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DESIGN OF SUSTAINABLE SANITATION SYSTEMS FOR IDP[A] CORAIL CAMP IN HAITI

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Abstract: Haiti is unfortunately the unluckiest tropical island in the world because of not only its political and economical issues but also due to natural disasters happening there. Especially after the earthquake in 2010, the life became more difficult for habitants in Haiti, mainly clean water scarcity and sanitation problems. The aim of this project is to review a range of available emerging sustainable sanitation systems, design and simulate that could provide solutions for Haiti, considering environmental, social and economical aspects after this earthquake. The aim is also to design and simulate the best systems. Finally the project aims to analyze how the best systems could be implemented in IDP (Internally Displaced Person) Camps and specifically in the Corail Camp in Haiti. The investigation is narrowed down through selection criterion, to the two most feasible systems, the DEWATS (Decentralized Water Treatment system) and composting toilet. The feasibility of these two systems for the camps is proven through simulation by BioWin tool and design. Through an economical analysis the two designs were developed for the Corail Camp. As a result, theoretically more than 90 % BOD removal was achieved by DEWATS through simulation and design. The composting toilet could also provide fertilizer for the area which cannot be connected to sewage system. Utilization of gravity in the camp will also reduce pumping requirements for sewage collection system

Keywords: Sustainable Sanitation, Haiti, IDP Camp, wastewater, BioWin, DEWATS, composting toilet.

1. Introduction

On January 12, 2010, an earthquake with a magnitude of 7.0 struck near Port-au-Prince, the capital of Haiti. Almost every water source in Haiti has become contaminated by human waste, causing infant mortality, illness in children and the spread of water-borne gastro-intestinal diseases, responsible for 50 % of deaths (International Action, 2011). The spread of cholera is currently one of the most prevalent threats to human health in Haiti. As of mid-December, 2010, 2,100 individuals had died from cholera and 47,000 individuals had been hospitalized. (One Year On: Haiti Earthquake Response, 2010).

The first aim of this project is to review a range of available and emerging human waste management systems that could provide sustainable solutions for post-earthquake Haiti, considering environmental, social and economical aspects. The aim is also to design and simulate the best systems. Finally the project aims to analyze how the best systems could be implemented in IDP camps and specifically in the IDP *Corail Sector 4* in Haiti.

2. Definition of key words

2.1. Sustainable Sanitation: In terms of waste water treatment in disaster areas, a general trend that can be seen globally, is identified; the need for recovering all possible resources to create a closed cycle. Using human waste as a resource has great potential and waste water treatment systems that allows for using by-products as fertilizers or for biogas production could bring positive social and environmental effects.

2.2. Haiti: Based on PESTEL (Political, Economical, Social Issues, Technological, Environmental, Legal) analysis, Haiti is a semi-presidential republic in which the President of Haiti acts as the head of state. According to World Corruption Reports, the country has consistently ranked as one of the most corrupt nations in the world. (Everett, 2010) It is the poorest country in the Western hemisphere and the third hungriest country in the world after Somalia and Afghanistan. There is no a very developed technological sector. (US. Department of State, 2010) In environmental view, as about half of the country has a slope of 40 % or higher, erosion is a major problem.

*2.3. IDP Coral Camp**:*** Corail Sector 4 is one of the largest IDP camps in Haiti. The camp is located on a treeless flood plain 16 kilometres north of Port-au-Prince. There is no existing sewage network, but high volume pit latrines that need de-sludging once every two years are used. Bathroom cabins are connected to soak pits. Currently, the number of people per toilet is 130 and the available area per person is 40 m2 (Marangu, 2011). See Figure 1 for the location of the camp.

2.4. Waste water: The water that has been used by a community and which contains all the materials added to the water during its use. It is thus composed of human body wastes (faeces and urine) together with the water used for flushing toilets, and sullage, which is the wastewater resulting from personal washing, laundry, food preparation and cleaning kitchen utensils.

2.5. BioWin: A tool in both troubleshooting and design, as it can work as an illustrative tool and through the use of multiple models can also allow for process optimization of environmental treatment systems.

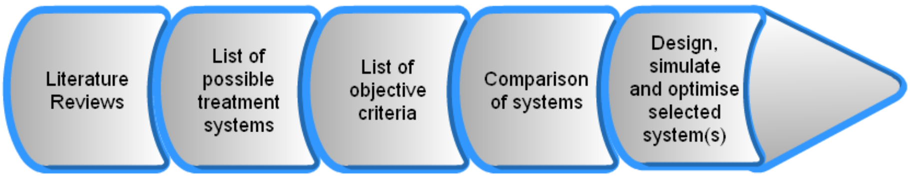
2.6. DEWATS: A decentralized water treatment system involves three stages: primary stage, secondary stage and tertiary stage.

2.7. Composting toilet: Dry system, which consists of two collection chambers. The chambers are properly ventilated to reduce excessive liquids. Through separation, the composting process can be simplified. The organic matter is degraded via aerobic degradation and can reduce the volume of the excreta by 70- 90%. These toilets can be used to composite excreta on site.

