Feasibility Study for the Lake Victoria Basin Integrated Water Resources Management Programme with High Priority Investments
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High Priority Investment
Kigali Faecal Sludge Treatment Plant

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Acronyms

ABR	Anaerobic Baffle Reactor
Afd	French Development Agency
AWE	Air Water Earth Limited, Environmental Engineers & Project Management Consultants (www.awe-engineers.com)
BOD	Biochemical Oxygen Demand
CAPEX	Capital Expenditure
CIP	Crop-Intensification Programme
COD	Chemical Oxygen Demand
CW	Constructed Wetland
DAC	Development Assistance Committee
DBO	Design Build Operate
EAC	East African Community
EDF	European Development Fund
EDPRS	Economic Development and Poverty Reduction Strategy
EIB	European Investment Bank
EMP	Environmental Management Plan
ESIA	Environmental and Social Impact Assessment
EIA	Environmental Impact Assessment
EPC	Engineering Procurement Construction
EU	European Union
EWSA	Energy Water and Sanitation Authority
FCR	Full-Cost Recovery
FIETS	Financial, Institutional, Environmental, Technological, Social aspects used to assess
FYBP	Five Year Business Plan
FS	Feasibility Study
FS	Faecal Sludge
FSTP	Faecal Sludge Treatment Plant
GDP	Gross Domestic Product
GIS	Geographical Information System
GNI	Gross National Income
HPI	High Priority Investment
HRT	Hydraulic Retention Time
IFI	International Financing Institutions
IWRM	Integrated Water Resources Management
KCC	Kigali City Council
KFW	German Development Bank
KM	Knowledge Management
LVBC	Lake Victoria Basin Commission
LVEMP-II	Lake Victoria Environmental Management Program - Phase II
LVWATSAN-II	Lake Victoria Water and Sanitation Programme - Phase II
MD	Managing Director
MD	Mechanical Dewatering
MDGs	Millennium Development Goals
MINIFRA	Ministry of Infrastructure
MOU	Memorandum of Understanding
MSF	Médecins Sans Frontières
NFP(O)	National Focal Point (Officers)

NISRI	National Institute of Statistics and Research of Rwanda
NGO	Non-Governmental Organization
NRW	Non Revenue Water
ODA	Official Development Assistance
OECD	Organisation for Economic Co-operation and Development
O&M	Operation and Maintenance
OPEX	Operational Expenditure
PIA	Project Implementation Agency
PIU	Project Implementation Unit
PRSP	Poverty Reduction Strategy Plan
REG	Rwanda Energy Group
RPSC	Regional Policy Steering Committee
RAP	Resettlement Action Plan
SDB	Sludge Drying Bed
SDG	sustainable Development Goals
SEA	Strategic Environmental Assessment
SOE	State of Environment
ST	Sludge Thickener
SWOT	Strength Weakness Opportunity & Threats Analysis
SWAp	Sector-Wide Approach
TA	Technical Assistance
TOR	Terms Of Reference
TS	Total Solids
TSS	Total Suspended Solids
TWG	Technical Working Group
USAID	United States Agency for International Development
VFCW	Vertical Flow Constructed Wetlands
VEI	Vitens Evides International
VS	Volatile Solids
VSS	Volatile Suspended Solids
VT	Vacuum Truck
WASAC	Water and Sanitation Corporation of Rwanda
WATSAN	Water and Sanitation
WBOP	World Bank Operational Policy
WHO	World Health Organization
WIM	Water Intervention Module
WP	Work Package
WRMIS	Water resources Monitoring Information System
WRM	Water Resources Module
WUM	Water Utilization Module
WWTP	Wastewater Treatment Plant
5YSBP	Five-Year Strategic Business Plan

Executive Summary

The rapidly deteriorating water quality in the Lake Victoria Basin (LVB) is the main reason to counteract against the pollution of the LVB. As a matter of fact, the Lake Victoria is the most important freshwater storage in East Africa, whereof 40 million people depending on its resources.

In this respect the East African Community (EAC) has established the regional cross-border institution, the Lake Victoria Basin Commission (LVBC) in order to coordinate sustainable development in the Basin among the Partner States of the EAC, Burundi, Kenya, Rwanda, Tanzania and Uganda. The main objective is to ensure the availability and quality of water resources through the trans-boundary and transparency IWRM Programme for the LVB through the implementation of regional IWRM investments and related measures. .

Although many programmes have been implemented over the last years, the planning, design and construction of water supply systems, wastewater treatment facilities and solid waste management do not keep up with population growth. Lack of sanitation facilities, open defecation and poor faecal sludge management lead to eutrophication and microbiological pollution of Lake Victoria and emphasis the focus on IWRM Programme.

For the short term a focus on the pressing and 'no-regret' issue of wastewater and sanitation has been chosen and has been translated in the concept of High Priority Investments. SWECO and partners were selected to execute the 'Feasibility Study for the Lake Victoria Basin Integrated Water Resources Management Programme with High Priority Investments' as a part of Work Package 2.

Four High Priority Investment (HPI) projects were selected in four riparian countries of Lake Victoria, based on a selection process guided by LVBC in close consultations with the stakeholders. The following HPIs were selected:

1. Wastewater treatment and sewerage in Mwanza, Tanzania;
2. Constructed Wetlands in Kampala, Uganda;
3. Faecal sludge treatment in Kigali, Rwanda;
4. Rehabilitation of the sewerage treatment network in Kisumu, Kenya.

For each of these HPIs a feasibility study has been prepared.

The stakeholders endorsed the selection of the HPIs for further feasibility review during the inception meeting on the 3rd of March 2016 in Kisumu.

For Kisumu, the selected project area has changed after discussions with Lake Victoria South Water Board and the EIB/ AfD and now covers sanitation in informal settlements in Kisumu.

In the City of Kigali, the HPI on the Faecal Sludge Treatment Plant (FSTP) has been selected. This feasibility study report presents the finding for the FSTP.

According to the national 2012 census, the capital of Rwanda, Kigali, hosts about 1.13 million people, which is around 10% of the country's total population. Apart from some neighbourhood sewerage systems and decentralized communal wastewater treatment plants, the population uses on-site systems such as pit latrines and septic tanks. When the volume capacity is exhausted, pit latrines are usually sealed and new ones built. If there is insufficient space, pit latrines need to be emptied. When septic tanks are full of sludge, the content ('septage') is emptied by means of a vacuum truck. At present, only a part of the collected content is treated, whereas the majority of the content is dumped.

The current crude dumping of septage and faecal sludge at the Nduba waste dump leads to unacceptable environmental pollution of: air, ground- and surface water, foul smell and hazards. Hence, it is recommended to cease dumping of faecal sludge at the Nduba waste dump and to replace crude dumping with environmentally sound treatment of collected septage and faecal sludge. To this end, the HPI for a new FSTP was developed.

The expansion of Kigali has negatively affected water quality management in the city, especially on wastewater management. Elevated levels of pollution have been reported in some of the major rivers passing through the City of Kigali, such as Nyabugogo River. In central and northern Kigali like in Nduba area where the dump site is located, the topography is relatively steep and all water is drained into the Nyabugogo River.

The Nyabugogo wetland receives all kinds of untreated wastewaters/faecal sludge and industrial wastewater (Nhapi, 2011). As the Nyabugogo River is a tributary of the Nyabarongo River, which in turn is joined by the Akanyaru River tributary to become the Akagera River that flows into and through the lakes Rweru and Mugesera and into Lake Victoria (Kigali SOE report, 2013, Quoted by RDHV in the Environmental and Social Impact Assessment / ESIA report, 2015). This means that the pollution of the Nyabugogo River contributes to the pollution of Lake Victoria.

Since 1991, the City of Kigali is preparing plans to replace the on-site systems with an off-site system: sewerage followed by wastewater treatment. Up to now there is no funding for this costly system and the City of Kigali realises that it needs to take measures to facilitate the servicing of on-site systems and the treatment of the collected septage and faecal sludge. The City of Kigali, through WASAC (Water and Sanitation Corporation of Rwanda) has hired an international consultant, AAW, to prepare a conceptual FSTP design that includes the selection of the site for a new treatment plant. The feasibility study team visited and studied the site and found it suitable. The access road, however, is not suitable for vacuum trucks. Hence, it is recommended to follow the advice of AAW and continue preparations for land acquisition and improvement of the access road (widening, tarmac).

WASAC has hired AAW also to determine the treatment process, produce EPC (Engineering Procurement Construction) tender documents for an FSTP with a horizon of 10 years and to prepare the Environmental Impact Assessment with an Environmental Management Plan. We used AAW's designs as input for the presented Feasibility Study. However, we adapted the AAW design as described in the preliminary interim report (April 2016) as we concluded it has several shortcomings. An example is the non-fulfilment of the environmental standards in terms of effluent quality[1]. Another example is the fact that AAW did not incorporate the promising technology of producing fuel out of septage and faecal sludge as being piloted by Pivotworks at the Nduba site (see
Figure **1**).

Hence, the feasibility study team proposes the following technical solution:

- Improvement (widening and tarmac) of the access road, which is around 2.5 km long;
- Trucks receiving area, screens, removal of grit and scum, sludge settling;
- Valorisation of sludge:
    - Either fuel production through the addition of polymers, mechanical sludge dewatering, solar drying, followed by heat drying and sales as fuel (preferred option); or

[1] On 20 July 2016, SWECO received information indicating that AAW has amended the designs and added Constructed Wetlands in line with SWECO's recommendations, see APPENDIX 6: Update on Chapter 4 AAW on Sludge Characteristics and Proposed Treatment Alternatives

- Co-composting with biodegradable waste and sales as compost;
- Anaerobic Baffled Reactor (ABR) to treat the supernatant water from the sludge settlers and the drainage water from the mechanical sludge dewatering device;
- Vertical Flow Constructed Wetlands to treat the effluent of the ABR.
-

Figure 1: Solar drying in greenhouses of mechanically dewatered septage and faecal sludge to be sold as fuel to industries (Pivotworks, Kigali, 2016)

The entire project comprises and requires several investments whereby the costs for each of them are indicated in the Table 1 (in € mln).

Table 1: *Required Investment Costs*

Description	**Cost (€ mln.)**	**Government of Rwanda / City of Kigali / WASAC (€ mln.)**	**KfW / EU (€ mln.)**
Detailed engineering design (design review), tendering document preparation, tendering	€ 0.40		€ 0.40
Construction FSTP	€ 3.12		€ 3.12
Capacity Building of WASAC	€ 0.05		€ 0.05
Purchase 4 vacuum trucks	€ 0.58		€ 0.58 (purchase & transport)
Land acquisition	€ 0.70	€ 0.70	
Road improvement	€ 1.78	€ 1.78	
Closure of Nduba dump site[2]	€ 0.25	€ 0.25	
Total Costs	***€ 6.88***	***€ 2.73***	***€ 4.15***

The Kigali City Council (KCC) is responsible for faecal sludge management. KCC has delegated the implementation of the FSTP to WASAC.

We advise WASAC to take into account the findings of the present feasibility study in order to improve the design of AAW and the tender documents:

- Add Vertical Flow Constructed Wetlands (VFCW) to treat the effluent of the ABR to up to East African / Rwanda discharge standards[3];
- Improve the design of the ABRs;
- Cover the sludge drying beds. Alternatively consider mechanical dewatering;
- Take into account the experiences to produce fuel from faecal sludge.

[2] Based on information by e-mail dated 20 July 2016.

[3] On 20 July 2016, SWECO received information indicating, that AAW has indeed amended the designs, see APPENDIX 6: Update on Chapter 4 AAW on Sludge Characteristics and Proposed Treatment Alternatives.

The two concepts are presented in Figure 2.

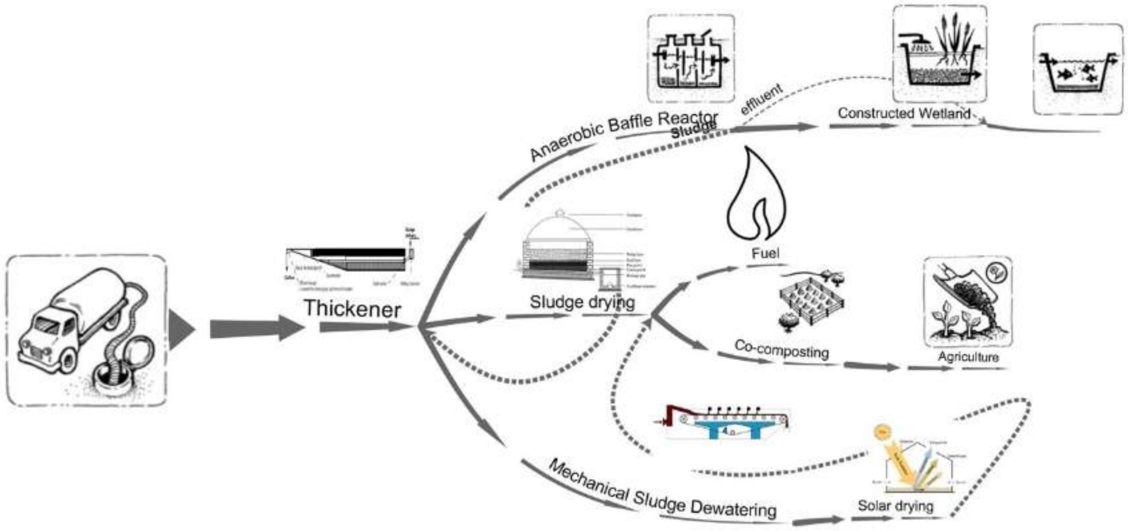


Figure 2: Two Concepts for Faecal Sludge Treatment in Kigali

Since WASAC is in a transitional phase, becoming a financially independent water corporation, its' staff is fully engaged in transferring into a customer-focused service provider that generates sufficient revenues to operate independently. To this end, the FYBP (Five Year Business Plan) has identified an intensive programme of institutional strengthening activities, ranging from integration of the financial system with the billing & collection system to defining high-priority investments and reviewing energy costs and reducing Non Revenue Water (NRW). In addition, a process of transfer of responsibilities to the Branch offices is undertaken.

WASAC is fully engaged in implementing a huge investment programme for water. The relevant targets and performance standards are laid down in the Water and Sanitation Sector Strategic Plan 2013-17, the Economic Development and Poverty Reduction Strategy (EDPRS 2) and *Imihigo*[4].

WASAC need its full attention to pursue these challenges.

WASAC will act as owner of the assets of the FSTP. This has been agreed with KCC. There are three generic options to contract and manage the FSTP:
1. A Design Build Operate (DBO) contract where the construction and management is outsourced to an external party that has sufficient expertise to run the plant for a certain period in the range of 10 - 20 years. Under such a contract, the private party will be responsible for the design and construction of the plant and will after the construction period also operate and maintain the plant. The operator would also operate the first batch of vacuum trucks to further develop the market. This period will allow the operator to cover the O&M costs. WASAC could manage the related contract and will receive a lease fee as owner of the assets;
2. A 'delegation' contract, where the design and construction part will take place by the implementing agency, WASAC. In fact, this is a traditional way of contracting, where the operator is operating the facility with technical assistance of an external party to gain experience in operating the FSTP. The operator wants to have this option on the table, to see whether they want to build up expertise in this field. Although WASAC is also the delegated owner it seems necessary to have some kind of contract, most likely between KCC and WASAC which would regulate the tasks and responsibilities of WASAC;
3. A mixed option where WASAC will operate the generic infrastructure and sells the solids to a private operator, which will use it as input for making fuel or compost.

Each of the three options has its advantages and disadvantages. These are elaborated in

[4] National Performance Standards

section 7, Legal and Institutional Analysis. There is a preference for the first option, as this option would bring about the largest project benefits; also for WASAC, while reducing the risks for WASAC additionally. Moreover, this option would allow WASAC to concentrate on the huge challenges they are faced with. In the e-mail of 20 July 2016, WASAC, expressed to be in favour of option 1, DBO. (Literally: *"WASAC is for a PPP / Design Build Operate where WASAC in principle sources out the operation and maintenance of the FSTP for 5-10 years. Again valorization is open. Staff of WASAC could be seconded at the operator to develop experience*"). Hence, it is advisable to create learning effects for WASAC with respect to a possible future involvement of WASAC in the FSTP; the contract should arrange some kind of involvement of WASAC staff in operations of the FSTP. However, WASAC and KCC could opt for option 2 or 3 because they could made a strategic choice to be more engaged in these kinds of activities. In Table 2, the financial outcomes of these three options are given. The table shows that project profitability and profitability for WASAC are the highest under a DBO contract. Under this contract, WASAC also runs no operational risks.

Table 2: *Profitability in Different Contractual Set-ups*

Implementing agent	Project profitability		WASAC profitability		Private operator profitability	
	IRR		IRR	NPV	IRR	NPV
DBO	15.0%		n.a.	€840,000	12%	€525,000
Mixed	14.8%		14%	€640,000	17%	€683,000
WASAC	11.5%		11.5%	€483,000	n.a.	n.a.

A soft market sounding was conducted to assess whether sufficient parties are interested in a DBO contract. The results indicate that that there are some six parties interested.

There are three kinds of activities that need to be considered:
1. Collection of septage from septic tanks by means of vacuum trucks and emptying of pit latrines with appropriate devices followed by transport of faecal sludge to the FSTP;
2. Processing of solids into fuel (or compost) from the faecal sludge;
3. Treatment of the effluent from the faecal sludge.

The collection of septage through the desludging of septic tanks is lucrative business. It is recommended procuring 4 project trucks. These trucks are additional to the current fleet of 12 trucks to ensure sufficient sludge can be collected for efficient treatment operations. Initially, four trucks will be needed and will be part of the investment costs to be funded. The trucks will be owned by WASAC and depending on the contractual form that is chosen, either leased out to a private operator or operated by WASAC itself. The one that is operating the trucks will become responsible for the fuel and O&M costs of the trucks. Instead of a separate lease fee for trucks in case of a DBO, it is proposed to levy an all-inclusive lease fee on the operator for using the facilities under such a DBO contract.

Future trucks could be bought or leased by the operator or purchased by private truck owners. Of course, the quality of the collection and the exhausters has to be safeguarded by a system of permits / service level agreements issued by the government and by the main contract between WASAC and the private operator.

The emptying of pit latrines is a less lucrative business. First of all, people owning pit latrines are relatively poor: 85% of the population of Kigali uses pit latrines, while 67% of the population of Kigali resides in informal settlements. Secondly, pit latrines contain relatively hard faecal sludge and sludge that is full of solid waste. When full, the preferred option is to seal the latrine and dig a new one. If this is not possible due to lack of land, emptying of existing latrines is done by digging 'burrow pits' to route the waste from one pit to another. These activities often take place at night, preferably during the rains so that the authorities do not notice these 'informal' emptying practices. For more details on pit latrine emptying we refer to APPENDIX 5: Pit Latrine Emptying Report Kigali .

Emptying of existing latrines in an environmentally sound way, where workers are protected properly and transport of the faecal sludge to the FSTP will not only improve environmental conditions in informal settlements, but will also increase the revenues of the FSTP. To make this possible, first of all, efficient emptying methods fit for the Rwanda conditions, need to be developed. Pivotworks is starting some trials using technologies developed in South Africa, see APPENDIX 5: Pit Latrine Emptying Report Kigali . However, more efficient methods have been developed in the region, for instance in Malawi. Secondly, the population needs to be motivated and capacitated in order to use these services of the pit emptiers. We have described an outline on how this could be achieved but did not include it in the costing, as this needs further decision making at KCC and WASAC level.

It is interesting to note that KCC plans to introduce bylaws that all new houses must have their (septic) tanks sealed, which will facilitate easy desludging. This means that less wastewater will leak into the soil and that more septage and faecal sludge will need to be contained and transported to the FSTP.

The processing of solids can provide an income. Solids can be processed into either compost or fuel. The latter is practiced by Pivotworks in Kigali on a pilot scale (see
Figure **1**).

Processing the solids into fuel is a challenge. To produce fuel efficiently, one needs to use mechanical dewatering devices, which require advanced skills. Hence, we should only recommend investment in 'advanced' FSTP (mechanical dewatering) to produce fuel if an operator can be found that is capable and willing to do so. If not, a simpler FSTP concept should be chosen, using (covered) drying beds. In that case, the final product will be compost, which has a lower commodity price than fuel (Pivot fuel is sold at US$ 40-60/t whereas compost comes to US$ 7-14/t).

Financial calculations of the investments have been done to get an indication on the robustness of the financial sustainability of the investment. Firstly, a total investment cost of € 4 million has been estimated. A development partner will finance these through a grant. Land acquisition (€ 0.7 million), road improvement (€ 1.78 million) and closure of the existing dump site (€ 0.25 million) are to be financed by the City of Kigali. Secondly, revenue streams and cash flows of the project have been estimated.

It is assumed that the financing of the investment costs is done by KfW. Even though the profitability of the project is solid (see Table 3), it is very doubtful that financing for a long period of 20 years could be obtained from other, commercial financing sources or from the private investor, given the perceived risks of the business environment in Rwanda.

The three elements of the project (collection of septage, processing of fuels and treatment of effluent) form an integral part of the project; it covers the full chain from collection to treatment and disposal. Therefore, it is important that all three elements are included in the project. Hence, we have set the financial boundary conditions (e.g. the tipping fee is set high enough) in such a way that all three elements are financially viable to prevent that for instance under a DBO contract, a private operator is not willing to undertake one of the elements of the value chain.

Figure 3 provides the development of the revenue streams.

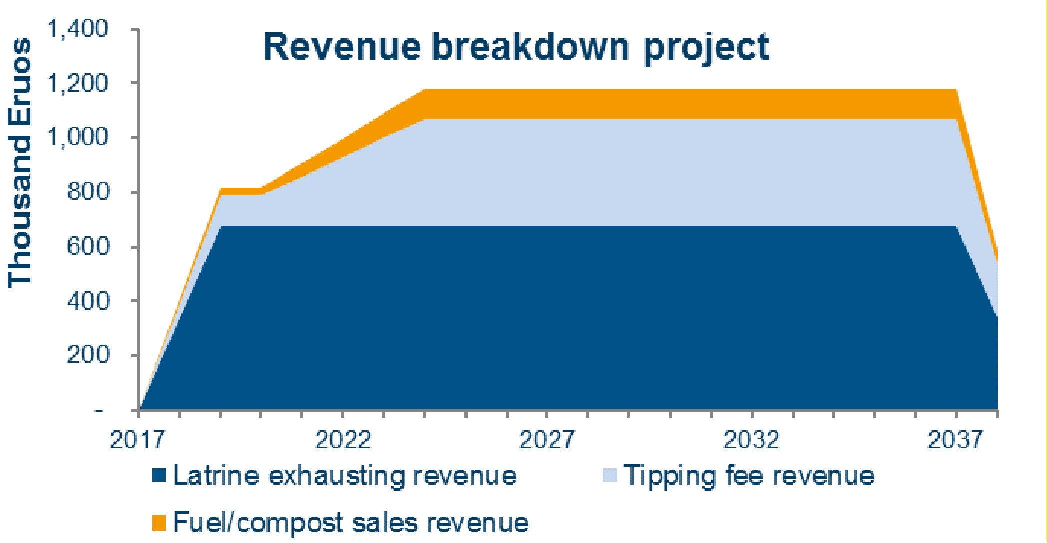


Figure 3: Breakdown of Revenue during Operations

The most significant revenue stream originates from the collection of sludge by the project-owned trucks. Both our calculations and qualitative information collected in the field show that the collection of sludge (from septic tanks) is a lucrative business.

Figure 4 presents the year-on-year cash flow of the project under operations (before financing).

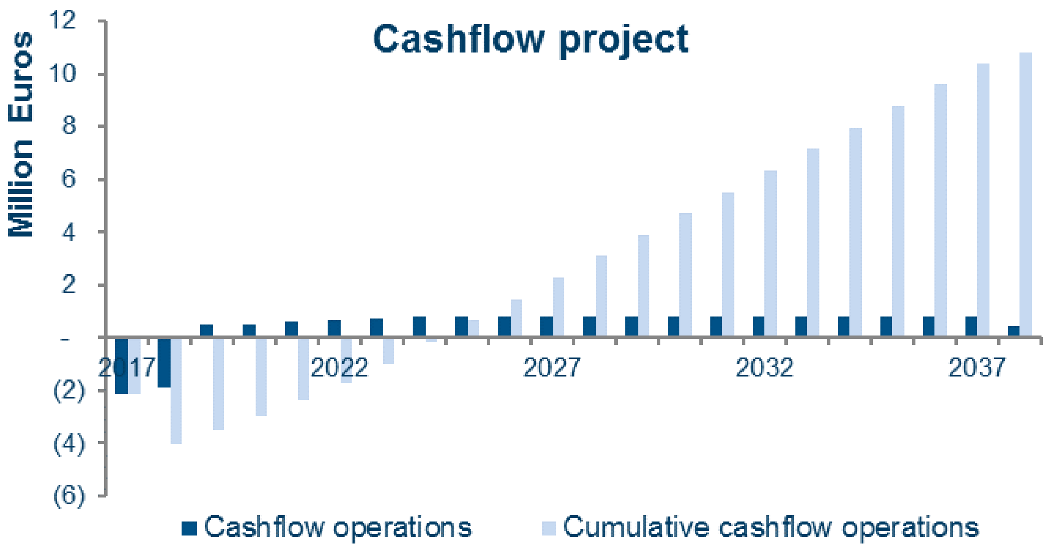


Figure 4: Cumulative and Year-on-year Cash Flow of Operations

The project generates sufficient revenue to cover operation and maintenance costs. The most important parameters are given in Table 3.

Table 3: *Key Results of Base Case*

Indicator	*Value*
Internal Rate of Return of operations – before finance	15%
Net Present Value (10%) – after finance (EUR)	3,323,840
Prime costs faecal sludge treatment (EUR/m^3)	1.83
Operating Cost Recovery ratio (revenue / O&M)	3.2
Full Cost Recovery ratio (revenues / (O&M + depreciation))	1.77

The Full Cost Recovery ratio shows that sufficient revenue is generated for future reinvestments. Additionally, the Net Present Value after finance (where the original investment costs are covered by a grant) is robust.

The financial sustainability of the project strongly depends on the ability to pay for septic/latrine exhaustion. A crucial issue is the affordability of the low-income households. We recommend applying a differentiated faecal sludge collection tariff scheme. This is beneficial from a social and environmental perspective, as more people will be able to afford sanitation services. In addition, it is also commercially attractive, as it will allow the operator to collect revenues from lower income households at a lower, although still sufficient, profit margin.

To test the robustness of the financial operations of the project, a sensitivity analysis has been done. Table 4 shows the impact of various changes in parameters on the Full Cost Recovery ratio. Even in the case of a 50% lower sludge collection the Full Cost Recovery ratio still does not fall below 1, indicating that even with a substantial lower level of sludge treatment the project is still robust.

Table 4: *Sensitivity Analysis*

Parameter change	Full Cost Recovery ratio
Base case	1.77
50% lower exhaust revenues	1.26
50% lower fuel price	1.72
25% higher investment costs	1.59
No tipping fee	1.32
50% lower sludge collection (= from 1,000 m3 to 500 m3 sludge/day with an unchanged cost-base)	1.4

Finally, the impact on profitability is shown in Table 5 where a different project set-up is applied. As discussed, the project can either apply mechanical dewatering or sunbed dewatering. Additionally, the projected increase in sludge collection capacity can be included in the project, taken up by private sludge collectors or a variation in between.

Table 5: *Profitability in Different Set-ups*

Set-up	Internal Rate of Return before Finance
Base case: - Private sector upscaling of sludge collection - Mechanical dewatering	15.0%
- Upscaling of sludge collection by project - Mechanical dewatering	25.7%
- Private sector upscaling of sludge collection - Drying beds dewatering	16.1%
- Upscaling of sludge collection by project - Drying bed dewatering	27.0%

It becomes clear from these figures that especially the collection of faecal sludge provides extensive commercial scope.

Update October 2016. On 24 October 2016, KfW has indicated it cannot support the purchase of the 4 vacuum trucks. This would mean that the private sector takes care of the collection of sludge, which is a lucrative business.

The treatment activities, being the treatment of sludge and valorisation into compost or fuel, are less profitable. The figure above shows that the profitability of these operations strongly depends on the level of the tipping fee. With the current 5,000 RWF per sludge deposit, the long-term Full Cost Recovery ratio of the operations excluding sludge collection stands at 1.3, suggesting that both O&M and depreciation of the operations are financially sustainable. The internal rate of return, however, would be at a low 0.8%. To achieve a healthier, although still commercially unattractive, internal rate of return of more than 5%, an increase of the tipping fee *to a level of 8,500 RWF would be needed. This would also provide sufficient revenues to keep the Full Cost Recovery ratio very close to 1 in the event of a 50% lower volume of sludge offered at the site.*

Considering the profitability of sludge collection operations, we would support the recommendation of KfW to separate these operations in the tendering. Furthermore, to safeguard financially sustainable operations under scenarios with lower volumes of sludge offered to the FCST, we recommend to increase the tipping fee to 8,500 RWF. A tipping fee of 5,000 RWF would be enough for FCR, but the IRR would be very low. An additional sensitivity analysis provides the following results:

- *Daily sludge tipped at the site remains at the present level of 100 t/day (10% capacity) and 8,500 RWF tipping fee:*
  - *FCR of treatment and fuel production: 0.355;*
  - *IRR of treatment and fuel production: n.a. (Nominal costs > nominal revenues);*
- *100t/day and 5,000 RWF tipping fee:*
  - *FCR of treatment and fuel production: 0.24;*
  - *IRR of treatment and fuel production: n.a. (Nominal costs > nominal revenues);*
- *Daily sludge tipped at the site: 250 t/day (25% capacity) and 8,500 RWF tipping fee:*
  - *FCR of treatment and fuel production: 0.557;*
  - *IRR of treatment and fuel production:-11%;*
- *250t/day and 5,000 RWF tipping fee:*
  - *FCR of treatment and fuel production: 0.378;*
  - *IRR of treatment and fuel production: n.a. (nominal cost > nominal revenues);*
- *Daily sludge tipped at the site: 500 t/day (50% capacity) and 8,500 RWF tipping fee:*
  - *FCR of treatment and fuel production: 0.965;*
  - *IRR of treatment and fuel production: -2.74%;*
- *500t/day and 5,000 RWF tipping fee:*
  - *FCR of treatment and fuel production: 0.65;*
  - *IRR of treatment and fuel production: -7.8%.*

The household expenses for water and sanitation, including the fee for septic tank, pit latrines emptying and the transport to the FSTP-to-be-build, are given in Table 6.

***Table 6:** Percentage of Income Spent on Sewerage for the Different Income Groups in Kigali*

Income group	**Average sanitation expenditure during project period (% of household income)**
Quintile 1	2.4%
Quintile 2	2.2%
Quintile 3	1.8%
Quintile 4	1.3%
Quintile 5	0.2%

The above table shows that for all households the expenditures remain within the affordability limit of 2.5% used by the World Bank. The following tables summarize descriptive information of the project.

***Table 7** Project Summary of Key Information*

General	
Name of the project	Kigali Faecal sludge treatment plant in Masaka
Country	Rwanda
Sector	Faecal sludge treatment
Date	January-April and June 2016
Narrative of the project	
Project objective	Replace the crude dumping site at the Nduba Landfill by a permanent faecal sludge treatment plant for citywide septic tank and pit latrine sludge.
Technical features of the project	Faecal sludge treatment and valorisation.
Population served	0.8 mln. (Total population 1.33 mln.)
Implementing agency	City of Kigali outsourced to WASAC

General	
Investment amount	Required investment from KfW/EU **~ € 4.15 mln. total investment required from KfW/EU** KCC investment ~ **€ 2.73 mln, total KCC investment** Total investment of the project: **€ 6.88 mln.**
Stand-alone project or part of larger project	Stand alone
Financial sustainability/business model (O&M costs coverage)	Based on tipping fees from vacuum truck and faecal sludge from pit latrines, discharging to the place, collection of faecal sludge and valorisation of sludge: fuel or compost.
Committed financing (international, government, municipality)	City of Kigali and the Ministry of Infrastructure are very committed; no further international financial commitment. City of Kigali finances the basic design, tender documents, closure of existing dump, access road and land acquisition.

The proposed site for the project location of the the Feacal Sludge Treatment Plant is shown in Figure 5 and Figure 6 on the following page.

Figure 5 *Proposed Site of the FSTP*

Figure 6 *Proposed Site of the FSTP (2)*

The current situation on site is illustrated through the pictures taken during the missions and shall demonstrate the crude situation on sit

Figure 7: Open Faecal Sludge Pond on Top of the Hill

Figure 8: Discharge of Untreated Effluent Mechanical Sludge Dewatering Device

Figure 9: Proposed Site for Treatment Plant

Figure 11: Proposed Site Treatment Plant

Figure 10: Mechanical Sludge Dewatering Device (Belt Filter Press by Pivotworks)

Figure 12: Drying Faecal Sludge in Greenhouse by Pivotworks

Issues to be solved/worries	
Resettlement	Farmers have to be resettled. It is unknown how many farmers are involved. There is a resettlement policy in place: once a site is identified as 'of public interest' there are three months to hold public hearings and three months to pay the resettlement allowance. No change of plans is possible.
Consequences for poor	• The farmers' land is private and the current farmers have to give up their land. They can choose between a compensation allowance (market value +5%) or an alternative plot of the same quality; • When valorisation would be practised, there would be several positions for low-skilled labour; therefore there would be employment opportunities for the local residents.
Design issues	• There is no feasibility study; only a site selection report and a Preliminary Interim report dated April 2016; • In parallel with AAW's work, Pivot has presented a proposal to the government authorities to valorise 250 tons of sludge per day as opposed to 2,000 t sludge/day by AAW. We think AAW's figure is an overestimation and propose to start with a capacity of 1,000 t sludge/day; • It is unclear whether the engineering design for the Masaka site is included in the current scope of works of AAW; • A power line runs nearby the new site. Hence availability of power is guaranteed. The site can be organized in such a way that many processes can be done under gravity and pumping can be minimized.
Environmental impacts	The preliminary designs of AAW do not fulfil environmental discharge standards for the effluent (Info, received on 20 July 2016 indicate that this has/will be rectified): additional treatment of effluent is needed. Otherwise very positive: • Existing crude dumping of faecal sludge is stopped; • Development Partner attention for faecal sludge will put it higher on the agenda; • Increased awareness on faecal sludge management is expected to lead to better operation and maintenance (regular desludging) of on-site systems in the City of Kigali.
Scope of the project (elements not covered)	Only limited collection system for septage, but such a system operates for the existing faecal sludge treatment plant. Additional vacuum trucks are included. Systematic pit emptying of existing latrines (instead of sealing or 'informal' emptying) needs to be developed further in a technological way (challenges of difficult access and 'difficult' sludge) as well as in a socio-cultural way (motivation and capacitation of the community to use pit latrine emptying services).
Sustainability	• The City of Kigali has no experience with running operations of FSTPs, so an international tender needs to be announced for operation and maintenance of the Faecal Sludge Treatment Plant assuming mechanical drying will be practiced; • In case there is no international interest for O&M of the FSTP, low tech solutions need to be selected such as (covered) sludge drying beds; • Production of bio fuel would contribute to the supply of renewable fuel in Kigali; • Revenue generation from fuel and/or compost would be a contribution to the financial viability of the facility and provides incentive for its on-going operation
Financing aspects	Studies, closure of the existing dump site and land acquisition and road improvement for the new site to be paid by the Government of Rwanda and the City of Kigali.

