Cost Estimates for 20-Seater Re-use Oriented Community Toilet Block

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on behalf of

German Technical Cooperation Agency's (GTZ) ecosan Program

gtz ecosan program
recycling oriented
wastewater management
and sanitation systems

Commissioned by:
Bundesministerium für
wirtschaftliche Zusammenarbeit
und Entwicklung

About this brochure

Content of this brochure is the sole responsibility of the author Mr. Martin Wafler. However helpful contributions and comments have been provided by Mr. Nanchoz Zimmermann, seecon gmbh, and are gratefully acknowledged.

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ABBREVIATIONS

ABR	Anaerobic Baffled Reactor
AF	Anaerobic Upflow Filter
BOD	Biological Oxygen Demand
HFCW	Horizontal Flow Constructed Wetland
PP	Polishing Pond

1 OBJECTIVES OF THIS BROCHURE

The objective of this brochure is to provide a cost estimate for an eco-friendly 20-seater toilet centre inclusive treatment and reuse of various flow streams such as treated wastewater, source-separated urine and biogas generated in the process of anaerobic degradation of organic matter.

2 OUTLINE OF COLLECTION, TREATMENT AND REUSE CONCEPT

A single-storeyed sanitation block having two independent enclosures for female and male users shall serve resident population (i.e. children, females, males, elderly, etc.) living nearby and passers-by in a peri-urban setting in India.

Each enclosure is equipped with 10 bucket-flush squatting-type toilets. No water taps are provided within the toilet cubicles, but central water stands (i.e. water tanks) are installed in each enclosure for fetching water. Waterless urinals are provided in the gents' compartment for the source-separate collection of urine, which is drained into a collection tank outside the toilet block; while the ladies' compartment has squatting-type urinals that drain to the treatment plant. Once a week the collection tank is emptied (using a non-corrosive pump) into one of 4 storage/hygienization tanks situated on a raised platform. After a hygienization period of 3 weeks the urine can be applied as nitrogen–rich liquid fertilizer on e.g. a banana plantation, the kitchen garden, etc. The urine collection tank is provided a fail-safe overflow emptying to the anaerobic treatment plant.

Toilet water (i.e. blackwater) along with greywater (i.e. wastewater from all non-toilet fixtures) is discharged via a covered gutter, running in-between the enclosures, to an on-site wastewater management plant comprising an Anaerobic Baffled Reactor (ABR), an Anaerobic Upflow Filter (AF), a Horizontal Flow Constructed Wetland (HFCW) and a Polishing Pond (PP).

The ABR comprises an integrated sedimentation chamber (i.e. the first chamber) for solid-liquid separation by means of sedimentation and/or floatation. Retained organic solids are subjected to anaerobic decomposition. The supernatant water is drained by gravity flow to an AF for further anaerobic treatment. Post treatment of the AF effluent happens in a small-scale HFCW. The final stage of the treatment concept is a shallow pond that doubles-up as storage tank.

Green house gas emissions from biogas plants and commonly applied anaerobic on-site wastewater treatment systems such as septic tanks, baffled reactors, etc. are usually considered as negligible. But, every anaerobic wastewater treatment plant, independent of its size, constitutes to the global warming potential if it is not properly designed, built, operated and maintained and if it is either not equipped with a gas cover or the gas is simply released to the atmosphere without flaring after collection. With anaerobic, reuse-oriented wastewater management schemes getting more and more popular, it is therefore of paramount importance not only to provide for their cultural, social and economic sustainability, but also focus on the environmental sustainability with particular regard to green house gas emissions and climate issues. Therefore, unlike conventional ABRs where biogas generated in the process of anaerobic degradation of organic matter is released to the atmosphere, this ABR is designed and built for recovery of biogas, which will be used as a substitute to electricity in lighting the toilet centre in wee hours and night time. In order to provide for a constant gas pressure, biogas is stored in a rubber balloon gasholder.

3 ASSUMPTIONS AND DESIGN PARAMETERS

The community based toilet block is situated in a peri-urban setting in India and serves resident population (i.e. children, females, males, elderly, etc.) living nearby and passers-by. Number of daily visitors to the toilet centre is set with ca. 800 heads for defecation and ca. 1,100 heads for urination (split into 600 visits from females and 500 visits from males).

It has to be stated that, although set in all conscience, assumed number of users to the toilet centre is totally notional and may vary in reality.

For example, the same 20-seater toilet block, that in the given setting serves an estimated population of 800 heads for defecation and ca. 1,100 heads for urination per day, may serve 60 resident girl and 80 resident boy students attending boarding school. According

table 1: Minimum numbers of sanitary conveniences for girl and boy pupils according to Indian Standards

Type of sanitary convenience	**Day-school**		**Boarding-school**	
	Girls	**Boys**	**Girls**	**Boys**
Toilet	1 per 25	1 per 40	1 per 6	1 per 8
Urinal	-	1 per 20	-	1 per 25

to Indian Standards, minimum numbers of sanitary conveniences for girl and boy pupils is 1 per 40, 25 and 8 and 6 for day schools and boarding schools/educational institutions, respectively. The 20-seater toilet block may therefore serve an additional 190 girls and 320 boys attend day school on a regular basis. Limiting total number of student served to 650 per day.

3.1 Average daily blackwater production and BOD contribution

It is assumed that about 800 people (split into 300 female and 500 male usersare using the toilet block on a day in, day out basis for relieving them.

Planning and design of the wastewater management system is based upon 5 litres of water (anal cleansing and flushing), 250 grams faeces along with 25 grams biological oxygen demand (BOD) per user per day [1]. Total daily **blackwater production** and **BOD load** is therefore **4,000 litres per day** (4.0 m^3/d) and **20,000 grams per day** (20.0 kg/d).

3.2 Average daily yellowwater (urine) production

Due to the non-availability of properly designed water-less female urinals collection of urine from females is (for the time being) not foreseen, but urine (cum cleansing water) is discharged to the treatment plant and treated along with blackwater and greywater.

It is estimated that about **500 litres** (i.e. 0.5 m^3/d) of **urine mixture** (i.e. urine cum cleansing water) **per day** will be collected from the female urinals and discharged to the treatment system.

Source-separated urine from water-less male urinals is collected, stored for hygienization and used as a nitrogen-rich liquid fertilizer.

It is estimated that about **150 litres** of source-separated **urine per day** will be collected from male's water-less urinals.

3.3 Average daily greywater production (washbasins, cleaning of toilet, etc.)

For estimation of average daily greywater production a specific greywater production of 1.5 litres per person per toilet/urinal visit is considered. Total daily number of visits to the toilets/urinals is set to be 1,900. Total daily greywater production from washbasins is estimated to be about 3,000 litres (i.e. 3.0 m^3/d). About 500 litres (i.e. 0.5 m^3/d) are spent on cleaning the toilet block.