3. Methodology

Figure 1 below shows the major steps that were carried out throughout the project. The initial literature review investigated the emergency sanitation response efforts in Haiti post the 2010 earthquake. Sources for the literature reviews included NGO reports, scientific papers and consultations with experts in the field. A PESTEL analysis was performed on Haiti.

Figure 1. Methodology



The secondary literature review considered the available and emerging waste water treatment techniques. The possible systems were analysed and compared based on identified needs and requirements of a treatment system in a disaster area. The comparison was divided according to the type of systems: *decentralized network system* or *stand alone units.* A comparison matrix was constructed. The five most important factors for successful waste water management technologies used for comparison were as follows;

- Energy requirements
- Space requirements
- Cost to construct system
- Time to construct system
- Frequency of de-sludging

In addition, the following factors were used for further analysis;

- Efficiency of treatment (effluent produced by the system);
    - Flow rate
    - Pathogens levels
    - COD
    - BOD
    - TSS levels
    - Total P
    - Total N
- Maintenance requirements (including time, cost, skilled works and on-going supplies)
- Origins of materials required
- Robustness/ stability of the system
- The expected life of the system
- Additional benefits to society
- Cultural constraints

The most favourable system is simulated using the *Corail* IDP camp in Haiti and the standard UN size IDP camp block of 1250 people as the basis for simulation. Using the standard of 1250 people allows the results of this study to be adapted to other IDP camps in the future.

4. Results and Discussion

4.1.Influent Characteristics

The following parameters are used to estimate the influent flow rate and characteristics to the composting toilet and the DEWATS;

- Average volume of urine and faeces produced per person per year
- Amount of grey water produced
- Average values for person equivalents (Dr. Masi, 2011)

The total amount of influent to the composting toilet (urine with flush ad faeces) can be seen in Table 1 and specifications for influent characteristics used can be seen in Table 2. On average, a person produces 1.4 L urine/day and 0.1 L faeces/day. The amount of grey water produced for the DEWATS is estimated to be 7 L/person/day, including 3 L for flushing per person per day (based on 1 L per flush and 3 flushes per day) and 4 L available for hygienic needs. The hygienic needs mainly include water used for washing hands and bathing. (The SPHERE, 2011) The grey water is not included in the scope of this project, but the volume needed for hygiene is included for the purpose of estimating influent flow rates and characteristics. This estimation is assumed to give a more realistic view of the use of the DEWATS. Basic needs and cooking needs are however not considered for the calculation. Basic needs include drinking water and water for cooking is assumed to be mainly consumed in the process.

Table 1: Volume produced for the composting toilet and DEWATS

	Composting Toilet (faeces)	Composting Toilet (urine)	DEWATS
Urine (L/person/day)	0.0	1.4	1.4
Faeces (L/person/day)	0.1	0.0	0.1
Water from flushing (L/person/day)	0.0	1.5	3.0
Water for basic hygienic needs (L/day)	0.0	0.0	4.0
TOTAL VOLUME (L/person/day)	0.1	2.5	8.5

Table 2: Influent characteristics for a UN standard size block

	Composting Toilet (faeces)	Composting Toilet (urine)	DEWATS
Number of people	1,250	1,250	1,250
Volumetric flow (m3/day)	0.1	3.6	10.6
N (mg/L)	8,219	2,409	966
P (mg/L)	4,109	283	161
COD (mg/L)	396,067	3,487	9,906
BOD (mg/L)	198,033	1,743	4,593
TSS (mg/L)	NDA*	NDA*	6,441