Uncertainties	As far as a valorisation through production of biofuel from septage and faecal sludge is concerned, this would be the first full-scale operation. This is a risk but the process has a track record in Kigali, works with local authorities, and has a proven market for its fuel.
Others	Location seems far, but it is some 20 – 30 minutes from the city. No congestion. Literature: • Pivotworks roadmap Kigali, 2016

Weighted criteria	
Effectiveness, removal BOD	Existing dumpsite is an environmental hazard. Provided that the existing dumpsite is closed properly the project is very relevant and its impact potentially large. 5 tons COD and approximately 2.5 tons BOD_5 will be removed per day.
FIETS Sustainability (FIETS stands for Financial, Institutional, Environmental, Technological and Social)	**F**= no regret investment **I** = training needed **E** = excellent **T** = provided that a good operator can be found, relatively advanced sludge dewatering techniques can be used; if not the technology of sludge drying shall be applied. Pivotworks has experience with fuel production. Emptying of pit latrines is a technological challenge given the solid structure of faecal sludge in the latrines, the amount of solid waste and the fact that latrines are difficult to reach. Hence, appropriate methods need to be developed. This is outside the scope of the current study. **S** = people use the prospective FSTP site for food production and when they have to move out they might resist. Pit latrine owners are not used having their latrines emptied and motivation and capacitation is required to use the full potential.
Water Quality Improvement	Unknown
Cost-effectiveness Euro/ton BOD removed	Euro 4 million / 2.5 ton BOD_5/day = Euro 1.6 million per ton BOD_5 removed/day
Leverage of funds / co-funding	If the valorisation option would be chosen and Pivotworks would be selected for O&M, the equipment in which Pivotworks has already invested would be relocated to the Masaka site and contributed to the facility.
Support stakeholders (Government, NGOs, local leaders)	Full support
Synergy with other projects	None

Overall conclusion
Immediate impact as the existing site is dangerous and a dangerous pollution hot spot can be removed. Promising project, but its success depends on the ability to find a good operator. There is experience with the production of fuel from faecal sludge. The design originally proposed by AAW does not fulfil the environmental standards but, according to the latest information, has been adapted.

1 Introduction

1.1 Background

Lake Victoria Basin Commission (LVBC) is intensifying its efforts on Integrated Water Resources Management (IWRM), in concordance with the sustainable development agenda of the East African Community (EAC). Cooperation in the international river basin of Lake Victoria is already strong; however, there is still an urgent need for regional coordination among the member states. Inter-sectorial and transboundary coordination of IWRM activities is still a challenge. Regulation and their enforcement regarding water resources and ecosystems protection are partly on going, but the process is very long.

Although many programmes have been implemented over the last years, the planning, design and construction of water supply systems, wastewater treatment facilities and solid waste management do not keep up with population growth. Lack of sanitation facilities, open defecation and poor faecal sludge management lead to eutrophication and microbiological pollution. One of the consequences of eutrophication has been high increases in growth of water hyacinths, which in turn leads to disruption of water transport, water intake and hydropower generation, blockage of fish landings and de-oxygenation of the lake. Microbiological pollution is an important cause for water borne diseases in the region.

The LVBC is committed to develop IWRM for the basin using a step-by-step approach. For the short term a focus on the pressing and 'no-regret' issue of wastewater and sanitation has been chosen. At the same time steps are taken to develop towards a regional water framework management plan and a related regional priority investment plan. The focus on pressing and 'no-regret' has been translated in the concept of High Priority Investments (HPI). During the Inception period this concept has been translated in three specific criteria that are presented in Figure 13.

Figure 13: Criteria HPI project

For the City of Kigali, the HPI on Faecal Sludge Treatment has been selected for further elaboration in a feasibility study.

1.2 Objective of this Feasibility Study

The selected HPI is to address urgent problems in wastewater and sanitation. Further investments in water and sanitation may follow: the 'pipeline' projects. In subsequent phases and in accordance with availability of further funding, investments in other areas of IWRM could be envisaged. In the long run, the program is to lead to the establishment of a regional water framework management plan and related regional priority investment plan.

The objective of this feasibility study is to provide all necessary information to the funders to execute the appraisal and at the same time setting a standard for pipeline projects. As KfW is the main potential funder, the feasibility study follows the *'Appraisal Guidelines for Financial Cooperation Projects Wastewater / Sanitation (KfW, April 2013): Programme Proposal Part A (Priority Area Selection), Part B (Financial Cooperation Module)'*. These include the development cooperation program's developmental effectiveness, geared towards the OECD (DAC) evaluation criteria (relevance, effectiveness, efficiency, impact, and sustainability).

In Kigali, the selected HPI is the Faecal Sludge Treatment Plant (FSTP) to be constructed in the Masaka area. The Water and Sanitation Corporation of Rwanda, WASAC, has already contracted a consultant, AAW, to prepare a basic design and prepare tender documents (see text box below). WASAC executes projects in close collaboration with the Kigali City Council (KCC). At the moment of preparing this Feasibility Study the consultant AAW is still working on the basic design. Intense communication with both WASAC and AAW has allowed us to advise on improvements of the basic design. A number of our suggestions have been taken into account, see APPENDIX 6: Update on Chapter 4 AAW on Sludge Characteristics and Proposed Treatment Alternatives but it remains unclear whether AAW will also produce the tender documents as planned.

Consultant Services for the conceptual design and Performance specifications of Septic Tank Sludge Management and Treatment Plant for KIGALI City
[Tender Ref. No. 11.07.053/5253/CS/008/QCBS/12/PROC-DWSD/PNEAR-DIR/YM/et]

The overall objective is to mobilize a comprehensive sludge management study solving a crucial environmental problem and delineating how the sludge will be collected, transported, treated and the technology proposed will allow onsite energy production, and organic fertilizers.

This study will provide a sustainable and operational solution to the sludge management in Kigali to ensure that sludge from septic tanks and others sources of sludge wastes is treated by suitable treatment options and disposed safely in the receiving environment. The specific objectives are:

- Determine treatment process and produce EPC tender documents of all the sludge treatment plant;
- Estimate power requirements for the entire treatment plant facilities and utility supplies as part of the cost for operation and maintenance;
- Devise and advise on method of construction;
- Confirmation of identified site of the plant. Quantify the current quantity and future septic tank sludge treatment needs for Kigali City for the horizon of 10 years, considering the on-going centralized projects;
- Propose the best energy efficient. Sludge reduction. High level of treatment. Efficient technology that can be applied in Kigali based on climate condition sand sustainability criteria;
- Design the most appropriate septic tank sludge treatment plant and disposal covering the needs for Kigali City for a horizon of 10 years;
- Carry out an EIA with its Environmental Management Plan (EMP);
- Prepare the tender documents with specific conditions and specifications for the recruitment/procurement of a construction company.

1.3 Objective of the Proposed High Priority Investment (HPI)

The objective of the HPI is to '*Replace the crude dumping site at the Nduba Landfill and implement a permanent faecal sludge treatment plant for citywide septic tank and pit latrine sludge*'. In Chapter 2 we elaborate on the current unacceptable and urgent situation at the Nduba Landfill in Kigali, where faecal sludge is simply dumped in a hole in the ground on top of a hill. In Chapter 3 we describe the sustainable solution that has been generated to provide an alternative. This HPI does NOT include a technical analysis of the closure of the Nduba Landfill.

2 Review of current Conditions

This chapter provides an overview of all relevant basic information on the country in general and the wastewater and sanitation sector specifically.

Figure 14: Location Rwanda

Figure 15: Location Kigali, (source Google maps)

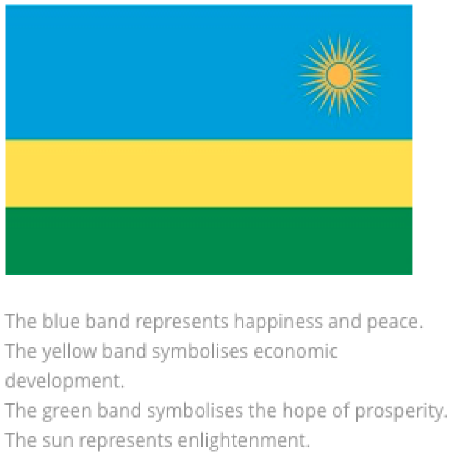


Figure 16: The National Flag of Rwanda

2.1 Introduction

Rwanda is found one of the success stories emerging from Africa in recent years. Long-term vision, strong leadership, political stability, good governance and economic growth have made it attractive to foreign investors and ecotourism has taken off. Agricultural production has doubled since 2007, improving food security, mining has been privatised and contributes 38% of export earnings, and industry and services are expanding, providing off-farm jobs for the growing population. Development is supported by 2,300 km of fibre optic cables recently laid across the country and by an increasing access to electricity, now at 10.5%. Over 95% of children enrolled in primary school in 2009. Six years after joining the East Africa Community, Rwanda is playing a leading and exemplary role in the region. Rwanda has ambitious Economic Development and Poverty Reduction goals that are steered by the Rwanda Vision 2020. Vision 2020 has been converted into action by a series of medium-term strategic plans. The first was the *Poverty Reduction Strategy (PRSP)*, which covered the period 2002-2006. It was followed by the first *Economic Development and Poverty Reduction Strategy (EDPRS)* covering the period 2008-2012. This was also followed by the second *Economic Development and Poverty Reduction Strategy II (EDPRS II),* which covers the period 2013-2018. See text box below. [5]

RWANDA VISION 2020

Objectives of Vision 2020: *The VISION seeks to fundamentally transform Rwanda into a middle-income country by the year 2020. This will require achieving annual per capita income of US$ 900, a poverty rate of 30% and an average life expectance of 55 years. (Rwanda Vision 2020, 2001)*

The following table presents the main targets of the Vision 2020.

[5] *Source: RHDHV, Draft Environmental and Social Impact Assessment of the Kigali Wastewater Project, commissioned by EIB, December 2015*

Objectives	Vision 2020 targets
Rapid economic growth to Middle Income status	➢ GDP per capita of $1240 ➢ Avg. GDP growth of 11.5%
Increased Poverty reduction	➢ Poverty reduced to 20% ➢ Extreme poverty eliminated
More off-farm jobs, more urbanisation	➢ 1.8 million new off-farm jobs ➢ 35% of population urban
Reduced external dependency	➢ Exports Growth of 28% p.a.
Private Sector as engine of growth	➢ Private sector takes dominant share of investment

Source: Rwanda Vision 2020, 2001, Adopted

Poverty Reduction Strategy (PRSP 2002-2006)*. PRSP was elaborated in a post-conflict environment where the main emphasis was on managing a transition from emergency relief to rehabilitation and reconstruction. Six broad areas were identified as priorities for action: rural development and agricultural transformation: human development, economic infrastructure; governance, private sector development and institutional capacity building.*

Despite strong economic growth, poverty fell during the PRSP period by only 2.2 percentage points. More than half the population continued to live below the national poverty line. Extreme poverty fell by 4.2 percentage points between 2001 and 2005, but still afflicted more than one third of the population. While income inequality as measured by the Gini coefficient, rose from 0.47 to 0.51.

In terms of non-income poverty, the PRSP was much more successful. Infant, under-five and maternal mortalities all decreased by 20-30% (Source: EDPRS II, 2013).

Economic Development and Poverty Reduction Strategy (EDPRS 2008-2012)*. Taking the lesson learned from the PRSP, the EDPRS I The policy and strategy focus under EDPRS 1 was, therefore to (a) accelerate growth and diversification by giving a bigger role to the private sector, and (b) further decentralise governmental functions to take developmental decision-making closer to the people, accompanied by strengthened accountability mechanisms.*

Remarkable progress has been made during EDPRS I. Main achievement include the following.

1. *Economic growth for the EDPRS 1 period 2008–2012 remarkable progress has been achieved. Real GDP growth averaged 8.2% annually, which translated into GDP per capita growth of 5.1% per year. The economy experienced a short period of difficulty following the global financial crisis in 2008-9, when GDP growth fell to 6.2% in 2009. However, growth well in excess of population growth returned during 2010-2012, permitting significant real increases in per capita incomes.*

2. *Strong and balanced economic performance has derived from sustained growth across all sectors of the economy. Services have been the main driver of growth. The sector grew at an average of 10.0% per year and produced around 52% of national output during the EDPRS 1 period.*

3. *The industrial sector grew at an average rate of 9.8% per year during EDPRS 1, driven by a rapid expansion of construction, which grew at 15.0% annually. The industrial sector produced 15.4% of national output between 2008 and 2012.*

4. *Agriculture grew at 5.4% sustained by higher than expected expansion of food production, mainly thanks to scaled-up public investments such as the crop-intensification programme (CIP). The agriculture sector contributed 32.7% of GDP and 28% of total growth. (Source: EDPRS II, 2013)*

Economic Development and Poverty Reduction Strategy II (EDPRS II 2013-2018):

EDPRS 2 prioritizes four thematic areas.

1. ***Economic transformation*** *for accelerated economic restructuring and growth striving for middle-income country status. The overall targets for the Economic Transformation thematic areas for EDPRS 2 include: (i) 11.5% per annum real growth over the duration of EDPRS 2; and (ii) a change in Rwanda's economic structures reflected through increased investments, exports, savings, private sector credit, and manufacturing, accompanied by an increase in urbanisation. In order to achieve these high-level targets, the GoR proposes a comprehensive Economic Transformation strategy that is framed around a multi-sectoral common vision and approach.*

2. ***Rural development*** *to address the needs of the vast majority of the population and ensure sustainable poverty reduction and rural livelihoods. The objectives for Rural Development are derived from the overarching objectives of EDPRS 2 – sustained poverty reduction and economic growth. The current headcount poverty ratio is 45% and extreme headcount poverty is 24%, with the EDPRS 2 target set at 30% and 9%, respectively.*

3. ***Productivity and Youth Employment*** *to ensure that growth and rural development are underpinned by appropriate skills and productive employment, especially for the growing cohort of youth. The overarching goal in this thematic area is to move Rwanda from an agriculture-based economy to an industry and services-based economy. Vision 2020 aims for half of the Rwandese workforce to be working off-farm by 2020, up from just 28% today. This is because non-farm workers are five times more productive than farm workers, and are 50% less likely to be in poverty. Reaching this goal will require creating an additional 200,000 non-farm jobs per year.*

4. ***Accountable Governance****, to underpin improved service delivery and citizen participation in the development process. The objective envisages empowering Rwandan citizens by engaging them in formulating, executing, monitoring and evaluating policies and strategies for accelerated growth and poverty reduction. This also implies raising their awareness of development policies and allowing citizens to be dynamic drivers in a really participatory way of the development agenda. Accountable governance underpins all the other themes since citizen participation is an essential ingredient of sustainability of development programmes. (Source: EDPRS II, 2013)*

The EDPRSP targets are ambitious but Rwanda seems to succeed in achieving many. That makes Rwanda unique among African countries South of the Sahara. The majority of Government staff is reported to be below 40 years with a high motivation and drive towards success in change and innovation in governance.

Rwanda is making serious efforts to changing from a purely agriculture-driven economy (in 2000: 90% of population was employed in agriculture) to a multiple-sector economy with more agro-processing, industrial development and service sector. It has the highest population density in Africa (408 persons/km^2). It is transiting a substantial portion of its land presently utilised for small-scale household-based farming into large-scale, modernised, mechanised farming. Rwanda is gradually increasing its present 17,000 ha of irrigated land to the 6-fold target of 100,000 ha in 2017. It needs to feed its growing population, some 11 million in 2011, and annually increasing with some 2.8%. (Source: EDPRS II report, 2013)

Health. According to USAID, MSF (Médecins Sans Frontières) and the World Health Organization (WHO), the health and livelihoods of Rwandans have greatly improved over the last decade. After the 1994 genocide, the healthcare system in Rwanda collapsed and epidemics of infectious diseases were devastating the country. Today however, as a result of the growing GDP, Rwanda's economy has been transformed and this has led to significant changes to the healthcare system.

The World Bank indicates that life expectancy at birth has dramatically increased for both men and women, with life expectancy at birth for females in 2013 at 66 years of age compared to 53 years of age in 2003. Life expectancy at birth for males in 2013 was 62 years of age compared to 51 years of age in 2003. This supports the improved efforts in the healthcare system. The WHO12 also reports a dramatic decrease in child mortality, with the decrease in maternal mortality; from 1,400 (per 100,000) live births in 1990 to 320 in 2013.

At the country level, the top three causes of child mortality are: respiratory infections, trauma & burns and diarrhoea. Septicaemia represents 16% of causes and 7% of deceased children had clinical features of malnutrition. Malaria represents 19% of cause. See Figure 17

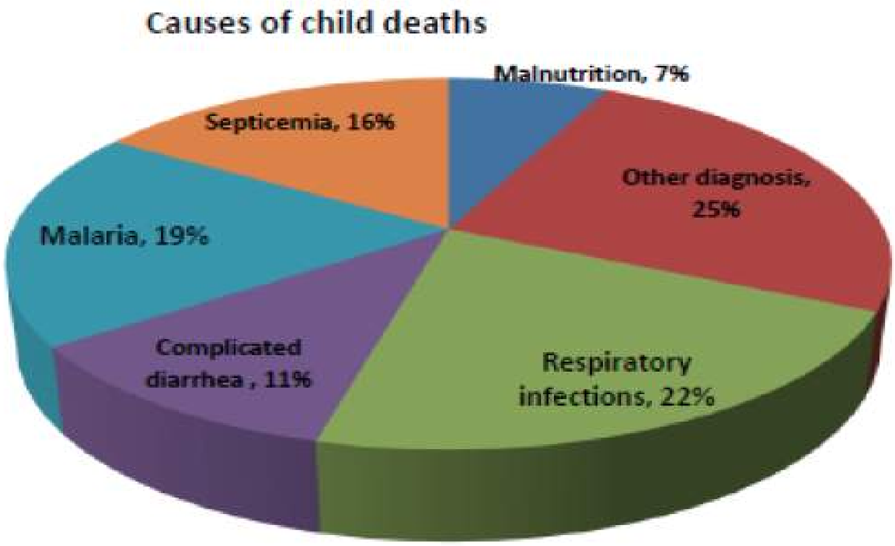


Figure 17: Causes of Child Deaths (Source: ESIA Kigali Sewerage Project)

2.2 Facts and figures Rwanda[6]

Topic	Descriptions
Government type:	Democratic republic
Political situation:	When Rwanda became independent in 1962, it was a poor underdeveloped country. In the 1990's, the country went through a phase of very dramatic interactions between the two ethnicities of the Hutu's and the Tutsi's, which has resulted in genocide with many deaths as consequence. Since the year 2000, Paul Kagame of the Rwandan Patriotic Front (RPF) is the ruling president and he is the most powerful actor in the government. Political participation of other parties is highly influenced which results in limited decision-making power of possible opponents of the ruling party. A number of parties have been banned officially from participation (e.g. MDR and the Party of Democratic Renewal). The government is embedded onto the village level, a system that works effectively throughout the country. State and religion are separated.

[6] *Source: Positioning Survey for the Dutch water sector in Rwanda, Aidenvironment, commissioned by RVO/NWP, April 2015*

Topic	Descriptions
Stability:	Despite its constant economic growth, Rwanda is still highly dependent on foreign development aid in the future. Development Partners, however, keep a sharp eye on the relationship between Rwanda and DRC with regard to their political and military involvement as well as illegal exploitation of mineral resources in DRC. This can all have effects on the international reputation and future economic development of Rwanda. The country has relative low corruption compared to neighbouring countries.
Language:	Kinyarwanda, French, English, Swahili
Population:	12,337,138
Population growth:	2.63%
Economic growth (GDP growth in %):	4.7 (2013), 7.2% (2014), 7.4% (2015), 7.4% (2016)
GDP (PPP):	USD 16.37 billion (2013)
GDP (PPP) per capita:	USD 1,500 (2013)
Unemployment rate (in%):	3.4%
Inflation rate + forecast 2020 (in %):	-3.1% (2014), -3.59% (2015), 0.19% (2020)
Foreign direct investments (in % of GDP):	1.5%
ODA in % of GNI:	12.3%
Imports:	USD 1.937 billion (2013)
Import partners:	Kenya (17.3%), Uganda (15.6%), UAE (8.9%), China (7.2%), India (5.6%), Tanzania (5%), Belgium (4.5%), Canada (4.1%)
BTI index on banking system:	8. Rwanda is still heavily dependent on agriculture; of which only one-third of the products reach the national market. The government is making efforts to improve the conditions for a diversified and market based economy. This contains property rights, anti corruption measures as well as attracting private foreign investments. It is possible that access to credit and investments are, however, influenced by the government. Foreign investments are still limited and investors seem to be reserved. In Rwanda, 72% of the population has access to banking. The sector is largely privatized, with 49% owned by foreign investors and 30% by the government.
Doing business index:	48 out of 189
WEF Global competitive index:	64 out of 144

2.3 Facts and Figures Kigali

The national 2012 census recorded the population of the City of Kigali as 1,135,428, representing 10% of the country's total population. Kigali City has witnessed a rapid urbanization in the last twenty years, due to the country's history of repatriation of refugees from neighbouring countries, rural-urban migration, natural population and politico-economic stability of the country after 1994 genocide. The population of Kigali City has grown from 765,325 to 1,135,428 inhabitants from 2002 to 2012 respectively, representing 48.4% of increase in ten years. With an annual population growth rate of 4% in the City of Kigali, this rate is nearly double the national annual population growth. In the city of Kigali, 48.3% of the population consisted of women (546,563) in 2012. (*Source: RHDHV, Draft Environmental and Social Impact Assessment of the Kigali Wastewater Project, commissioned by EIB, December 2015).*

Figure 18: Map of Kigali

***Table 8:** Population Kigali (Source: National Institute of Statistics and Research of Rwanda (NISRI) 4th housing and population census 2012, AAW)*

District	2002 Total Population	2012 Population		
		Males	Females	Total
NYARUGENGE	236,990	148,282	136,578	284,860
GASABO	320,516	274,342	256,565	530,907
KICUKIRO	207,819	162,755	156,906	319,661
KIGALI CITY	765,325	585,379	550,049	1,135,428

2.4 Sanitation Coverage Kigali

In 2008 (SGI) 95% of the households had individual sanitation, of which 80% have pit latrines and 20% flush toilets. More recent studies mention 85% pit latrines versus 15% septic tanks. Wastewater disposal of flush toilets in Kigali is mainly in septic tanks and soakaways, and in some cases direct discharge into open watercourses (See text boxes below). The Kigali City Master Plan (2013) includes a target of 20% for sewerage coverage in the City by 2025 and the wastewater and storm water drainage system should be separated in 20% of the City. The use of pit latrines has to be phased out gradually by 2025 (*Source: RHDHV, Draft Environmental and Social Impact Assessment of the Kigali Wastewater Project, commissioned by EIB, December 2015).*

Today, wastewater in Kigali is collected predominantly in septic tanks and soakaways. Septic tanks are currently emptied by tanker trucks, which discharge the wastewater in dedicated ponds near the city's central solid waste disposal site, however wastewater from these ponds infiltrate into the soil and groundwater, or overflow into the open surface water surrounding the city. In addition, most of generated wastewater is discharged directly in open watercourses and channels without any treatment, ending in Nyabugogo River carrying all pollutants from the City of Kigali (CoK). A small part of the generated wastewater in Kigali today is treated in decentralized wastewater treatment plants connected to hotels, major governmental buildings and a small housing area covering about 30 households.

However, the majority of the inhabitants make use of private or shared pit latrines, while only a part of them is emptied by tanker trucks, who dispose the waste at the municipal landfill. In addition, sewage (treated or untreated) is collected in drainage ditches, which are mostly *covered, but not completely, posing a risk for contact with the sewage. As in the current situation there is no separate discharge system for sewage and storm water in the city, so that in periods of heavy rain the drainage ditches can overflow, bringing sewage water into the streets, where people can get into contact with it.*

In the current situation sewage from a large part of Nyarugenge District (including Muhima and Nyarugenge sectors) is drained into the Nyabugogo River, which flows to the west, passing the proposed WWTP site and conflates downstream with the Nyabarongo River. Especially in the dry season, when the pollutants of the sewage are less diluted by rain and river water, the levels of pollutants increase substantially.

The Nyabugogo River is a tributary of the Nyabarongo River, which in turn is joined by the Akanyaru river tributary to become the Akagera River that flows into and through lakes Rweru and Mugesera and into Lake Victoria (Kigali SOE report, 2013). Potentially this means that the Nyabugogo River contributes pollution to the Lake Victoria.

The current wastewater situation in Kigali poses a direct threat to the environment and the public health, as evidenced by the heavily polluted rivers flowing through the city, including the Ruganwa River from the East, the Rwanzekuma from the North, Yanze and Mpazi rivers, all tributaries of Nyabugogo River towards the West, which flows into Nyabarongo River (Figure 2). Levels of Biological Oxygen Demands (BOD_5) in these rivers vary from 10 – 20 mg / l during the wet season and up to 25 – 35 mg / l during the dry season. As a reference, typical values for pristine rivers have BOD_5 values below 1 mg / l, while moderately polluted rivers may have BOD values in the range of 2 to 8 mg / l. High concentrations of heavy metals (cadmium, lead and chromium) and nutrients exceeding eutrophication thresholds at outflow of Nyabugogo swamp due to industrial areas previously located in Gikondo industrial park were also recorded in previous studies (Sekomo et al., 2010 and Nhapi et al., 2011)
Source: RHDHV, Draft Environmental and Social Impact Assessment of the Kigali Wastewater Project, commissioned by EIB, December 2015

Although Kigali is focussing on (complex and expensive) sewerage systems, it needs to be taken into account that for a long time to come, the city will depend on on-site systems due to financial constraints. The following text box provides some insights in the challenges of on-site sanitation systems.

In Kigali, Rwanda's capital city, like many other cities in developing countries, the most widely used sanitary facilities in the poor neighbourhoods are pit latrines, occasionally supplemented with flushing toilets and septic tanks. Conventional pit latrines provide a cheap way to handle human waste and require little maintenance; however, they provide limited comfort, attract flies and spread diseases such as diarrhoea and dysentery through contamination of the environment. Rapid population growth and urbanization associated with the proliferation of informal settlements are often accompanied by environmental degradation. In Kigali, the population is growing faster than the provision of services. In 1996, the population was 358,200, but by 2012, it had increased to 1,135,428. Much of the urban growth has taken place in unplanned settlements that now accommodate 62.6% of the population. The 2010 Demographic and Health Survey reported 88.7% of sanitation to be improved; although this number falls to 46.2% if the JMP definition, which excludes shared sanitation, is used. However, this percentage does not point out the disparities in conditions within the formal and informal parts of the urban area.

Pit latrines in the informal settlements are often poorly maintained and rarely emptied; the pits are generally not lined with bricks and can collapse after a period of use. Furthermore, there are few suction trucks available to empty pits and septic tanks, and often sites are not accessible due to the narrow steep roads, which lead to the latrines. Even if there is a possibility to empty liquid from pits, the sludge is not always disposed of in a proper manner. However, neglecting pit emptying or employing poor quality emptying services can have serious health and environment consequences.
Source: Aime Tsinda et al, Challenges to Achieving Sustainable Sanitation in Informal Settlements of Kigali, Rwanda, in Int. J. Environ. Res. Public Health 2013, 10, 6939-6954; doi:10.3390/ijerph10126939, 10 December 2014 .

Pit latrine emptying. Pit latrines are rarely emptied and the emptying of pit latrines is not a lucrative business. First of all, people owning pit latrines are relatively poor: 85% of the population of Kigali uses pit latrines, while 67% of the population of Kigali resides in informal settlements. Secondly, pit latrines contain relatively hard faecal sludge and are usually full of solid waste. The preferred option is to seal a full latrine and dig a new one. If this is not possible due to lack of land, emptying of existing latrines is done by digging 'burrow pits' to route the waste from one pit to another. These activities often take place at night, preferably during the rains so that the authorities do not notice these 'informal' emptying practices. For more details on pit latrine emptying we refer to the reports of Pivotworks and the text box below.

HOW THE EXISTING PIT LATRINES ARE BEING EMPTIED AT THE MOMENT

When the pit is full, a person should stop using it and then there are two options:

- *Stop using the latrine and construct a new one*
- *Empty the contents and reuse it.*

Often, the lack of available space or lack of funds for constructing a new latrine superstructure and pit means that pit emptying may be the only practical alternative. The conventional method for pit emptying is the vacuum tanker. This is a truck-mounted tank between 5 to 20 m^3 in capacity with a vacuum pump connected to the tank to suck out the sludge. However, there are technical limitations to the use of the vacuum tanker in areas with inadequate road access and shortage of spare parts. On the other end of the technological scale, manual emptying is used which involves accessing the pit, which in some cases done by destroying the squatting slab and digging the sludge out with simple hand tools such as spades, shovels and buckets by a team of workers, sometimes borrowed or rented from the customer. If the sludge is liquid, buckets and rope may be used to scoop the sludge out. This method is discouraged, however, mainly due to the pathogenic nature of the sludge and the undesirable nature of the work. If the sludge is not liquid at a desired level, chemicals are used to liquefy the sludge.

The cases of frogmen who empty during night are not recognized in Kigali.

Source: WASAC, 20 July 2016

2.5 Dumping at Municipal Solid Waste Site in Nduba

At present, vacuum trucks dump the faecal sludge and septage from septic tanks (mainly wastewater) at the solid waste dumpsite in Nduba, see Figure 19, Figure 20 and Figure 21. The volume of sludge from septic tanks that is currently transported to Nduba dumping site is between 250-300 m^3/day[7]. This crude dumping site does not function as a proper Faecal Sludge treatment system: there is no treatment, there is foul smell, rodents have free access to the sludge and during rains overflows or landslides might occur. The Nduba site has not sufficient space to build a proper FSTP and the location is not appropriate for faecal sludge treatment. In addition, the transport by vacuum trucks poses health risks; see Figure 22 and Figure 23. The crude dumping of faecal sludge leads to foul smell. The absence of treatment leads poses a threat to the environment.

[7] Source: AAW, 2016. Pivotworks reports that only 80-100 ton/day is brought to the site (Personal communication, April 2016)

Figure 19: Location Solid Waste and Faecal Sludge Dumpsite Nduba (Source: Google maps, 20 April 2016)

Figure 20: Faecal Sludge Dumpsite Nduba (Google maps, 20 April 2016)

Figure 21: Open Pit full of Faecal Sludge Nduba

Figure 22: Vacuum Truck to Dump Site Nduba, Kigali

Figure 23: Spreading of Fresh Faecal Sludge Nduba, Kigali

Figure 24: Effluent Discharge in Open Pit Nduba, Kigali

2.6 Problem Analysis

In Figure 25 we present the ‘problem tree’ associated with the crude dumping of faecal sludge at the Nduba dumpsite. The open, foul smelling pits do not only pose problems at the dumpsite itself: the fact that there is no regular pit latrine and septic tank emptying in Kigali also leads to malfunctioning on-site systems and spreading of diseases. The main cause for the crude dumping is the fact that the dump is located on top of a hill, far from the city: of course nobody likes to have a stinking dump in the backyard.

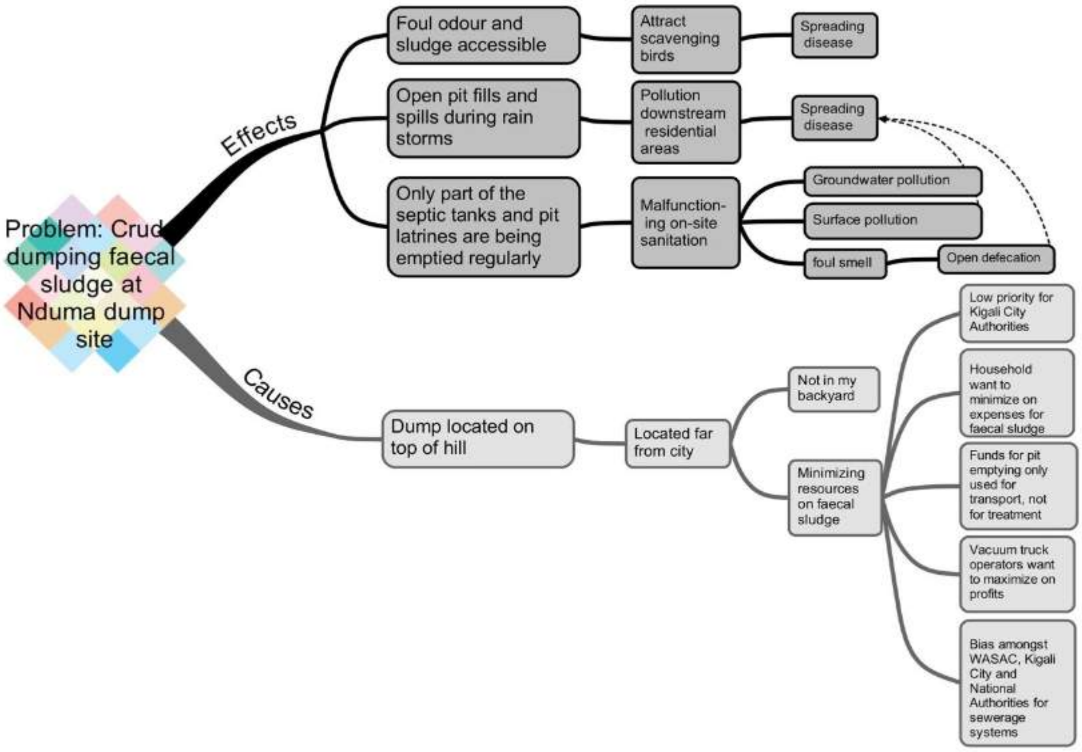


Figure 25: Problem Tree Crude Dumping Faecal Sludge

It is expected that the High Priority Investment project on faecal sludge treatment in Kigali will remove the underlying causes of the present problems. This is explained in Table 9.

Table 9: *Underlying Causes of the Present Problems Related to faecal Sludge Management in Kigali*

Underlying cause for problems associated with crude dumping: expenses and resources on faecal sludge management are minimized	**Solution: environmentally sound management of faecal sludge, collection, treatment and valorisation**
It is not a popular subject for city authorities and has low priority	Attention from the international Development Partner community puts the topic high on the agenda
Households have other priorities and minimize on the operation and maintenance of their toilets	The communication associated with the new faecal sludge treatment plant including improved and affordable pit and septic tank emptying services is to lead to marketing the importance of adequate operation and maintenance of on-site systems.
Charges for pit emptying are used for transport and optimizing profits, not for treatment	By valorisation of the faecal sludge, costs associated with faecal sludge management can be lowered.
There is a bias amongst the authorities and the service operator for sewerage: all attention and plans last 40 years were focused on a water borne system, not on the adequate functioning of on-site systems as these are seen as ‘backward’ technologies.	Attention for faecal sludge management makes the responsible authorities realize that on-site treatment has the same environmental benefits as off-site treatment at a fraction of the cost.

2.7 Other Development Partner Involvement and Development Partner Coordination

As already mentioned in section 1.2, the High Priority Investment is 100% in line with the on-going project: *Consultant Services for the conceptual design and Performance specifications of Septic Tank Sludge Management and Treatment Plant for KIGALI City.*

As far as we know, other Development Partners fully concentrate on off-site systems. The approach towards adequate sewerage and wastewater treatment for Kigali has a long history of unfulfilled dreams including several projects that were not implemented:

- In 1991 the first Master Plan for Wastewater Management in Kigali was developed;
- In 2007, Electrogaz, the predecessor of EWSA and WASAC, commissioned SGI to update this Master Plan to the horizon of 2020 and to identify priority works;
- In 2012 Mott MacDonald reviewed this Master Plan and proposed a WWTP in Gitikinyoni and a phased implementation of the sewer system, starting with areas 1a and 2a, covering Kiyovu-Rugenge, Nyarugenge, Gitega and Muhima;
- The WWTP includes chemically enhanced primary treatment, sludge digestion and drying (12,000 m^3/day) as well as a pilot secondary treatment (30,000 m^3/day);
- This phased approach shall enable the Government of Rwanda and WASAC to “learn by doing”, as this is the first centralized WWT project in Rwanda;
- In addition, the Kigali City Master Plan promotes the phasing out of latrine toilets and replacing them with flushing toilets.

The future of the off-site system is unknown as it is prohibitively expensive: the total investment is estimated at € 78 mln. The European Investment Bank has indicated that it is willing to fund 50% of the investment provided other Development Partners fund the remaining 50%.

Decentralized Wastewater Treatment

In the framework of the Kigali Master Plan it is compulsory for project developers of major new building projects to develop and finance a system of wastewater treatment before construction permits will be issued. In practice many project developers have opted for the Airoxy® mechanical wastewater treatment plant concept, based on activated sludge treatment – SBR (Sequencing Batch Reactor).

Other relevant water and wastewater projects on-going in Kigali are:

- The preparation of a financial and institutional Feasibility Study for the Kigali Wastewater Project, carried out by Atkins UK;
- Assistance to water and sanitation by the World Bank through the Lake Victoria Environmental Management Program (LVEMP2). As far as we know LVEMP2 concentrates on small towns and not on Kigali;
- Water and Wastewater Master Plan for Kigali, focusing on sewerage;
- UN Habitat MoU with the Ministry of Infrastructure for urban planning.