Total daily **greywater production** is estimated to be about **3,500 litres** (i.e. 3.5 m^3/d).

3.4 Mean daily and peak hourly flow

Daily total wastewater flow (blackwater, urine mixture and greywater) is about **8,000 litres** (i.e. 8.0 m^3/d). Peak hourly flow is assumed to be **2,000 litres per hour** (i.e. 2.0 m^3/h).

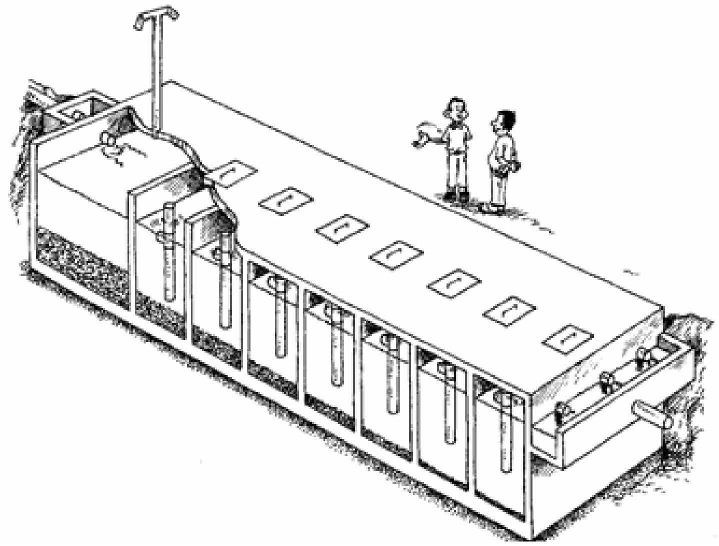
Based upon an estimated daily BOD load of 20.0 kg, average BOD concentration of the raw wastewater is calculated to be 2,500 mg/l.

4 DETAILS OF TREATMENT AND REUSE CONCEPT

4.1 Treatment

4.1.1 Anaerobic Baffled Reactor

In Anaerobic Baffled Reactors (ABR), a number of mechanical and anaerobic cleansing processes are applied in sequence. The reactor consists of different chambers (connected in series) in which the wastewater flows up-stream. On the bottom of each chamber activated sludge is located. During inflow into the chamber wastewater is intensively mixed up with the sludge and wastewater pollutants are decomposed. In the first chambers the easily degradable substances are removed. In the following chambers, substances, which are less easily biodegradable, are removed. The more chambers are applied the higher the performance. The design shown below includes an integrated sedimentation chamber for pre-treatment [2].



(source: [2])

figure 1: Cut-away view of anaerobic baffled reactor

Green house gas emissions from biogas plants and commonly applied anaerobic on-site wastewater treatment systems such as anaerobic baffled reactors are usually considered as negligible. But, with anaerobic, reuse-oriented wastewater management schemes getting more and more popular, it is of paramount importance not only to provide for their cultural, social and economic sustainability, but also focus on the environmental sustainability with particular regard to green house gas emissions and climate issues. Therefore, unlike conventional ABRs where biogas ventilated to the atmosphere, this ABR is designed and built for recovery of biogas. A common concrete slab covering the sedimentation chamber and the baffle chambers renders the treatment plant gastight and allow for recovery of most of the biogas generated. Anticipated daily biogas production from the sedimentation compartment and the ABR is ca. 3.0 m^3 and 6.0 m^3, respectively. In order to provide for a constant gas pressure, biogas is stored in a rubber balloon gasholder having a storage capacity equalling one-days biogas production (i.e. 9 m^3).

The useable volume of the settlement compartment is 8.0 m^3. Clear length and width of the settlement compartment are 2.80 m and 1.60 m, respectively. Water depth is 1.80 m. The anaerobic baffled reactor comprises of 5 compartments each having a volume of ca. 4.5 m^3 (length/width/depth of water level = 1.20 m/1.60 m/1.80 m).

4.1.2 Anaerobic Upflow Filter

An Anaerobic Upflow Filter (AF) is a fixed-bed biological reactor. As a stand-alone treatment system the AF consists of a sedimentation tank or septic tank followed by the filter chambers. But, an AF can also be an advanced treatment step downstream e.g. an ABR. As wastewater flows through the filter, particles are trapped and organic matter is degraded by the biomass that is attached to the filter material.

The anaerobic up-flow filter volume is ca. 12.8 m^3. The up-flow filter comprises 4 compartments of ca. 3.2 m^3 each (length/width/depth of water level = 1.55 m/1.20 m/1.70 m). The height of the filter media (gravel of 45 mm diameter) is 0.75 m.

4.1.3 Horizontal Flow Constructed Wetland

Length and width of the horizontal flow constructed wetland is 12.00 m by 6.00 m. Main filter media is fine gravel with a grain size of 4 – 8 mm. Height of filter media (at inlet) is ca. 0.70 m. Saturated water depth is ca. 0.60 m.

4.1.4 Collection pond

The pond has an effective volume of 16 m^3 at a maximum depth of about 1.20 m.

4.1.5 Urine storage/hygienization tanks

Source separated urine from waterless urinals is drained to a collection tank outside the toilet block. Once a week the collection tank is emptied (using a non-corrosive pump) into one of 4 one-m^3 storage/hygienization tanks situated on a raised platform. The capacity of the storage tanks is chosen to provide for a hygienization period of 3 weeks.

4.2 Reuse

4.2.1 Reuse of water

Final effluent is used for watering a small kitchen garden and irrigation of e.g. (Hybrid) Napier grass (also referred to as "elephant grass" due to its tallness and vigorous vegetative growth, "Sudan grass" or "king grass"), which is an improved fodder grass that produces a lot of high-protein forage, or a banana plantation.

4.2.1.1 About (Hybrid) Napier grass

Information on (Hybrid) Napier grass is taken from [3]:

The grass grows throughout the year in the tropics. The optimum temperature is about 31ºC. Light showers alternated with bright sunshine are very congenial to the crop. Total water requirement of the grass is about 800 - 1,000 mm. Hybrid Napier grass (i.e. Hybrid Pennisetum) can grow on a variety of soils. Light loams and sandy soils are preferred to heavy soils. The grass does not thrive well on waterlogged and flood prone lands. Phenomenal yields are obtained from very deep fertile soil rich in organic matter. It tolerates pH ranging from 5 to 8.

A spacing of 60 x 60 cm is recommended for pure crop of Hybrid Napier. In intercropping system, spacing is adjusted to accommodate the companion crops. The planting rate depends upon the spacing and the weight of the cuttings or rooted slips used. It is modified in crop mixtures or intercropping with other forage crops. Farm yard manure @ 25 t/ha, and P_2O_5 and K_2O @ 50 kg/ha each may be applied at the time of land preparation. Apply N @ 200 kg/ha in two or three split doses followed by gentle raking, if possible.

