraulic loading surface (m^3/m^2h)	2.0
3. Effluent weir load (l/s.m)	1.7
4. Settling time (h)	1.5
5. Effective volume of sedimentation tank(m^3)	2264.3

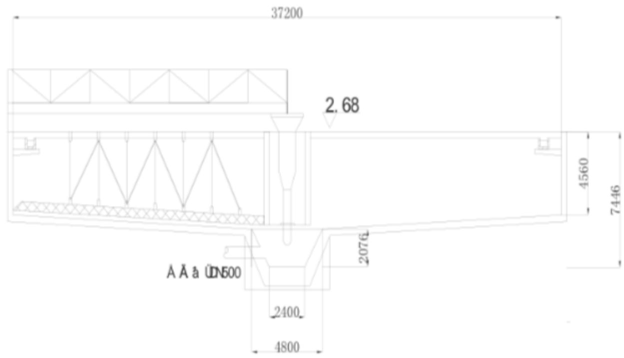

Figure -23: Schematic plan of sedimentation tank

3.6.5. Sludge Thickener

The design parameters and output is shown in table 9 and schematic plan is shown in figure 24.

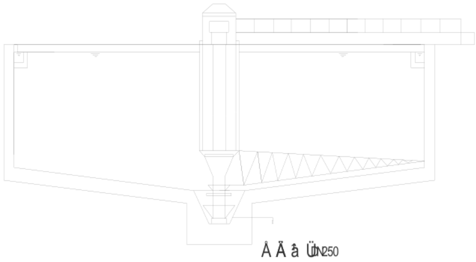

Figure -24: Schematic plan of sludge thickener

Table -9: Parametric data and design of sludge thickener.

Design Parameter	Value
1. Biological Sludge Production	12817.73 kg
2. Excess sludge	6281.88 kg/d
3. Total Area of concentration tank	298.57$m^2 \approx 300m^2$
4. Thickener portion height	4m
5. Ultrahigh	0.3m
6. Bottom diameter	1.0m
7. Total height of pool	7m
8. Volume	995.25m^3/d

3.6.6. Discussion

It can be found that the removal rate of the work can meet COD≤50mg/L, BOD5≤10mg/L, SS≤10mg/L, TN≤5mg/L, TP≤0.5mg/L. These results show that the effluent can meet the discharge standards.

4. MANAGEMENT PRACTICES

4.6.4. Graywater management

Regarding greywater management, the diagram (figure 25) presents the facilities for managing greywater mainly from:

- Body wash, shower or bath
- Laundry
- Dishes

There are essentially modes of graywater management which are the collective type and autonomous type. Collective management involves the collection and disposal of wastewater to a treatment site before reuse or discharge. Autonomous management involves essentially infiltration or evapotranspiration works to eliminate greywater. Meanwhile, many communities operates on combined sewer system which carries both graywater and faecal water to the disposal outlet and hence increases volume of influent to be treated and in the end effects to higher cost of treatment. If necessary, higher considerations must be given to modes of gray water collection.

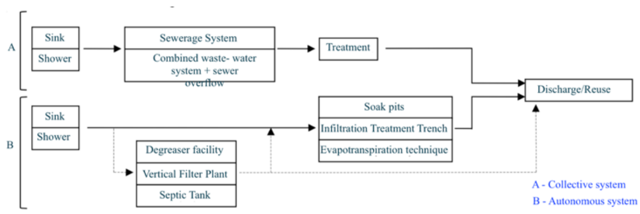

Figure -25: Diagram of simplified graywater management

4.6.4. Management of excreta and wastewater.

With respect to excreta and sewage management, the main distinctions should be at the following levels:

- Autonomous or collective sanitation
- Toilets using or not using water
- Production or not of faecal sludge to be drained and treated.

Figure 26 shows an effective management plan for collecting, treating and disposal of faecal waste water.