3 Description of the Proposed HPI

3.1 Description Proposed HPI

The proposed HPI is a Faecal Sludge Treatment Plant (FSTP), located in Masaka, having the following configuration:

- Improvement (widening and tarmac) of the access road around 2.5 km long. The funding of the road is outside the scope of the Development Partner: The Government of Rwanda, through WASAC is taking care of this;
- Trucks receiving area;
- Screens and removal of grit and scum and sludge settling tanks;
- Sludge holding tank with concentrated sludge pumping;
- Valorisation of sludge:
    - Either fuel production through addition of polymers, mechanical sludge dewatering, solar drying followed by heat drying and sales as fuel (Preferred Option); or
    - Co-composting with biodegradable waste;
- Supernatant and site draining siphon/pump station;
- Storage area fuel or co-compost;
- Anaerobic Baffled Reactor (ABR) to treat supernatant water from sludge thickener and drainage from sludge drying beds;
- Constructed Wetland to treat the effluent from ABR;
- Administration building;
- Fence.

The set up is presented in Figure 26.

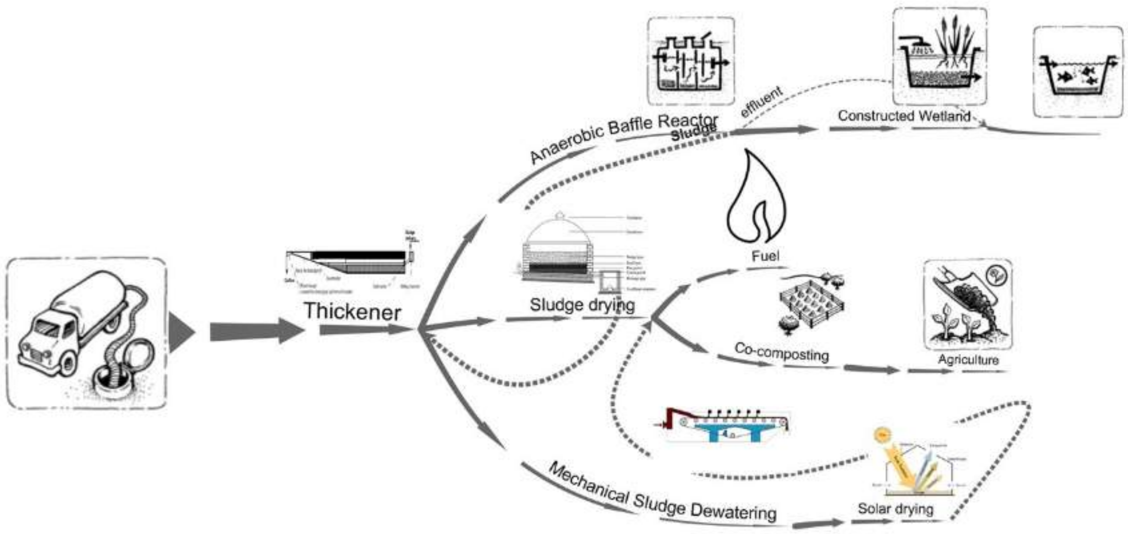


Figure 26: Schematization of HPI

As will be explained in chapter 4, this is a deviation from the design prepared by AAW as presented to us on 19 April 2016 as AAW's design has several shortcomings:

- The effluent from the ABR does not fulfil effluent standards for discharge into natural swamps. Hence, this needs to be treated. In chapter 4 we show that constructed wetlands are the recommended option;

- In case no proper operator can be found, mechanical sludge dewatering and solar drying is to be replaced by covered sludge drying beds as sludge dewatering requires operation and maintenance skills that are not present in Rwanda at the moment.

The FSTP is to be located in Masaka in line with the site selection by AAW. See map in Figure 27 and Figure 28, and photographs of the site: Figure 29 and Figure 31.

Figure 27: Proposed Site for the Faecal Sludge Treatment Plant

Figure 28: Proposed Site for the Faecal Sludge Treatment Plant

Figure 29: Proposed Site for Treatment Plant

Figure 31: Proposed Site for Treatment Plant

Figure 30: Sludge Belt Press by Pivotworks (Mechanical Dewatering)

Figure 32: Drying Faecal Sludge by Pivotworks

3.2 HPI Objective and Indicators

The objective of the HPI is to '*Replace the crude dumping site at the Nduba Landfill and implement a permanent faecal sludge treatment plant for citywide septic tank and pit latrine sludge*'.

The overarching objective is that on-site systems in Kigali will fulfil the Sustainable Development Goal on sanitation (Goal 6): *"By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally".*
The indicators and assumptions that relate the HPI to this objective are presented in Table 10.

Table 10: *Indicators and Assumptions that Relate to the HPI*

Indicator	Assumption
In December 2017 the Masaka FSTP has the capacity to treat 1,000 m^3 Faecal Sludge per day[8]	• Land acquisition and road improvement is done in time; • Tendering for Design, Construct and Operate is successful; • Funds for implementation released.
In 2018 50% of the target faecal sludge (500 m^3/day) is collected, transported and treated. In 2020 75% (750 m^3/day)	• Sufficient desludging devices available; • Desludging devices are also able to empty latrines that are not easy to access and with

[8] This is 50% of the design capacity of AAW as will be explained in section 4.1

Indicator	Assumption
and in 2023 100% (1,000 m^3/day)	'difficult' sludge; • The population is motivated and capacitated to have their facilities emptied; • The relevant (government) authorities have put adequate laws and regulations into practice and are actively enforcing them.
100% of the collected sludge is treated in an environmentally sound way: • Co-composting does fulfil national and International standards for agricultural use; • Effluent fulfils national and international discharge standards; • Any produced fuel fulfils environmental standards.	• The operator is checking the quality; • Qualified labs available that can do the testing; • The relevant (government) authorities have put adequate control mechanisms into practice and are actively enforcing; • The operator is certified for producing compost and/or fuel.

3.3 Potential Impact of the HPI

The fact that the site proposed to develop the HPI is agricultural land implies that the cost of involuntary displacement (toward effective implementation of the HPI) is likely to be low. According to the Government of Rwanda, obtaining agricultural land that is privately owned does not pose a significant challenge: affected persons will readily accept to be displaced as long as it is for a compelling public purpose and the resettlement is conducted in compliance to the legal framework of the country. The resettlement should be in compliance with World Bank OP 4.12, and where these two regulations diverge, World Bank OP 4.12 prevails. From consultations with government officials, this is possible.

3.4 Partner Structure: Executing Agencies and Intermediaries

WASAC[9], the Rwandan Water and Sanitation Corporation, was established by presidential decree in January 2014 and has been in operation effectively since July 2014 as part of a utility sector improvement strategy. The decree allowed the separation of EWSA (Energy Water and Sanitation Authority), a state agency, into two independent corporations, one for water & sanitation and one for energy, respectively named WASAC and Rwanda Energy Group (REG). The main drivers for the separation of EWSA into two companies were improvement of efficiency and improvement of investment planning.

EWSA Water & Sanitation owns and operates sixteen drinking water treatment plants (WTP) covering Kigali and thirteen other urban centres, with a total production capacity of 105,680 m^3/day.

WASAC is currently in a transition phase to become a financially independent and autonomous utility. The transition period is expected to last for 5 years. During this time WASAC should become a fully autonomous service provider that does not receive financial support from the government, for instance on energy and on O&M. Investment support will remain necessary in the coming years, especially in view of the huge investment challenge to reach full coverage on water and sanitation services.

In Figure 33 the current organization structure of WASAC is given. It is a functional model with six main directorates under the MD. These are:

- Urban Water and Sanitation Services;
- Water and Sanitation Development Services;
- Rural Water Services;
- Customer Services;
- Finance;
- Support Services.

[9] Based on the Draft Five-Year Strategic Business Plan, Mott MacDonald, October 2015

A Director leads each of these directorates.

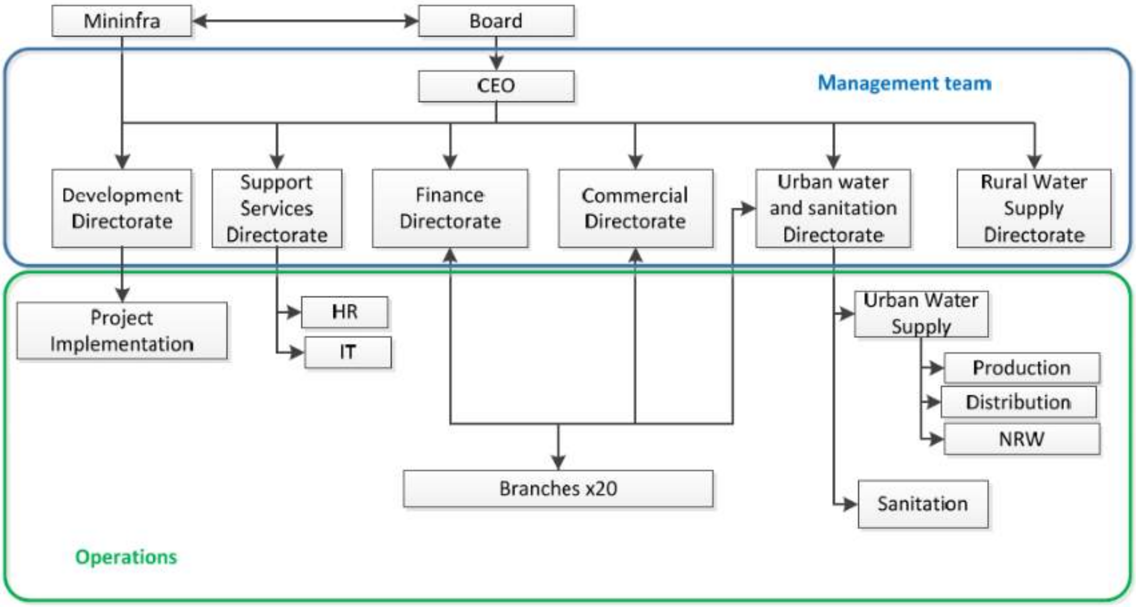


Figure 33: Current Organizational Structure of WASAC

The five-year strategic business plan (5YSBP) recommends changing the organizational structure to become even better suited to tackle its future challenges. One of the main changes foreseen is the delegation of responsibilities to branch offices. This will allow a better services provision, as they will be closer to their clients. The central office will mainly be engaged in policy & strategy development and investment planning. They will also offer dedicated support services to the branch offices. See Figure 34.

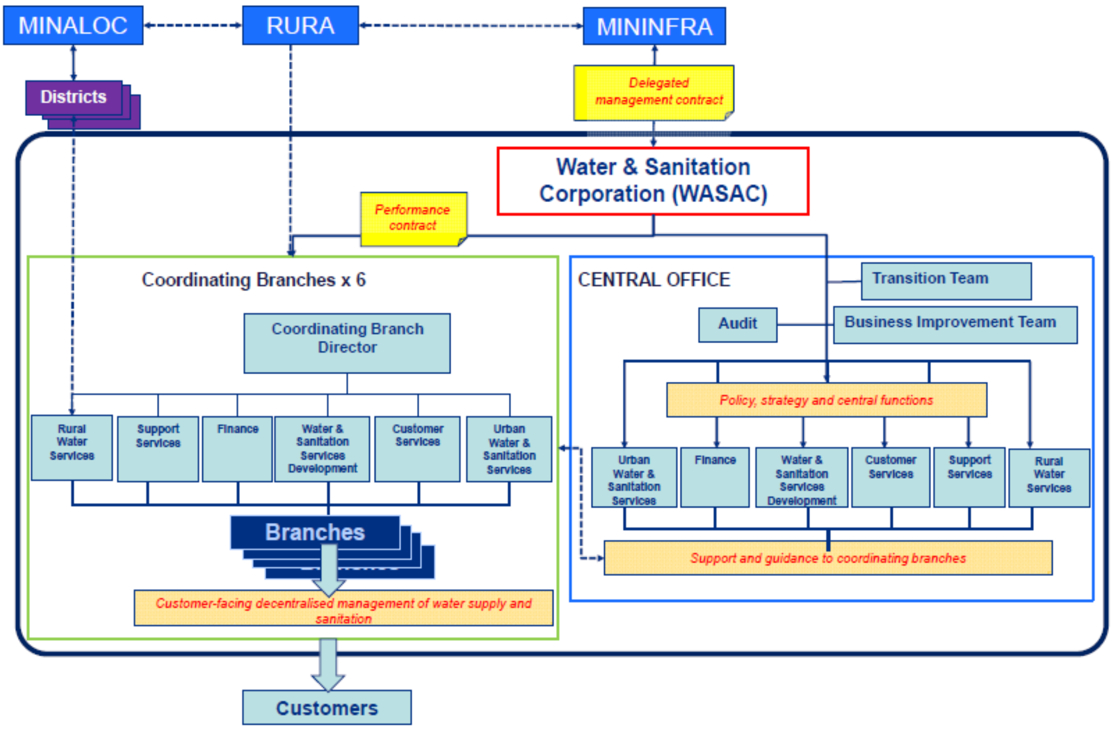


Figure 34: WASAC Branch Division and Relation with other Organizations

3.5 HPI Cost

The HPI requires an investment of € 3.12 mln. to construct the FSTP. In addition to that it requires an investment of:

4 vacuum trucks:	€ 0.58 mln.
Engineering design:	€ 0.40 mln.
Capacity building of WASAC:	€ 0.05 mln.
Land acquisition:	€ 0.7 mln.
Access road preparation:	€ 1.78 mln.
Closure of the dumpsite	€ 0.25 mln.

Kigali City Council (KCC) covers the land acquisition, access road preparation costs and closure (€ 2.73 mln). Therefore, the total project cost for the HPI, including and excluding KCC investment, is € 6.88 mln. and € 4.15 mln., respectively.

3.6 HPI Financing Plan

It is assumed that for the HPIs, the development partners, through a contribution, will cover the investment costs. These investment costs comprise the hardware for the equipment, facilities, and electrical-mechanical installations (if any). Also included in the investment costs are the preparatory costs, tender & detailed design costs and training costs that are needed to train staff to run the facilities. Access roads, electricity and other public services are not included in the investment costs; these are to be provided by the government.

It has been assumed that the financing will be grant financing, because KfW and EU are the initiators of the feasibility studies that are presently executed. However, if other financiers would step in or would co-finance, other financing modalities could be incorporated. If grant funding is to be replaced by loan financing or equity financing, the financial viability of the HPI projects would be lower as financing costs would have to be included in the calculations (Profit and Loss statement). Any follow-up financing of investments later on in the project will have to be financed through non-project sources. This could be internally generated funds of the implementing agency, contributions by the government, commercial financing (if possible) or other sources.

Depreciation is included in the calculations to ensure that at the end of the economic lifetime of the project, sufficient sources will be available to do new investments. Also the O&M costs have to be covered by the project. The revenues should be sufficient to cover both these costs, which is reflected by the Full-Cost Recovery ratio (FCR), which is determined by dividing the revenues by the operational costs and depreciation costs.

3.7 Relation with the National Strategy[10]

The Rwandese water sector is guided by two main economic development strategy documents: Rwanda's overall development strategies of Vision 2020 and the Economic Development Plan EDPRS. These strategies contain also generic objectives for the water sector. The EDPRS 2, which runs from 2012/13- 2017/18, has set targets for the water supply and sanitation sector, aiming to reach 100% coverage rate for water supply by 2017. This target is a revision of the targets set in Vision 2020, which aimed to reach this coverage level by 2020.

The EDPRS 2 has prioritized water supply and sanitation services as a critical thematic service that will contribute significantly to attainment of the social and economic growth needed for Rwanda during the next five years. It is from this perspective that WASAC needs to ensure effective delivery of adequate, reliable, and sustainable services.

[10] *Source: RHDHV, Draft Environmental and Social Impact Assessment of the Kigali Wastewater Project, commissioned by EIB, December 2015*

Besides the two development strategic plans mentioned above, the Millennium Development Goals have also influenced the targets for water and sanitation coverage. The sector policy that is defined in the National Water & Sanitation Policy (2010) translates these general development objectives into policy statements per sector.

The Water and Sanitation Sector Strategic Plan 2013/14 - 2017/18 is a thorough and detailed Plan designed to assist implementation of the main strategic documents. It also provides an implementation and financial framework for different regions, including Kigali City, and the northern, western, southern and eastern districts.

Targets include 100% rural water supply by 2018, 100% safe, reliable and affordable urban water supply by 2018 and strengthening of related water service providers;

- Improved sanitation services, including 100% coverage for schools, health facilities and other public institutions by 2018;
- Development of safe, well-regulated and affordable facilities for wastewater management, including sewerage, ***treatment and reuse / disposal*** for densely populated areas by 2018.

Hence, the HPI is in line with the National Strategy.

3.8 Relation with the City Plan

To solve liquid waste management challenges, WASAC in cooperation with KCC, has prioritised three projects; Kigali faecal sludge treatment plant in Masaka (this project), revamping of decentralised sewage treatment installations for estates and phase 1 Kigali sewerage and WWTP.

3.9 Enhancement of Pit Latrine Emptying

As indicated in the Problem Analysis (§ 2.6), the implementation of a FSTP will pave the way to improve the accessibility to and performance of sound on-site sanitation. Emptying of a latrine is cheaper than constructing a new one and having access to a latrine that is usable will prevent open defecation. One condition is the emptying of existing latrines in an environmentally sound way, where workers are protected properly and transport is hygienic. Transport of the contents of the faecal sludge to the FSTP will not only improve environmental conditions in informal settlements but will also increase the revenues of the FSTP. To make this possible, first of all, efficient emptying methods, fit for the Rwandan conditions, need to be developed. Pivotworks is starting some trials using technologies developed in South Africa, see APPENDIX 5: Pit Latrine Emptying Report Kigali . However, more efficient methods have been developed in the region, for instance in Malawi, see text box below.

Importance of fluidising

Fluidisation of the sludge is needed to be able to remove the sludge from the pit latrine. This is done by injecting small amounts of water with high pressure with a special lance and nozzles into the sludge. Without fluidising none of the equipment manages to remove significant amounts of sludge from the pit latrines. In most cases the amount of water used during the fluidisation process was about 15% of the total sludge removed. After fluidisation it was found that the solids content of the sludge was around 20%. Optimum pressure for fluidisation is 100 bar but for safety reasons 60 bar is recommended.

Figure 35: *Fluidization (Source: WASTE, 2014)*

Role of solid waste removal – fishing

Like fluidisation, the removal of the larger items from the sludge is essential to prevent the suction hose to be blocked. The sludge was found to invariably contain various forms of solid waste and rubbish, which must be manually removed after fluidising but before mechanical pumping of the sludge. Most households throw rubbish in the pit because of a lack of solid waste collection services or because they want to dispose certain types of solid waste privately. Examination of the fished out products, revealed items as old clothes, shoes, bottles, plastic carrier bags, maize cobs; menstrual cloths, medicine bottles (e.g. ARVs), and rubbish from the pit structure itself: gravel, stones and even large rocks falling from the pit wall. Therefore fishing through a 2 meters metal rod with welded hooks is an essential part of the emptying process to remove the larger rubbish that would simply block the suction or discharge pipes: It was found that the equipment can also get blocked during disposal by the smaller items (e.g. medicine bottles, cloths, plastic, stones, etc.) that could not easily be removed during the manual fishing process but accumulate inside the holding tank.

Figure 36: *Fishing in Malawi (Photo: Jan Spit, 2013)*

Pumping and transportation

The ROM2 performed the best in terms of effectiveness, but required major modifications to make it more efficient for the operator; and the machine was subsequently tested with these modifications. Given the field test and experienced gained in Malawi it is now possible to recommend a design of a transportable pit emptying machine that can handle most sludge in lined and unlined pit latrines as well as septic tanks, and can access a high percentage of difficult to reach toilets.

The key features of a vacuum operated machine targeting the emptying of toilets with old dried sludge should compromise of:

- *A fluidiser that can spray high-pressure water of around 60 bar in the latrine sludge using special lance or at least 1 meters length and nozzles. Optimising the nozzle design and operating pressure can make for more efficient fluidising but due to safety concerns pressure should be less than 100 bar. The length of the fluidising hose should be at least 30 meters;*
- *A vacuum pump that can create a vacuum of 0.5 bar and a capacity of at least 2,000 litres per minute;*
- *3 inch flexible suction of at least 30 meters length and outlet hoses in order to avoid frequent blockages by unfished rubbish and with good quality quick release connectors;*
- *A holding tank with a capacity of 800 to 1500 litres to store and transport sludge. The inside of the tank should be easily accessible to clean any blockages. A gauge should indicate the filling progress;*
- *Preferably the unit should be mounted on a small trailer or be fitted on the back of a pickup vehicle;*
- *Improving the operations logistics including access to localised disposal site (or a transfer station) – then it is possible to desludge up to 8 pits in 1 working day;*
- *In order for this equipment to function well in most pit latrine the removal of large items from the sludge in the pit latrines is still required this can be done through fishing with metal rod fitted with hooks.*

Figure 37: *ROM 2 (Source: WASTE, 2014)*

Source: 38th WEDC International Conference, Loughborough University, UK, 2015, Water, sanitation and hygiene services beyond 2015: Improving access and sustainability Desludging of 'difficult' sludge with 'easy' equipment designs: Results of field-testing in Blantyre – Malawi J. Spit, W. Carter, J. De Gabriele & J. Heeger, (The Netherlands)

Enhancing the motivation of the population.

Secondly the population needs to be motivated to accept and value the services of the pit emptiers. The following text box presents the way WASAC intends to motivate the population.

Currently the big challenges that the City of Kigali is facing in emptying of latrines is the access to the pit, we seriously face an issue of access roads to the households. To overcome that issue, the City of Kigali has developed a master plan which leads the:

- *The development of physical plans for sub-areas of the jurisdiction;*
- *The study of subdivision regulations, zoning standards and maps;*
- *The location and design of thoroughfares and other major transportation facilities;*
- *The identification of areas in need of utility development or extensions;*
- *The acquisition and development of community facility sites;*
- *The acquisition and protection of open space;*
- *The identification of economic development areas;*
- *The incorporation of environmental conservation;*
- *The evaluation of short-range plans (zoning requests, subdivision review, site plan analysis) and day-to-day decisions with regard to long-range jurisdictional benefit; and*
- *The alignment of local jurisdictional plans with regional plans.*

People are communicated through different channels such as radios, TV, during monthly communal works etc. to ensure the efficiency of transmitted message and thereafter the health inspectors (composed of the representative of Sectors, Districts and City of Kigali) follow for daily, weekly and monthly inspections.

Source: WASAC, 20 July 2016

We propose to put in more effort to enhance the motivation of the population, for example by using the six 'weapons of influence' of Cialdini[11]:

- Reciprocation - People tend to return a favour. Thus, KCC could initiate the improvement of roads and schools (or other community priorities) in an area to create a positive attitude towards pit emptying;
- Commitment and Consistency - If people commit, orally or in writing, to an idea or goal, they are more likely to honour that commitment. So if the community has first expressed their desire for comfort (a toilet free of smell that is always accessible), they feel in a later stage committed to use the services of a service provider that provides this comfort;
- Social Proof - People will do things they see other people doing. Hence, if some people in the community start emptying their latrines, others will follow;
- Authority - People will tend to obey authority figures. Hence if the community leader starts emptying his latrine, others will follow;
- Liking - People are easily persuaded by other people that they like. People are more likely to empty the latrine if they like the person selling the services to them;
- Scarcity - Perceived scarcity will generate demand. For example, offers to empty the latrine that are available for a 'limited time only' encourages sales.

In addition to motivation, the process needs ***capacitating.*** Capacitating deals with increasing the ability of a household to have its latrine emptied. Capacity has three aspects:

- Financial aspects (ability to pay). A farmer may have the capacity to pay for pit emptying only immediately after the harvest. The financial capacity of poor households to pay for pit emptying might be increased with credits or subsidies;
- Physical aspects. For example: emptying of difficult sludge in difficult accessible areas is impossible with the existing vacuum trucks. Tailor made solutions as piloted in Malawa re required;
- Knowledge aspects (ability to understand how a pit latrine can be emptied and how it is used appropriately). For example: if a person is convinced that the only option to have an accessible latrine is to dig a new one, it is difficult to market the emptying. Posters, videos, radio broadcasts or TV special can be used to increase the mental aspects.

[11] Dr Robert Cialdini is best known for his popular book on persuasion and marketing, Influence: The Psychology of Persuasion (ISBN 0-688-12816-5). His book has also been published as a textbook under the title Influence: Science and Practice (ISBN 0-321-01147-3).

4 Comparative Analysis

4.1 Design Proposed HPI

The main objective of the Kigali project is to replace the crude dumping site at the Nduba Landfill and implement a permanent faecal sludge treatment plant for the sludge collected from pit latrines and septic tanks of the City of Kigali. The new FSTP at the Masaka site is to replace the Nduba dumping site, which is in a dire situation.

In order to design a faecal sludge treatment plant, the volume of faecal sludge that will be treated at the treatment plant, its characteristics and effluent quality standards need to be known. However, the diversity of onsite sanitation technologies in use in Kigali, such as pit latrines, public toilets and septic tanks, makes it difficult to quantify and characterize the faecal sludge (FS).

Input Data

Quantification of FS. Estimation of the volume of sludge, which is to be treated at the FSTP, is essential for the proper sizing of the FSTP. The volume of the faecal sludge estimated by AAW[12] is based on the sludge produced in Kigali:

- Per capita solid content: 60 – 100 g/d;
- Volatile solids percentage: 60 – 80 %;
- Volatile solids destruction in the septic tank: 40 – 60 %;
- Solids percentage in the septic sludge: 1 – 4 %;
- Population served: 0.80 million capita (Based on the fact that 75% of the population of the city is served by the sludge collection system);
- Total faecal sludge production: approximately 2,000 m^3/d.

This information has been updated on 20 July 2016, the new design figure 1,925 m^3/d[13].

However, at the moment only 100 m^3/day[14] - 250 m^3/day[15] is being transported to the dumpsite and to construct a new FSTP for 2,000 m^3/day is rather risky as it is unknown how successful the marketing, motivation and capacitating efforts will be (Refer § 3.9). Therefore, we recommend designing the plant for 2,000 m^3/day but to finance and construct a FSTP of 50% of the AAW design capacity: 1,000 m^3/day. This equals the annual sludge accumulation collected per working day; not taking into account the desludging intervals (septic tanks 1 per 2-5 years; pit latrines 1 per 8-10 years) see Table 11.

Table 11: *Calculation sludge production*

Description	unit	Value
Population served	capita	800 000
% septic tanks	%	15%

[12] Consultant Services for the conceptual design and Performance specifications of Septic Tank Sludge Management and Treatment Plant for KIGALI City, AAW Preliminary Interim Report, April 2016.

[13] Update on chapter 4 of the Preliminary Interim report, status unknown, received on 20 July 2016 from Eng. GAFISHI M. Clement, MSc. NATIONAL PROGRAM COORDINATOR LVWATSAN II & KCSS-WWTP PROJECTS

[14] Source: Pivotworks field visit March 2016

[15] Source: Consultant Services Report AAW, April 2016

Description	unit	Value
% pit latrines	%	85%
Population septic tanks users	capita	120 000
Population pit latrines users	capita	680 000
Sludge accumulation septic tanks	l/cap/year	25
Sludge accumulation pit latrines	l/cap/year	40
Annual sludge accumulation septic tanks	t/year	3 000
Annual sludge accumulation pit latrines	t/year	27 200
Total annual sludge accumulation	t/year	30 200
Working days/year	days	200
Theoretical supply per working day	t dry sludge/day	151
% dry solids septic tank discharge	%	3%
Annual septic tanks discharge	t/year	100 000
Daily septic tank sludge discharge	t wet sludge/day	500
% dry solids pit latrine sludge discharge	%	20%
Annual pit latrine sludge discharge	t/year	136 000
Daily pit latrine sludge discharge	t wet pit sludge/d	680
Total daily wet sludge discharge	***t wet sludge/d***	***1 180***

Characteristics of Faecal Sludge. The parameters for the characterization of faecal sludge include solids concentration (TS, VS), organic concentrations (COD and/or BOD_5), nutrients and pathogens. Given the significant variability of faecal sludge characteristics, it is important to collect data from specific locations when designing a faecal sludge treatment system. In August 2015 and January 2016, sludge samples from vacuum trucks were taken and analysed at the University of Rwanda in Kigali (AAW Preliminary Interim report, April 2016). It can be assumed that the wastewater from the vacuum trucks is representative as the faecal sludge is transported to the FSTP using vacuum trucks as far as septage is concerned. The results of the analysis are presented in Table 12.

Table 12: *Characteristics of FS in Kigali (AAW Preliminary Interim Report, 2016)*

Parameter	August 2015		January 2016			Average
	First Truck	Second Truck	Truck No. 1	Truck No. 2	Truck No. 3	
pH	8.35	6.53	5.23	5.60	7.42	
TSS (mg/l)	10065	7938	1140	13850	11375	8873.90
COD (mg/l)	6300	6700	936	4850	4810	4719.20
Oil and grease (mg/l)	1.826	1.458	------	------	------	0.66
TS (mg/l)	16850	9850	4590	40000	25970	19452
VS (mg/l)	6480	5290	2140	22020	17680	10722
Total Nitrogen (mg/l)	105	55	158.6	458.6	305.1	216.46
Total Phosphorus (mg/l)	28.3	22.4	27.3	113.5	83.7	55.04
Ammonia Nitrogen (mg/l)	72.9	36.3	69.5	162.50	165.0	101.26
Faecal Coliforms /100ml	$7 * 10^1$	$6 * 10^5$	$< 1 * 10^0$	$1 * 10^1$	$< 1 * 10^0$	--------------
Ascaris Lumbricoides	++	++	Absence	Absence	Absence	--------------
Trichuris trichura	+	+	Absence	Absence	Absence	--------------

Effluent Quality Standards:

Table 13: *Tolerance limits for discharged domestic wastewater (Rwanda Standard RS110-2009)*

Parameter	Limits	Test Methods
TDS (mg/l)	< 1500	ISO 6107-2
TSS (mg/l)	< 50	ISO 11923
pH	5 - 9	ISO 10523
Nitrates (mg/l)	< 20	ISO 5663
Nitrites (mg/l)	< 2	ISO 6777
Total Nitrogen	< 30	ISO 11905
Total Phosphorus (mg/l)	< 5	ISO 6878
Temperature variation of treated water compare to ambient temperature of water °C	< 3	Thermometer[1]
BOD5 (mg/l)	< 50	ISO 5815-2
8 COD (mg/l)	< 250	ISO 6060
Faecal Coliforms /100ml	< 400	ISO 4831
Oil and grease (mg/l)	< 10	ISO 9377-2
Chlorine (mg/l)	< 2	ISO 7393
Sulphate (mg/l)	< 500	ISO 22743
Color Pt-Co	< 200	ISO 7887
[1]The thermometer used should be calibrated according to National Measurement Act		
NOTE: Limits are the values not to be exceeded during periodic measurement under normal conditions.		

Population Data

Population growth scenarios

Kigali City is currently witnessing a growth of 6.2% p.a. as against 2.8% for the rest of the country. Population growth projections for the future population are created for three scenarios: A high growth, medium growth, and low growth scenario are projected by taking EICV3 2011 as the base year.

The low growth rate assumes a growth rate of 4.1% until 2025, which reduces to 1.8% by 2040. The medium growth rate scenario assumes a growth rate of 5% until 2025 and 2.5% hence. And the high growth rate scenario assumes growth rate of 5.8% till 2025 and 2.5% thereafter. The two population main growth factors being:

- *Fertility rate at the current rate of 3.5% until 2025 and 3.0% in 2040.*
- *Immigration into the city.*

The assumptions for the three projections are as follows:

- *In the low case scenario, the population of the city is projected to be 2.3 million by 2025 and 3.5 million by 2040.*
- *In the medium case scenario, the projected population by 2025 is 2.5 million and 4.3 million by 2040.*
- *In the high case scenario, the population is projected to be 2.9 million by 2025 and 5 million by 2040.*

Source: Kigali City Conceptual Master Plan Report, 2013

Topographic Data. AAW has selected the FSTP site for Kigali city. The selected site is located at the Masaka area; more specifically in Kajuvuba (see Figure 27 and Figure 28). A visit to the site under the guidance of KCC has been done to check the suitability of the site. As shown in Figure 38, the site is hilly and excavation costs could be significant. On the other hand, the slope of the site helps minimizing pumping needs and provides the opportunity to use technologies that do not require electricity or fuel such as siphon systems (as suggested in this study to distribute the effluent from the Anaerobic Baffle Reactor to the Vertical Flow Constructed Wetland).

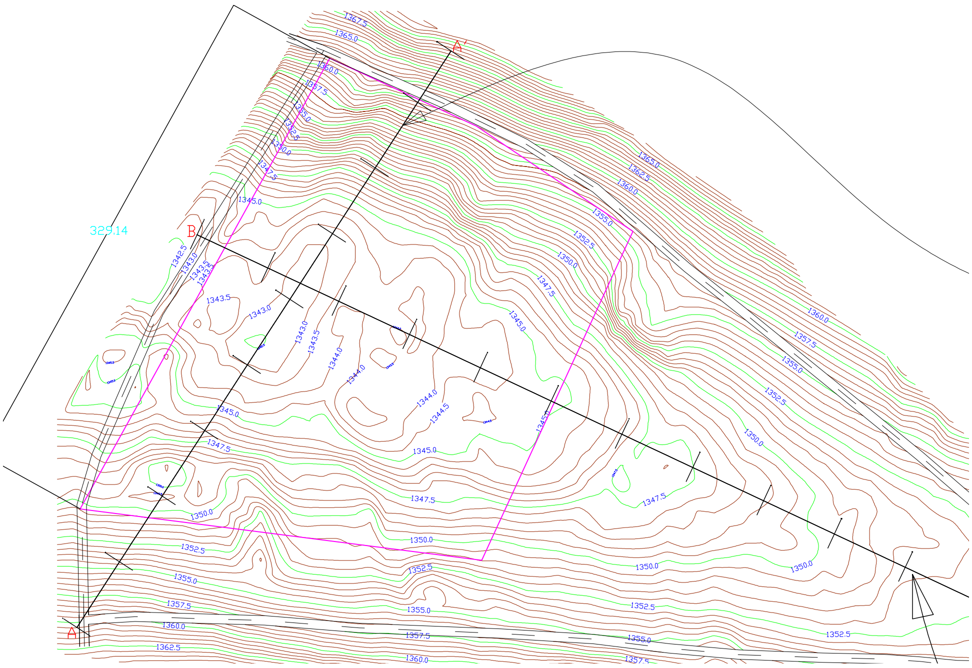


Figure 38: FSTP Proposed Site (Source AAW Interim Report, 2016)

4.2 Alternative Scenarios

AAW has prepared two FSTP options. The two alternatives were adapted in this study to form two additional options. Hence, in total four alternatives are presented and evaluated in this report.

Alternative 1: Supernatant and percolate treatment with ABR and sludge drying using drying beds

As presented in Figure 39, the pre-treatment step consists of a truck reception unit to dump the collected faecal sludge, followed by screens and a grease trap. The main aim of the pre-treatment step is to separate and remove coarse materials, grit, grease and scum so that these materials do not hinder the treatment processes in the subsequent sections of the treatment plant. After the pre-treatment, the sludge is collected and stored in the thickener (mostly up to 2 hours) to settle in order to separate the settleable solids from the liquid part. The thickener has two waste streams: one liquid stream (supernatant) and a stream with a high concentration of solids (settled sludge). The settled sludge is dried in sludge drying beds. The sludge drying beds contain two waste streams: dried sludge and percolate. The dried sludge from drying beds is further processed in a co-composting plant. The supernatant of the settler together with the percolate from the drying beds is further treated in anaerobic baffle reactors (ABR) for solids and organic reduction before they are disposed into natural swamps and subsequently the river.