The first cut is taken 9 - 10 weeks after planting. Subsequent cuts are taken after four to six weeks or when the plant attains a height of 1.5 m. Annually at least six to eight cuts are possible. In order to encourage quicker regeneration from the basal buds, stubbles of 10 - 15 cm is left out at harvest. Green fodder yield ranges 200 - 250 t/ha per year from 6 to 8 cuttings.

4.2.2 Reuse of urine

4.2.2.1 Commonly applied artificial fertilizers

Commonly applied artificial fertilizers and there nutrient/chemical agent (P_2O_5, K_2O, etc.) content are listed below (source [4]):

Nitrogen fertilizers:

- Ammonia (80% N)
- Ammonium Sulphate (21% N)
- Ammonium Bicarbonate (17% N)
- Calcium Nitrate (16% N)
- Sodium Nitrate (16% N)
- Ammonium Nitrate (about 34% N)
- Ammonium Sulphate Nitrate (26-30% N)
- Urea (45-46% N)
- Calcium Cyanamide (20% N)
- Nitrophosphate = NP (20-23% N, 20-23% P_2O_5)
- Monoammonium Phosphate = MAP (11% N, 52% P_2O_5)
- Diammonium Phosphate = DAP (18% N, 46% P2O5)
- liquid Ammonium Polyphosphates (e.g. 12% N, 40% P_2O_5)
- NPK
- etc.

Phosphate fertilizers:

- Single Superphosphate (18-20% P_2O_5)
- Triple Superphosphate (45% P_2O_5)
- partly acidulated Phosphate (23-26% P_2O_5)
- Rock Phosphate (finely-powdered soft type, e.g. 30% P_2O_5), with reactivity indicated by formic acid-solubility; permitted minimum is about one-half of total P_2O_5 content)
- NP
- PK (mixtures very commonly used)
- NPK

- etc.

Potash fertilizers:

- Potassium Chloride or Muriate of Potash (40-60% K_2O)
- Potassium Sulphate (50% K_2O)
- Potassium Magnesium Sulphate also known as Sulphate of Potash Magnesia or Patentkali (e.g. 40% K_2O, 6 % Mg)
- etc.

4.2.2.2 Fertilizer equivalent of human excreta

The very basic objective of faecal matter and urine management is to provide sustainable, socially acceptable and hygienically safe sanitation concepts that allow for the reuse and application of recyclates (sanitised human excreta) in agricultural production.

Human urine contributes the largest share of nutrients to household wastewater. If no phosphate detergents are used, at least 60% of the phosphorus and 80% of the nitrogen in household wastewater comes from urine. The total quantities of nutrients in human urine are significant when compared with the quantities of nutrients in the mineral fertilisers used in agriculture [5]. By source-separating human urine, the amounts of nutrients recycled on arable land can be significantly increased while at the same time the nutrient load of wastewater can be significantly reduced. Furthermore, the use of recycled toilet products as fertilisers will reduce the use of chemical fertilisers containing the same amounts of nutrients, as well as the resources (energy etc.) needed to produce and distribute them [6]. A further advantage of using human urine instead of chemical fertilisers or sewage sludge is the very low concentrations of heavy metals found in urine [6]. Although faeces contain fewer nutrients than urine, they are a valuable soil conditioner. After pathogen destruction through dehydration and/or decomposition, the resulting inoffensive material can be applied to the soil to increase the organic matter content, improve water-holding capacity and increase the availability of nutrients [7].

table 2: Estimated excretion of nutrients per capita per year in India

	Nitrogen [kg/cap,yr]	Phosphorus [kg/cap,yr]	Potassium [kg/cap,yr]
total	2,7	0,4	1,5
urine	2,3	0,3	1,1
faeces	0,3	0,1	0,4

(source: [8])

Based upon FAO (Food and Agriculture Organization) statistics on the food supplied, the average excretion of nutrients per capita per year in India is estimated to be 2.7 kg Nitrogen, 0.4 kg Phosphorus and 1,5 kg Potassium (table 2).

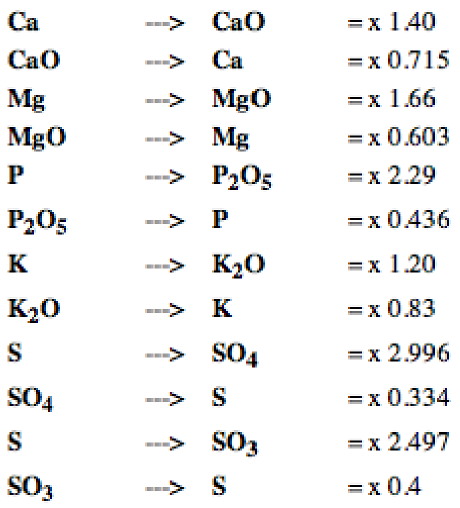
Say ca. 55,000 litres of urine are collected per year (equals the amount of urine excreted by 110 people per year), the fertilizer equivalent in regard to Nitrogen, Phosphorus and Potassium is ca. 250 kg/yr, ca. 30 kg/yr and about 120 kg/yr, respectively (see table 3).

table 3: Estimated nutrient content in collected urine

Nitrogen [kg/yr]	Phosphorus [kg/yr]	Potassium [kg/yr]
ca. 250	ca. 30	ca. 120

Factors for conversion of pure nutrients to chemical agents (P_2O_5, K_2O, etc.) and vice versa are summarized in table 4.

table 4: Conversion factors



Ca	--->	CaO	= x 1.40
CaO	--->	Ca	= x 0.715
Mg	--->	MgO	= x 1.66
MgO	--->	Mg	= x 0.603
P	--->	P_2O_5	= x 2.29
P_2O_5	--->	P	= x 0.436
K	--->	K_2O	= x 1.20
K_2O	--->	K	= x 0.83
S	--->	SO_4	= x 2.996
SO_4	--->	S	= x 0.334
S	--->	SO_3	= x 2.497
SO_3	--->	S	= x 0.4

(source: [9])

250 kg N are contained e.g. in ca. 540 kg Urea (@ 46% N), ca. 1200 kg Ammonium Sulfate (@ 20.6% N) or ca. 740 kg Ammonium Nitrate (@ 33.5% N).

30 kg P are contained e.g. in 430 kg Single Super Phosphate (@ 16% P_2O_5) or 240 kg Rock Phosphate (@ 28.4% P_2O_5).