*NDA: No Data Available

4.2. Comparison and Selection of Systems

4.2.1 Stand Alone Units

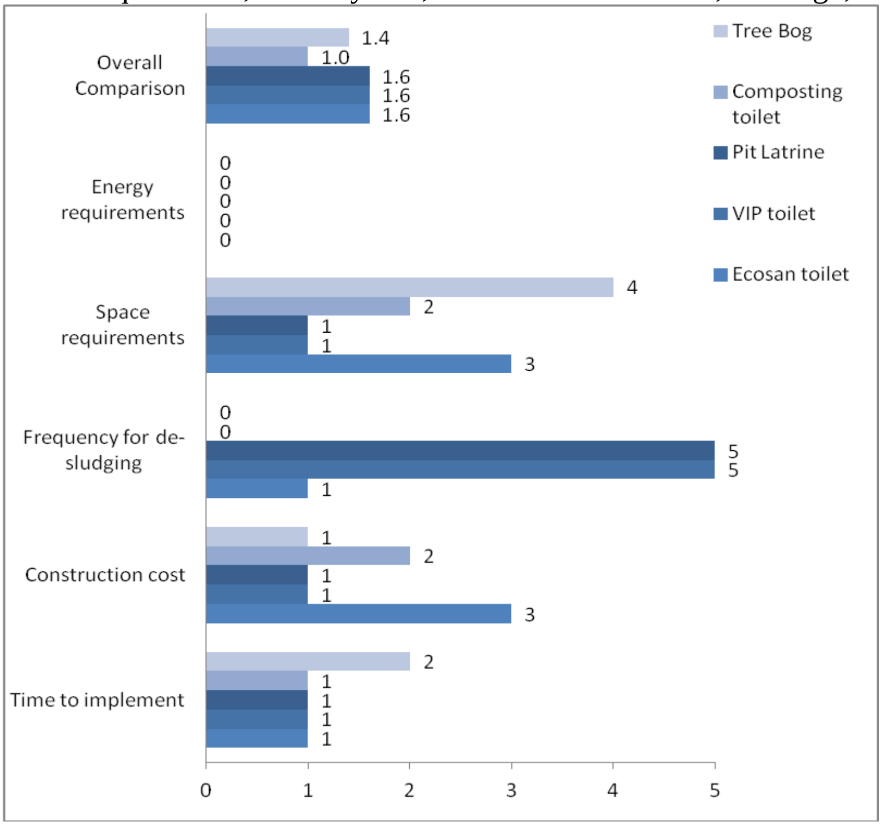
The stand-alone units that pass through the selection criteria were pit latrines, VIP toilets, composting toilets, treebog and Ecosan toilets. For a quick overview of the comparison, a ranking system on scale from 1 to 5 (0 = no requirement, 1 = very low, 2 = low 3 = medium, 4 = High, 5 = very high) is used, shown in Figure 2

.

However, the composting toilet are slightly cheaper, demand slightly less area, requires no water for flushing of faeces and materials mainly be found locally. Diversion is advisable for more efficient composting by aerobic degradation. The separated urine has high nutrient content and less pathogens, thus it can be used as fertiliser. The composting toilet is chosen for further study.

Figure 2: Comparison of stand-alone systems

Ranking: 0 = no requirement, 1 = very low, 2 = low 3 = medium, 4 = High, 5 = very high

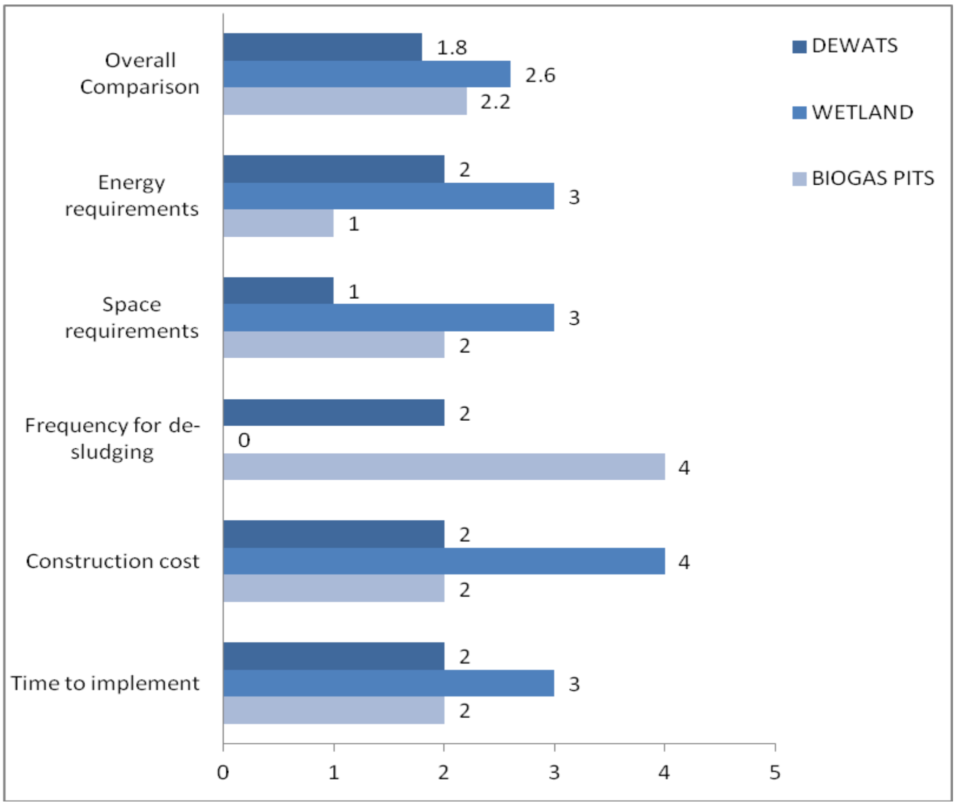


4.2.2. Decentralized Networks

The decentralized networks that passed through the selection criteria were DEWATS, constructed wetland and biogas pits. The same raking was done as described in stand-alone units. The result of ranking is shown in Figure 3.