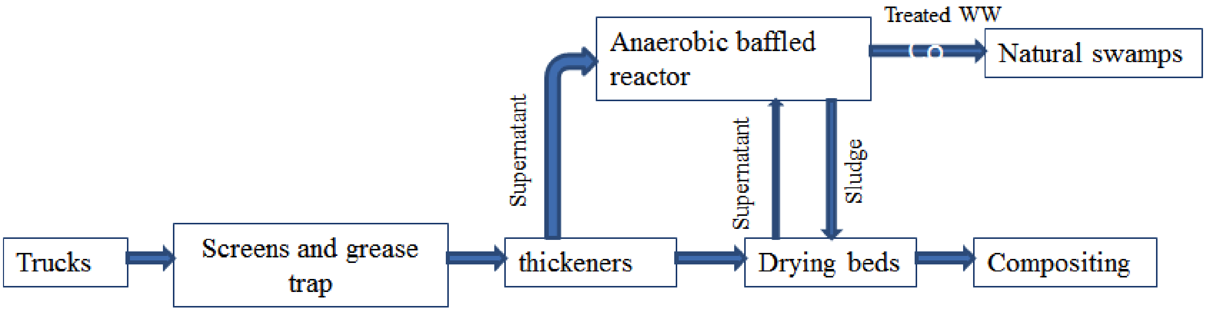


Figure 39: FS Treatment Flow Diagram Alternative 1 (Source: AAW Preliminary Interim Report April, 2016)

Alternative 2: Supernatant and percolate treatment with ABR and sludge drying using mechanical dewatering

The main difference between this alternative and Alternative 1 is the drying system. In this alternative, mechanical dewatering (belt filter press) is used for dewatering of sludge (see Figure 40. Compared to Alternative 1 this system requires less land for sludge dewatering. However, it has higher O&M needs and requires relatively skilled manpower to operate. Like alternative 1, in this alternative the supernatant of the sludge thickener and percolate from mechanical dewatering are treated in an ABR system before they are discharged into the natural swamps and the river. The concentrated sludge from the mechanical dewatering is also processed in the co-composting plant to prepare compost.

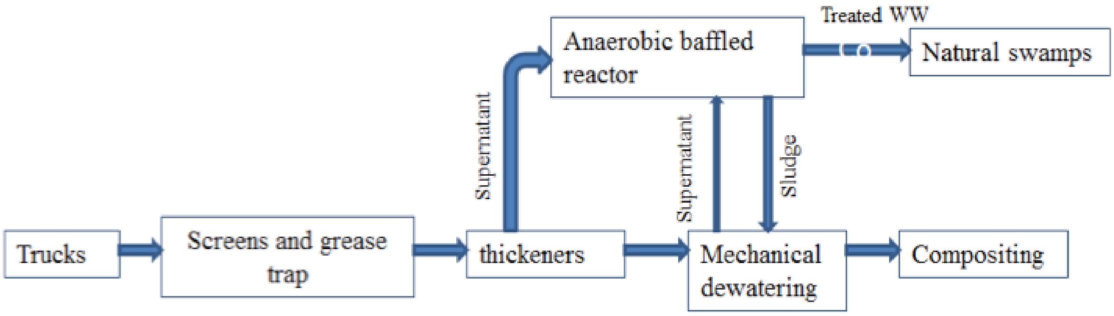


Figure 40: FS Treatment Flow Diagram Alternative 2 (AAW interim Report, April 2016)

Summary Alternatives 1 and 2

AAW prepared two options for the FSTP. In both options, faecal sludge enters the thickeners after the preliminary treatment steps. The supernatant of the thickener is treated in an Anaerobic Baffle Reactor (ABR) and is discharged into the environment in both options. The difference between the two options is the way they deal with the concentrated sludge stream from the thickeners. Alternative 1 uses sludge drying beds to further dewater the concentrated sludge stream while Alternative 2 uses a mechanical system (belt filter press) for dewatering. Compared to Alternative 1, Alternative 2 requires less land for sludge dewatering but it has higher O&M needs and relatively skilled manpower to operate. The solids either from sludge drying beds or from the sludge dewater device is then co-composted in a composting site.

In both the alternatives the effluent from the ABR systems is discharged into the natural swamps without further treatment. Despite the great benefits of ABR systems, they hardly produce effluents that comply with discharge standards. On top of that, the treatment efficiency of an anaerobic reactor in terms of N, P and pathogens is poor. This is especially valid when treating faecal sludge that contains high organic (COD, BOD_5) and nutrient concentrations (N, P). The design calculation confirmed that the effluent from both options do not achieve the Rwandan quality standards in terms of organics. Therefore, the effluent from the ABR needs further treatment and is to be polished by other supplementary technologies that can treat organics, nutrients and pathogens. Recent information indicates that AAW has taken these recommendations into account[16].

From the received documentation on Alternates 1 and 2, it is not clear whether the drying beds shall be covered or not. If they are uncovered, the sludge-drying period could be much longer than anticipated. In Kigali it rains for almost 10 months per year although the duration varies from month to month. This means that the drying beds need to be protected with a cover. This enhances the drying of sludge without the influence of rain during the rainy seasons. See Figure 41 and Figure 42.

[16] Source: Update on chapter 4 of the Preliminary Interim report, status unknown, received on 20 July 2016 from: Eng. GAFISHI M. Clement, MSc. NATIONAL PROGRAM COORDINATOR LVWATSAN II & KCSS-WWTP PROJECTS

Figure 41: Sludge Drying Kampala

Figure 42: Sludge Drying Kampala

The 3rd and 4th alternative provided in this study are based on the above-described alternatives recommended by AAW, thereby providing answers to the shortcomings noted.

Alternative 3 (variant of Alternative 1): Liquid treatment using combination of ABR & CW and sludge drying using drying beds followed by composting

This alternative is a variant of Alternative 1. The difference between this alternative and Alternative 1 is that in this alternative, the effluent of the ABR and the percolate of the sludge drying beds is treated using constructed wetlands for further organic polishing as well as for nutrient and pathogen treatment before it is discharged into the natural swamps and the river (see Figure 43).

Constructed Wetlands (CW) are waste water systems that consist of ponds that contain an inert porous medium such as stones, gravel and sand and special type of plants that grow at the surface of the pond. The constructed wetlands usually have an impermeable layer of clay or synthetic membrane, and structures to control the flow direction, hydraulic retention time and water level. CWs are not only good in polishing the organics and pathogens but also take up the N and P that are mineralised in the anaerobic system, in this case the ABR. Subsurface type of CW are more appropriate to receive effluents from septic tanks and anaerobic bioreactors. In this study a subsurface vertical flow CW system is proposed.

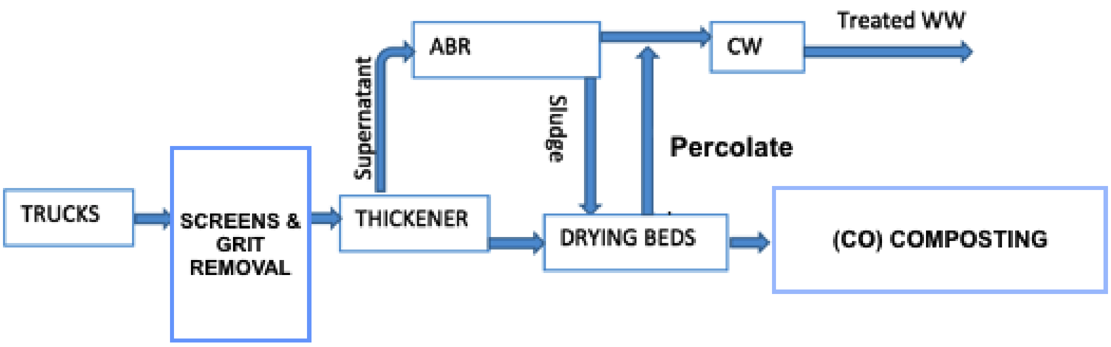


Figure 43: FS Treatment Flow Diagram Alternative 3

Alternative 4 (variant of Alternative 2): Liquid treatment using combination of ABR & CW and mechanical sludge dewatering followed by either composting or fuel production

This option is a variant of Alternative 2. The difference between this alternative and Alternative 2 is that the effluent from the ABR and the percolate from the sludge drying beds is treated using constructed wetlands like that of Alternative 3. In addition, the dewatered sludge from the mechanical dewatering process can be processed to produce fuel or compost (see Figure 44).

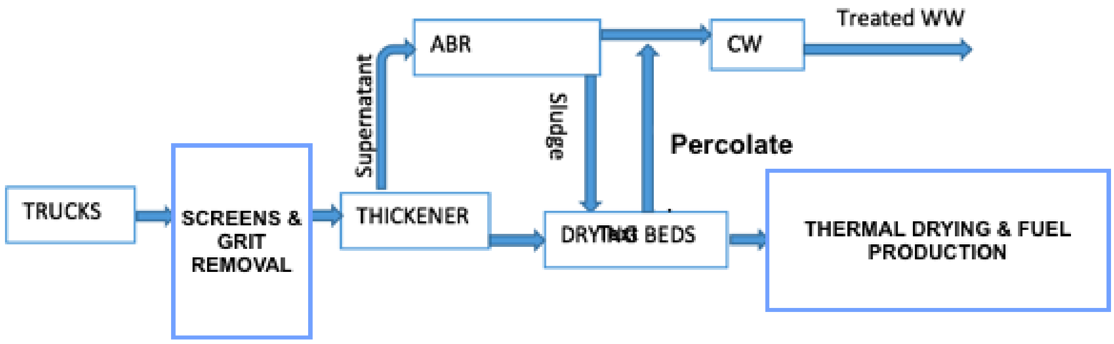


Figure 44: FS Treatment Flow Diagram Alternative 4

Compared to Alternative 3 this system requires less land for sludge dewatering; however, it has higher O&M needs and relatively skilled manpower to operate. This alternative provides a more flexible approach for the dense solids from the dewatering plant to make compost or fuel based on the need of the operator compared to the other three alternatives.

During the visit to Kigali, it was observed that using solar and thermal drying processes can further dry solids and fuel can be produced (see
Figure **1**). This can be another alternative for reuse and should be considered.

From the data gathered and the preliminary calculations, an area of 4,200 m^2 (say 0.5 ha) land should be sufficient to recover resources, either as a co-compost or fuel production (not including solar drying). Therefore an area of 0.5 ha should be reserved and a shelter/greenhouse like structure should be constructed so that co-composting or fuel production can be done without the influence of rain during the rainy season.

In general, the proposed treatment schemes provide an excellent opportunity to reuse the solid part of the faecal sludge by separating it at the early steps of the treatment system using a mechanical dewatering machine. The solids can then be co-composted using and additional carbon source (biodegradable part of collected solid waste) or can be further dried by using solar and thermal drying processes to produce fuel.

As fuel sells at a higher price than compost, fuel production is suggested.

4.3 Technical Design of Proposed HPI and of Alternative Scenarios

4.3.1 Preliminary Treatment

As presented in the above sections, a pre-treatment step is included in all options. The preliminary treatment would consist of screening and grit removal components. These components can be integrated with the settling tank to lower the investment and O&M costs.

Screening. The main function of the screening is to remove non-faecal solids larger than 10 mm particle size from the faecal sludge so that the downstream processing equipment is protected from damage that could lead to breakdowns and to a higher O&M costs.

Grit Removal. The main function of the grit removal is to remove sand and grit larger than 0.2 mm particle size having a specific gravity of at least 2.5 t/m^3 from the faecal sludge in order to reduce the operating volume of the main process units. Grits and debris can cause wear on pumps and other process equipment.

Figure 45: Scum on Sludge in Reception Area in Kampala

4.3.2 Sludge Thickeners/Sludge Settling Tanks

The function of the Sludge Thickener (ST) is to remove solids thereby removing organic matter, nutrients and pathogens associated with solids from the faecal sludge prior to the main biological treatment steps. In addition, they are used to remove floating matters in the form of scum.

The settling tank can be integrated with the receiving chamber, screening and grit removal components (Figure 46 and Figure 47). The integration helps to lower the investment and O&M costs.

Figure 46: Sludge Reception with Screen in Surabaya, Indonesia (Photo: Jan Spit, 2011)

Figure 47: Sludge reception Surabaya (Photo by Jan Spit, 2011)

Design Recommendation. For the design capacity of 2,000 m^3/day, three equally sized STs will help to accommodate low and high flows, and provide maintenance flexibility where one ST can be taken offline for maintenance without overloading the other tanks. Our calculations show that 3 STs (each 18 m' diameter and 3.5 m' depth) are sufficient (2 STs to be constructed for the first phase of 1,000 m^3/day). However, AAW has suggested four tanks of the same size for Alternatives 1 and 2. Hence, according to our findings, this is overdesigned and incurs higher investment costs for Alternatives 1 and 2.

Both investment and O&M costs can be lowered by using simple settling tanks with inlet, out let, scum bafflers and sludge extraction outlet (see Figure 48). These simplified sludge settling/sedimentation tanks are suggested for Alternatives 3 and 4.

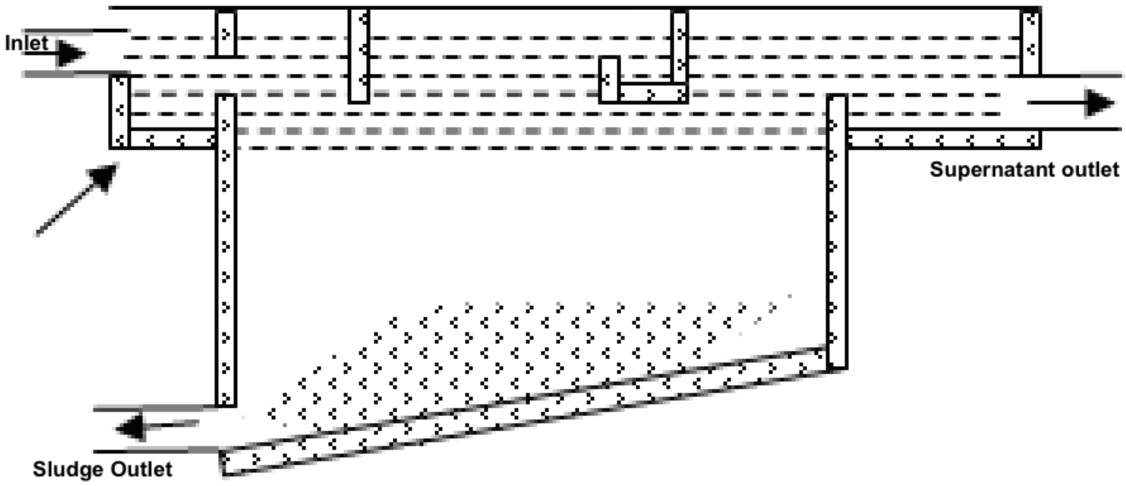


Figure 48: Sludge Settling/sedimentation Tanks Suggested for Options 3 and 4

The design summary and the mass balance in the STs are provided in Table 14 and Figure 49.

Table 14: *Design Summary ST*

Summary: Primary Settling Tank Dimensions			
Parametre	unit		Remark
Vc (settling velocity)	m/h	1.5	Settling velocity range 1-2.5m/hr
Q	m3/d	2000	
Peak hour	h	8	
Q peak	m3/d	6000	
Retention time	h	2	4 cycles per day
Avarage Tank Height, H	m	3.50	
D, Diametere of tanks	m	18.00	
Volume of 1 tank	m3	3560.76	m3
Number of tanks needed	no	3	3 Settling tanks of 18m diametres and 3.5m average height

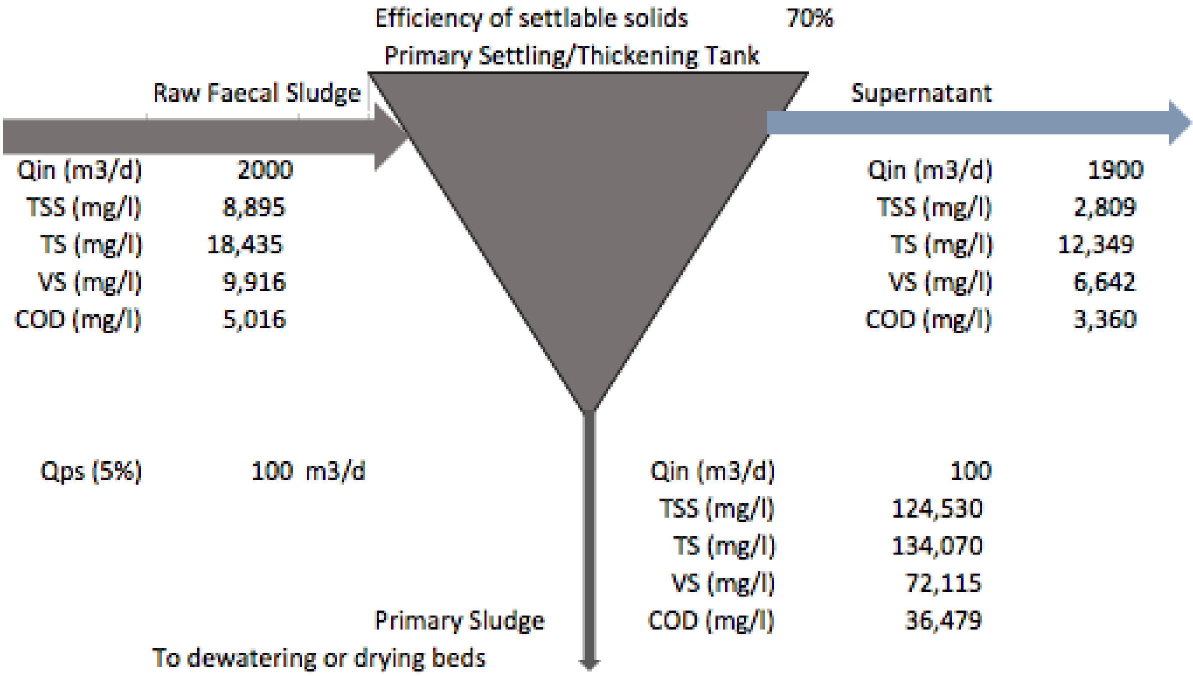


Figure 49: Mass Balance STs

4.3.3 Anaerobic Baffle Reactors (ABR)

An Anaerobic Baffled Reactor (ABR) is an improved septic tank with a series of baffles over which the incoming wastewater is forced to flow. The increased contact time with the active biomass (sludge) results in improved treatment. The majority of settleable solids are removed in the sedimentation chamber at the beginning of the ABR, which typically represents 50% of the total volume. The up-flow chambers provide additional removal and digestion of organic matter: BOD may be reduced by up to 90%, which is far superior to that of a conventional septic tank. As sludge is accumulating, desludging is required every six to twelve months.

The most critical design criteria include:

- The up-flow velocity should not exceed 2 m/h;
- The organic load should be below 8 kg COD/m^3*d;
- Total Hydraulic Retention Time (HRT) longer than 24 hours but shorter than 72 hours.

According to this feasibility study, four equally sized ABRs (width: 10 m', length: 20 m', water depth: 4.5 m') should be provided to treat the supernatant of the sludge thickener and percolate from the drying beds/mechanical dewatering device for the design capacity of 2,000 m^3/day (2 ABRs for the first phase of 1,000 m^3/day). AAW has suggested two ABRs of the same dimensions for Alternatives 1 and 2. Hence, AAW has under–sized the ABRs. The number of up-flow chambers is four as experience shows that there is no added value in terms of improved treatment if the number is higher.

Table 15: *Design Summary ABR (capacity FS flow of 500 m^3/day)*

Dimensions of Settler			Dimensions of Baffled Tanks					
Length of settler	inner masonnary measurements chosen acc. to required volume		Length of chambers	Width of chambers	Depth of outlet	Number of upflow chambers	Width of downflow shaft	Upflow velocity
Length (m)	width (m)	Depth (m)	m	m	m	no	m	m/h
6	10.00	4.5	2.25	10	4.5	4	0.5	1.98

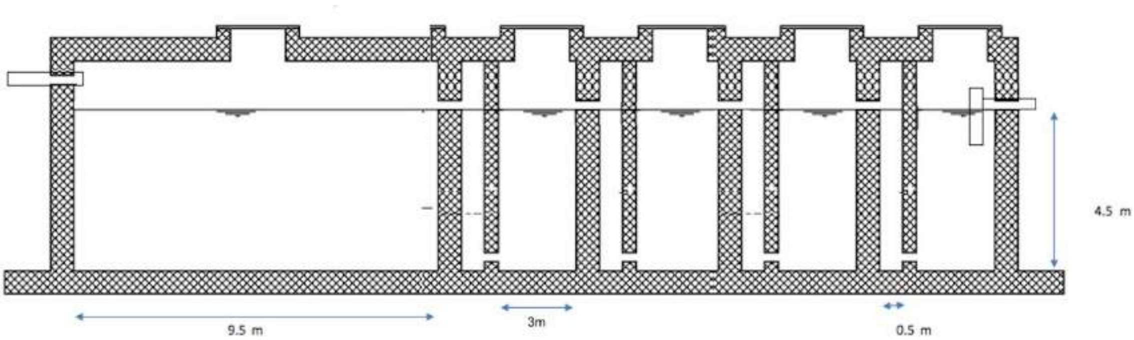


Figure 50: Longitudinal Cross Section of ABR with Inside Dimensions (Hydraulic Dimensions)

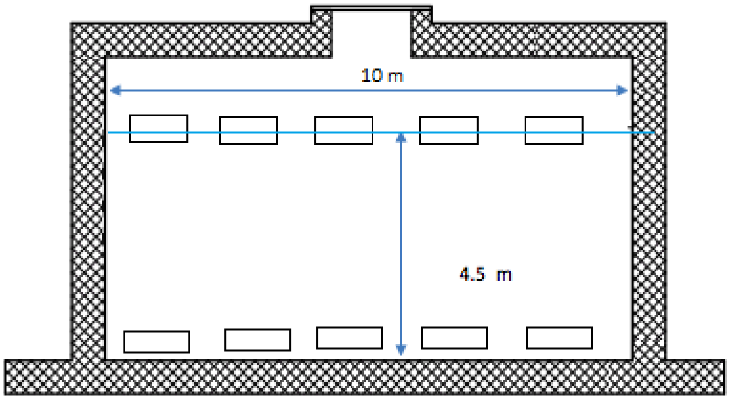


Figure 51: Vertical Cross Section of ABR

4.3.4 Sludge Drying Beds

The main function of Sludge Drying Beds (SDB) is to reduce the water content of sludge using a permeable base and a passive evapotranspiration of water to the atmosphere leaving a dry sludge behind. Drying beds are less complex, easier to operate, and require less operating energy than mechanical dewatering. However, a larger area of land is required compared to mechanical dewatering systems. In a typical sand drying bed, sludge is discharged on the bed in a 20 to 30 cm layer and allowed to dewater by drainage through the sludge mass and supporting sand layer and by evaporation from the surface exposed to air. Sludge drying beds can be covered to avoid dilution with rain during the rainy season, but they must be also well ventilated to facilitate the transport of the saturated air away from the beds. Since Kigali has a long rainy period in a year, covering of the sludge drying bed is required.

Design

- Sand (2-6mm) layer of 150mm at the top, gravel (7-15mm) layer of 150mm, gravel (20-30mm) layer of 150mm at the bottom (See Figure 52 and Figure 53);
- Drying period (including filling and excavation) of 30 days;
- For sludge from ABR 45 days drying beds (for easier management). Desludging interval is 3 months implying 2 ABRs need to be desludged and dried every 3 months with 1 and half month interval between them;
- Sludge filling depth 30 cm.

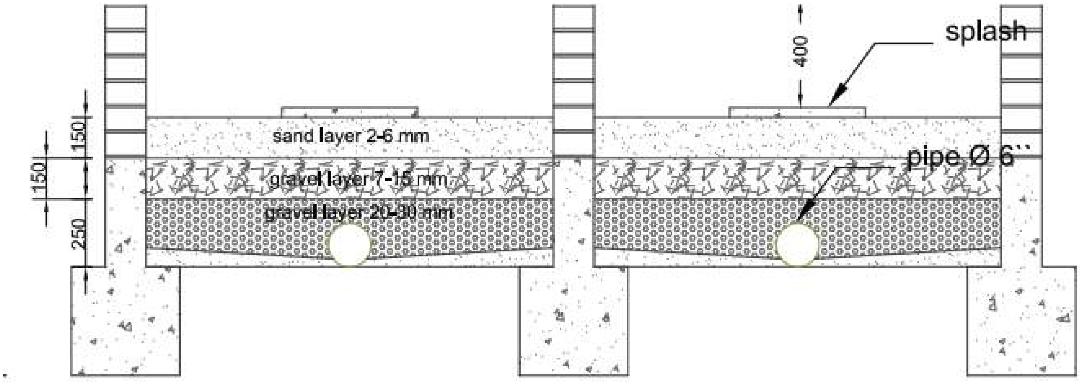


Figure 52: Cross Section Sludge Drying Bed

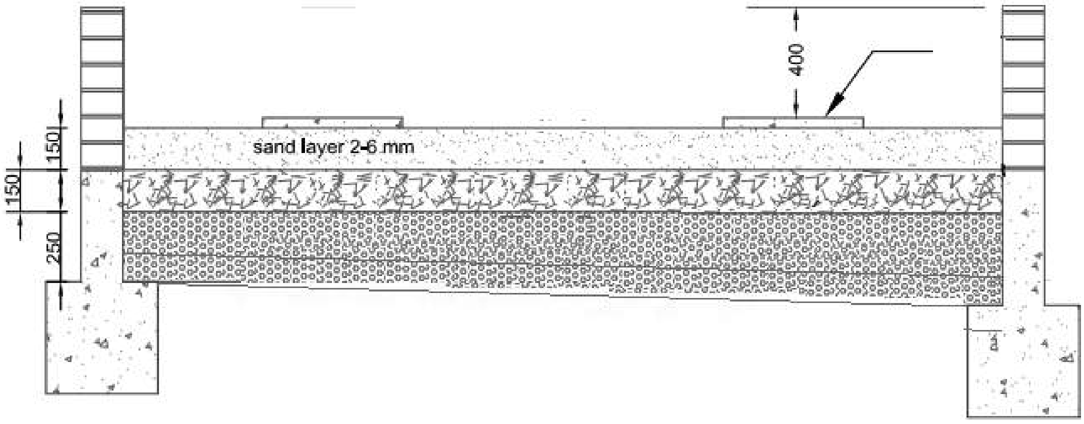


Figure 53: Longitudinal Section Sludge Drying Bed

Using the above design criteria, an area of 1.2 ha of land would be required for sludge drying for Alternative 3 for design discharge of 2,000 m^3/day. This means that for the 1st phase of 1,000 m^3/d an area of 0.6 ha is required. This is much smaller than the 3 ha calculated by AAW.

The summary of the conceptual design dimensions of the sludge drying beds is presented in Table 16.

Table 16: *Design Summary of SDBs for Design Discharge of 2000 m3/day*

Sludge drying beds	**for sludge from ABR**	**for sludge from Sludge Settling Tank**	**Remark**
cycle per year	8	12	
1 Drying period including filling and excavation in Days	45	30	
Number of SDBs	1	1	
V (m3) =	310	3,000	
h (m) =	0.3	0.3	
A (m2) =	1,033	10,000	
L (m) =	32	100	
W (m) =	32	100	
Rounded L (m) =	32	100	
Rounded W (m) =	32	100	
Rounded up A (m2) =	1,024	10,000	Total area needed is
Design W	25	25	
Design L	32	32	
Area of 1 SDB	800	800	
Number of Sludge Drying Beds	2	13	In total 15 SDBs are needed

Table 17: *Sludge Produced from ABR and Settling Tanks*

Total Sludge Production	
Sludge production from 4 ABRs	FS m3/d from primary sludge
m3/ months	m3/d
620.00	100.00

Alternatively, sludge drying in concrete beds can be considered. In this way, there is no mixing with the sand and the sludge is more useful for fuel production. See Figure 54 and Figure 55.

Figure 54: Sludge drying in open concrete beds (Photo: Jan Spit, Bonaire 2015)

Figure 55: Sludge drying in open concrete beds (Photo: Jan Spit, Bonaire 2015)

4.3.5 Mechanical Dewatering (Belt Filter Press)

After the sludge thickening process, additional reduction of the water content is necessary and this can be done either naturally using sludge drying beds or using a mechanical process such as centrifugation or pressing. The objective of sludge dewatering is to concentrate the sludge - make it as dry as economically possible for post processing and reuse or disposal purposes. The mechanical processes used to dewater sludge are belt filter presses; drum filters (vacuum technologies), pressure filter presses, screw press and centrifugation.

Design recommendation. The belt filter press is recommended for alternatives 2 and 4. Belt filter presses types are relatively low in both equipment and operational costs. The performance is enhanced by the use of polymers.

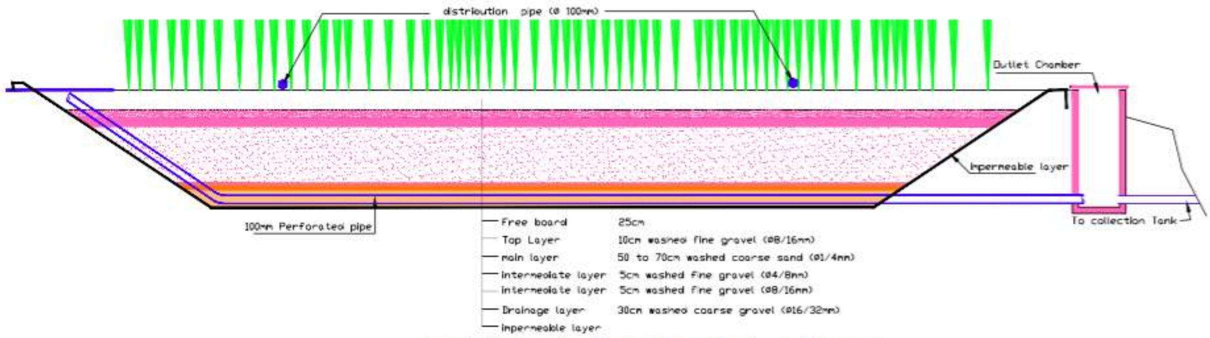
Figure 56: Micro screen type mechanical dewatering, Pivotworks Kigali (January 2016)

Figure 57: Belt filter press (Pivotworks, Kigali, 2016)

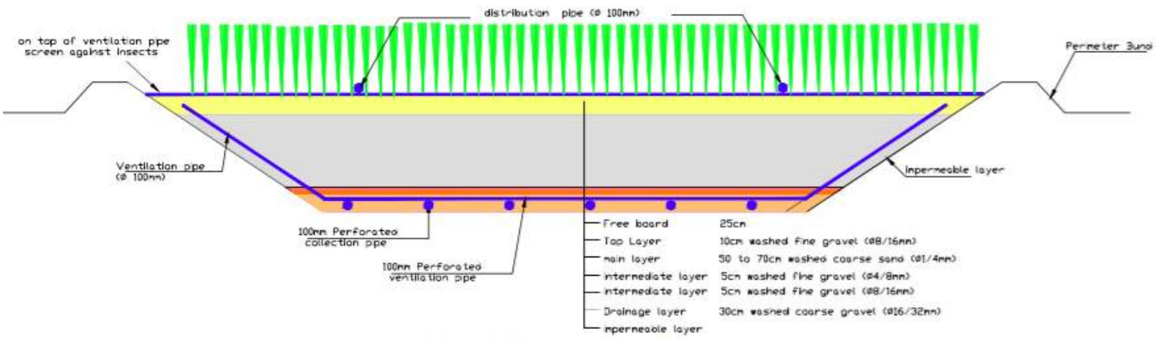
4.3.6 Vertical Flow Constructed Wetlands

Constructed wetlands are wastewater systems consisting of ponds that contain an inert porous medium such as stones, gravels and sand and a special type of plants that grow on the surface of the pond. In spite of the great benefits of ABR systems, they hardly produce effluents that comply with discharge standards. An ABR is poor in nutrient and pathogen reduction. Hence, in Alternative 3 and 4, it is suggested to include vertical flow constructed wetlands (VFCW) to polish the effluent from the ABR tanks to meet the effluent quality standards before they are disposed to the river.

Design recommendation. Subsurface types of CW are more appropriate to receive effluents from septic tanks and anaerobic bioreactors. VFCW are chosen over HFCW due to the fact that they require smaller surface areas. Sections of the VFCW are presented in Figure 58.



Longitudinal section Vertical Flow Constructed Wetland



Cross section Vertical Flow Constructed Wetland

Figure 58: Cross Sections of Vertical Flow Constructed Wetland

The constructed wetlands usually have an impermeable layer of clay or synthetic membrane, and structures to control the flow direction, hydraulic detention time and water level. The details of the layers are presented in Figure 59.

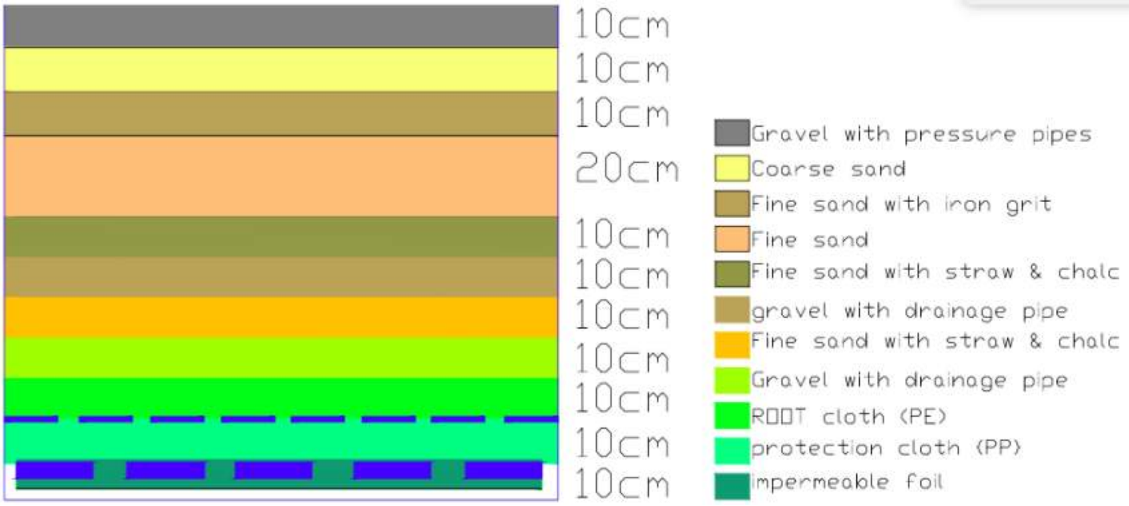


Figure 59: Details of the Layers Vertical Flow Constructed Wetland

According to this design study, an area of about 1 hectare of land is required for the VFCW for the design discharge of 2,000 m^3 sludge per day. This means that for the 1st phase of 1,000 m^3/d FS an area of 0.5 ha is required. Equally sized VFCWs are suggested to receive equally divided flows (see Figure 60).

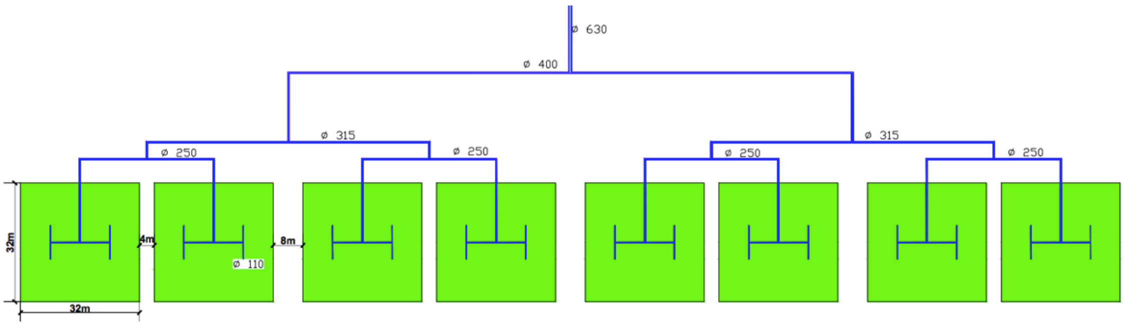


Figure 60: Flow Distribution of VFCW

Another main design suggestion is the feeding system (transporting the effluent to the CWs). It can be done either by pumping or through siphoning. Pumping requires higher operation and maintenance costs. To apply the siphon system, (Figure 61) sufficient slope is required. Looking at the topography of the Masaka site, there is sufficient slope to apply the siphon system that requires much less operational and maintenance costs.