120 kg K are contained e.g. in 240 kg Murate of Potash (@ 60% K_2O).

table 5: Common artificial fertilizer equivalent of collected urine

	Nitrogen	Phosphorus	Potassium
Urea [kg]	540	-	-
Ammonium Sulfate [kg]	1,200	-	-
Ammonium Nitrate [kg]	740	-	-
Single Super Phosphate [kg]	-	430	-
Rock Phosphate [kg]	-	240	-
Murate of Potash [kg]	-	-	240

4.2.2.3 Nutritional requirements of common field crops and fruit trees

The size of agricultural land required for application of urine according to “conventional” fertilizer recommendations is exemplified for the cultivation of banana trees and based upon common fertilizer recommendations and the conversion of the recommendation into Nitrogen (N), Phosphorus (P) and Potassium (K). Dosing of nutrients (full dose, split doses) is not taken into consideration.

For the cultivation of banana trees it is recommended to give 180 g N, 108 g K_2O and 225 g P_2O_5 per sucker per growing season and 100 g N, 108 g K_2O and 200 g P_2O_5 per ratoon crop. [10] 1 kg P_2O_5 and K_2O contain ca. 0,44 kg P and 0,83 kg K, respectively.

Common life cycle of banana plants is 5 years, therefore 1/5 of all plants of a plantation are suckers and 4/5 ratoon crops. Average nutritional requirements of a banana plant equal 116 g N, 48 g P and 170 g K per growing season.

table 6: Nutritional requirements of common field crops and fruit trees

plants	FYM [kg/plant,yr]	Nitrogen [g/plant,yr]	Phosphorus [g/plant,yr]	Potassium [g/plant,yr]
pineapples	n.d.	12	1.8	10
cashewnuts *	n.d.	500	55	105
mango **	50	1,000	500	1,000
sapota ***	70	100	500	500
papaya ****	n.d.	200 - 350	200 - 300	200 - 600
bamboo *****	n.d.	40	4.4	62.2

FYM	farmyard manure (i.e. decomposed mixture of cattle dung and urine with straw and litter used as bedding material and residues from the fodder fed to the cattle) [11]
n.d.	no data
*	from the 3rd year onwards
**	from the 10th year onwards [12]
***	from the 7th year onwards [12]
****	depending on varity [12]
*****	in 1 to 2 year old plantations [13]

Based upon the nutrient content of the collected urine (see table 3) and the nutritional requirements in regard to Nitrogen, Phosphorus and Potassium about 2,100, 600 and 700 banana plants may be cultivated, respectively. Taking possible Nitrogen losses into consideration about 600 banana trees can be fertilized.

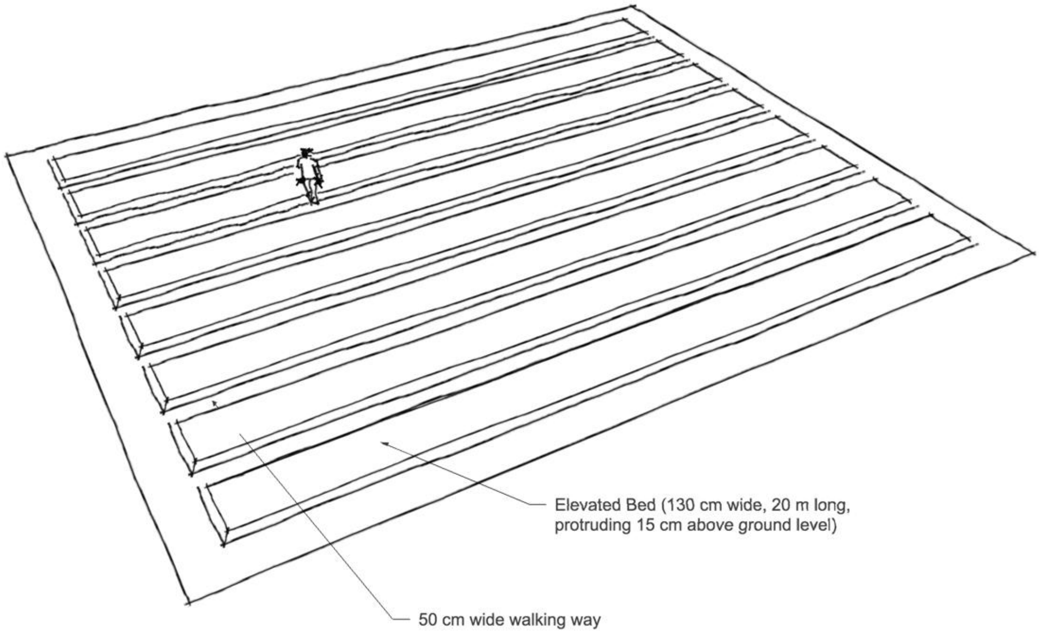
At a common density of 4,500 plants/ha [5] (practiced e.g. in Maharashtra and Gujarat), the surface area of the plantation is 0.14 ha (1,400 m^2).

4.2.2.4 Kitchen garden

Kitchen garden can come in any shape and size. The layout of a kitchen garden may be done in such a way that it fits local site conditions (e.g. space available, etc.) best.

A common size for a single-family kitchen garden is about 300 m^2 (20 meter by 15 meter). The garden comprises 8-raised bed of 1,30 m width and 20 m length. The beds shall be raised about 0,15 m above the surrounding soil to prevent flooding during rainy season. Between and surrounding the beds walking ways of 0,50 m width shall be provided for ease of access [8].

Common sowing and transplanting times and the harvest period for selected vegetables (i.e Bitter Gourd, Brinjal, Chillies, Cucumber, Mungbean, Okra, Sweet Corn and Tomato) are summarized in table 10. For site specific times refer to or contact agricultural specialists (e.g. local Agricultural Universities or Colleges, Extension Centres, etc.).



(source: M. Wafler)

figure 2: Schematic diagram of single-family kitchen garden

Spacing of plants and their mean average number per bed (at a length of 20 meters) are given in table 7.

table 7: Common spacing and number of plants per bed

vegetable	**rows**	**distance between rows [cm]**	**distance between plants [cm]**	**plants (20 m long bed)**
Bitter Gourd	2		50	80
Brinjal	2	70	40	100
Chillies	2	60	60	66
Cucumber	2		40	100
Mungbean	3		5	1,200
Okra	2	70	40	100
Sweet Corn	2		30	132
Tomato	2	70	40	100

4.2.3 Reuse of biogas

4.2.3.1 LPG equivalent of biogas

Conversion of daily biogas production into LPG (Liquefied Petroleum Gas) equivalent is based upon the calorific values of biogas and LPG, a mixture from Butane and Propane. The calorific value of Butane, Propane and biogas are 13.6 kWh/kg, 13.9 kWh/kg and ca. 6.0 kWh/m^3, respectively [14].

Energy from 9.0 m^3 biogas is ca. 54 kWh_{biogas}, which is equivalent to 3.9 kg LPG (@ 13.75 kWh/kg; the mean calorific value of LPG) or ca. one-fourth cylinder of LPG (@ 14.2 kg of LPG per container). The estimated annual biogas production of ca. 3,300 m^3 (equals 1,400 containers of LPG) is worth INR. 560,000 (@ present costs of about Rs. 400 per cylinder).