The influent characteristics requirements for efficient biogas production in biogas pit are high BOD values, meaning no grey water mixing to the black water. For wetland, low SS concentrations in the influent are necessary to avoid clogging. A primary treatment is therefore necessary for the wetland. The DEWATS system can treat any kind of black water even highly settleable solids, grey water and industrial water. Furthermore, one unit is sufficient to treat black water from one UN standard size block of 1250 people, it has low space requirement (excluding tertiary treatment) and low energy requirement. The process of implementing the DEWATS is relatively fast, which is important as a midterm response for disaster area. The DEWATS is therefore chosen for further study.

Figure 3: Comparison of decentralized networks
Ranking: 0 = no requirement, 1 = very low, 2 = low 3 = medium, 4 = High, 5 = very high

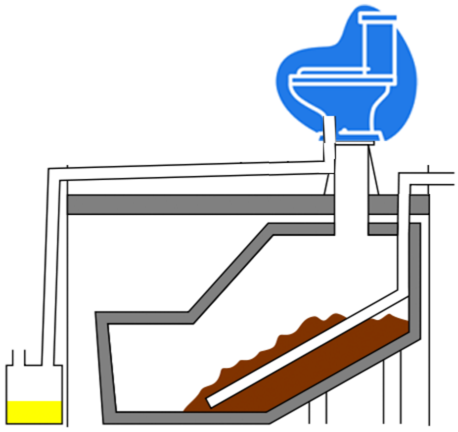


4.3. Design of Chosen Systems

4.3.1 Stand- alone unit: Composting Toilet

The chosen stand-alone unit is the composting toilet system based on a design recommendation from Sustainable Organic Integrated Livelihoods (SOIL), an NGO working in Haiti. One unit can treat waste from 25 people. The system involves faeces and urine separation Figure 4. The urine is stored in urine storage tank and then used directly as a fertilizer, while the faeces are decomposed via an aerobic process. There is no water or energy requirement for this system. Maintenance requirements include adding sawdust (or other carbon-rich material) to the toilet to ensure appropriate C:N (carbon:nitrogen) ratio and mixing the compost. (Jenkins, 2005) The low cost, production of fertilizer and low energy requirements are some of the main benefits and the determining reasons why the composting toilet was chosen as a possible option to design and simulate for a standard UN sized block of 1250 people and implemented in Corail Sector 4 in Haiti.

Figure 4: Composting toilet



The design of the soil composting toilet involved the creation of an MS Excel spreadsheet, which investigated a range of different possible solutions.

The amount of waste produced by each standard IDP block was considered. Based on the simulation, 84 faeces collection bins will be filled by a standard IDP block in the 3 month composting period. While 7 urine collection bins will be filled by a standard ISP block per day. The urine storage tank can hold 150m^3 of urine for the incubation 6 month period. Thus a standard IDP block required 3 urine storage tanks.

The number of toilets within a standard IDP block depends on the amount of labour available at the camp and the available space for toilets and area for the compost to decompose. Table 3 shows the area requirements for faeces composting depending on the frequency of bin changes and number of people per toilet determined above.

Table 3: Number of people per toilet in relation to composting time and area requirement

Number of people per toilet	Composting time (days)	Total Area Required for compost (m^2)	Total Area Required (m^2)
10	70	170	1070
20	37	133	1033
30	24	125	1025
50	14	120	1020

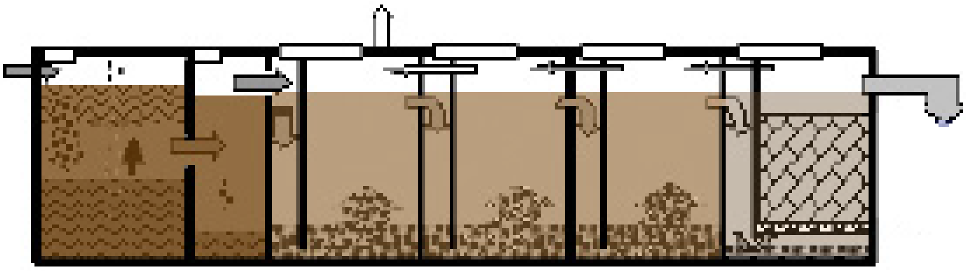
Table 3 above shows that the area required decreases with a decreasing number of toilets. The best option for any IDP camp is to have the maximum number of toilets which can fit within the camp area.

4.3.2 Decentralized Network: DEWATS

The chosen *decentralized network* is the DEWATS and specifications on design and operation can be obtained from the publication *DEWATS - Decentralized Wastewater Treatment in Developing Countries* (Sasse, 1998). A system has also been built by Auroville Centre for Scientific Research (CSR) CSR in Auroville, India (Beatens, 2011). The DEWATS aims to provide an efficient, low-cost and low-maintenance solution for areas where connecting to traditional sewage systems is not an option.

The system can treat waste water flows in the range of 1–500 m3/day. There are four major treatment steps; primary treatment (septic tank with screen), secondary anaerobic treatment (baffle tank and anaerobic filter), tertiary anaerobic treatment (constructed wetlands, sub-surface filters or vortex) (See Figure 4). Neither technical skills for operation and maintenance nor energy is required for the system to work efficiently. The low cost, low maintenance and low energy requirements are some of the main benefits and the determining reasons why the DEWATS was chosen as a possible system to design and simulate for a standard UN sized block and implemented in *Corail Sector 4*. To implement the DEWATS, regular toilets can be used as interfaces and a network to connect to the system is needed.