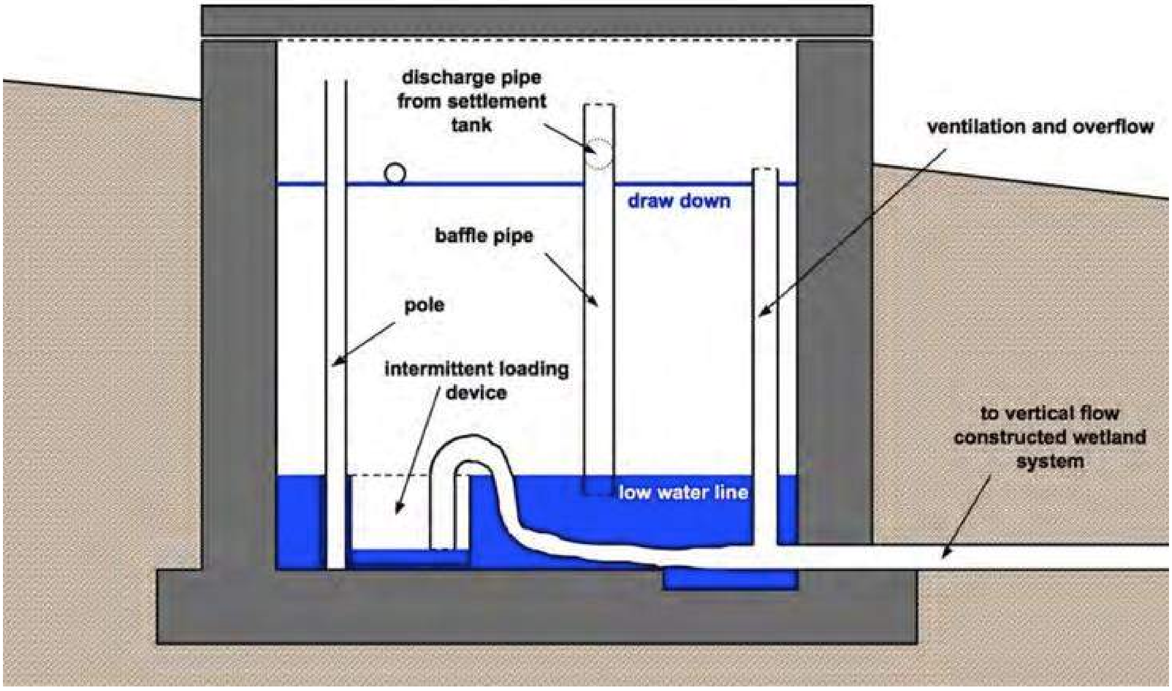


Figure 61: Siphon for Flow Distribution (Source: adopted from ECOSAN Module, 2008)

4.3.7 Reuse Options

4.3.7.1 Co-composting

Composting is a biological process that involves a decomposition of organic matter by aerobic microorganisms. The end product from the composting process is a stabilized organic matter that can be used as a soil conditioner. It is an often considered and easy and cost effective process. However, depending on the type of the onsite sanitation technology, faecal sludge can be semi-stabilized and is mostly rich in nutrients, but lacks sufficient carbon for the composting process. Hence, an additional carbon source is needed which results in co-composting with biodegradable solid waste. Composting is a labour intensive process and also requires a lengthy processing period, sometimes it needs months.

Design. In Alternatives 1, 2 and 3, co-composting is recommended. An estimated area of 4,200 m^2 is needed to do the composting for this faecal sludge treatment project (for the design capacity of 2,000 m^3/day, for the 1st phase of 1,000 m^3/day: 2,100 m^2 are required). The current price of compost in Kigali is approximately € 11 / ton. The process recommendation is presented in the box below.

BOX 1: COMPOSTING PROCESS

To ensure an optimal composting process, the following parameters need to be controlled (EAWAG and IWMI, 2003):

- A carbon to nitrogen ratio (C:N) between 20-30:1 to ensure biological availability; as the organisms degrading organic matter need carbon as a source of energy and nitrogen for building cell structure. High nitrogen enhances ammonia loss due to volatilization. Higher C:N ratio hinders optimal growth of the microbial populations due to insufficient nitrogen. The compost heap will remain cool and degradation will proceed slowly. High carbon in the final compost product can create problems as microbial activity in the soil may use any available soil nitrogen to make use of still available carbon, thereby "robbing" the soil of nitrogen and thus hindering its availability for plants. During composting carbon is converted to CO and the C:N ratio decreasestoaratioofaround10:1 when the compost is stabilized.
- An oxygen concentration of 5-10% to ensure aerobic microbiological decomposition and oxidation. Aeration can be ensured by either providing passive ventilation structures (air tunnels) or can be enhanced by blowing or sucking air through the waste heap (called active or forced aeration). With forced aeration external energy is required. In open systems mechanically or manually turning the heaps can also contribute to better aeration, although the main objective of this turning is to ensure that material on the outside of the heap is moved to the centre where it will be subject to high temperatures.
- A moisture content between 40 and 60 % by weight to ensure adequate moisture for biodegradation, and that piles are not saturated creating anaerobic conditions. Turning removes water vapour and thus the turning frequency depends primarily on the moisture content of the material, as high moisture content reduces the availability of air in the pore space (Cooperband, 2002). If compost heaps become too dry, water must be added to ensure continuous biological activity.
- A particle diameter of less than five centimetres for static piles. Smaller particles degrade more rapidly as they provide more surface area for microbial decomposition. But on the other hand with smaller particles size aeration through the pile is hindered if structural strength cannot be maintained. Thus particles size influences pore structure and aeration as well as surface area for degradation.

In a properly operated composting heap the temperature rises rapidly to 60-70°C as heat is released when carbon bonds are broken down in an exothermic process. Pathogen die-off is highest during this time of high temperature. After approximately

4.3.7.2 Fuel Production from FS

The 4th alternative that is proposed in this study provides the opportunity to reuse the solids, after the mechanical dewatering process, as a fuel product (as is done by Pivotworks in Kigali). Unlike (co) composting, production of fuel is a much faster process and conserves the energy that is present in the faecal sludge. A week is sufficient to make fuel (up to 6 days of solar drying and a couple of hours of thermal drying, as observed in Kigali-Pivotworks).

Design/Process Recommendation. In order to produce fuel, the concentrated sludge, after the dewatering process, is further dried in a greenhouse structure (Figure 62). Sufficient ventilation should be provided to let the water vapour out by thermal drying (150 degrees C) (Figure 64) processes that kill all the pathogens that are present in the faecal sludge. The end product can then be sold as fuel. It is tested that the calorific value is slightly higher than fuel from sawdust or coffee husk. It has also been seen that there is a clear market for it. The current price of fuel is about € 40 per tonne (Pivotworks).

Land requirement for solar drying (for the design capacity of 2,000 m^3/d:

- Assuming 25 m^3/day of dewatered faecal sludge is further processed in solar drying beds;
- About 75 m^3/day of faecal sludge from pit latrines directly processed in solar drying beds;
- Drying time of 6 days;
- 4 cm sludge thickness on drying beds;
- An area of approximately 1.5 ha land is required. This indicates that for the first phase 0.75 ha of land is required for solar drying.

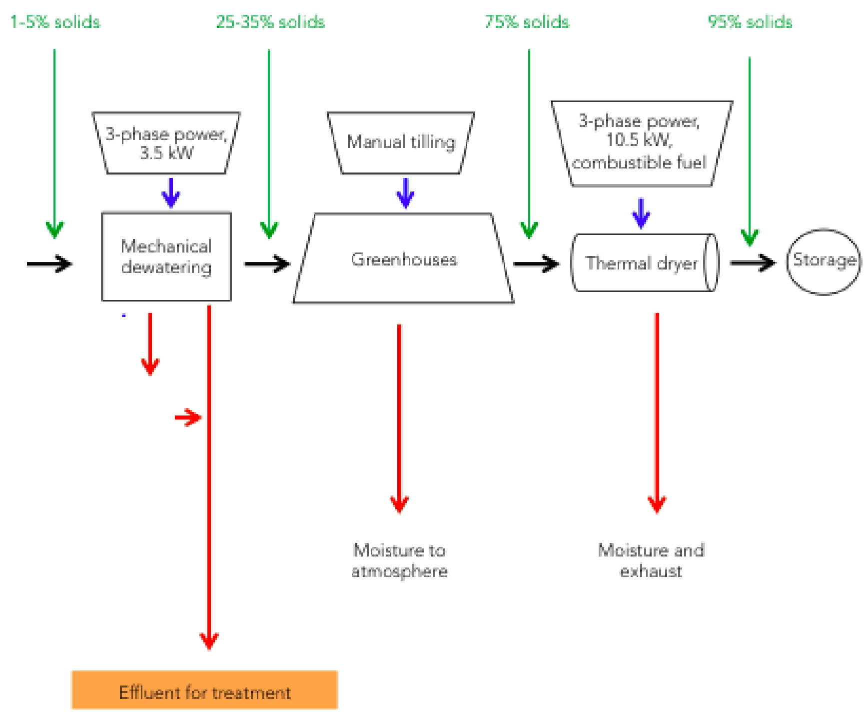


Figure 62: Production of Fuel from Faecal Sludge (Source: Pivotworks, 2015)

Land requirement for thermal drying:

- 2 thermal dryers are suggested to be purchased and installed;
- Assuming length of 50 m' and width of 10 m' for each dryer;
- An area of 1,000 m^2 should be sufficient.

Hence, in total an area of 4,200 m^2 (almost half a hectare) land should be sufficient to do the resource recovery processes either as a co-compost or fuel product. Therefore, an area of half a hectare should be reserved and a shelter/greenhouse like structure should be constructed so that fuel production can be done without the influence of rain during the rainy season.

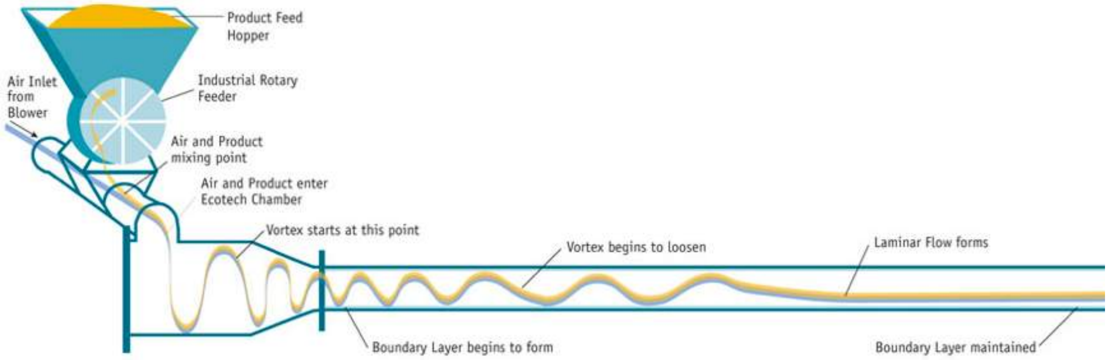


Figure 63: Thermal Drying Processes

Figure 64: Thermal drying unit at Pivotworks, Kigali, 2016 (Photo: Henock Belete, 2016)

Figure 65: Fuel from faecal sludge at Pivotworks, Kigali, 2016 (Photo: Henock Belete, 2016)

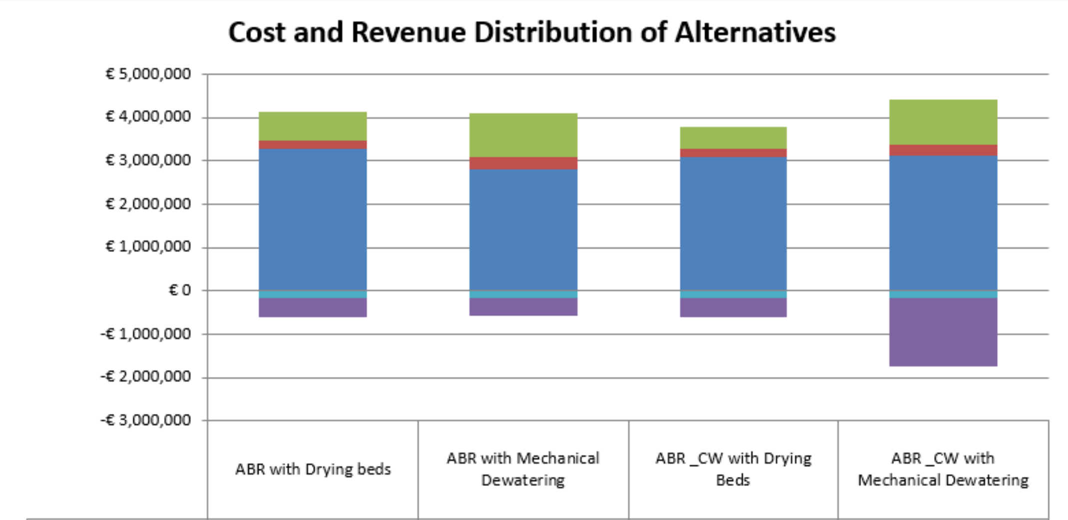
Compared to Alternative 3; this system requires less land for sludge dewatering; however, it has higher O & M needs and requires relatively skilled manpower to operate. This alternative provides a flexible approach for the dense solid from the dewatering plant to make fuel (Figure 65) or compost based on the need of the FSTP operator compared to the other 3 alternatives.

4.4 Cost Estimates and Footprints of Alternatives

4.4.1 Cost Estimates

Four alternatives have been developed for treating the FS from the city of Kigali. The design discharge (faecal sludge coming to FSTP) is estimated to be 2,000 m^3 per day. Considering the current FS collection rate; which is about 100 m^3/d, it is recommended to implement the FSTP in two phases (1st phase implemented now and 2nd phase depending on the successes of marketing). It is suggested that during the first phase, the maximum capacity of FSTP is 1,000 m^3/day (half the design flow). The preliminary costs that include the investment, O&M and revenues have been estimated for the first phase only.

It is noted in the previous sections that both Alternative 1 and Alternative 2 do not achieve the effluent quality standards. Hence, they are excluded for further analysis. Alternative 4 requires slightly higher investment cost, € 3.12 mln., than Alternative 3, € 3.096 mln and the NPV of its O&M costs is € 1.03 mln.; more than twice the NPV of O&M of Alternative 3, € 0.49 mln. On the other hand, the revenue generated from Alternative 4, is almost four times higher than the revenue generated from Alternative 3. This is attributed to the higher selling price, about four times, of the fuel compared to that of compost. If the plant functions at 90% capacity or higher, the revenue generated from Alternative 4 fully covers the O&M maintenance costs, while in all the other alternatives the revenue does not cover O&M costs even when the plant functions at full capacity (Figure 66). In general; the total cost/profits for the proposed alternative (Alternative 4) is the lowest of all the options.



	ABR with Drying beds	ABR with Mechanical Dewatering	ABR _CW with Drying Beds	ABR _CW with Mechanical Dewatering
Σ O/M Costs	€ 670,615	€ 1,022,736	€ 491,214	€ 1,030,544
Σ Reinvestment Costs	€ 200,830	€ 261,990	€ 188,440	€ 257,435
Investment Costs	€ 3,266,611	€ 2,810,833	€ 3,096,365	€ 3,123,887
Σ Revenues	-€ 433,231	-€ 433,231	-€ 433,231	-€ 1,575,386
Final Residual Values	-€ 177,196	-€ 150,319	-€ 168,835	-€ 167,298

Figure 66: Investment and O&M Costs (2016 prices, Net Present Value for 20 years at 10% Discount Rate)

In addition to the FSTP costs, this project includes the purchase of four vacuum trucks. The average capacity of one vacuum truck is assumed to be 10 m^3. One vacuum truck makes an average number of five trips per day. Based on these assumptions the 4 additional vacuum trucks increase the daily sludge discharge by 200 m^3. Thus, the additional trucks enable to operate the faecal sludge treatment plant at more than 25% of its design capacity. The total investment costs of the four vacuum trucks are estimated to be € 0.575 mln. The O&M costs and revenue generated are calculated in chapter 8 of this report. KCC has also estimated the land acquisition and improvement of access road costs to be about € 0.7 mln and € 1.78 mln, respectively. In addition; an investment cost of € 0.4 mln and € 0.05 mln for detailed engineering design[17] and tendering, and capacity building of WASAC, respectively, is required.

4.4.2 Footprint of Alternatives

Table 18 provides the footprint of the different alternatives. Footprints are calculated for the total design flow of 2,000 m^3/d. It is suggested to acquire the land for both phase 1 and 2 implementations.

***Table 18:** Footprints of All Alternatives for Design Flow capacity of 2,000 m^3/d*

Component	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Inlet works with grit removal (m^2)	500	500	500	500
Sludge thickening/Settling tanks (m^2)	300	300	300	300

[17] Originally we have mentioned a figure of € 0.25 mln. for review only as it was expected that the actual DED would be done by AAW. Informal information received in October 2016 learns that this might not be the case anymore.

Component	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Sludge drying/dewatering (m^2)	30,000	700	12,500	1,000
Sludge composting area (m^2) /Solar and thermal drying for fuel	4,200	4,200	4,200	15,000
ABR (m^2)	500	500	500	500
VFCW (m^2)			10,000	10,000
Total Area required including ancillary works (hectares)	**6.0**	**3.0**	**5.0**	**4.5**
Remarks	**AAW**	**AAW**	**This study**	**This Study**

Alternatives 1, 2, 3 and 4 require 6, 3, 5 and 4.5 hectares of land, respectively. Area needed for Alternative 1 and 3 is higher than for Alternative 2 and 4 (see Table 18). This is due to the fact that Alternatives 1 and 3 use sludge drying beds. The higher land requirement leads to the higher land acquisition cost.

4.5 Comparison of Proposed HPI with Alternative Scenarios

In total four alternatives, two prepared by AAW and two from this study, are considered for the FSTP in Kigali. In Alternatives 1 and 2, proposed by AAW, faecal sludge enters the sludge thickeners after the preliminary treatment steps (grit and sand removal). The supernatant of the thickener is treated in an Anaerobic Baffle Reactor (ABR) and is discharged into the environment in both options. The difference between the two options is the way they deal with the concentrated sludge stream from the thickeners. Alternative 1 uses sludge drying beds to further dewater the concentrated sludge stream, while Alternative 2 uses a mechanical system for dewatering. In both the alternatives the effluent from the ABR systems is discharged into the natural swamps without further treatment. Although ABR systems can achieve high organic and solids removal, they hardly produce effluents that comply with discharge standards. In addition, they hardly treat nutrients (N and P) and remove pathogens. In Alternatives 3 and 4, variants from Alternatives 1 and 2, respectively, developed to meet the effluent standards, the treatment systems are supplemented by a complimentary post treatment system, Vertical Flow Constructed Wetlands (VFCW), to further polish the effluent from the ABR. According to our design calculations, Alternatives 1 and 2 will not meet the effluent quality standards. Therefore, these two alternatives will not be considered further.

The difference between the proposed HPI (Alternative 4) and Alternative 3 is the way it treats the concentrated sludge from the sludge settling tanks and the reuse product it produces from the solids of the FS. The proposed option requires twice the amount of the O&M costs of Alternative 3. However, the revenues generated from selling fuel are higher than from selling compost.

4.6 Conclusion of the Analysis

Amongst the four options, Alternative 4 requires the highest investment and Alternative 3 requires the lowest O&M costs. Alternative 2, the preferred option by AAW, has the lowest investment cost requirement. However, as noted in previous sections, Alternatives 1 and 2 do not achieve the effluent standards. This means that Alternatives 3 and 4 are recommended options for implementation and Alternative 4 is preferred.

The investment costs of Alternative 4, the preferred option, are slightly higher than alternative 3. Although the O&M cost of alternative 4 are three times O&M of Alternative 3, its revenue stream can covers the O&M cost. The revenues generated in Alternative 3, however, do not cover its O&M cost even when the plant functions at full capacity.

5 Project Implementation

The implementation plan developed for the FSTP in Kigali is divided into three phases:
- Engineering Design and Construction Phase;
- Construction Preparation Phase;
- Operation and Maintenance Phase.

Detailed Engineering Design and Construction Phase. In this phase a detailed and final design of the preferred option, including a detailed costing shall be executed. Construction tendering documents shall also be prepared. Contract advertising for the construction and award will be carried out during this phase. When AAW submits the detailed engineering design (which is not certain), a design review is needed to accommodate the suggestions given in this study. It is suggested that:
- Significant modification is needed in the settling design. To minimize the investment and O&M costs simplified settling/sedimentation tanks should be designed instead of conventional sludge thickeners;
- The number of the ABR tanks should be doubled from 2 to 4;
- The effluent from the ABR needs polishing. VFCW is suggested as a post treatment unit;
- The reuse site (for compost or fuel production) needs a cover to protect the influence or rain in the processes.

To minimize errors in the construction, we suggested a design and build contract. This means at this stage the physical structure of the FSTP will be constructed

Construction Preparation Phase: In this phase the land required for the construction of the FSTP should be fully acquired and KCC should pay the required compensation to the landowners. At this stage all the land required for phase 1 and 3 need to be acquired to assure future expansions of the FSTP. In addition, the present access road to the site, 2.5 km from the main road, needs improvements for easier access of vacuum trucks. This shall be done during this phase by KCC. This phase can be done in parallel to the detailed engineering design phase.

Start-Up and Operation Phase: the treatment systems shall be activated and tested during this phase. After a successful start-up period operation can fully start.

Assuming financing of the project is secured in early 2017, the detailed design stage can begin in Q1 2017 and end in Q2. As described above, the construction preparation phase can be done in parallel to the detailed design work and end in Q2 2017. The construction and start-up phase can be begin in Q3 2017 and end in December 2017. Tendering typically takes at least three or four months. This can be done in Q2 2017. Construction could start in July 2017 the earliest after tendering.

6 Operation and Maintenance

6.1 General

FSTPs need continuous operation and maintenance (O&M) activities in order to function for a long term and ensure long-term functionality. In general, a FSTP requires a clear operational manual that contains the FSTP technical engineering drawings and specifications, manufacturers equipment operational guidelines, task descriptions of operators and tools required to perform the task, activity planning, health and safety measures, and aspects that need to be monitored and recorded. The main maintenance tasks that are required include corrosion control (by scraping rust, painting metal surfaces and repaid corroded materials), grit and scum removal, maintenance of values (checking functionality and repair/replace damaged parts), and greasing of pumps, trucks, and mechanical rotating parts. The detailed engineering design shall include the preparation of the O&M manual for the FSTP.

Pre- treatment and sludge settling. As described in chapter 4, it is suggested to combine the pre-treatment facilities, grit and sand removal, with settling tanks to lower investment and O&M costs. The screening and grit removal section require regular cleaning to ensure proper functioning. Longer maintenance frequencies result in odour creation due to anaerobic degradation of settled solids. The solids collected should be disposed in environmentally sound way. In the proposed alternative, the purpose of the settling tank is only settling and not stabilizing of sludge. This means that the extraction of settled sludge is frequent. The settling tank is designed for a 2 hours settling period and immediately after the settling time has reached, the sludge needs to be extracted and process further in the mechanical dewatering step. If the sludge stays for longer durations than required, anaerobic degradation process begins and build-up of gas occurs. This in turn hampers the sedimentation process by suspending part of the settled solids. This has also a negative effect on the reuse. It means that part of the energy that would have been used to make solid fuel, has lost during the anaerobic degradation process. This significantly affects the revenue stream. In addition; the scum layer on the top of the tank should be removed often.

6.2 Anaerobic Baffle Reactor

Anaerobic baffle reactors require a lengthy start-up period, commonly up to 6 months, to function at the full treatment capacity. To speed up the start-up period, the ABR tanks are inoculated with sludge that contains anaerobic bacteria. The common practice is use sludge from anaerobic digesters or cow dung. Septic tank sludge can also be used for inoculation in the absence of cow-dung. At the beginning of the start-up period the ABR is filled to 25% of the daily flow. The loading rates are increased to full capacity in a three month period. This gives anaerobic bacteria, as they are slow growing bacteria in nature, sufficient time to multiply before they get washed out (SASSE, 1998). The presence of toxic chemicals significantly hinders the growth of bacteria and thereby the treatment process and entry of such chemicals should be avoided.

The scum and sludge levels needs to be checked and monitored regularly. The ABRs are designed with a desludging period of 6 months in mind. However, the exact accumulation rate needs to be checked during the operation of the ABR. During desludging of ABR, it is important that some active sludge is left in each of the compartments so that stable treatment process can be achieved. ABR tanks should be checked from time to time to ensure that they are watertight.

6.3 Vertical Flow Constructed Wetland

In general, the operation and maintenance of the VFCW includes the following:

- During the first growing season, it is important to remove weeds that can compete with the planted wetland vegetation;
- The effluent from the ABRs is further processed in the VFCW. Pipes distribute the wastewater. These distribution pipes should be cleaned once a year to remove sludge and biofilm that might block the holes;
- With time, the gravel will become clogged by accumulated solids and bacterial film. Resting intervals may restore the hydraulic conductivity of the bed. Otherwise replacing of the material is a necessity;
- In VFCWs wastewater is fed alternatingly by using siphons. This feeding system enhances the oxygen transfer that leads to high aerobic degradation;
- Occurrence of odour indicates formation of anaerobic conditions. This is very critical condition and the filter should be rested and loads should be adjusted (Hoffman et al. 2010).

6.4 Mechanical Dewatering

Mechanical systems generally require higher degree of operation follow up and maintenance needs. To avoid damage of mechanical dewatering devices, the primary treatment should work properly. Main mechanical dewatering parts such as filters, belts, tension and bearing systems need periodic inspection and have to be maintained according to the operation and repair manual of the manufacturer.

6.5 Record Keeping

For effective O&M of FSTPs, a proper record keeping is necessary. The main record keeping types include operations logbook, reception monitoring reports and treatment unit operation sheets.

Operator's logbook: This is the most important of the record keeping part. Typical entries include the names of people on duty, weather conditions, any equipment malfunctions, operating problems, important phone messages, security information and actions taken in response to unusual circumstances.

Reception monitoring reports: It mainly records the amount of FS received at the plant each day, amount of trucks that disposed faecal sludge, and the tipping fees collected.
Treatment unit operation sheets: This sheet records the quantity of FS loaded into each treatment unit, extraction of process products etc. Number of operators and relevant skills required are also recorded in this.

7 Legal and Institutional Analysis

7.1 The Sector

The developments of the sanitation sector (including drainage and solid waste) are mainly geared by the following policies and strategies[18]:

- Vision 2020. This strategic document sets the broader development objectives for Rwanda;
- EDPRSII (Economic Development and Poverty Reduction Strategy (2013 – 2018). In the EDPRSII Rwanda has committed itself to reaching very ambitious targets in sanitation, among them the vision to attain 100% sanitation service coverage by 2017/18. The importance of adequate access to sanitation as a driver for social and economic development, poverty reduction and public health is fully acknowledged in Rwanda's flagship policy documents and national goals;
- Sanitation policy of 2010 and the strategy of 2013. These documents reflect a signification change of approach, which significantly changes the sector context. The decentralization of responsibilities for rural sanitation, private sector participation in sanitation and solid waste management, the emerging Sector-Wide Approach (SWAp) had all been envisaged in 2010/2013 but has gained decisive momentum since;
- Imihigo which are the performance standards that follow from the strategies;
- The SDG (sustainable Development Goals). In September 2015, the United Nations adopted the 2030 Agenda for Sustainable Development to end poverty and promote prosperity for all while protecting the environment and addressing climate change. The new 2030 Agenda has water and sanitation at its core.

Figure 67 shows the change of focus of the new SDGs with more emphasis on the treatment, at the end of the value chain. This means that it is not sufficient to build latrines and toilets; a 'public service' must provide 'safe' services for transportation and treatment for both on-site and off-site systems. This approach has been incorporated in Rwanda's new sector policy. It is acknowledged in the policy that faecal-sludge collection and treatment will be an important element in the value chain.

[18] National Sanitation Policy and Strategy, December 2015

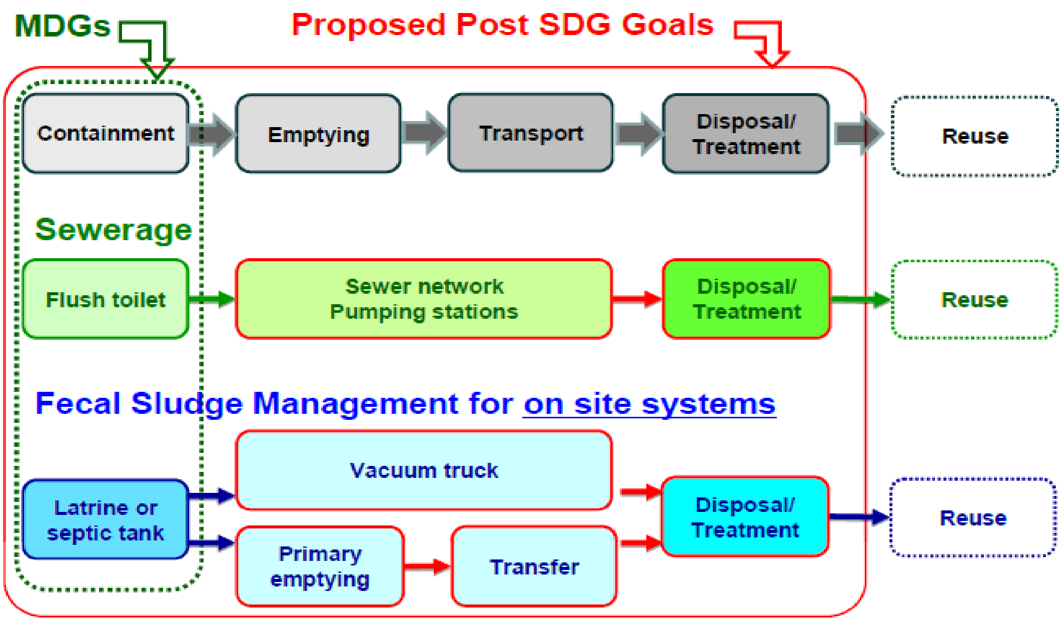


Figure 67: Sustainable Development Goals (Source: National Sanitation Policy and Strategy)

In practice, faecal sludge management is a part of the solid waste sector in Rwanda. There is no systematically implemented integrated solid waste management approach, but the sector has seen different interventions carried out by districts and the private sector, the latter mostly in Kigali. Problems arise at all stages of waste collection and disposal. The water strategy 2011 – 2015 stipulated that only some 24% of solid waste generated is disposed at this landfill. Kigali's waste contains 70% of organic, biodegradable waste. While some waste sorting, composting and recycling activities have been developed over the last years, Rwanda did not yet invest in sanitary landfills.

There is only one official landfill in Kigali; the Nduba landfill, where the faecal sludge is dumped too. Landfills fall under the authority of KCC. KCC is responsible for the construction of the landfills. As to the new faecal-sludge treatment plant identified under the HPI programme, KCC has delegated the implementation to WASAC.

7.2 The Implementing Agency: WASAC

WASAC[19], the Rwandan Water and Sanitation Corporation, was established by presidential decree in January 2014 and has been in operation effectively since July 2014 as part of a utility sector improvement strategy. The decree allowed the separation of EWSA (Energy Water and Sanitation Authority), a state agency, into two independent corporations, one for water & sanitation and one for energy, respectively named WASAC and Rwanda Energy Group (REG). The main drivers for the separation of EWSA into two companies were improvement of efficiency and improvement in investment planning.

EWSA Water & Sanitation owns and operates sixteen water treatment plants (WTP) covering Kigali and thirteen other urban centres, with total daily production capacity of 105,680 m^3/day.

WASAC is currently in a transition phase to become a financially independent and autonomous utility. The transition period is expected to last for 5 years. During this time WASAC should become a fully autonomous service provider that does not receive financial support from government, for instance on energy, on running operations and doing maintenance. Investment support will remain necessary in the coming years, especially in view of the huge investment challenge to reach full coverage on water and sanitation services.

In Figure 68 the current organization structure of WASAC is given. It is a functional model with six main directorates under the MD. These are:

[19] Based on the Draft Five-Year Strategic Business Plan, Mott MacDonald, October 2015

- Urban Water and Sanitation Services;
- Water and Sanitation Development Services;
- Rural Water Services;
- Customer Services;
- Finance;
- Support Services.

Each led by a Director.

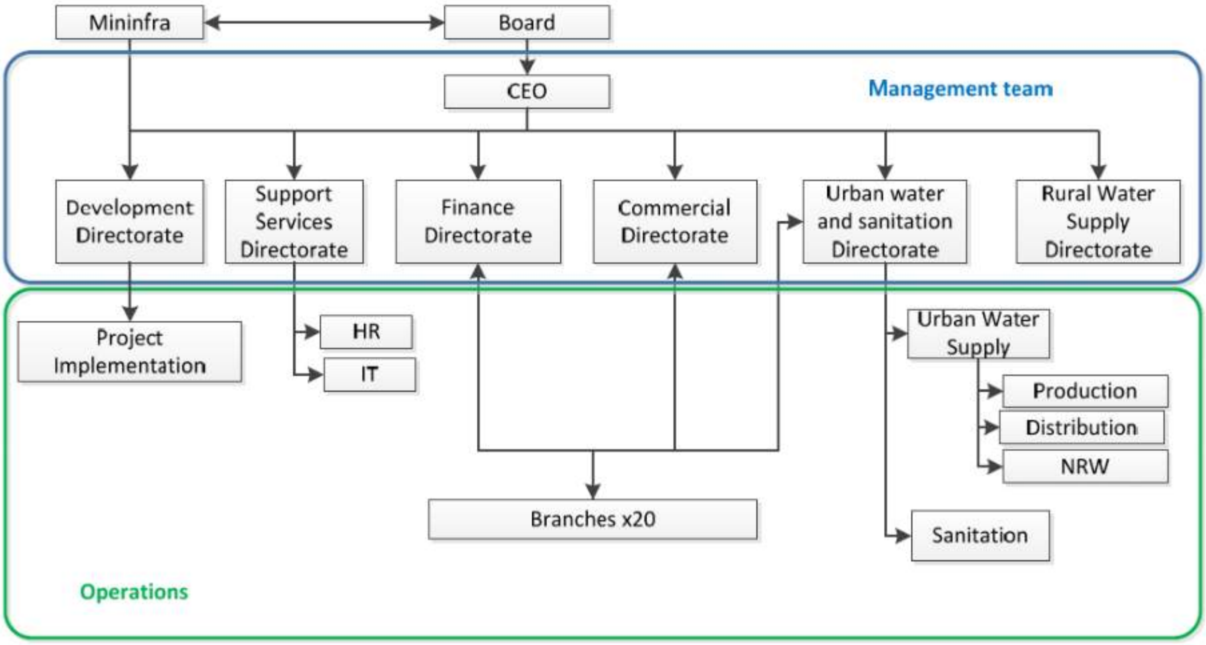


Figure 68: Current Organisation Structure of WASAC

As indicated before, total staff is around 800.

The five-year strategic business plan (5YSBP) recommends changing the organization structure to become even better equipped for its future challenges. One of the main changes is a delegation of responsibilities to branch offices. This will allow a better services provision, as they will be closer to their clients. The central office will mainly be engaged in policy & strategy development and investment planning. They will also offer dedicated support services to the branch offices.

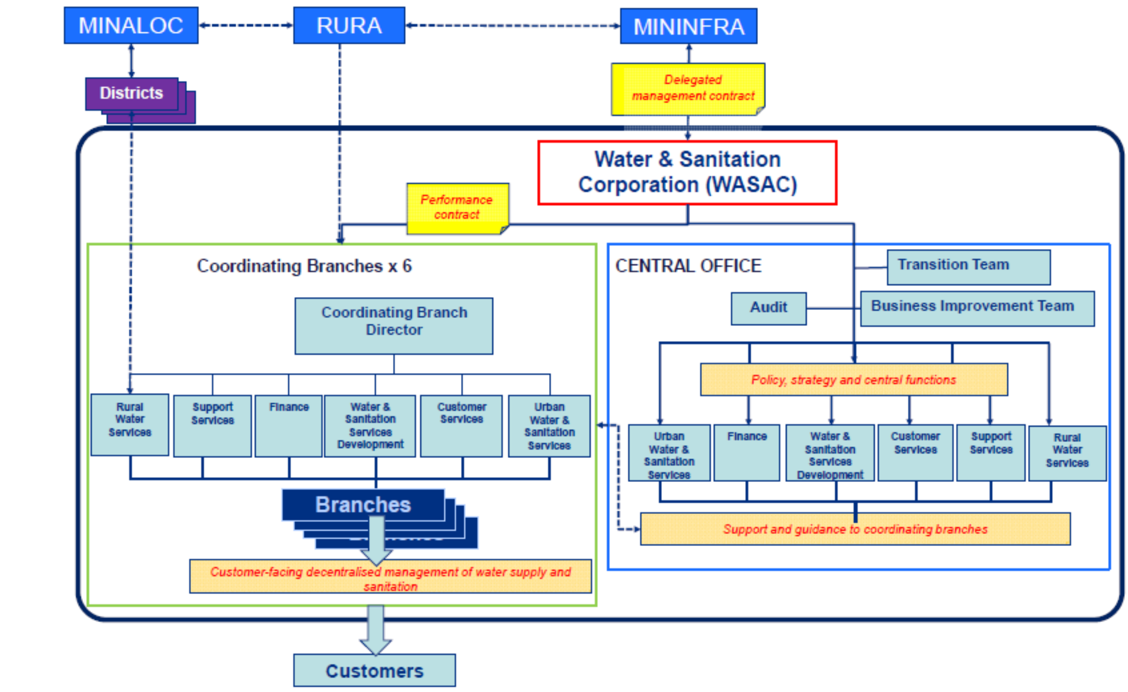


Figure 69: Recommended Long-term Organizational structure for WASAC (Source: WASAC Five-years-strategic Business Plan)

A Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis (see Table 19) was carried out in the framework of the 5YSBP to clearly identify opportunities and strengths to harness for the successful implementation of this business plan. It also points out the threats and weaknesses, which form some of the drivers for change, and ensures that identified issues are addressed in the strategic business plan. Based on the SWOT, the action plan for the transition period with the different measures to improve operational, technical, financial and institutional performance was developed.