4.2.3.2 Direct usage of biogas for lighting

Most biogas burners and lamps operate at a gas pressure of 8 to 10 cm [7] and 5 to 15 cm [6] water column, respectively. In order to provide for a constant gas pressure, biogas is stored in a rubber balloon gasholder.

Assuming daily biogas production to be ca. 9 m^3, 10 gas lamps consuming 120 to 150 litres per hour each can be lit for illumination of the public toilet centre during wee hours and night time (@ 6 working hours per day).

Guide values for gas consumption of household burners and gas lamps are summarized in table 8.

table 8: Guide values for biogas consumption

household burner	200 to 450 litres per hour
gas lamp, equivalent to 60 W bulb	120 to 150 litres per hour

(source: [15])

5 COST ESTIMATE

Block cost estimates for the 20-seater community toilet centre and the treatment system, comprising an Anaerobic Baffled Reactor, an Anaerobic Upflow Filter, a Horizontal Flow Constructed Wetland, a Polishing Pond and a urine storage facility, suggest construction costs of ca. INR 1,580,000 (about € 25,000 @ a rate of exchange: 1 € = INR 62.8833; November 2008). Total cost split into INR 1,200,000, INR 230,000, INR 100,000 and INR

50,000 for the toilet centre, the ABR & AF, the PP and the urine storage facility, respectively (table 9).

table 9: Cost estimates for toilet centre and treatment facilities

Facility	**Costs [INR]**
20-seater toilet centre	1,200,000
Anaerobic Baffled Reactor & Anaerobic Upflow Filter	230,000
Horizontal Flow Constructed Wetland	100,000
Urine Storage Facility	51,000
Total	**1,581,000**

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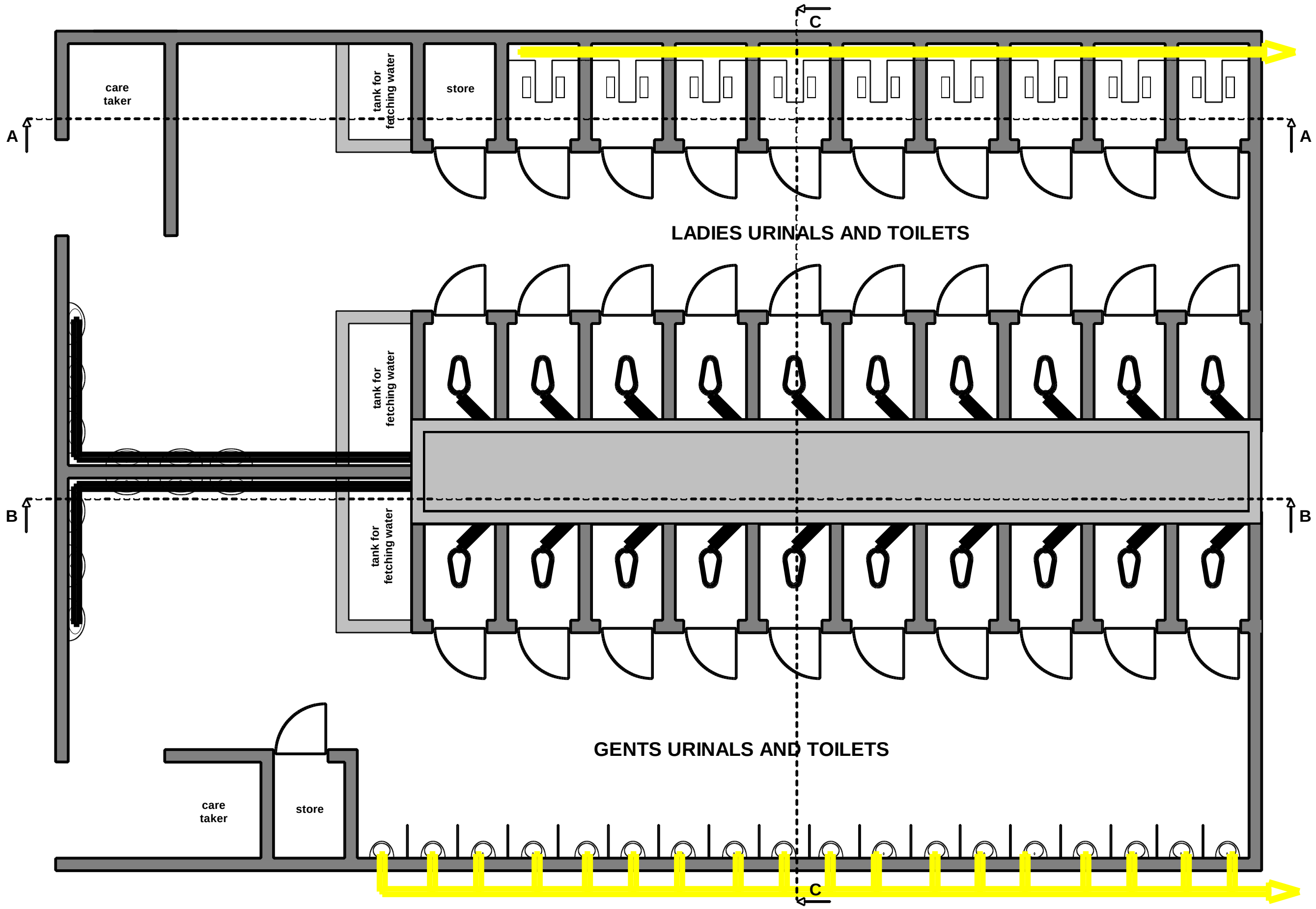
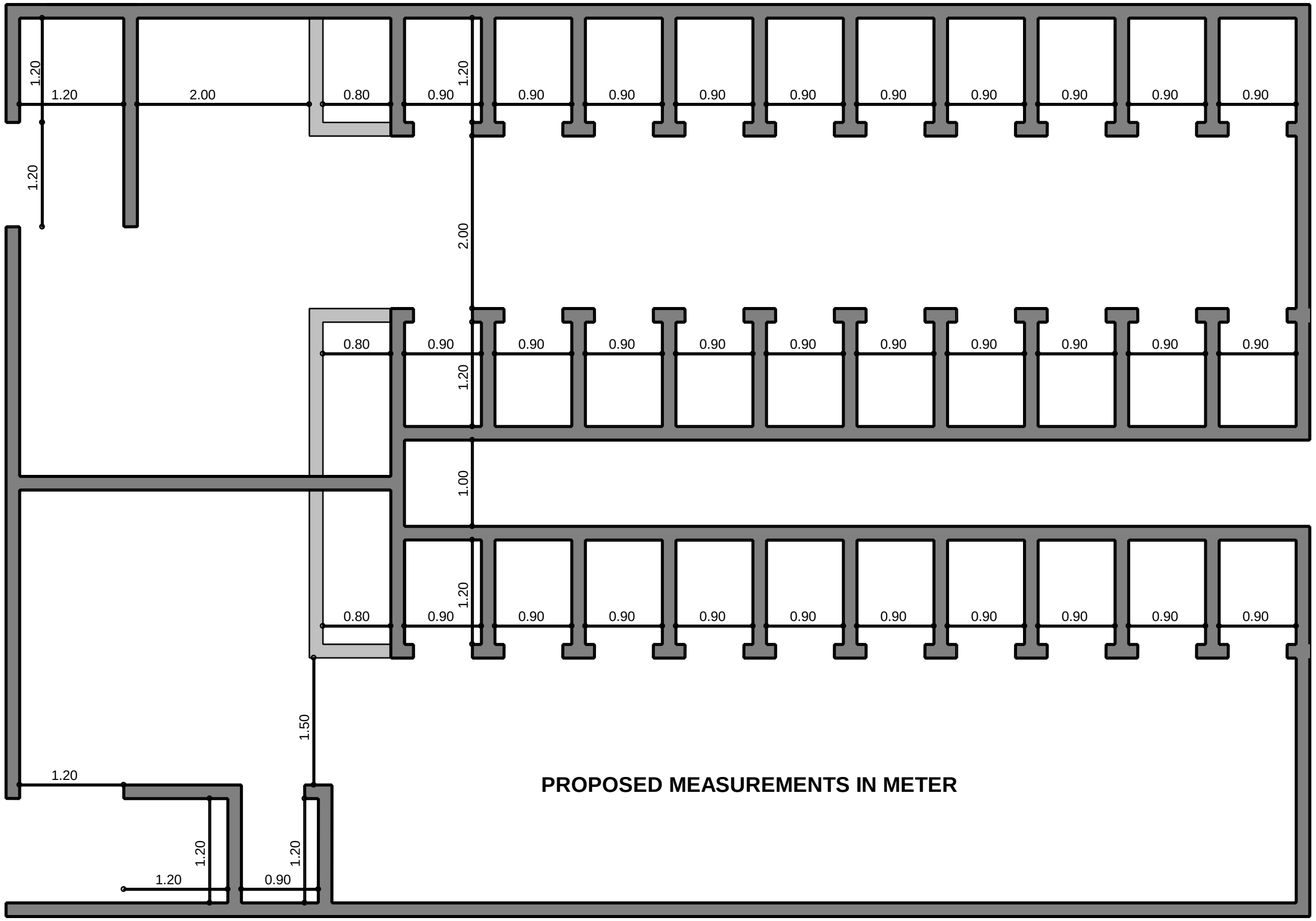
7 SKETCHES