Figure 5: Schematic of the DEWATS system using
a septic tank an anaerobic baffle tank an anaerobic filter



In order to design DEWATS, the inlet flow rate and influent characteristics were calculated (see section 4.1 for more detail). Table 14 shows the results of the calculation. The COD outflow obtained from the initial designed based on the *MS Excel* spreadsheet calculations is 75 mg/L which corresponds to a 93% COD removal compared to the influent.

Table 4: Influent flow rate and influent parameters for DEWATS

Parameter	Value
Flow rate (m3/day)	10.6
Nitrogen (mg/L)	966
Phosphorous (mg/L)	161
COD (mg/L)	9,906
BOD5 (mg/L)	4,953
TSS (mg/L)	6,441
TSS/COD ratio	0.7
Faecal coliforms (per 100 mL)	10^8

To design the DEWATS system, the spreadsheets given by the DEWATS handbook were used as reference. The following decisions for the initial design were made according to design criteria of DEWATS and other recommendations in the handbook;

- Time of most flow was taken 12 hrs assuming water coming mostly during the day time.
- HRT was taken 1.5 hours for settler to prevent settling of all particles in the first unit (Metcalf&Eddy, 2003) and to provide good organic matter for microorganisms in further anaerobic process.
- For the initial design of the anaerobic baffled tanks, a depth of 1.5 m and a width of 0.75 m were taken as per guidelines in the DEWATS Handbook.
- According to Metcalf & Eddy (2003), adding baffled tanks increases removal efficiencies better compared to increasing the volume of existing tanks. Additionally, the DEWATS Handbook states that the number of baffled tanks should be at least four. The initial design of the system was made with five baffled tanks. Using the chosen depth and width of baffled chambers, the length and HRT was calculated accordingly.
- HRT requirement in the anaerobic filter is high in order to provide good biomass production. Therefore, HRT was taken to be 30 hrs which is within the recommended range of 24 to 48 hrs.

HRT is the most important parameter for optimizing the efficiency of BOD removal in the system. The HRT also determines the volume needed as volumetric flow rate is determined by the initial conditions (the required volume is calculated by dividing volumetric flow rate by HRT). Several other factors affect BOD removal in the anaerobic filter and baffled tanks such as wastewater strength and organic load.

4.4. Optimization and Simulation of DEWATS

The simulation focused on the primary and secondary stage of the treatment process. In order to design and optimize the system, simulation software was used. Computer simulation involves imitating a situation or situations through the use of mathematical, physical, or empirical models, in order to reproduce or predict real processes. For this project, the simulation software *BioWin* was utilized.

In Haiti, no general standards for effluent quality exist. In order to evaluate the performance of DEWATS, the Environmental Protection Agency (EPA) Secondary Treatment Standards (EPA, 2010) for pollutant limits are used (see Table 5)

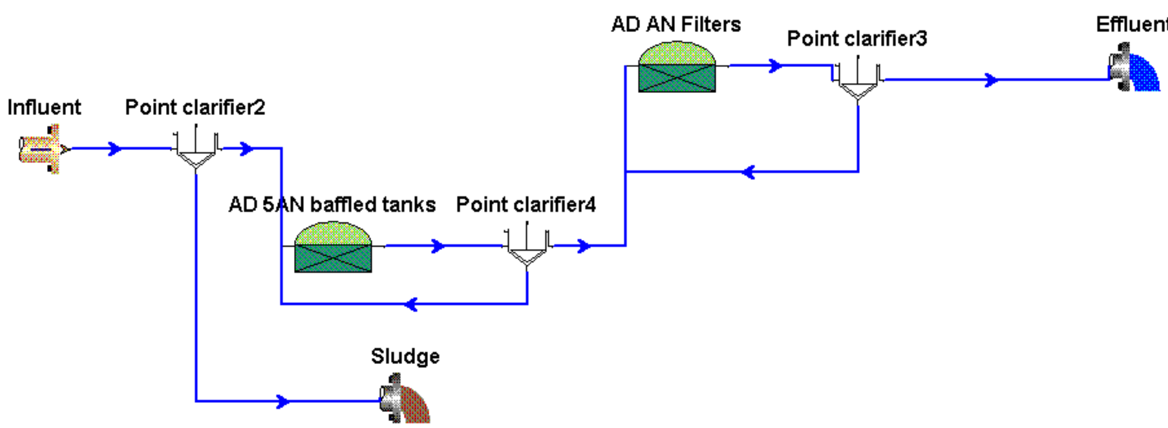
Table 5: Effluent characteristics of Secondary Treatment

Parameter	30-Day Average	7-Day Average
BOD_5	30 mg/L	45 mg/L
TSS	30 mg/L	45 mg/L
pH	6-9	-
Removal	85% BOD_5 and TSS	-

Based on the influent (see section 4.1) and effluent data (Table 5) the following substances need to be reduced: COD, BOD and TSS.