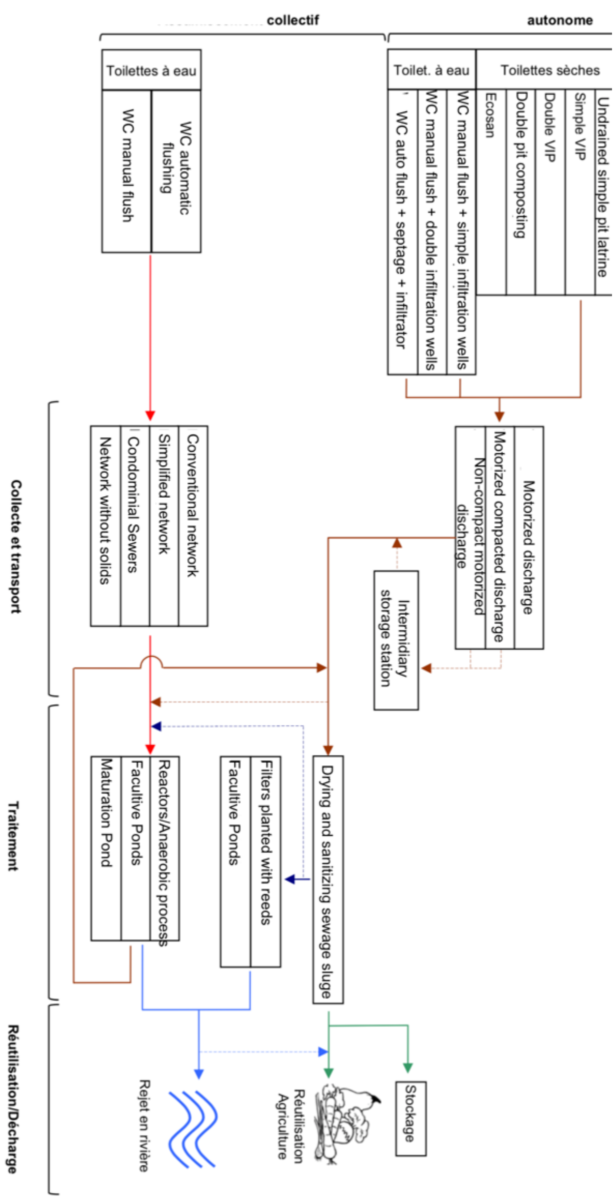

Figure -26: Diagram of simplified excreta/wastewater management.

4.6.5. Reuse of treated wastewater.

Given the rainfall and abundance of other water resources, the reuse of purified wastewater is not a priority objective for the city of Bujumbura. However, in the event that it can be envisaged, the applicable quality standards may be guided by the limits set out in the FAO recommendations which are given in table 11 for the main parameters.

Table -10: Water quality requirements for reuse in agriculture

Parameter	Unit	Max. Concentrations
1. pH	–	6.5-8.5
2. Conductivity	μS/cm	7000
3. DCO	mg/l	90
4. DBO_5	mg/l	30
5. MES	mg/l	30
6. Substances dissolutes(TDS)	mg/l	2000
7. Chlorures	mg/l	600
8. Fluorures	mg/l	3
9. Coliformes fecals	Nb/100ml	200 - 1000

4.6.6. Proposed rejection standards.

The proposed rejection standards for the main parameters in the case of a discharge to the sewerage network (indirect discharge) or a release to the natural environment (direct discharge) are presented in the table 11 below.

Table -11: Water quality requirements for reuse in agriculture, Source: FAO

Param	Unit	Collective network	Surface waters
1. pH	–	6.5-9.0	6.5 - 8.5
2. Temperature	°C	≤35	≤30
3. DCO	mg/l	3000	150
4. DBO_5	mg/l	1000	50
5. MES	mg/l	1000	100
6. Total hydrocarbons	mg/l	10	2
7. Cyanides	mg/l	1.0	0.1
8. Phenolic compounds	mg/l	1.0	0.05
9. Coliformes fecals	Nb/100ml	-	10,000
10. Oil & Fats	mg/l	30	10

4.6.7. Toilet system

Toilet systems has run through series of evolution from traditional pit latrines, shared latrines and improved latrines.

The basic form of toilet system is unimproved latrines, such as traditional pit latrines, which do not ensure hygienic separation of human excreta from human contact. It is important that community sanitation authorities upgrade existing unimproved latrines in a gradual order to reach the improved VIP system. This is illustrated in figure 27. Figure 28 shows a presentation of simple VIP integrated in a house which is however recommended.

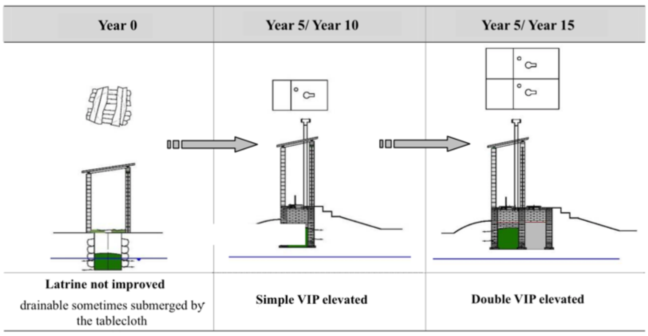

Figure -27: Diagram of Sample Evolution Sequence

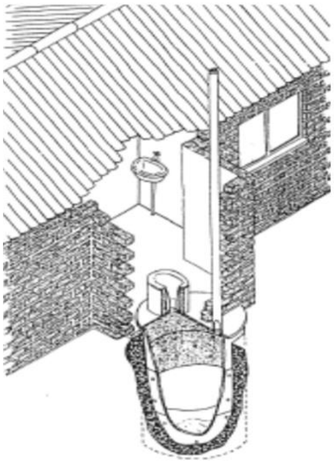

Figure -28: Simple VIP integrated in a house

5. CONCLUSIONS

Dysfunctional toilet facilities, increased rate of open defecation and unsafe disposal are probable results of poor faecal sludge management(FSM) practices and higher cost of sludge collection & treatment in general. Selection of a proper treatment technique is a good step to optimizing the cost of treatment to a lower rate. On-site treatment techniques have closely been looked at and the main cost influencers are the cost and availability of land and labor and hence its recommended for mainly rural areas. However, in consideration of centralized sewage treatment technique (anaerobic - anoxic - aerobic treatment process), the cost influencers are cost of construction of long distance sewage channels, recruitment of well-trained staff, availability of constant electricity, cost of technical equipment, etc. Because of its economies of scale and less fluctuating influent characteristics, this technology is more effective for the treatment of large volumes of flows of urban municipal wastewater from medium to large towns.

This technology (anaerobic - anoxic - aerobic treatment process) was applied to a case study in Bujumbura. It is confirmed that this process has less total hydraulic retention time. It is however expected to compose of simple structures and a more economical construction operation.

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