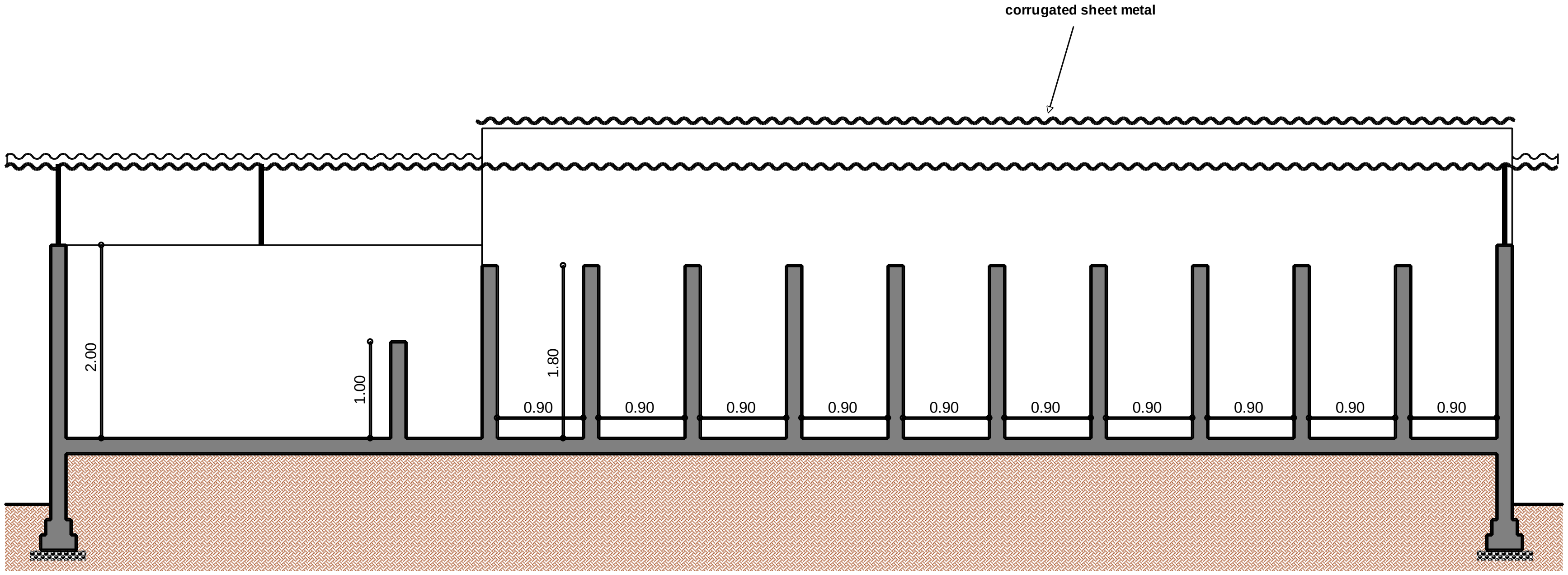
(source: M. Wafler)