The DEWATS system was simulated using the model shown in Figure 6 and the configuration for the model is shown in Table 6. However, Table 7 below shows how the model results compare with the effluent criteria.

Figure 6: Model used for *BioWin* simulations



The excel spreadsheet calculation was used to size the units and to determine the HRT and the SRT. After calibrating each unit individually the below Biowin configuration was created.

Table 6: Configuration for DEWATS simulation in *BioWin*

BioWin Unit	**Parameter and Specifications**			
Clarifier 2	**Split Specification***	***de-sludging once a year**		
	1,00			
AD 5AN Baffled tank	Volume (m3)	Depth (m)	Width (m)	Head Space (m3)
	7,5	1,5	1	2
AD AN Filter	Volume (m3)	Depth (m)	Width (m)	Head Space (m3)
	13,8	1,5	2	3,6

Table 7: Comparison of effluent parameters from BioWin and MS Excel sheet with EPA Secondary Treatment Standard

Parameter	**Effluent from BioWin Simulation**	**Effluent from MS Excel sheet**	**EPA Standard**	
			30-Day Average	**7-Day Average**
BOD_5 (mg/L)	44	38**	30	45
TSS (mg/L)	39	NAD*	30	45
pH	6.8	NAD*	6-9	NAD*
BOD Removal Efficiency	99 %	99 %	85% BOD_5 and TSS	NAD*

*NDA: No Data Available
**COD/BOD ratio was taken 2

Table 8 below looks at how each of the reactors reduces the different compounds. From the table it can be seen that the Carbonaceous BOD is significantly reduced by the anaerobic baffled tank. The TSS and the total COD is significantly reduce by the anaerobic filter.

Table 8: Effluent characteristics from each unit of the DEWATS in the simulation

Parameter	**Influent**	**AD 5AN Baffled tank**	**AD AN Filter**	**Effluent**
Carbonaceous BOD (mg/L)	4953	5739	141	43
TSS (mg/L)	6442	24729	18718	38
Total COD (mg/L)	10410	32370	23006	628

4.5. Implementation of Systems in Corail Sector 4
4.5.1. Requirements in Corail Sector 4

According to the requirements for IDP camps specified by the SPHERE project, the maximum number of people per toilet should be 20 and the maximum distance to a toilet should be 50 meters. These were the two determining parameters when analyzing *Corail Sector 4* and the options for implementing an improved waste water treatment scheme for the camp. An economic analysis was then performed to find the optimum solution. The camp was divided into blocks based on an estimated number of people and the configuration of the camp in terms of existing roads (see Figure 7). The blocks are approximately standard UN sized blocks, but the analysis is primarily adjusted to fit the specific conditions in *Corail Sector 4*. Table 9 shows the estimated number of people per designated camp block, the area available, the number of toilets per person and the maximum distance to the toilets.

Figure 7: *Corail Sector 4* divided into blocks

Table 9: Analysis of needs of waste water treatment scheme in *Corail Sector 4*

Block no.	Estimated number of people	Area (m^2)	Area per person (m^2/person)	Required number of toilets	No. of clusters with toilets	No. of Toilets per cluster	No. of people per toilet	Max Distance to Toilets (m)
1	1,000	25,600	25.6	50	5	10	20	50
2	775	19,600	25.3	39	4	10	20	50
3	1,000	25,600	25.6	50	4	13	20	50
4	850	21,600	25.4	43	4	11	20	50
5	1,000	27,950	28.0	50	5	10	20	50
6	675	17,000	25.2	34	3	11	20	50

4.5.2. Implementation of DEWATS In Corail Sector 4

The DEWATS system costing was based on construction of a ferrocement tank, with material costs based on a “School Construction Costs in Haiti” prepared by Schools for the Children of the World. No allowance was made for the actual toilets or sanitation wear. Table 10 below gives a break-down of the costs for each option.

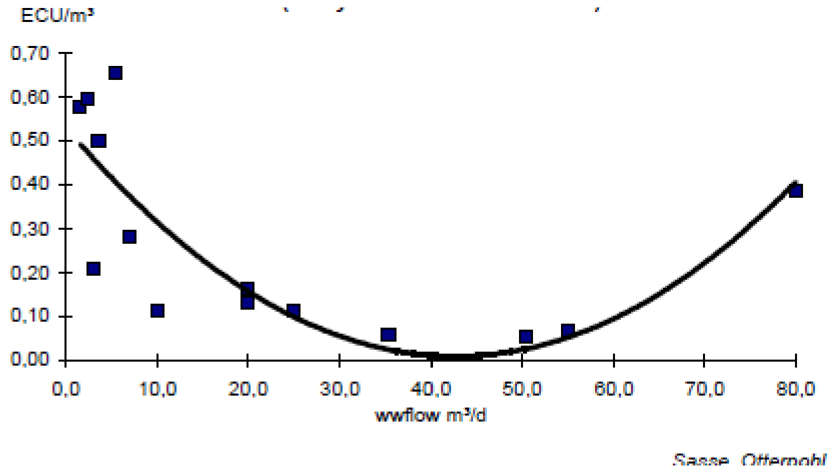
Table 10: Cost analysis of three options for DEWATS configurations

Option	Number of DEWATS units	Cost (US$)
1	3	29,713
2	2	29,896
3	1	29,459

Based on the cost break down above, option 3, with only one DEWATS is the most cost effective solution. This finding is in line with conclusion from the DEWATS handbook.