Table 19: *SWOT Analysis (Source: 5YSBP)*

Strengths	**Weaknesses**
Clear vision, mission, slogan and visual identity	Water supply rationing issues
High staff commitment	Lack of collaboration with stakeholders
WASAC is a strong Brand	Too infrastructure delivery driven
Professionalism of all staff	Heavy bureaucracy
Culture of performance/ success	Cumbersome internal processes
Well maintained production units	Little integration between systems (IT)
Good management of large customer management	Lack of efficiency and quality control of water supply services
Current rural water framework (i.e. need of MOU & all schemes are managed)	Little automated technical monitoring
MININFRA support for investments	No centralised data management
MINALOC support on rural initiatives	Silo organization

Sense of initiative	Conservative approach to maintenance
Good problem identifications and solving capacities	Topography
Water resource availability	Time Management
Opportunities	**Threats**
On-going recruitment process	Water resources scarcity (due to inadequate operation and maintenance management)
Reform- • Sector Reform – New Policies • Better defined scope of activities	Financial Viability
Housing policy	Financial investments in infrastructure at the expense of operational expenditure
Integrated Water Resource National Management roll out	Staff retention
To become a customer driven organization	Billing system & customer records issues
Moving from an authority to a corporation	Lack of delegation
Urban sanitation Business Stream creation plus Kigali centralized sewerage project	Aging Network
Salary increase	NRW
New tariffs	Lack of capacity building
Improved M&E	Lack of specific financial management
Staff development opportunities following recruitment	Unclear role of branches
Decentralization/ coordinating branches creation GIS	Disorganized development i.e. no Master plan
Embedding sustainability in future developments	Lack of mid- term production strategy
Kigali: Bulk Water PPP	Energy efficiency
	Pressure management (for water supply network)
	Absence of customer satisfaction measurement indicators
	Lack of customer strategy for urban sanitation

The financial performance of the EWSA Ltd Water (predecessor of WASAC) was low and it has been deteriorated over the last years. It heavily relied on cross subsidies for the electricity and subsidies from the government. Based on the low tariffs and with the present operational performance the viability was a challenge and they would meet even bigger financial challenges without these subsidies. An important component was the high-energy costs for water pumping which represented 30% of total operating revenue. It was the second highest cost element of the water activities of EWSA's present cost structure.

Non-Revenue Water (NRW) levels were also significantly high and on the increase over recent years: 34% in 2011/12, 38% in 2011/12 and 41% in 2012/13. On the basis of the revenue collection rate of 90%, around 47% of water supplied to customers was not paid for and amounting to RWF 4.9 billion (US$ 7.1 million) annually or 409 RWF million (US$ 592,800) each month.

Part of the problem was also the low water tariff. Every year EWSA sends a request for tariff revision to be based on increased costs of operation, but EWSA's water tariffs were last revised in 2006[20].

The transition phase will be used by WASAC to increase financial performance, by:

- Lowering the NRW from the current levels of 40% to more internationally accepted levels of 25;
- Decrease the energy consumption and low the share of energy costs in total operating costs;
- Integrate IT systems for commercial, financial and technical operations to allow for an improved billing & collection which is based on an integrated GIS system;
- Agree with MININFRA and RURA on financial support and tariff increases during the transition period;
- Implement the support programme during the transition phase to strengthen the capacities of WASAC staff.

Based on the transition period, the 5YSBP foresees the following developments of the financial KPIs.

Table 20: *Financial KPIs of WASAC*

KPIs	2015/16	2016/17	2017/18	2018/19	2019/20
Income (RWF billion)	1.89	3.05	4.71	5.98	6.29
OPEX (RWF billion)	34.11	41.17	44.41	54.17	50.84
Net Profit (RWF billion)	0.24	0.44	1.01	1.20	0.56
Cash flow (RWF billion)	1.79	2.86	4.78	6.13	6.79
Tariff increase %	15%	17%	20%	23%	26%

7.3 The Structure of the KfW Programme

Since WASAC is in a transitional phase becoming a financially independent water corporation, its staff is fully engaged in transferring into a customer-focused service provider that generates sufficient revenues to operate independently. To this end, the FYBP has identified an intensive programme of institutional strengthening activities, ranging from integration of the financial system with the billing & collection system to defining high-priority investments and reviewing energy costs and NWR. Also a process of transfer of responsibilities to the Branch offices is undertaken.

Moreover, they are also fully engaged in implementing a huge investment programme for water but especially for sewerage to reach 100% coverage in 2018, which are laid down in the Water and Sanitation Sector Strategic Plan 2013-17, the Economic Development and Poverty Reduction Strategy (EDPRSII), and *Imihigo* which are the performance standards that follow from the strategies.

Hence, WASAC will need full attention to pursue those high challenges. It is expected not give attention for the implementation and management of the faecal-sludge treatment site. Hence, it is proposed to source out the construction and management to an external party that would have sufficient expertise to run the plant for a period of 10 – 20 years. WASAC could manage the contract. It would be in line with the plan to have WASAC have the contract management of the rural water schemes that are run by private parties. Having said this, it is also important for

[20] This year a tariff increase has been approved by RURA

WASAC staff to gain experiences in the FSTP-operations for possible future involvement. This should be arranged properly in the contract.

There are three kinds of activities that need to be considered:
- Vacuum trucks;
- Solids from the faecal sludge;
- Liquids from the faecal sludge.

The trucks will be owned by WASAC but leased out to a private operator or run by WASAC itself, depending on the type of contract that is chosen (see below). The private operator will become responsible for the fuel and O&M costs of the trucks. Instead of a separate lease fee for trucks, it is proposed to levy an all-inclusive lease fee on the operator. The level of the lease fee will have to be determined in the contract and will depend on the business case (see also next chapter). It is possible that the number of trucks provided under the contract will not be sufficient to capture all waste streams to the treatment plant. The operator could than buy or lease additional trucks or he could also sub-contract the collection of the waste to private truck owners. Of course the quality of the collection and the exhausters has be safeguarded by a system of permits issued by the government and by the main contract between WASAC and the private operator.

The first two activities are supposed to generate income, the third will mainly cost. Sludge can be used for energy generation, as is done now by Pivotworks on a pilot scale. Alternatively, solids can also be used for to produce compost.

The three elements of the project (collection of septage, processing of fuels and treatment of effluent) form an integral part of the project; it covers the full chain from collection to treatment and disposal. Therefore, it is important that all the three elements are included in the project. Hence, we have set the financial boundary conditions (e.g. the tipping fee is set high enough) in a way that all three elements are financially viable to prevent that for instance under a DBO contract, a private operator is not willing to undertake one of the elements of the value chain.

Considering that a development partner will finance the investments, there are three generic options for the contractual arrangement.

Firstly, a 'Design Build Operate' (DBO) contract, where the construction, management and operations are outsourced to a private party. Under such a contract, the private party will be responsible for the design and construction of the plant and will after the construction period also operate and maintain the plant for a certain period, in the range of some 20 years. The operator will also operate the first batch of vacuum trucks. This period will allow the operator to cover the O&M costs. The private operator may choose to sub-contract parts of the contracts, such as the design and construction, to a sub-contractor. After the contract, the treatment plant is transferred back to the owner. The private operator pays a lease fee to the owner for the use of trucks.

Secondly a 'delegation' contract, where the design and construction part will take place by the implementing agency, WASAC. In fact, this is a traditional way of contracting, where the operator is operating the facility with technical assistance of an external party to gain experience in operating the FSTP. The operator wants to have this option on the table, to see whether they want to build up expertise in this field. Although WASAC is also the delegated owner it seems necessary to have some kind of contract, most likely between KCC and WASAC which would regulate the tasks and responsibilities of WASAC.

Thirdly, a mixed option where WASAC will operate the generic infrastructure and sells the solids to a private operator, which will use it as input for making fuels or compost

There are all kinds of blend forms possible. For example, under option 2, a management contract, WASAC could delegate the design and construction to a third party, while doing the operations. Under option 1, the private operator, could source out the operations of the vacuum trucks to another private operator. In order to avoid too much complexity, we are concentrating now only on the three generic options that were mentioned above.

Each of the three options has its advantages and disadvantages, see Table 21.

Table 21: *Pros and Cons Different Contracts*

Contract form	Advantages	Disadvantages
DBO contract	• Strong incentive to optimize production processes and revenue streams; • Business risks are transferred to the private operator; • No risks for WASAC and a fixed lease fee for WASAC, so even with disappointingly low profits WASAC still receives its lease fee; • Clear contractual relations: the operator has to perform and WASAC monitors their performance; • Private operator will bring in own investments also (PPP contract); • One contract needed: a DBO contract	• Possible windfall profits will go to operator, while WASAC will have a fixed lease fee; • No building up of experiences by FST
Management contract	Building up experiences with FSTP (only relevant if this is a strategic choice)	• Loss of efficiency, certainly in the first years of operation • Since FST is very different from sewerage treatment, high investment by WASAC is needed to build up knowledge and capacity • Quite specific expertise is needed to run a FSTP with high-end market products • As operations and ownership are in one hand, contractual relations between owner and operator as they are both WASAC are more difficult to achieve; less possibilities to steer on performance
Mixed form	Private operator could concentrate on his competitive edge: production of high-end market products	• Mixed responsibilities where private operator could blame WASAC for not delivering level of produce required • More coordination problems with execution of production process because of joint responsibilities • Two contracts needed: one for WASAC and one for private operator; more complexity

It depends on the specific conditions and objectives which option is the best to pursue:

- The strategic direction of WASAC. If they consider the faecal sludge treatment option as one of the essential solutions to pursue in meeting the sanitation needs of the population, they need to gain experience and make faecal sludge collection and treatment one of the cornerstones of their strategy. In that case it is needed to build up experiences in FST. On the other hand, if they don't consider FST as a major option to pursue, there is less need to invest in knowledge on FST;
- Tendering and procurement responsibilities. As the tendering and procurement will be done at LVBC level, the question is whether there are sufficient incentives for WASAC to be engaged in a management contract.
- AAW's assignment is to provide detailed design and prepare tender documents. It is unknown to what extent the findings of this Feasibility Study can be integrated in the work of AAW. As shown in section 4, there is a difference in the technical solutions. For instance,

AAW does not consider a constructed wetlands option, which we deem necessary in order to reach the necessary environmental standards;

- The experiences and interests of the potentially interested parties. If they would be willing and experienced in doing also the design and construct activities, it would be possible to tender for one contract. If not, there must be two contracts;
- The complexity of the technical solution of the treatment plant. If the solution proposed is more technically advanced, it would be better to have it under one contract. In the end the operator that has to run the plant would want to be sure that the designs and construction are adequate for them to perform;
- From efficiency point of view, one contract seems to be preferable, as it would give an operator more room to use his experiences to optimize the designs. On the other hand, risks of non-functioning, flaws in design and not meeting effluent standards seem to be larger also. In the end, an assessment has to be made on the expected quality of services of the operator. Therefore, it is very important to have proper design requirements.

Before the start of the detailed design-work, a choice on the preferred option has to be made.

Like WASAC (Info 20 July 2016) we have a preference for the first option, as this option would bring about the largest project benefits and benefits for WASAC while reducing the operational risks. Also this option would allow WASAC to concentrate on the huge challenges they are faced with. However, WASAC could opt for option 2 or 3 because they made a strategic choice to be engaged in these kinds of activities.

Table 22 provides the financial results of the different options. The first figure gives a summary of the profitability of the three options. The next figures give the profitability of the project and WASAC in each of the three options.

Table 22: *Profitability in the Three Different Contractual Set-ups*

Implementing agent	**Project profitability**		**WASAC profitability**		**Private operator profitability**	
	IRR		**IRR**	**NPV**	**IRR**	**NPV**
DBO	15.0%		n.a.	€840,000	12%	€525,000
Mixed	14.8%		14%	€640,000	17%	€683,000
WASAC	11.5%		11.5%	€483,000	n.a.	n.a.

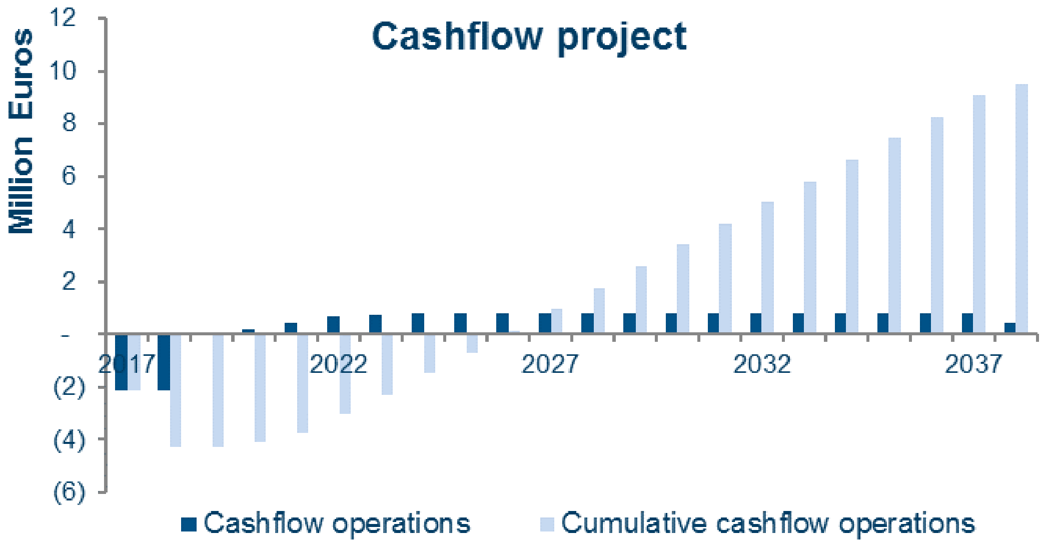
In the Figure 70 the cash flow of the project under a DBO is given where the private operator has maximum incentive to perform.

Figure 70: Project Cash Flow under a DBO contract

In Figure 71, the cash flow of WASAC under a **DBO** is given. The cash flow only consists of the lease fee that has to be paid by the private operator. The lease fee per year is set at € 125,000/ year, which is 30% of the annual operational costs. No operational costs are run by WASAC under this contract.

Figure 71: Cash flow of WASAC under a DBO contract

In Figure 72 the project cash flow under a **WASAC management contract** is given. Project cash flow is lower due to loss of collected waste volume and products sold to the market because of lack of experience. Also when a consultant or operator would assist WASAC, these services have to be paid, which means loss of revenues in the same order of magnitude. It is



assumed that three years is needed for WASAC to reach the same operational efficiency as a private operator.

Figure 72: Project cash flow under a WASAC management contract

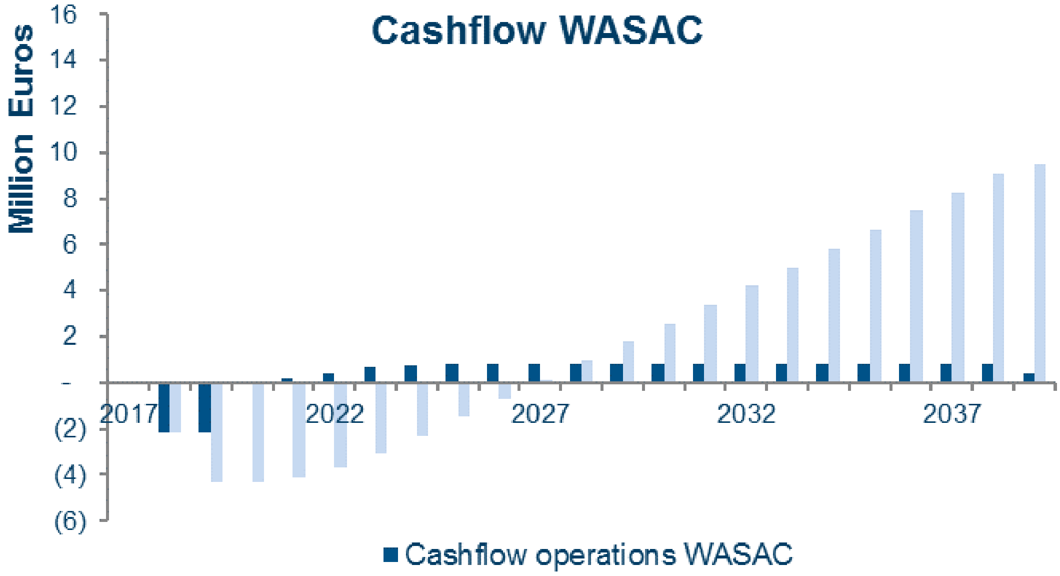


Figure 73: WASAC Cash Flow under a WASAC Management Contract

In Figure 74 and Figure 75 the project and WASAC profitability is given under a mixed contractual model, where WASAC will operate the collection and treatment of the sludge and the private operator buys the products from WASAC as input for the production of granules for fuel or composting. It has been assumed that due to the fact that there are two parties involved there will be a percentage of '*fall-out*' products that cannot be used for fuel production. It has been assumed that some 10% of the output of WASAC will not meet the required criteria for fuel production by the private operator. Since the revenues on fuels only form a minor part in the total revenues, the effect on the project cash flow will not be substantial.

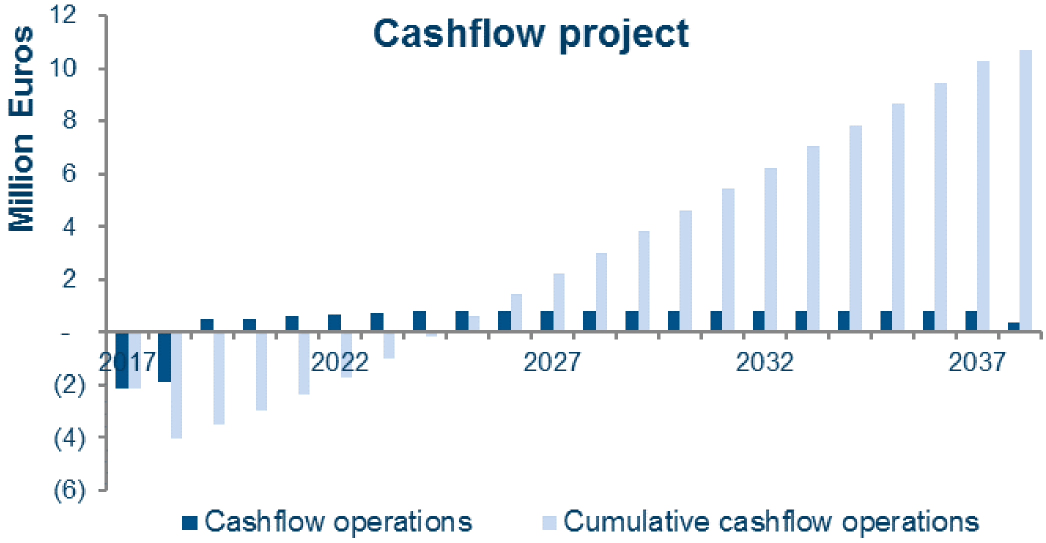


Figure 74: Project Cash Flow in a Mixed Contract Model

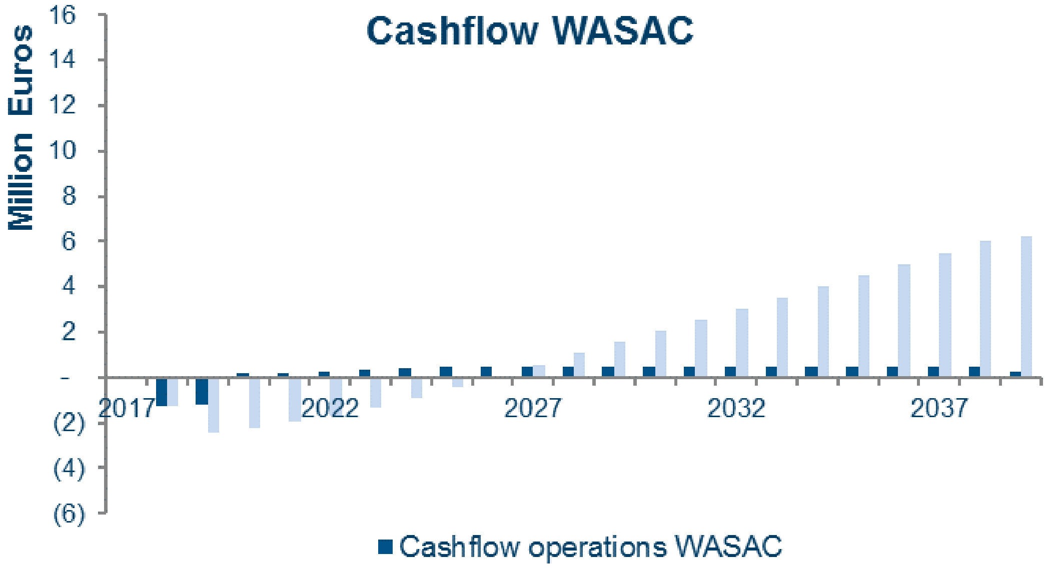


Figure 75: WASAC Cash Flow in a Mixed Contract Model

As indicated, WASAC has a preference for a DBO contract, which is supported by us. In Figure 76, the option of a DBO contract has been elaborated. In this setting, the design, construction work and operations will be done through a private operator against a lease fee and WASAC manages the contract.

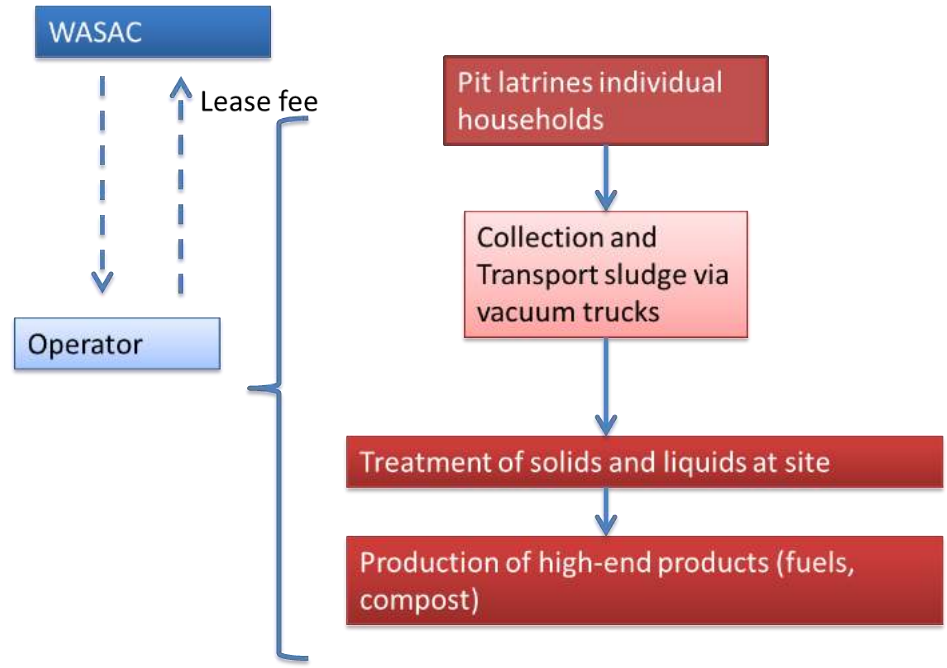


Figure 76: Faecal-sludge: Contractual Arrangements

An inventory to sound out potential interest from operators showed that there are 6 potentially interested firms/organisations (list provided by KCC):

1 Enviroclean Technologies Ltd;
2 Kenluxury Rwanda Limited;
3 Eco Protection Ltd;
4 Biobox Rwanda / Aerox Investment Ltd;
5 Technomark Corporation Ltd;
6 Pivot (presently doing the pilot on faecal sludge reuse as renewable fuel).

So far, Pivot, Enviroclean and Ecoproduction have indicated that they would be genuinely interested to participate in a tender for such a contract. The answer of the others is still pending.

This implies that more parties are potentially interested to participate in a tender for this project, of course depending on the specific conditions and requirements.

7.4 Sustainability

The proposed setting is sustainable for the following reasons:

- WASAC has experiences in managing large international contracts and are acquainted with working with international development Development Partners;
- WASAC is building up experiences with managing PPP-contracts, not only the large PPP contract for the wastewater treatment plant but also with smaller rural PPP contracts;
- There is appetite of a number of private operators to tender for the contract for the faecal-sludge treatment facility;
- A PPP contract will enable to strictly regulate through the contract the performance of the operator for faecal sludge treatment and collection; the contract can incorporate a strong incentive for the operator to perform through financial penalties by non-performance;
- The market for faecal-sludge collection is huge; collection and treatment are presently only performed on a pilot scale, while septic tanks are increasingly used.

8 Financial and Economic Analysis

8.1 Assumptions

Table 23 presents the assumptions taken for the financial and economic analysis.

Table 23: *Assumptions Financial Analysis*

Variable	Value	Unit	Source / rationale
Generic			
Exchange rate RWF to EUR	875	x RWF to 1 euro	www.xe.com
Exchange rate USD to EUR	0.89	x USD to 1 euro	www.xe.com
Construction period	1	Years	Assumption
Project duration	20	Years	Assumption
Period of operations	Q3 2018 – Q3 2038		Assumption
Operational days per year	365	days	Assumption
Lease fee from private operator to WASAC	125,000	EUR / year	Assumption
Sludge production			
Sludge transport to existing Nduba dumping site	100	m^3/day	Personal communication
Sludge production by current population	1,000	m^3/day	AAW, Interim design report
Revenues			
Average tipping fee Rwanda (fee to offer sludge to the landfill/treatment plant)	5,000[21]	RWF	Kigali City Council - personal communications
Latrine exhaust fee	9,000	RWF / m3	Kigali City Council – personal communications
Fuel production (Pivot Fuel) per m^3 of sludge	7.5	kg fuel / m3 sludge	See chapter 6.
Market price of produced fuel (Pivot Fuel)	0.040	EUR / kg	PIVOT works - personal communications
Market price of compost	0.0109	EUR / kg	SNV – personal communications
Cost estimates			
See chapter 4 for Faecal Sludge Treatment Plant cost estimates			
Investment cost vacuum truck, incl. shipping	143,650	EUR / truck	Kampala City Council – personal communications

[21] Please note that a higher tipping fee of 8,500 RWF was applied for the actual calculations. We increased the tipping to a level where treatment activities (= activities excluding sludge collection) are sufficiently profitable (IRR>5%).

Variable	Value	Unit	Source / rationale
Trips per day	5	x of trips	Expert judgement project team
Average distance per trip	10	km	Expert judgement project team
Truck engine efficiency	5	km / litre of diesel	Expert judgement project team
Diesel price	1.14	EUR / litre	Various websites[22]
Labour costs truck driver	10,588	RWF / working day	Kigali City Council – personal communications
Labourer shifts per truck per day	2	RWF / working day	Assumption
Overhead labour (planner, financial, manager)	0.25	# Labourers per truck drivers	Assumption
Labour cost overhead staff	15,882.35	RWF / working day	Assumption
Sludge load - average use of sludge capacity per trip	0.90	%, 0 - 1	Assumption
Truck maximum sludge capacity	10.00	m^3 of sludge	Assumption
Maintenance cost per km	0.75	EUR / km	Assumption
Depreciation rate vacuum truck	4	years	Assumption

We have assumed a 100% invoicing efficiency, considering that the payment needs to be completed before or during the provision of services. Unlike services for utilities, this is realistic for these types of services.

For the projections of future sludge production, we have based the calculations on the work done by AAW in their feasibility study.

We have assumed constant real prices and tariffs based on 2016 price levels.

It is assumed that KfW does the financing of the investment costs. Even though the profitability of the project is solid (see Table 3), it is very doubtful that financing for a long period of 20 years could be obtained from other, commercial financing sources or from the private investor, given the perceived risks of the business environment in Rwanda.

8.2 Results

Figure 77 presents the year-on-year cash flow of the project under operations before inclusion of finance or funding.

We have defined the base case of the project as follows:

- Application of mechanical dewatering and production of fuel;
- Sludge collection beyond the 'project starting trucks' is done by the private sector;
- Activities are taken up by private contractor through a DBO-contract;

[22] https://energypedia.info/wiki/Fuel_Prices_Rwanda, http://www.numbeo.com/gas-prices/city_result.jsp?country=Rwanda&city=Kigali, http://allafrica.com/stories/201403071099.html, https://www.expatistan.com/price/gas/kigali

- A tipping fee of 8,500 RWF is charged.

The tipping fee is higher than the present tipping fee, to allow that also the treatment of the sludge is profitable (IRR of 5%). It is important that also treatment is a profitable activity, otherwise operator could choose to restrict himself to collection and fuel production and leave the loss making treatment to the public sector. But also by increasing the tipping fee to the proposed level, it will be possible to increase the profitability of a private operator under a DBO contract to an acceptable level of 15%.

The level of the tipping fee could be reduced when the level of operations of sludge treatment increases further.

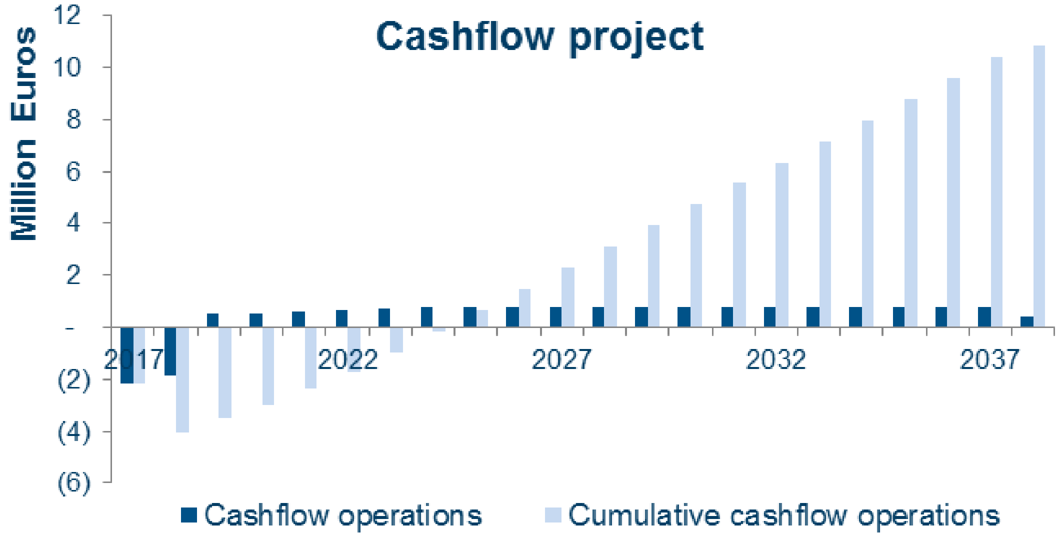


Figure 77: Cumulative and Year-on-year Cash Flow of Operations

What can be observed is that in the base case, the project generates sufficient revenue to cover operation and maintenance costs and provide a return on investment.

Table 24: *Key Results of Base Case*

Indicator	***Value***
Internal Rate of Return of operations – before finance	15%
Net Present Value (10%) – after finance (EUR)	3,323,840
Prime costs faecal sludge treatment (EUR/m3)	1.83
Operating Cost Recovery ratio (revenue / O&M)	3.2
Full Cost Recovery ratio (revenues / (O&M + depreciation))	1.77

Other key indicators on the financial performance of the project are presented in the table above. The Full Cost Recovery ratio shows that sufficient revenue is generated for future reinvestments. Additionally, the Net Present Value after finance (where the original investment costs are covered by a grant) shows that any expansion of treatment or faecal sludge collection capacity is realistic.

Figure 78 provides more detailed results, presenting the components of which the revenue is built up.

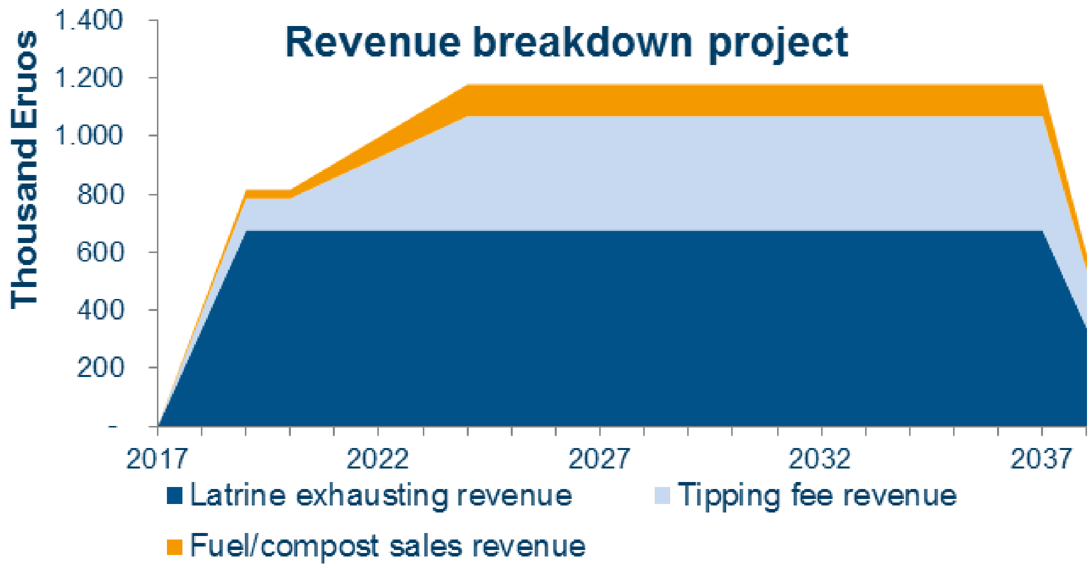


Figure 78: Breakdown of Revenue during Operations (Base Case)

The most significant revenue stream originates from the collection of sludge by the project-owned trucks. Both our calculations and qualitative information collected in the field show that the collection of sludge is a lucrative business.

The financial sustainability of the project strongly depends on the willingness to pay for septic/latrine exhaustion. If faecal sludge collection fees are not affordable (for lower income groups) less sludge will be collected, affecting all three revenue streams.

We expect that the projected revenues are realistic, based on the following considerations:

- It is important to underline the effectiveness of enforcement of the regulatory framework in Kigali, Rwanda. This limits the opportunity for illegal dumping of faecal sludge, both by households and sludge collectors;
- We have applied tariffs, which are already charged and considered acceptable in practice. We do, however, recommend the operator to apply tariff differentiation by target group (industry, commerce, institutional, domestic) to optimise revenues.

Additionally, the project does not depend on latrine exhausting revenue alone for its operations. The tipping fee, which is collected from vacuum trucks to allow the deposition of faecal sludge at the site, and sales of fuel/compost together generate sufficient revenue for full cost recovery of the Faecal Sludge Treatment Plant operations and depreciation.

To test the robustness of the financial operations of the project, we have conducted a sensitivity analysis. Table 25 shows the impact of various changes in parameters on the Full Cost Recovery ratio. The Full Cost Recovery ratio does not fall below 1, indicating that even under significant underperformance, financial sustainability of the project can still be expected.

Table 25: *Sensitivity Analysis*

Parameter change	Full Cost Recovery ratio
Base case	1.77
50% lower exhaust revenues	1.26
50% lower fuel price	1.72
25% higher investment costs	1.59
No tipping fee	1.32
50% lower sludge collection (= from 1,000 m3 to 500 m3 sludge/day with an unchanged cost-base)	1.4

We have assessed the impact on key indicators when a different project set-up is applied. As discussed, the project can either apply mechanical dewatering or sunbed dewatering. Additionally, the projected increase in sludge collection capacity can be included in the project, taken up by private sludge collectors or a variation in between. The table below shows the impact on the Full Cost Recovery ratio.