figure 3: Schematic diagram of 20-seater community toilet block



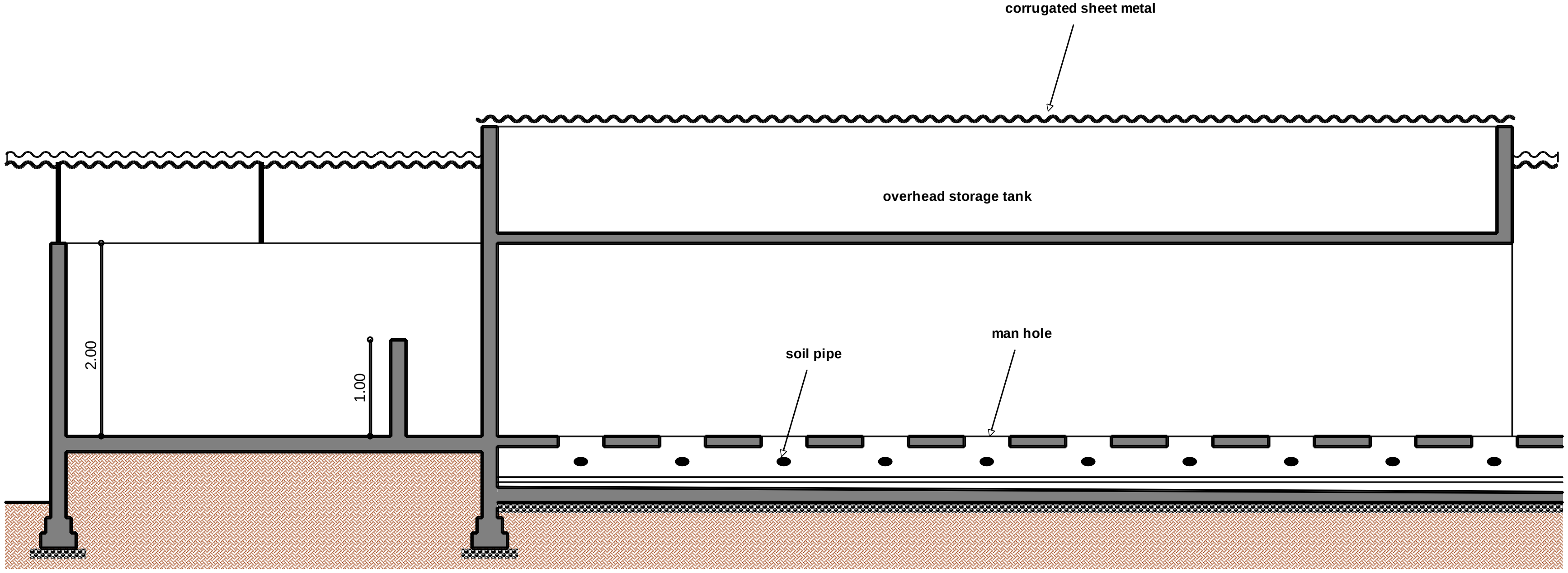
(source: M. Wafler)

figure 4: Ground plan 20-seater community toilet block



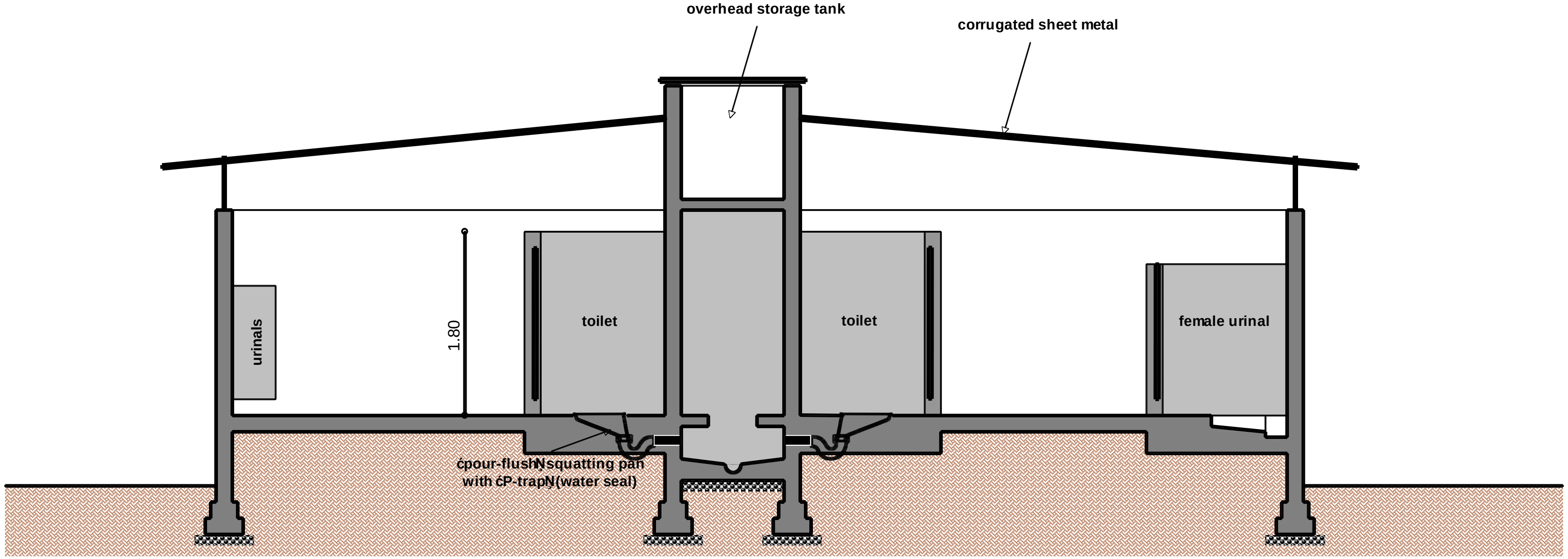
(source: M. Wafler)

figure 5: Section A–A 20-seater community toilet block



(source: M. Wafler)