Figure 8 shows how the cost of waste water treatment is related to plant size. The optimum plant has a daily flow in the order of 40 m^3/day. In option 3 the plant flow rate is 45.1 m^3/day.

Figure 8: Cost of wastewater treatment in relation to plant size (daily flow of wastewater)



Based on the economic analysis, the best DEWATS scheme for *Corail Sector 4* is as shown in Figure 9 and specified Table 11.

Figure 9: DEWATS in *Corail Sector 4*

*Note: that toilets, pipes and DEWATS are not to scale.

Table 11: Implementation of DEWATS in *Corail Sector 4*.

	Length (m)	Height at beginning of pipe (m)	Height at end of pipe (m)	Height difference (m)	Number of toilets connected
Pipe 1	238	31	27	4	41
Pipe 2	336	34	27	7	43
Pipe 3	641	44	27	17	86
Pipe 4	651	46	27	19	96
Pipe 5	86	27	27	0	0
Pipe 6	147	27	27	0	0

*Note that pipe 1 is the most western pipe, pipe 4 the most eastern, pipe 5 connects pipes 1 and 2 and pipe 6 connects pipes 3 and 4.

4.5.3. Implementation of Composting Toilets in Corail Sector 4

Using the *MS Excel* composting toilet design spreadsheet, the space required for composting toilets at *Corail Sector 4* was calculated and is shown in Table 12.

Table 12: Area requirement calculation for composting toilet

Number of people per toilet	Area Required for toilets and compost (m^2)	Total Area Required (m^2)
10	719	3719
20	562	3562
30	530	3530
50	634	3634

The best option for Corail camp is to have the maximum number of toilets which can fit within the camp area. Based on research, the available space at Corail camp in the order of 7000 m^2 thus the optimum number of toilets per person would be 10.

This would mean that the faeces bins within the toilets need to be changed every 70 days and an area of 720 m^2 would be required for storing the matter to decompose. In addition 10 urine storage tanks (each 150m^3) will be required.

Figure 10: Composting toilets in *Corail Sector 4*. Note that toilets are not to scale.

Figure 10 shows a visualisation of how the composting toilets could be implemented in *Corail Sector 4* and Table 13 shows the results of the rough cost analysis of implementing this solution.

Table 13: Cost analysis of composting toilets in Haiti

Item	Item Cost (US$)	Number of units	Cost (US$)
Faeces storage bins	40	572	22,880
Urine Storage bins	40	562	22,480
Urine Storage tank	2,000	10	20,000
Faeces compost area	1,405	1	1,405
TOTAL COST			**66,765**

4.6. Discussion

The Corail IDP camp has existed for 1.5 years, however according to NGOs working in the camp, it is still considered temporary. As such, the systems analyzed in this report may not be consider appropriate for this camp, according to the NGOs, as they offer a more long term solution. However, according to finding of this report, the *Corail Sector 4* ICP camp will be required for several years and in order to overcome the current health and environmental issues, more permanent waste water treatment solutions are required.

The initial system selection method has some weaknesses. The report only focuses on the two most promising systems based our initial selection criterion. The main weakness of the method is that some systems may not appear appropriate from the initial review however may have been more appropriate if further analysis was carried out. The implication of this on the results is that the two systems may not be the only feasible solution for the camps, and further investigation would be required to determine the optimum solution.

4.6.1. Discussion of Composting Performance

The by-products of the composting toilet include the composted faeces and the sterilised urine. Aerobic composting normally gives efficient pathogen removal and the compost and the fertigation water can be used as fertilisers. There is no need for de-sludging. Because of this, the composting toilet mitigates the most prevalent risk in Haiti: the spread of pathogens to nearby waters while also offering additional benefits for the population. Composting toilets could have been used right from the start of the emergency relief in *Corail Sector 4*, but could also be implemented at this stage and work as a long-term solution. It is also a system that could easily be implemented in other emergencies as it does not depend on local conditions for it to work efficiently. The system does however rely on some knowledge of the user and although maintenance requirements are low, it is crucial that they are carried out properly.