Table 26: *Results in Alternative Project Set-up*

Set-up	Internal Rate of Return before finance
Base case: - Private sector upscaling of sludge collection - Mechanical dewatering	15.0%
- Upscaling of sludge collection by project - Mechanical dewatering	25.7%
- Private sector upscaling of sludge collection - Drying beds dewatering	16.1%
- Upscaling of sludge collection by project - Drying bed dewatering	27.0%

It becomes clear from these figures that especially the collection of faecal sludge provides extensive commercial scope.

Update October 2016. On 24 October 2016, KfW has indicated it cannot support the purchase of the 4 vacuum trucks. This would mean that the private sector takes care of the collection of sludge, which is a lucrative business.

The treatment activities, being the treatment of sludge and valorisation into compost or fuel, are less profitable. The figure above shows that the profitability of these operations strongly depends on the level of the tipping fee. With the current 5,000 RWF per sludge deposit, the long-term Full Cost Recovery ratio of the operations excluding sludge collection stands at 1.3, suggesting that both O&M and depreciation of the operations are financially sustainable. The internal rate of return, however, would be at a low 0.8%. To achieve a healthier, although still commercially unattractive, internal rate of return of more than 5%, an increase of the tipping fee to a level of 8,500 RWF would be needed. This would also provide sufficient revenues to keep the Full Cost Recovery ratio very close to 1 in the event of a 50% lower volume of sludge offered at the site.

Considering the profitability of sludge collection operations, we would support the recommendation of KfW to separate these operations in the tendering. Furthermore, to safeguard financially sustainable operations under scenarios with lower volumes of sludge offered to the FCST, we recommend to increase the tipping fee to 8,500 RWF. A tipping fee of 5,000 RWF would be enough for FCR, but the IRR would be very low. An additional sensitivity analysis provides the following results:

- *Daily sludge tipped at the site remains at the present level of 100 t/day (10% capacity) and 8,500 RWF tipping fee:*
  - *FCR of treatment and fuel production: 0.355;*
  - *IRR of treatment and fuel production: n.a. (Nominal costs > nominal revenues);*
- *100t/day and 5,000 RWF tipping fee:*
  - *FCR of treatment and fuel production: 0.24;*
  - *IRR of treatment and fuel production: n.a. (Nominal costs > nominal revenues);*
- *Daily sludge tipped at the site: 250 t/day (25% capacity) and 8,500 RWF tipping fee:*
  - *FCR of treatment and fuel production: 0.557;*
  - *IRR of treatment and fuel production:-11%;*
- *250t/day and 5,000 RWF tipping fee:*
  - *FCR of treatment and fuel production: 0.378;*
  - *IRR of treatment and fuel production: n.a. (nominal cost > nominal revenues);*
- *Daily sludge tipped at the site: 500 t/day (50% capacity) and 8,500 RWF tipping fee:*

- *FCR of treatment and fuel production: 0.965;*
- *IRR of treatment and fuel production: -2.74%;*
- *500t/day and 5,000 RWF tipping fee:*
  - *FCR of treatment and fuel production: 0.65;*
  - *IRR of treatment and fuel production: -7.8%.*

Because of this significant difference, we have assessed to what extent the financial sustainability depends on the profitability of faecal sludge collection. We find that the Full Cost Recovery Ratio of operations excluding any faecal sludge collection is similar (1.81 versus 1.8) to the base case, where four trucks are operated by the project. This suggests that the operations of faecal sludge treatment alone are also financially sustainable.

The main difference between mechanical and sunbed dewatering is level of the operation and maintenance costs and the price of the produced commodity. It is more expensive and complex to produce fuel (mechanical dewatering and thermal heating to remove pathogens) instead of compost (sunbed dewatering), but the commodity price is approximately a factor three higher.

When comparing the mechanical with the sunbed dewatering, it should be added that the sunbed dewatering option requires more 1.5 hectares of additional land. The costs are not included in this analysis, as they are not incurred by the project, but by the municipality of Kigali. In the below table the household income figures per month are given for the different regions of Rwanda (source: national institute of statistics of Rwanda 2012). Table 27 provides the incomes per quintile.

Table 27: *Household Wage Income: Mean Values of Sub-components (RWF) (Source: National Institute of Statistics of Rwanda 2012)*

	Cash	In kind	Cash	In kind	Provision of house	Provision of other benefits	Total wage income	No. of HHs (000s)
All Rwanda	11,480	1,287	82,169	5,814	3,120	5,175	109,045	2,253
Kigali City	5,925	627	424,862	34,000	13,201	20,968	499,583	223
Southern Province	11,566	522	35,402	1,922	1,079	2,443	52,934	549
Western Province	11,478	1,296	37,946	3,087	2,708	2,478	58,993	528
Northern Province	13,849	2,316	60,825	3,468	2,499	6,693	89,650	411
Eastern Province	11,890	1,546	47,420	2,565	1,900	2,903	68,224	542
Q1	14,877	470	9,738	195	63	5	25,348	381
Q2	13,563	812	12,685	328	75	73	27,536	415
Q3	12,405	1,264	18,206	513	165	65	32,618	448
Q4	11,227	1,435	32,760	1,581	492	647	48,142	490
Q5	6,763	2,147	292,653	22,889	12,825	21,727	359,004	519

Base: All households. Real values, base 2011.Source: EICV3.

These quintile distributions for all Rwanda are translated into the figures for Kigali, given the following incomes per quintile for Kigali (own calculation).

Table 28: *Household Incomes for Kigali*

Income group	Average income (RWF per month)
Quintile 1	116,130
Quintile 2	126,155
Quintile 3	149,437
Quintile 4	220,560
Quintile 5	1,644,755

The household expenses for water and sanitation, including the fee for septic tank, pit latrines emptying and the transport to the FSTP-to-be-build, are given in Table 29.

Table 29: *Percentage of Income Spent on Sewerage for the Different Income Groups in Kigali*

Income group	**Average sanitation expenditure during project period (% of household income)**
Quintile 1	2.4%
Quintile 2	2.2%
Quintile 3	1.8%
Quintile 4	1.3%
Quintile 5	0.2%

The above table shows that for all households the expenditures remain within the affordability limit of 2.5% used by the World Bank.

8.3 Conclusions

The financial sustainability of the project is robust, as shown by the sensitivity analysis. Even when the collection of faecal sludge is 50% lower than expected, full cost recovery of operations and depreciation is still realistic.

The business model of faecal sludge collection is different from treatment of the sludge. It is therefore possible to separate these activities in different legal entities. This would mean that the private sector takes care of the collection of sludge. The results show that faecal sludge collection is a highly lucrative business.

The treatment activities, being the treatment of sludge and production of fuel, are less profitable. Despite revenues from fuel production, an increase in the tipping fee for these activities to approximately 8,500 RWF (roughly 10 EUR) per sludge deposit is required to become financially sustainable. Revenues from sludge collection can compensate for this lower profitability. Nonetheless, we recommend increasing the tipping fee to ensure that faecal sludge treatment activities are still able to fully recover costs when the majority of sludge collection activities is taken up by the private sector.

We have tested the technological set-ups of mechanical dewatering and drying beds. The operations are sustainable under each of these set-ups.

The main risk of the project is the collection of faecal sludge from low-income households. We recommend applying a differentiated faecal sludge collection tariff scheme. This is beneficial form a social and environmental perspective as well as commercially attractive. Sludge collection tariffs can be up to close to 35% lower than the prevailing average value without dropping below profitability margin of 15%.

9 Project Risk Analysis

Risk in inevitable in any infrastructure projects. Risks occur during the design, construction, and operating phases. The larger the project, the higher the potential risk. Examples of typical project risks are design errors, construction delay, operational failures etc. The main risks identified and the remedial actions are presented in the following table.

Table 30: *Risks and Mitigation Measures*

Risk	Description	Remedial action
Design and construction errors	Design contains errors or omissions that are not discovered until the construction period, i.e. contractor-initiated change order risk.	Design and build tender.
FS collection estimations too optimistic	There is no clear and robust method to quantify the design FS volume. 2,000 m^3/d FS discharge, estimated by AAW, is very optimistic and risky.	Construct costly structures (ABR and CW) in phases. Two phases are suggested. Start with 1,000 m^3/d and re-evaluate when about 1,000 m^3/d capacity is reached.
The operator of the FSTP is not capable	Effluent standards are not maintained, fuel is inferior quality, co-compost is substandard	Independent monitoring structure, clauses in the Service Level Agreement that dismiss the operator
Other project-WWTP with sewerage	WASAC has a plan to construct Sewerage network and WWTP, although such a project is costly (estimated €80M for phase 1 of 5 alone) and could not happen in a short period of time. Connection to the sewerage line reduces the amount of FS to be treated in the FSTP. This would result in the FSTP to function below its capacity and generate less revenue than anticipated.	Design the WWTP in such a way that it can handle wastewater from neighbouring high-income areas.
Collection of FS and Operation of FSTP by WASAC	WASAC doing FS collection using vacuum trucks instead of leasing them. WASAC doing the operation of the FSTP instead of servicing it out to a competent operator. Facility not constructed on time for all reasons other than City-induced delays	Establish service level agreement between KCC and WASAC
Law Enforcement fails	Strong enforcement is needed to avoid illegal dumping.	We have observed that Rwanda law enforcement is strong (implying low risk)
Other players enter the market	Business is less profitable than expected and Operator goes bankrupt	Regulation via annual permits.

10 Environmental and Social Impact Assessment

10.1 Social and Community Development Aspects

Potential Impact of the Project: Involuntary Displacement vis-a-vis Crop Production. The proposed site to locate the project consists of agricultural land that is privately owned. Hence, for effective implementation of the Project, compulsory acquisition of privately owned agricultural land is necessary.

The proposed mitigation is:

- Development of a Resettlement Action Plan (RAP) during detailed design phase of the project. The RAP should be developed in compliance with the legal framework of Rwanda and the requirements of World Bank Operational Policy (WB OP) 4.12;
- The budget for the implementation of the RAP is the responsibility of the Government of Rwanda;
- During selection of local construction workforce, persons that were directly benefiting from utilising the compulsorily acquired land should be given first priority.

Potential Impact of the Project: Involuntary Displacement vis-a-vis Structure. Observations from a field visit of the site proposed to locate the HPI show that the site is free from structures for housing and commercial use. The implication of this is that, towards effective implementation of the Project, compulsory acquisition of privately owned agricultural land will not result in relocation of either households or commercial entities. Subsequently, the potential level of disruption of implementing the project at this proposed site is expected to be low.

10.2 Environmental Impact Assessment

This following sections present both Environmental and Social Impact. They inc recommendations and mitigation and enhancement measures, if and when required. These measures aim to reduce potentially significant adverse impacts to acceptable levels, including traffic, dust, odour, waste, flooding risks, and compensate residual effects. The plan includes prevention or minimization of any potential adverse environmental and social impacts of the Project that have not already been identified, e.g. actions for labour management, contractor management and performance in accordance with good international construction practices. This chapter aims to define certain aspects of the Tender Documents to be prepared for realization of the FSTP.

This chapter includes a monitoring program to provide information on the environmental and socio-economic impacts of the project during implementation and on the effectiveness of mitigation and enhancement measures. The latter intended to allow corrective responses where results are insufficient.

In this chapter we describe the positive and negative environmental and social impact of the proposed HPI, the Kigali FSTP. We distinguish between:

- Pre-construction phase;
- Construction phase;
- Post-construction phase;
- Operation and Maintenance phase.

As far as the environmental impact is concerned we describe any positive and negative effects, on the one hand and on the other hand, we describe the mitigating measures putting into practice for concerned negative effects.

10.3 Pre-construction Mitigation Measures

The mitigation measures during the pre-construction phase are described below.

Impact	Mitigation Measures
Detailed Design preparation/Design review FSTP	Confirm size and type: screening, grit channel, settling tanks, anaerobic baffle reactor, vertical flow constructed wetlands, mechanical dewatering, fuel production
Design review ABR followed by VFCW	Confirm that designed ABR-VFCW system reach effluent standard of < 50 $mgBOD_5/l$
Prevention of Bypassing influent	Confirm that FSTP design and related pumping stations/siphons are robust enough to maintain influent treatment during periods of high and low FS
Effluent Discharge	Design effluent discharge below river surface level and optimize dilution with river water flow
Flooding Risks	Confirm that adequate flood protection measures are included in the design of the FSTP if needed
Odour emissions (design)	Prepare for Odour Mitigation Measures during design phase: (1) anaerobic baffle reactors, (2) prepare design for a basic weather station for recording wind speed, direction, humidity and rainfall at the FSTP.
GHG emissions (design)	Apply reusable building materials where possible
Resettlement Action Plan for the FSTP	Implement land acquisition and RAP for the FSTP site
Water Quality Monitoring	Design a chemical and biological laboratory on the site of the WWTP for weekly analysis of influent, effluent and ambient water quality (COD, TSS, total Nitrate, Phosphate and pH)
Social impact of reallocation of land	When a project is considered a national priority land can be nationalized. Current policies foresee compensation, which is 5% higher than the market value. They also can get alternative land. Farmers can hire themselves independent evaluators to value their land. There is also a complaint procedure. It is important that the operator monitors the execution of this policy and also registers any possible complaint. Close contact with farmers involved is necessary.
Electricity	(1) Confirm capacity of central electricity net, to supply sufficient energy to the pumping stations, mechanical dewatering and thermal drying to other consumers of the electricity net; (2) confirm sufficient stand alone back up energy capacity for FSTP and pumping station

10.4 Construction Mitigation Measures

The mitigation measures during construction are presented as follows:

Impact	Source / Subject	Mitigation Measures
Reallocation of farmers	Social impact	The operator should closely monitor the appropriate execution of what has been agreed with the farmers on compensation or reallocation of land. Possible complaints should be considered. Involvement of farmers or their family members in the operations of the FSTP project should get priority

Impact	Source / Subject	Mitigation Measures
Disturbance to local residents during construction works	Location of construction works close to neighbouring living areas	Contractor shall submit construction yard logistics to Client, including means of separation from living areas
Traffic Management Plan	Construction Vehicles and traffic management	The Contractor shall elaborate a Traffic Management Plan, which shall be coordinated with the City of Kigali and the relevant traffic authorities and the police. This plan shall be approved prior to the start of the construction works, and will include: • Traffic routes for construction equipment and building materials, including foreseen timing and frequency of traffic movements; • Identify critical traffic safety and accident risk locations along the route, and propose related mitigation measures, including speed control and road signs; • Timing and access of construction material delivery vehicles to site should be strictly controlled to avoid the disturbances to the local community; • Appropriate traffic signage must be erected on site by the Contractor to alert other road users to construction activities; • The Contractor should strategically position the site entry and exit points to ensure that there is minimum impact to the traffic flow on neighbouring areas; • A low speed limit shall be adhered to on site; • Construction vehicles must utilise existing main road and access roads and not create new unauthorised access roads; • The Contractor must ensure that local access roads are not damaged by construction vehicles. If damage does occur, it needs to be attended to immediately to avoid long term problems; • Lighting used to facilitate construction at night should not disturb neighbouring residents. Down lighting should be employed where practicable; • Accessibility of public buildings (among others offices, hospitals, schools, universities, businesses and culturally important sites) needs to be guaranteed during normal working hours. Specific attention shall be given to accessibility for people with disabilities
Storm water discharge to neighbouring residents	Storm water and drainage at construction site	Contractor shall attend storm water drainage on construction site, to prevent soil erosion and flooding
Unauthorized access to site camp	Access points	The site yard must be secure at all times to prevent unauthorised access at the construction site. The Contractor must ensure that construction trenches and material storage areas are sealed off with barrier tape/fences. There must be security at the entrance gate controlling access to the site.
Site contamination	Storage and use of equipment and hazardous	Hazardous substances need to be kept in a secured storage area, which is funded and/or has an impermeable floor layer that is able to contain spillages.

Impact	Source / Subject	Mitigation Measures
	substances	The hazardous substance storage area needs to be locked at all times. Spill kits must be kept at the hazardous substance storage facility to treat and manage any spills immediately. All contaminated soil/clothing/material must be disposed of at a licensed or approved hazardous landfill site. The hazardous material storage facility should be sited away from storm water drainage lines. Clear warning signage must be placed at all storage areas containing hazardous substances / materials. Staff dealing with these materials / substances must be aware of their potential hazard and follow the appropriate safety measures.
Site contamination	Solid waste handling	Sufficient waste bins shall be provided on site to encourage waste separation and for recycling purposes, if such systems are available. Refuse bins shall be placed at strategic positions to ensure that litter does not accumulate on site. Construction workers need to be encouraged to use the waste bins provided at all times, and littering should be prohibited. The Contractor must engage with the local authorities or a private waste service provider regarding to the provision of waste containers. Waste containers should be kept on site to dispose of construction rubble. Containers must be removed when they fill up to maintain a clean site. Waste must be disposed of at the official landfill, approved by the authorities. If the waste disposal facility does not issue a record of the waste disposed, it is recommended that the Contractor keep a record at the construction site of the volumes of waste taken to the facility. Burning of waste on site or in waste containers is prohibited. Hazardous waste may not be stored on site in excess of a 90 calendar day period.
Site contamination	Sanitation	The Contractor shall install toilets on the site and place them in a designated area. The Contractor needs to establish hand washing facilities and soap to maintain good hygiene on site. Staff shall be sensitised to use these facilities at all times. Ablution facilities shall be within 100m from workplaces. The Contractor should arrange that the service provider services the toilets regularly.
Air and soil pollution	Handling of cement, asphalt, fuel, paints and other chemicals	Cement or asphalt mixing must take place on impermeable/-protected surfaces. Use of ready mixed cement/asphalt will require the establishment by the Contractor of proper truck and equipment wash bays with an impermeable floor layer. Used paint tins/brushes must be disposed of as hazardous waste and paint washings collected in receptacles for later safe disposal. Paint must not be washed into stormwater drains on site.
GHG Emissions	Air emissions	Purchase reusable building materials where possible; minimize construction transport distances and related transport air pollution
Noise	Construction noise	Construction works related noise levels must be kept within acceptable limits. The noise and sound generated shall adhere to the Tanzanian noise standard specifications and take account of nearby residents when work is performed at night. No sirens and hooters

Impact	Source / Subject	Mitigation Measures
		may be utilized except where required or in emergencies. The playing of loud music at the construction yard is prohibited. The Contractor should keep the local community informed of unavoidable noisy activities and their duration.
Dust generation	Dust from excavations, cement and construction materials	Excavations and other site clearing activities shall only be undertaken during agreed working times to avoid the spreading of sand and dust into neighbouring areas. The Contractor shall be responsible for dust control (water spraying) on site to ensure no nuisance is caused to the neighbouring landowners and the local community. A speed of 20 km/h shall not be exceeded on site. The Contractor must attend to complaints resulting from dust generation immediately. The Contractor should commence with rehabilitation of exposed soil surfaces as soon as practically possible after completion of earthworks. All material resulting from excavation must be put in a location protected from wind and regularly sprinkled with water until reused for fill Dust suppression measures must be implemented where required.
Fire risks	Potential fires	The Contractor shall have operational fire-fighting equipment available on site at all times. The level and capacities shall be sufficient to address any major fire outbreak. Open fires shall be prohibited on the site
Surface Water pollution	Chemical and hazardous materials	All hazardous materials shall be placed in containment areas on sealed floor surfaces and 100m away from any water bodies. The Contractor must remove contaminated wastewater resulting from construction activities and dispose of it at a licensed commercial wastewater treatment facility. Temporary cut-off drains and berms must be erected in order to capture surplus storm water and promote infiltration. Used oil on site must either be collected by a registered waste oil collector or disposed of to a registered processing or disposal facility. Manual cement/asphalt mixing activities must take place in a lined are to prevent runoff from the area entering the storm water drainage system. It is recommended that ready mixed cement/asphalt be utilised to prevent onsite water pollution and impacts on surrounding areas, where possible. A designated, properly designed impermeable washing area for vehicle and the Contractor must establish construction equipment if this cannot be undertaken off-site. Any accidental spillages that occur on site must be contained and remediated as soon as possible. On site ablution facilities need to be serviced regularly and placed in a special area. Storm water needs to be managed especially during the wet season. It should not be allowed to drain into trenches nor should it be allowed to flood areas where construction materials or equipment are stored. A storm water management plan must be prepared by the Contractor and approved by the ESO, ECO and /or the Independent Engineer. Water pumped from any excavations/trenches must be safely disposed of and be free from silt and sediments.

Impact	Source / Subject	Mitigation Measures
Safe water use	Leakage and wasting	The contractor needs to provide safe drinking water to its employees, meanwhile avoiding wastage and timely repair of leakages
Disturbance of wetland ecology	During construction maturation ponds	Construction work site shall be physically separated from surrounding wetlands/ paddy fields. Nuisance and pollution of the surrounding wetlands shall be fully prevented, including dust, noise, wastewater emissions, and particularly waste generation and disposal. The contractor shall prevent that animals, fishes and other fauna will be disturbed, trapped, hunted or killed by the workers and staff involved in the construction works. In case of emergencies accidents with impacts on the wetland ecology beyond the boundaries of the construction site, the relevant authorities shall be informed immediately, and related mitigation measures shall be prepared and implemented as soon as possible
Occupational Health and Safety Impacts	Workers and community safety	A health and safety plan shall be drawn up by the Contractor to ensure the safety of workers. Contractors shall ensure that all equipment is maintained in a safe operating condition. A record of health and safety incidents shall be kept on site. Any health and safety incidents shall be reported to the Employer immediately. First aid facilities shall be available on site at all times. Workers have the right to refuse work in unsafe conditions. Material stockpiles or stacks shall be stable and well secured to avoid collapse and possible injury to site workers.
Occupational Health and Safety Impacts	Use of Protective gear	Personal Protective Equipment (PPE) shall be made available to all workers and use of PPE shall be made compulsory. The minimum PPE includes: • Hard hat; • Safety shoes • Overalls; • Gloves; • Reflector vests; Certain operations may require additional PPE such as: • Ear plugs; • Eye protection glasses; • Face masks; No person is to enter the construction site without the necessary PPE.
Occupational Health and Safety Impacts	Site safety issues	The FSTP construction yard shall remain fenced at all times. Potentially hazardous areas such as trenches are to be demarcated and clearly marked. Adequate warning signs of hazardous working areas shall be erected in suitable locations. Emergency numbers for the local police, clinic/hospital and fire department shall be placed in a prominent area. Fire fighting equipment shall be placed in prominent positions across the site where it is easily accessible. This includes fire extinguishers, a fire blanket as well as a water tank. Workers need to be trained on how to operate the fire fighting equipment. All flammable substances shall be stored in safe areas which do not pose an ignition risk. Smoking may only be conducted in demarcated areas as agreed upon by the SHE officer and the Contractor.

Impact	Source / Subject	Mitigation Measures
		A speed limit of 20km/h shall be adhered to by all construction vehicles and machinery. The works that take place in the public space, especially the construction of the sewer network and the trunk main, need specific health & safety planning, traffic safety planning, and training of the construction workers to limit public the safety risks, such as falling into holes, pools or ditches or collisions with construction equipment.
Stakeholder Engagement Planning	Stakeholders	Stakeholder engagement should continue into the construction phase. Specific attention should be given to communication about public health & safety risks and measures to mitigate these. The project council with representatives of the local residents should be in regular contact with the City of Kigali and WASAC. A grievance mechanism should be established and managed.
Neighbouring Community	Community relations	The Contractor must be courteous at all times when dealing with the neighbouring community and their rights need to be respected at all times. A complaints register should be kept on site and the Contractor must attend to any public complaints as soon as possible. No interruptions other than those negotiated shall be allowed to any essential services, including access to water sources and local infrastructure. Damage to local infrastructure shall not be tolerated and any damage shall be rectified immediately by the Contractor. A record of all damages and remedial actions shall be kept on site. Where possible, unskilled job opportunities should be afforded to local community members in order to transfer employment skills. The Contractor will need to engage with the municipal local Councillors or other community leaders to assist with the recruitment of the local unskilled labour when required.
Neighbouring Community Impacts	Infection risks from HIV / AIDS. Ebola and other diseases	The Contractor must coordinate and implement an awareness campaign on HIV/Aids, Malaria and other potential sicknesses within Kigali and Rwanda. The campaign must aim at sensitizing the employees and neighbouring communities to potential health risks and regulating behaviour.
Neighbouring Community Impacts	Alcohol and drug abuse	The consumption of alcohol and drugs by employees must be prohibited on and surrounding the construction area
Employment opportunities	Labour recruitment	Where possible local residents, including women, shall be given the opportunity to apply for construction jobs and to supply materials, food and beverage.

10.5 Post-construction Mitigation Measures

Following the completion of the construction works, the following post-construction actions need to be implemented by the Contractor:

- The construction yard is to be checked for spills of substances such as oil, paint, chemicals, other types of waste, and these shall be cleaned up;
- The Contractor must arrange for the cancellation of all temporary services, e.g. toilets;
- All areas where temporary services were installed are to be rehabilitated to the satisfaction of the local authorities and the Independent Engineer, if assigned;

- Surfaces are to be checked for waste products from activities such as concreting/asphalting and cleared accordingly;
- All surfaces hardened due to construction activities are to be ripped and concrete/asphalt material removed;
- Topsoil must be replaced back to disturbed surfaces and used to re- vegetate disturbed areas;
- The use of a geotextile cover is particularly important where there is a slope, or where the soils are likely to remain exposed for any period of time while the new vegetation establishes itself;
- All construction waste and rubble is to be removed from the site and disposed of to the municipal or recognized/approved landfill site;
- The site is to be cleared of all litter and temporary cabins and structures should be dismantled;
- Fences, barriers and demarcations associated with the construction footprint are to be removed from the site;
- All residual stockpiles must be removed from the site;
- The Contractor must repair any damage that the construction works has caused to neighbouring properties;
- Quarries used for sourcing construction material must be rehabilitated accordingly.

Public Information to prepare for Construction Works

The Project Affected People and general public shall be informed through the City of Kigali about the type and duration of the upcoming construction works, as well as during these works. This shall include information on the timing and planning of the construction works, the impacts on roads and traffic such as road closures and rerouting of vehicle and pedestrian traffic, potential temporary environmental nuisance and temporary traffic signs and warnings.

10.6 Mitigation Measures During Operation and Maintenance

The mitigation measures during operation and maintenance are presented as follows:

Impact	Mitigation Measures
Effluent water quality	Establish effluent monitoring program in line with RS 109 2009 Water Quality, and optionally with EU Directive 91/271/EEC and amendment 98/15/EEC, particularly for BOD, Ammonia and SS and occasionally for non-typical components
Monitoring and reporting	The operator should maintain records of air emissions, effluents, and hazardous wastes sent off site, as well as significant environmental events such as spills, fires, and other emergencies that may have an impact on the environment. The information should be reviewed and evaluated to improve the effectiveness of the monitoring. It should further include procedures for handling of accidents and disaster preparedness.
Occupational Health and Safety during operations (management system)	Establish an OH&S management system in line with RS 183 2013. Supervisors must first have the proper attitude and interest in OH&S, and shall gain a full working knowledge and understanding of the many ways in which they can prevent accidents and occupational illness.
Occupational Health and Safety during operations (chemical handling)	Many of the materials and chemicals used in the wastewater treatment are corrosive, poisonous, explosive, or flammable. Handling of these materials requires proper precautions.
Occupational Health and Safety during operations (ventilation)	Wastewater treatment plants require careful analysis of and provision for ventilation needs, because plant ventilation prevents dangerous gas mixtures, and helps to maintain safe working conditions.
Occupational Health and Safety during operations	All equipment, buildings and fire alarm systems should comply with local, state, and national fire codes and standards

Impact	Mitigation Measures
(fire prevention)	
Occupational Health and Safety during operations (electrical hazards)	Most of the equipment in the FSTP uses electricity as the primary power source. Maintenance of the equipment requires strict safety measures against exposure to electrical hazards that may result in shock or death.
Noise	Confirm that FSTP operations with meet the ambient noise standards according to RS 236 2014
Air Quality	Confirm that FSTP operations with meet the air quality standards according to RS EAS 751 and 752
Influent Water Quality	Establish influent monitoring to confirm that the influent is not mixed with industrial produced wastewater
Prevention of Bypassing influent (operations)	Confirm that Operations of FSTP and treatment of influent continues during periods of high water / flooding
Sludge Quality	Analysis of Final Sludge Quality, and evaluate against WHO / Rwanda limit values for reuse in agriculture
Sludge Reuse	Provision of training and support to agricultural sector, if sludge reuse standards are met and sludge is provided to agricultural sector
Sludge final disposal	Sanitary disposal of sludge, if sludge reuse standards are not met
Wastewater Reuse	Study options for wastewater reuse near FSTP, based on total flow, effluent quality, and local (agricultural) market options.
Faecal Sludge Treatment Fees	Ensure financial sustainable operations, including effective and adequate fee collection system and adequate pro-poor provisions
Buffer Zone and Visual Impacts	Maintain buffer zone and trees in this zone, including water supply, and maintain spatial plan around the project area. Enforcement of spatial planning around the FSSTP limiting new developments of housing in the area of influence around the FSTP
Flooding Risks	Main flood protection measures (dam and surface water drainage) and operate them during periods of high water level and floods for the FSTP
Water Quality Monitoring	Establish FSTP WQ monitoring program, upstream + downstream of FSTP effluent point, particularly for BOD, coliform, Ammonia and SS and occasionally for non-typical components.
Water Quality Analysis	Operate the chemical and biological laboratory on the site of the FSTP on a weekly basis for analysis of influent, effluent and ambient water quality (COD, TSS, total Nitrate, Phosphate and pH)
Odour emissions (monitoring)	(1) Set up effective odour monitoring program with participation from neighbouring population; (2) operate the basic weather station for recording wind speed, direction, humidity and rainfall at the FSTP.
Odor emissions (operations)	Implement odour reduction measures (covering up and air filtering) if monitoring program measure structural odour nuisance
GHG emissions (Operations)	Implement gas emission reuse for power generation once this is possible financially and market / demand wise.
Inequality Compensation	Provide piped water supply and sanitation services for project affected people
Electricity Supply	(1) Confirm capacity of central electricity net, to supply sufficient energy to FSTP, pumping stations throughout operations and (2) operate and maintain stand alone back up energy capacity for FSTP and pumping station
Labour Opportunities	Assess operational job opportunities for local residents

11 Conclusions and Recommendations

In Table 31 we present the conclusions and recommendations of the Feasibility Study on Faecal Sludge Management in Kigali.

Table 31: *Conclusions and Recommendations*

Conclusions	Recommendations
The current crude dumping of faecal sludge at the Nduba Waste dump leads to unacceptable environmental pollution: air, ground- and service water, foul smell and hazards.	Stop dumping of faecal sludge at the Nduba waste dump and replace crude dumping with environmentally sound treatment of collected faecal sludge.
The City of Kigali, trough WASAC (Water and Sanitation Corporation of Rwanda) has hired an international consultant, AAW, to select the site for a new treatment plant. The site was visited and found suitable. The access road is not suitable for vacuum trucks.	Follow the advice of AAW and continue preparations for land acquisition and improvement of the access road (widening, tarmac).
The City of Kigali, trough WASAC (Water and Sanitation Corporation of Rwanda) has hired an international consultant, AAW, to determine the treatment process, to produce EPC tender documents for a Faecal Sludge Treatment Plant (FSTP) with horizon of 10 years and to prepare the Environmental Impact Assessment with a Environmental Management Plant. The treatment process described in the preliminary interim report (April 2016) has several shortcomings: • It has a very optimistic projection of the daily volume of sludge that will arrive at the FSTP; • Its does not fulfil the environmental standards in terms of effluent quality; • Some structures are over-sized (sludge settler) some are under-sized (Anaerobic Baffle Reactors/ ABR); • It does not take into account the prolonged wet season in Kigali, thereby rendering open sludge drying beds inefficient; • It does not take the positive results of the pilot on valorisation of faecal sludge and therefore misses the opportunity to receive income that can be used for covering part of the operation and maintenance costs of sludge management.	WASAC is advised to hand over the findings of the present feasibility study in order to improve the design of AAW and the tender documents: • Implement only 50% of AAW's design flow: 1,000 m^3 sludge per day; • Add Vertical Flow Constructed Wetlands to treat the effluent of the ABR to up to standards that meet the standards; • Improve the design of the ABRs; • Cover the sludge drying beds. Alternatively consider mechanical dewatering • Take into account the experiences to produce fuel from faecal sludge.
The operation and management of the FSTP requires knowledge and skills that are outside the competences of WASAC.	Outsource the operation and maintenance of the FSTP to a competent operator.
Sales of fuel produced from Faecal Sludge (FS) provide income. Mechanical dewatering devices that require advanced skills are them most efficient method to produce fuel.	Investments in 'advanced' FSTP (mechanical dewatering) to produce fuel should only be done if an operator can be found that is capable and willing to do so. If not a 'fool-proof' FSTP concept should be chosen, using covered drying beds.

Conclusions	Recommendations
The desludging of septic tanks is lucrative business.	Besides the investments in the FSTP, vacuum trucks are to be purchased. Vacuum truck operators are to lease the trucks from WASAC.
The full costs of the combination of an FSTP producing fuel and the purchase of desludging trucks can be recovered, provided more than 50% of the FSTP design capacity (> 1,000 m^3 sludge / day) is being collected and treated.	Invest € 4 mln. in a FSTP and desludging trucks. Proceed with land acquisition: € 0.7 mln., with road improvement: €1.78 mln. and closure of Nduba dump site: € 0.25 mln.
There are three options for the contractual arrangement for the FSTP:## • A Design Build Operate (DBO) contract; • A Management Contract: Design and Construction under WASAC and operation and maintenance of the FSTP and desludging by private partner; • A mixed option where WASAC will operate the generic infrastructure and sells the solids to a private operator, which will use it as input for making fuels or compost The options have their pro's and con's. In a DBO contract the operator takes the risk for design or construction flaws.	Implement the FSTP using a DBO contract.

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- *20150819_RS 180 2013 Solid waste disposal sites, guidelines for safe management - Code of practice*
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- *20150819_RS 126-3 Wastewater treatment plant- safety principles*
- *20150819_RS 126-2 Wastewater treatment plant- construction principles*
- *20150819_RS 126-1 Waste water treatment plant-vocabulary*
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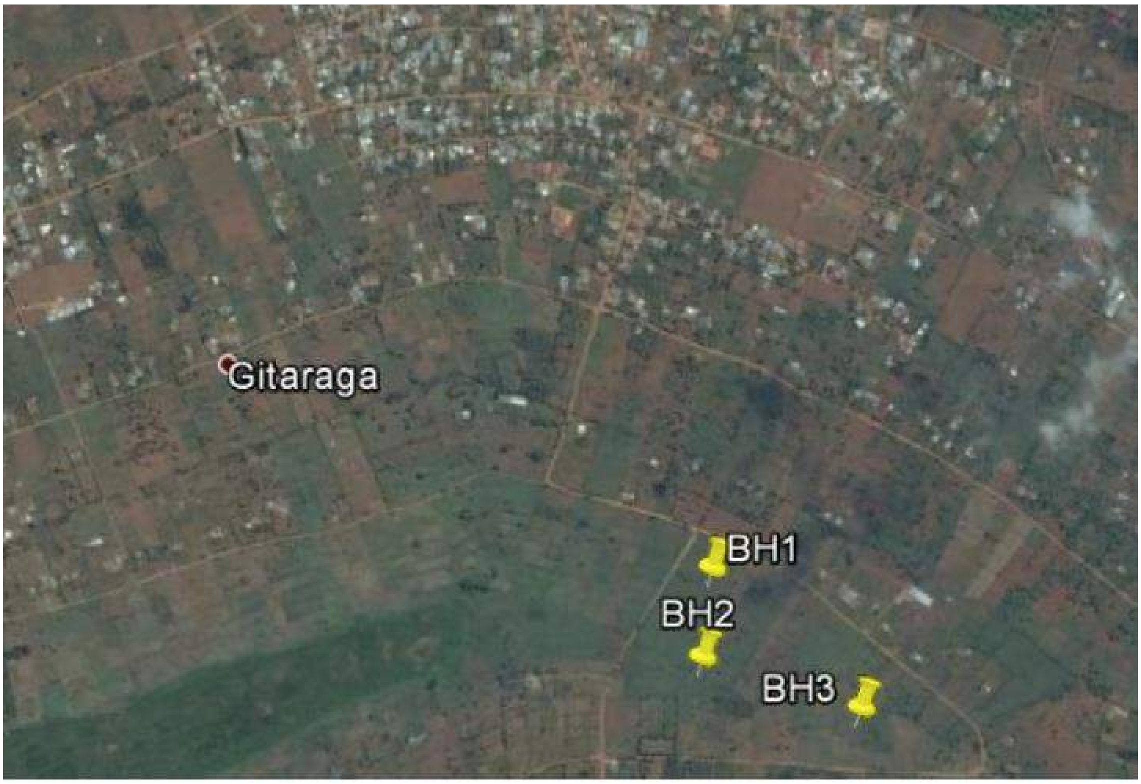
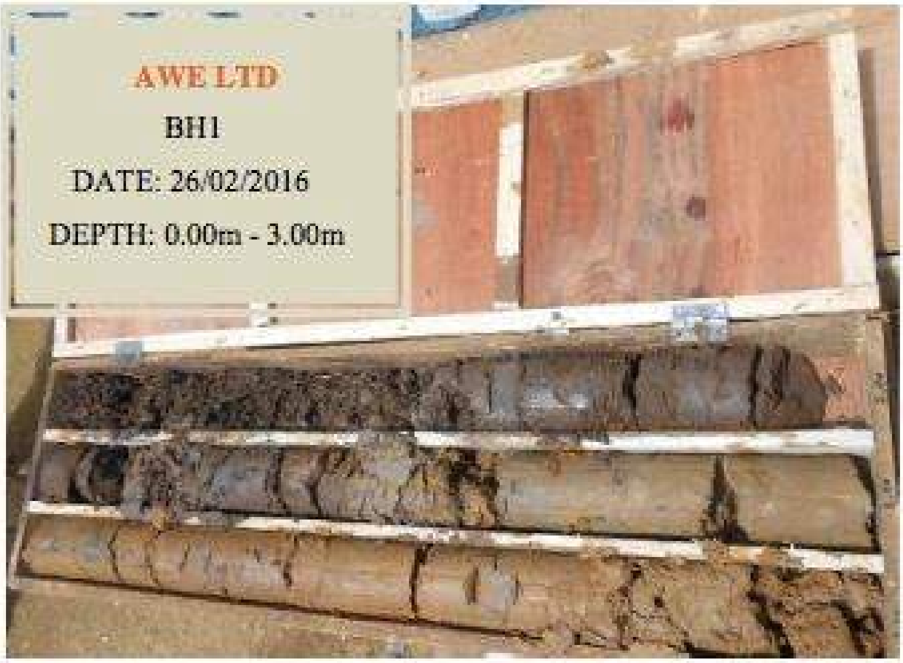
APPENDIX 1: Geotechnical Data

Geotechnical data from the AAW geotechnical investigation report, 2016.