In this project, the composting process was not simulated. Simulation of the composting could be beneficial, but as an accurate simulation of the composting is very difficult to achieve, the added value of this could be minimal. The reason why the simulation is challenging is because it is a biological process and many different factors affect the biological growth

4.6.2. Discussion on DEWATS Performance

The DEWATS efficiently removes pathogens and produces nutrient rich sludge with longer intervals (1–3 years) and continuous fertigation water from the system. The effluent parameters obtained from *MS Excel* and *BioWin* design and simulations are compared with *Secondary Treatment Standards of EPA*. The effluent BOD value achieves the EPA 7-Day Average BOD discharge value. However, the effluent obtained from *MS Excel* does not achieve the value for EPA 30-Day Average discharge value. Nevertheless, the BOD removal efficiencies achieved in both the design and simulation are high. TSS values obtained from the *BioWin* simulation is under the limit value of EPA.

The DEWATS design assumes several simplifications and adopts several design criteria recommended in the DEWATS handbook. The design gives initial guidelines and a detailed design in combination with a site visit is necessary for implementing this solution in *Corail Sector 4*. For example, the design relies on the natural grade of the area where the camp is located. The natural conditions determined the piping and the positioning of the toilets in relation to the DEWATS. These conditions should be confirmed. The simulation of the DEWATS performance in BioWin gives indications on the performance of the DEWATS in *Corail Sector 4*. Although BioWin is reliable software and the results of the simulation gives good indications of the performance, the DEWATS is relying on a biological process that is relatively sensitive to local conditions.

4.6.3. Response in CORAIL

The composting toilet is identified as the best *stand-alone* solution and the DEWATS is identified as the best *decentralised network* solution for *Corail Sector 4.* The IDP camp is expected to remain for several years and currently, problems along the waste water treatment schemes exist. The composting toilet and the DEWATS system are both effective at reducing pathogens. The composting toilet separates the urine from the faeces. A small amount of water is used for flushing the urine whereas no water is used for the faeces. The influent will therefore most likely be fairly constant in terms of volumetric flow and constituent concentrations. The DEWATS system can perform well even at varying influent condition. These factors ensure that the pathogen removal remains high for the two systems if operated and maintained well. Other benefits of both systems include the low energy and space requirements (excluding tertiary treatment for DEWATS), quick implementation time and ease of operation.

In *Corail Sector 4*, the composting toilet could have been an efficient system that could have been implemented directly from the time of the disaster to the long-term phase. It could also quickly replace the existing system (latrines that need de-sludging and potentially cause contaminants to leak to the ground water). The compost that is produced can directly be used as fertiliser. A possible challenge for the successful implementation of this system in *Corail Sector 4* is the fact that it requires decentralised maintenance and operation. The population within the camp therefore needs to have good knowledge and good practices in place. On the other hand, increased knowledge is necessary for decreasing the spread of cholera and other related diseases. Increased knowledge can also lead to increased sense of ownership of the system and thereby better care for the system.

The DEWATS is a decentralised network, meaning that the treatment of the camp is centralised to, in this case, one treatment unit. The treatment technique, like the composting toilet, does not require a connection to a central network. Instead a decentralised network connecting the treatment unit to the toilets throughout the camp is needed. The centralisation of the treatment to one location within the camp can increase the quality of maintenance and operation unit. One single unit can also provide treatment for a volumetric waste water flow up to 500 m^3/day, allowing for expansion of the camp and a varying use of toilets within the camp. Compared to the composting toilet, the DEWATS have higher demands for implementation in terms of cost, time and labour. An additional challenge of the DEWATS is the infrastructure for tertiary treatment.

5. Conclusions

Proper management of human waste in disaster are as saves lives and forms the first barrier to reduce the spread of cholera and other water borne diseases. Environmental and economic benefits can also be obtained by using innovative solutions, for example by returning the nutrient rich by-products to the soil. This is a very important aspect in Haiti as 66% of the population is employed within the agricultural sector while erosion and nutrient loss causes big problems. The current situations in Haiti show a lack of sustainable solutions, in mid- to long-term emergency response efforts. This study investigates alternative waste water treatment systems for IDP camps in general and in Haiti. Both stand alone systems and decentralised network systems are considered.

The investigation is narrowed down through selection criterion, to the two most feasible systems, the DEWATS and composting toilet. The feasibility of these two systems for IDP camps is proven through simulation and design. Through an economical analysis the two designs were developed for the Corail Sector 4 IDP camp.

This study only touched on several larger issues, which could be investigated in future research. It is recommended that a comparison is made between the current pit latrine systems utilised at *Corail Sector 4* IDP and the DEWATS and composting toilets proposed in this report. The comparison should consider the cost, effectiveness and area requirements of all the systems.

In regard to the DEWATS and composting toilets, more investigation can be carried out regarding tertiary treatment systems. This investigation could also consider the infrastructure required for end use of the by product.

Further simulation and design could be carried out regarding the composting toilet. This simulation could allow for the decrease of the faeces waste volume with time and thus giving a more accurate area requirement and cost estimates.

The maintenance cost of the DEWATS and composting toilets could be investigated in more detail; allowing for a full life cycle analysis of the systems to be carried out.

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Conflict of Interest

"The authors declare no conflict of interest".

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