Machine Used :AP 450	**Borehole 1**		
Water ground Level: -------	Coordinates	X(s)	02°00'31.1"
Drilling period:26/02/2016 to 26/02/2016		Y(E)	030°11'30.1"

Depth. (m)	LOG	SPT (Sample N0	Lithological description	Diameter	Sampling depth UDS	RQD
0			Top soil,blackish silt with the roots	Ø 80		No rock cored
1		(1) SPT:2-2-3	Soft fine schisty clay			
2		(2) SPT:5-9-8				
3		(3) SPT:7-10-10			UDS-1	
4		(4) SPT:11-9-8	Fine brownish clayey sand			
5		(5) SPT:6-7-9				


AWE LTD
BH1
DATE: 26/02/2016
DEPTH: 0.00m - 3.00m


AWE LTD
BH1
DATE: 26/02/2016
DEPTH: 3.00m - 5.00m

Machine Used :AP 450	Borehole 2		
Water ground Level: 4.5m	Coordinates	X(s)	02°00'35.7"
Drilling period:27/02/2016 to 27/02/2016		Y(E)	030°11'29.6"

Depth. (m)	LOG	SPT (Sample N0	Lithological description	Diameter	Sampling depth UDS	RQD
0			Top soil, Blackish silt with roots	Ø 80		No rock cored
					UDS-1	
1		(1) SPT:4-4-6	Soft fine schisty clay			
2		(3) SPT:4-7-6				
3		(6) SPT:4-7-10				
4		(9) SPT:2-4-5	Fine brownish clayey sand			
			underground water level			
5		(11) SPT:6-4-6				


AWE LTD
BH2
DATE: 27/02/2016
DEPTH: 0.00m - 3.00m


AWE LTD
BH2
DATE: 27/02/2016
DEPTH: 3.00m - 5.00m

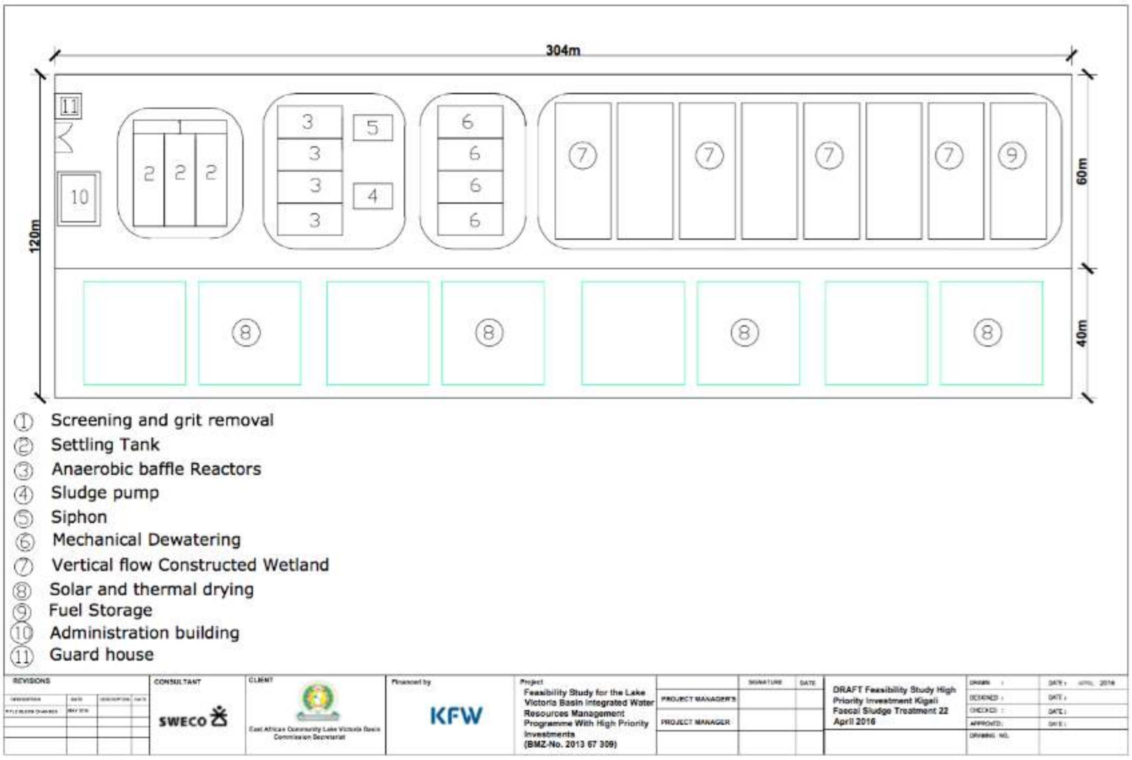
Machine Used :AP 450			Borehole 3			
Water ground Level:---			Coordinates	X(s)	02°00'38.2"	
Drilling period:28/02/2016 to 28/02/2016				Y(E)	030°11'37.7"	
Depth. (m)	LOG	SPT (Sample N0	Lithological description	Diameter	Sampling depth UDS	RQD
0			Top sol,very soft blackish silt	Ø 80		No rock cored
1		(1) SPT:3-3-2	Blackish schisty clay			
2		(3) SPT:3-3-5				
3		(6) SPT:4-4-5	Brownish sity Clay		UDS-1	
4		(9) SPT:3-6-3				
5		(11) SPT:4-6-6				


AWE LTD
BH3
DATE: 28/02/2016
DEPTH: 0.00m - 3.00m


AWE LTD
BH3
DATE: 28/02/2016
DEPTH: 3.00m - 5.00m

APPENDIX 2: Lay-out alternative 4

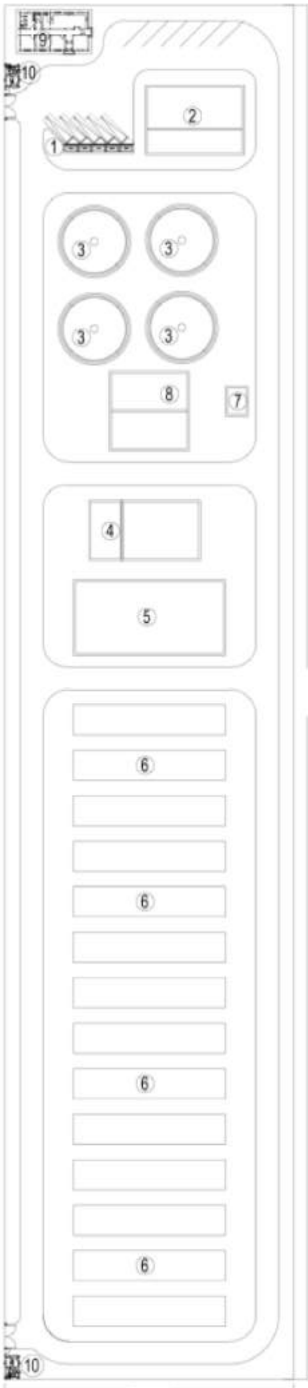
Preferred Option:



APPENDIX 3: Lay-out Alternative 2

Preferred option of AAW preferred:

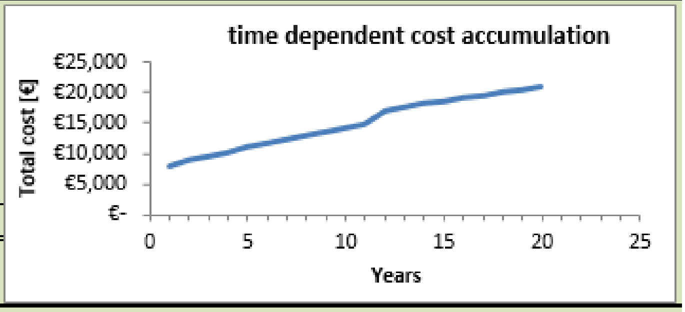
SITE COMPONENTS OPTION 2	
1-	TRUCKS COLLECTING
2-	SCREENS - GRASE - EQUALIZATION AND PUMPING
3-	SLUDGE THICKENER TANKS
4-	THICKENED SLUDGE PUMPING
5-	SLUDGE MECHANICAL DEWATERING
6-	SLUDGE COMPOSTING RAWS
7-	SUPERNATANT AND SITE DRAINAGE PUMP STATION
8-	ANAEROBIC BAFFLED REACTOR
9-	ADMINISTRATION BUILDING
10-	GUARD ROOM



APPENDIX 4: Cost Estimates of Technologies Considered in Alternative 4 Phase I

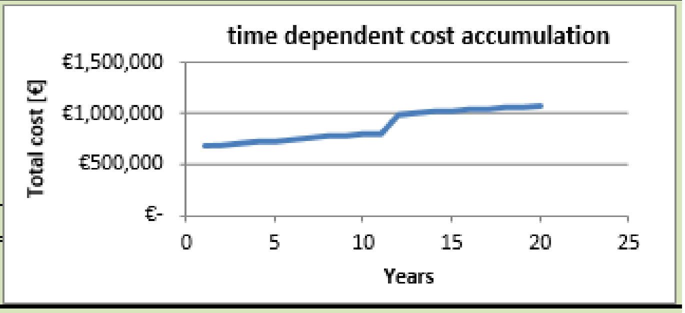
Bar Screens

Results	Screen
Investment Costs	-€ 7,987
Σ OM Costs (NPV)	-€ 11,644
Σ Reinvestment (NPV)	-€ 1,680
Σ Revenues (NPV)	€ 0
Residual Value	€ 397
Total Cost	**-€ 20,914**



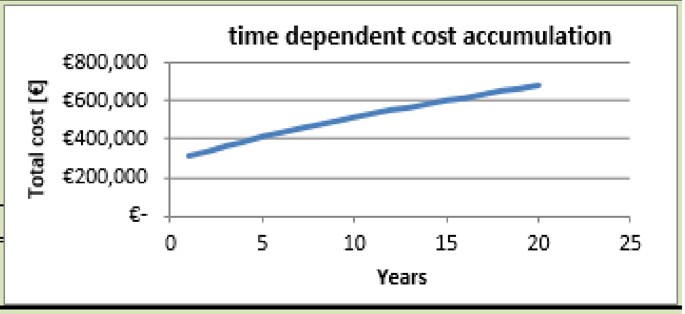
Sludge Thickeners

Results	Sludge thickener
Investment Costs	-€ 672,152
Σ OM Costs (NPV)	-€ 227,619
Σ Reinvestment (NPV)	-€ 173,539
Σ Revenues (NPV)	€ 0
Residual Value	€ 32,352
Total Cost	**-€ 1,040,959**



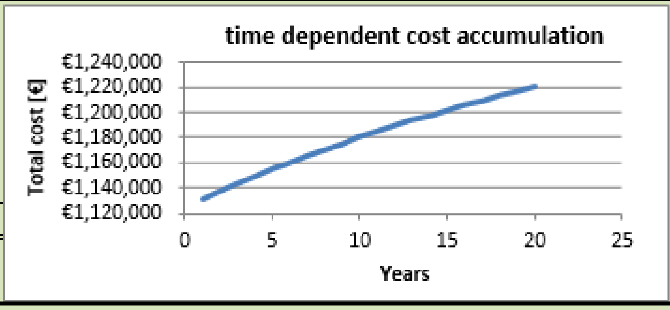
Mechanical Dewatering (Belt Filter Press)

Results	Belt filter press
Investment Costs	-€ 313,400
Σ OM Costs (NPV)	-€ 376,594
Σ Reinvestment (NPV)	€ 0
Σ Revenues (NPV)	€ 0
Residual Value	€ 17,707
Total Cost	**-€ 672,287**



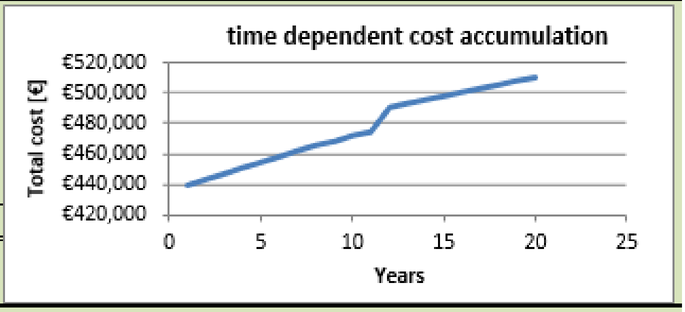
Anaerobic Baffle Reactors

Results	robic baffled reactor (ABR)
Investment Costs	-€ 1,131,254
Σ OM Costs (NPV)	-€ 91,922
Σ Reinvestment (NPV)	€ 0
Σ Revenues (NPV)	€ 0
Residual Value	€ 63,915
Total Cost	**-€ 1,159,261**



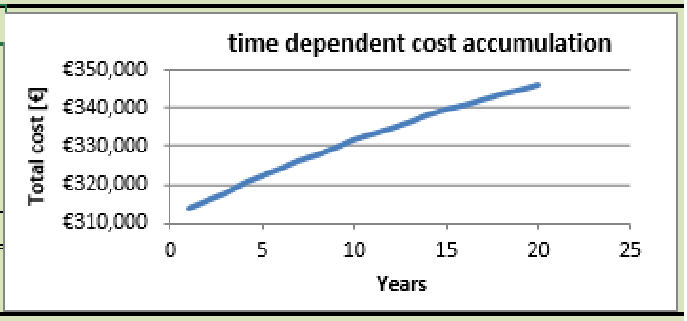
Vertical Flow Constructed Wetlands

Results	Vertical flow (VF) CW
Investment Costs	-€ 439,532
Σ OM Costs (NPV)	-€ 59,678
Σ Reinvestment (NPV)	-€ 13,220
Σ Revenues (NPV)	€ 0
Residual Value	€ 24,405
Total Cost	**-€ 488,025**



Solar Sludge Drying Beds

Results	Solar Sludge Drying
Investment Costs	-€ 313,594
Σ OM Costs (NPV)	-€ 33,727
Σ Reinvestment (NPV)	€ 0
Σ Revenues (NPV)	€ 0
Residual Value	€ 17,718
Total Cost	**-€ 329,604**



APPENDIX 5: Pit Latrine Emptying Report Kigali

Source: Pivotworks

Fecal Sludge Sourcing Interim Report

Prepared for Osprey Foundation & Stone Family Foundation

Pivot Ltd • June 2016

Fecal sludge sourcing project objectives

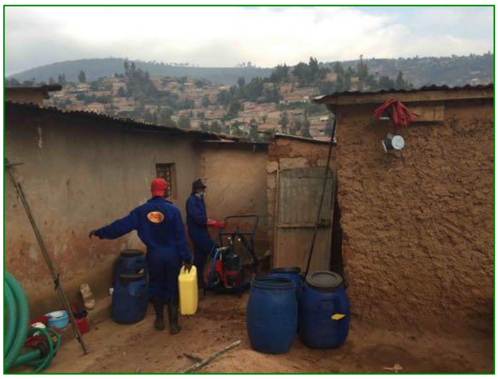
Guiding project goals

- Design 1-2 transfer stations in Kigali and operate those stations for 9 months to determine the economics of the collection and transfer model.
- Develop a replicable model for reliable sludge collection with well-defined and understood economics – even if that model would require donor subsidies to be sustained going forward.

Sourcing project activities

Extension to pit emptying

Because there are no existing mechanical solutions for pit emptying in use in Kigali, Pivot found itself needing to work with "builders" (people we found in the communities who were providing undercover manual emptying services) to equip them with the appropriate tools and protective equipment for safely and efficiently carrying out the work of pit latrine emptying.



To that end, we have undertaken a trial period of pit latrine emptying using the eVac, a tool provided to us by Water for People. Pivot has trained a team of emptiers to use the equipment and have found the technology to be relatively well suited for the work. The emptiers are not hired employees but rather a team who are being paid out of the fee paid by households for pit emptying. The remainder of the household fee goes toward transport, and Pivot has subsided shortfalls in operational expenses.

Status of "transfer stations"

To maintain as much flexibility as possible in the early stages of this trial and to accelerate start-up time of the project, we are using a rented room in the community and a hired truck to together serve as our transfer station. This has several advantages to a stand-alone transfer station, particularly in the near-term:

1. It is quick and easy to move into new neighborhoods because finding an existing room where we can store equipment is

much easier than finding an empty lot where we can park a transfer station;

2. It is allowing us to prototype and experiment with different methods of moving sludge before locking ourselves into one system. For example, because of the incredibly hilly terrain of Kigali, movement of the fecal sludge between pits and the holding room or truck is proving very labor intensive, and therefore expensive. We are researching the feasibility of pumping sludge directly from the pit to a roadside transfer tank but again the terrain lends to that being a major technical challenge (i.e. due to head losses). Therefore, we have yet to make any significant capital investments in a customized transfer station.

3. It will allow us to work in several communities simultaneously without a large new capital outlay for each expansion.

Calendar of key activities

- February 22 and March 21 2016 – Rapid market assessment (RMA)
- May 1-June 1– Phase I Pilot collection service in Gitega
- May 20 – Nicola Greene (expert supported by SFF) joined team full-time
- June 6-ongoing – Phase II collection in Gitega (re-worked fee structure)
- June 13 – Start pilot collection service in Gikondo

Key performance indicators

- Pits Emptied: 22
- Households Served: 20
- Emptiers trained and equipped with PPE: 6

Key Financial & Operating Indicators	
Opex - First 12 empties (RwF)	481,800
Customer Payments - First 12 empties (RwF)	111,250
Avg. Opex/empty (transport, labor, water) (RwF)	40,150
Avg. Customer payment/empty (RwF)	9,271

Near-term plans

- Trial of new pricing strategy (40,000 RwF flat rate/empty) in communities of differing incomes and socioeconomic status. The ultimate goal is to see how much of the market we can capture at a price that achieves full cost recovery on operational expenses. (The original price structure was intended to achieve cost recovery but labor requirements proved far greater than we anticipated.) At the time of writing, we had emptied 10 pits at the new price and have a pipeline of at least 10 customers, eight of whom are in a new community.

- Quantify:
  - Market exhaustion rates
  - Total feces managed through our service model
  - Unit cost of feces management via our service vs. other models
  - Service and financing gaps, donor/subsidy needs

- Develop and populate database
  - Emptying logistics
  - Business model efficiency
  - Public health impact/exposure reduction

Business & financial learning and strategy

The value of pit sludge

Average characteristics of pit latrine waste received to date:

Average volume per pit (m3)	1.1
Average solids content (%)	12
Average sand content (%)	25
Average trash content (%)	15
Potential Pivot Fuel production (t/pit)	0.08
Retail value of Pivot Fuel ($/pit)	5.00
Pits per ton Pivot Fuel	12.5

We have been surprised by the relatively small volume of combined fecal sludge and trash that the team is able to extract per pit latrine. This is due to them being much shallower than reported (by and large a good thing for the local environment). The numbers are not entirely encouraging when looked at from the perspective of how many pits it will take to achieve a 1-ton increase in Pivot Fuel production – 12.5 pits to produce 1 ton of fuel. The solids concentration being an average 12% is a function of having to fluidize latrines before pumping them out; this is not ideal but not unexpected. Sand concentrations are also less than ideal but within the range we expected from unlined pits.

Finding high volumes of trash in pits is a ubiquitous problem across the pit emptying sector. BUT does it have to be considered a problem? That's the question we're asking ourselves! Check it out…

Average trash content (%)	15
Volume trash per pit (m^3)	0.165
Density trash (t/m^3)	3.2
MSW Pivot Fuel production (t/pit)	0.53

3

Retail value of MSW Pivot Fuel ($/pit)	31.68
Pits per ton MSW Pivot Fuel	2

Clearly, finding a means to incorporate solid waste retrieved from pit latrines into Pivot Fuel would COMPLETELY change the economics of this endeavor making it cost-effective and compelling to promote emptying of pit latrines.

Because Pivot produces industrial fuel and not an agricultural product, MSW, in theory, can be seamlessly incorporated into our product without compromising its quality or performance for target customers. Indeed, there are countless cement plants across Europe that routinely burn MSW as a source of energy.

Turning disposal problems into resources is written into Pivot's genetic code, so we're very excited about exploring the incorporation of MSW (initially just from pits) into our fuel product.

Integration of pit sludge into Pivot Works process and operations
The ultimate purpose of going after pit latrine sludge is to increase the volumes of waste delivered to Pivot Works and subsequent Pivot Fuel production levels and revenues. On the receiving end, we are focused on:

1. Developing standard operating procedures for receiving pit sludge. This entails gaining deeper understanding of the following:
    a. Average solids concentration of sludge – can we count on putting it directly into solar drying process or will it need mechanical dewatering?
    b. Sand content and settleability in thicker sludge – is it possible to build a receiving hopper in the greenhouses that includes sand settling? Or, does sandy sludge need to be settled in the inlet tank?
    c. **How can we incorporate trash into the fuel? Where in process does it make the most sense to macerate the trash? What's the added cost of maceration?**
        i. We are researching macerator technologies and talking with operators to understand operating challenges and maintenance expectations;
        ii. Characterizing the trash that is in the pit latrines: materials, size, CV
        iii. Ultimately hope to incorporate MSW into sample batches of Pivot Fuel for trials and feedback from customers
2. Streamlining container cleaning process, which is currently labor intensive and thus adding to production costs
3. Quantifying value of fuel derived per pit compared to processing costs

Engineering learning and strategy (eVac)
Learning

- eVac was designed for more watery sludge of South Africa but copes well in the majority of pit latrines tested on Gitega to date

4

APPENDIX 6: Update on Chapter 4 AAW on Sludge Characteristics and Proposed Treatment Alternatives

Update on chapter 4 of the Preliminary Interim report, status unknown, received on 20 July 2016 from:

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NATIONAL PROGRAM COORDINATOR
LVWATSAN II & KCSS-WwTP PROJECTS
Phone: +250785056556 / +250786962939

E-mail: gafishiclement@yahoo.com

WASAC Water & Sanitation Corporation

REPUBLIC OF RWANDA
WATER AND SANITATION CORPORATION (WASAC)
Consultant Services for the conceptual design and Performance specifications of Septic Tank Sludge Management and Treatment Plant for KIGALI City
[Tender Ref. No. 11.07.053/5253/CS/008/QCBS/12/PROC-DWSD/PNEAR-DIR/YM/et]

AAW CONSULTING ENGINEERS

CHAPTER (4)

4.1 Introduction

This chapter provides information about septic sludge characteristics and shows summery of the laboratory tests that were made by the consultant, and also deals with treatment options alternatives and comparison of them resulting to select the optimum alternative from the technical and economical point of view.

4.2 Sludge Design Characteristics

University of Rwanda based on an agreement with the consultant made analysis for the septage sludge from different trucks, the tested parameters were the most common parameters related to sludge. The following table shows the septage sludge sample analysis summery which was done by the University of Rwanda.

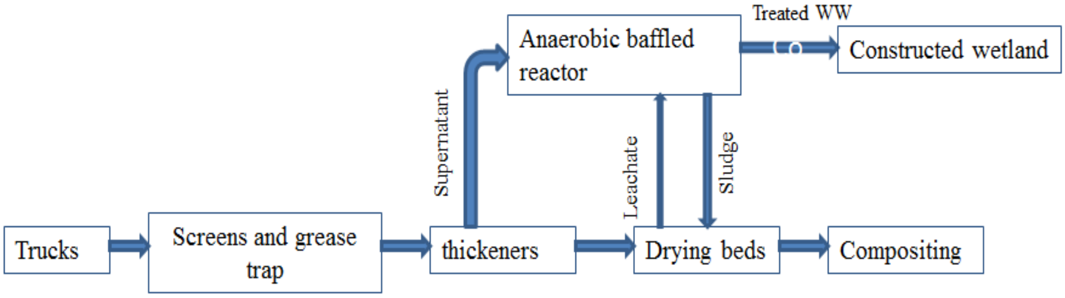
Table (4.1) Septage sludge sample analysis

Parameter	**Average**
pH	6.63
TSS (mg/l)	8873.90
COD (mg/l)	4719.20
Oil and grease (mg/l)	0.66
TS (mg/l)	19452
VS (mg/l)	10722
Total Nitrogen (mg/l)	216.46
Total Phosphorus (mg/l)	55.04
Ammonia Nitrogen (mg/l)	101.26
Faecal Coliforms /100ml	--------------
Ascaris Lumbricoides	--------------
Trichuris trichura	--------------

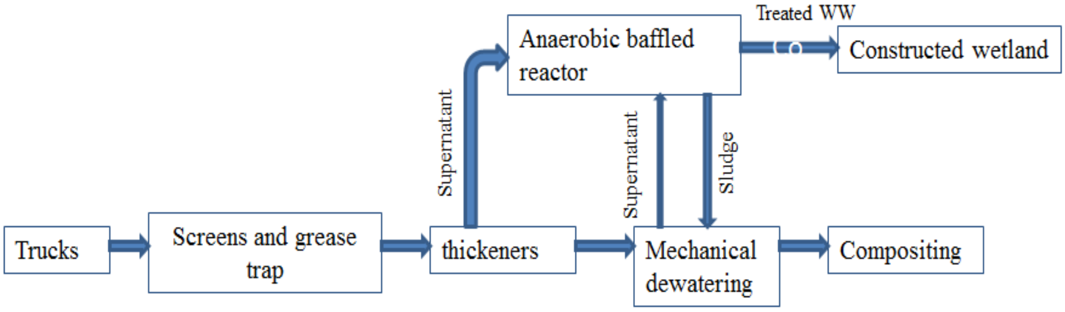
From the above table the VS/TS equal to 55.12% which implies that the septage sludge is stabilized and if biogas reactor will be used the expected biogas production will be small.

4.3 The proposed septic sludge treatment system

The following figure show the two proposed sludge treatment flow diagram options which contains a stream for sludge treatment with aside stream for supernatant water. The first option consists of a truck reception unit followed by a screen and grease trap unit then sludge will be transferred to gravity thickeners , the thickened sludge will then be dewatered by conventional drying beds and then composted. The side water streams collects the supernatant from gravity thickeners and drying beds will be treated using Anaerobic Baffled Reactor (ABR) with retention time more than 18 hr. Based on the assumed retention time removal of the COD could reach up to 90%. The final effluent will be discharged to constructed wetlands.



Option 1 (dewatering by drying beds)



Option 2 (dewatering by mechanical system)

The second option was different regarding the sludge dewatering system. As it consists of a truck reception unit followed by a screen and grease trap unit then sludge will be transferred to gravity thickeners , the thickened sludge will then be dewatered by mechanical dewatering and then composted. The side water streams collects the supernatant from gravity thickeners and drying beds will be treated using Anaerobic Baffled Reactor (ABR) with retention time more than 18 hr. Based on the assumed retention time removal of the COD could reach up to 90%. The final effluent will be discharged to constructed wetlands.

4.3.1 Components sizing

The following table (4-2) shows the preliminary estimated dimension for the two proposed treatment options

Table (4-2) Dimensions of the treatment options components

Component	Option 1	Option 2
Sludge thickening	3 tanks each 20.00m diameter with 4.0 m	

	depth	
Sludge dewatering area (m²)	drying beds 30,000	Mechanical dewatering building 700
Sludge composting area (m²)	4,200	
Water stream	2 ABR tanks each 20 m * 10 m * 4.50 m Constructed wetland (200 m * 100 m *1.0 m)	
Total required area (hectare)	6.00	3.00

4.3.2 Selected Alternative

The selection of a suitable septage management option does not depend strictly on technical considerations. For example, regulatory requirements may take precedence over the technical issues. Site availability may prohibit the selection of a particular land disposal option, or the distance to an existing municipal treatment plant may obviate co-treatment due to excessive hauling costs.

Based on the fact that the available land for the septage sludge treatment plant is 3.60 hectare the second treatment option will be the feasible option.

Selected option components

1- Trucks receiving chamber
2- Screens and grease trap
3- Gravity thickeners
4- Sludge holding tank with thickened sludge pumping
5- Mechanical dewatering building
6- Composting area
7- Supernatant and site draining pump station
8- Composted sludge storage area
9- Anaerobic Baffled Reactor
10- Administration and laboratory building

The attached drawing showed the conceptual layout of the proposed option

And the following table contains the expected capital cost of the septic sludge treatment plant (not including sludge transportation and land cost)

Table (4-3) Expected capital cost of selected alternative

Component	Capital cost (€)
Sludge thickening	750,000
Sludge mechanical dewatering *	1,900,000
Sludge composting	1,650,000

Sludge reception and sludge holding	1,200,000
Site preparation and Administration	500,000
Water stream	900,000
Total	6,900,000

* including chemical conditioning

Appendix 7: MEMO Questions raised by KfW

Background. In the final workshop on the Feasibility Studies for the "LVB IWRM Programme with High Priority Investments (HPI)" on 3 November 2016, a ranking of the 4 HPIs will be presented on the basis of the results of the Draft Final Feasibility Studies which were submitted for final review in August 2016, taking into account final feedback and questions received from KfW. On 24 October 2016, KfW requested clarification on some aspects of the FS of the selected HPIs.

Aim of this memo. To clarify the pending issues that were raised by KfW so that an unambiguous decision can be made.

Approach. We present the question and the response in this note. After discussion with KfW and LVBC, the excerpts will be incorporated into the final FS reports, due 30 November 2016.

HPI Kigali. Question on profitability. The way the financial feasibility is presented suggests that the project is commercially viable. Explain why this project needs donor grant funding, taking into account that KfW is not inclined to fund the vacuum trucks demanded by WASAC.

Answer HPI Kigali, profitability*.* We refer to section 8 (Financial and Economic Analysis) of the Final Draft Feasibility Study on the HPI Kigali Faecal Sludge Treatment Plant. The revenues of the project are clearly illustrated in Figure 80 of the report, see Figure 80.

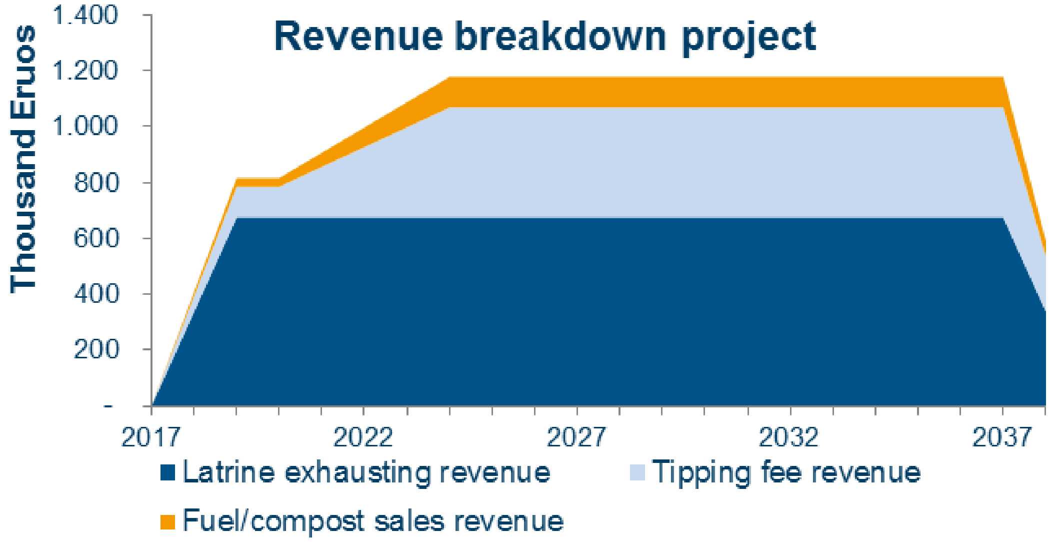


Figure 79 Report Breakdown of Revenue during Operation

It is clear that the business model of faecal sludge collection is different from treatment of the sludge. It is therefore possible to separate these activities in different legal entities as suggested by KfW in the conference call on 24 October 2016. This would mean that the private sector takes care of the collection of sludge, which is a lucrative business.
The treatment activities, being the treatment of sludge and valorisation into compost or fuel, are less profitable. The figure above shows that the profitability of these operations strongly depends on the level of the tipping fee. With the current 5,000 RWF per sludge deposit, the long-term Full Cost Recovery ratio of the operations excluding sludge collection stands at 1.3,

suggesting that both O&M and depreciation of the operations are financially sustainable. The internal rate of return, however, would be at a low 0.8%. To achieve a healthier, although still commercially unattractive, internal rate of return of more than 5%, an increase of the tipping fee to a level of 8,500 RWF would be needed. This would also provide sufficient revenues to keep the Full Cost Recovery ratio very close to 1 in the event of a 50% lower volume of sludge offered at the site.

Considering the profitability of sludge collection operations, we would support the recommendation of KfW to separate these operations in the tendering. Furthermore, to safeguard financially sustainable operations under scenarios with lower volumes of sludge offered to the FCST, we recommend to increase the tipping fee to 8,500 RWF. A tipping fee of 5,000 RWF would be enough for FCR, but the IRR would be very low. An additional sensitivity analysis provides the following results:

- Daily sludge tipped at the site remains at the present level of 100 t/day (10% capacity) and 8,500 RWF tipping fee:
    - FCR of treatment and fuel production: 0.355;
    - IRR of treatment and fuel production: n.a. (Nominal costs > nominal revenues);
- 100t/day and 5,000 RWF tipping fee:
    - FCR of treatment and fuel production: 0.24;
    - IRR of treatment and fuel production: n.a. (Nominal costs > nominal revenues);
- Daily sludge tipped at the site: 250 t/day (25% capacity) and 8,500 RWF tipping fee:
    - FCR of treatment and fuel production: 0.557;
    - IRR of treatment and fuel production:-11%;
- 250t/day and 5,000 RWF tipping fee:
    - FCR of treatment and fuel production: 0.378;
    - IRR of treatment and fuel production: n.a. (nominal cost > nominal revenues);
- Daily sludge tipped at the site: 500 t/day (50% capacity) and 8,500 RWF tipping fee:
    - FCR of treatment and fuel production: 0.965;
    - IRR of treatment and fuel production: -2.74%;
- 500t/day and 5,000 RWF tipping fee:
    - FCR of treatment and fuel production: 0.65;
    - IRR of treatment and fuel production: -7.8%.