figure 6: Section B–B 20-seater community toilet block



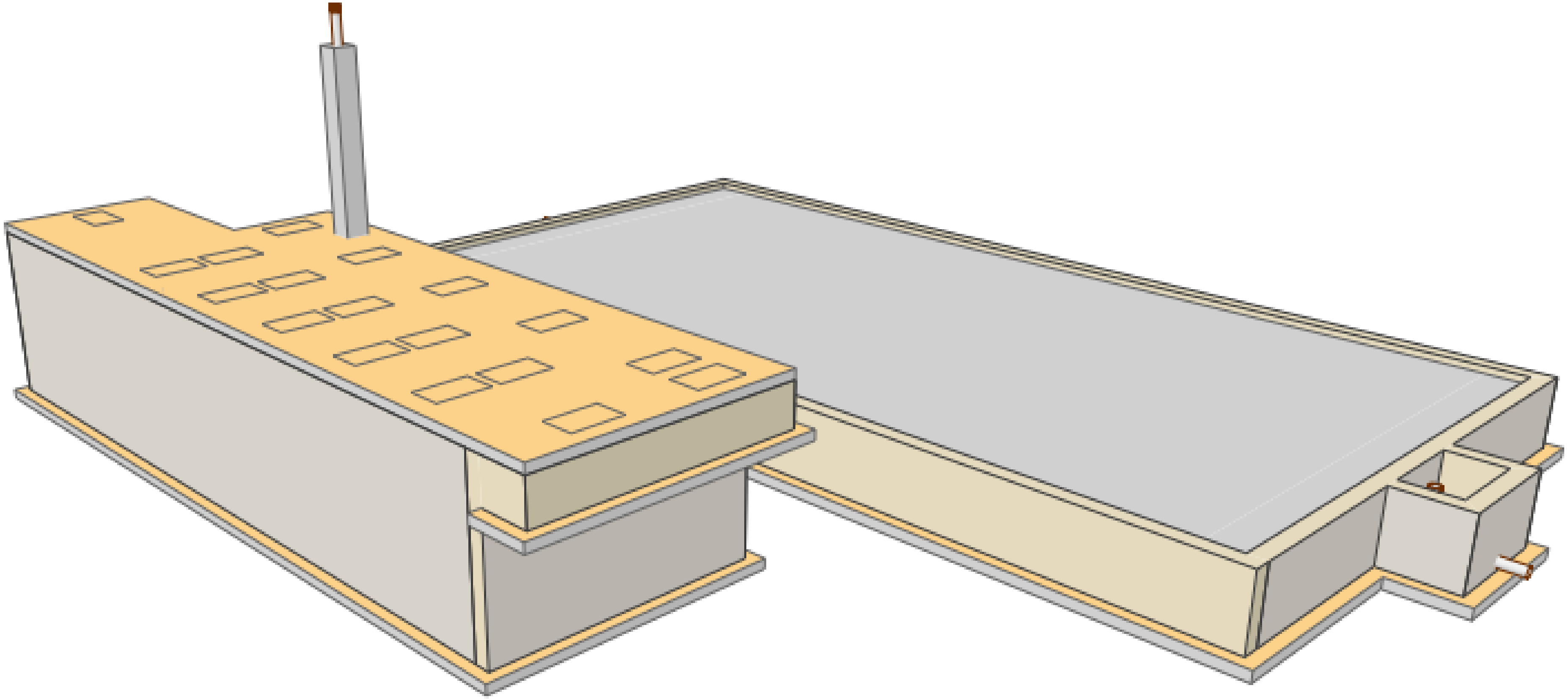
(source: M. Wafler)

figure 7: Section C–C 20-seater community toilet block

table 10: Sowing (brown bars) and transplanting time (yellow bars) and harvest period (green bars) of selected vegetables

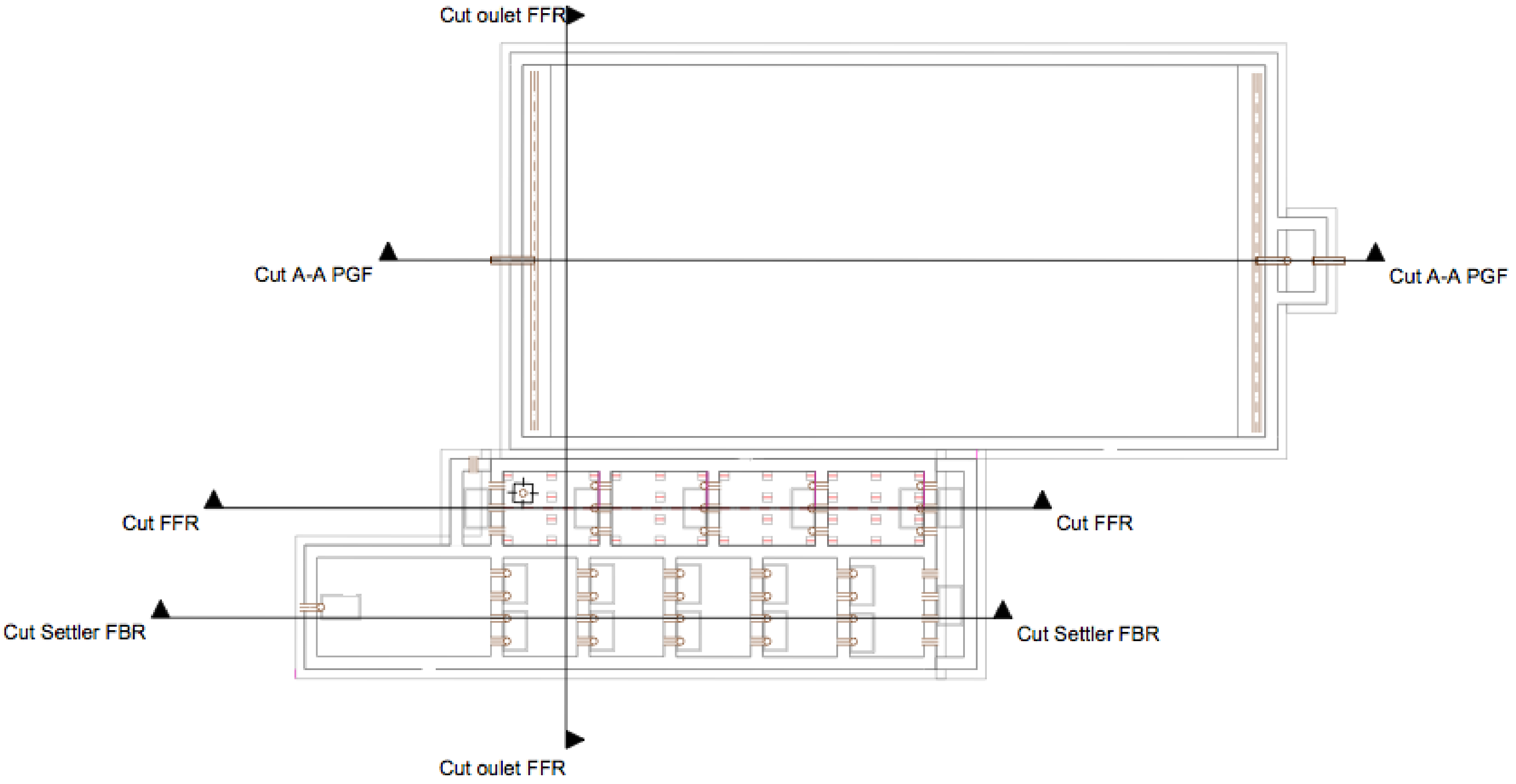
Vegetable	**Month**											
	Jan.	**Feb.**	**March**	**April**	**May**	**June**	**July**	**August**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
Bitter Gourd		🟫	🟫			🟫	🟫					
					🟩	🟩	🟩	🟩	🟩	🟩		
Brinjal	🟫	🟫			🟫	🟫				🟫	🟫	
	🟨	🟨	🟨			🟨	🟨					
				🟩	🟩	🟩			🟩	🟩	🟩	
			🟩	🟩	🟩				🟩	🟩	🟩	
Chillies	🟫				🟫	🟫					🟫	🟫
	🟨	🟨	🟨			🟨	🟨					
				🟩	🟩	🟩			🟩	🟩	🟩	
Cucumber		🟫	🟫			🟫	🟫					
					🟩	🟩	🟩	🟩	🟩	🟩		
Mungbean												
Okra		🟫	🟫			🟫	🟫					
			🟩	🟩	🟩	🟩		🟩	🟩	🟩	🟩	
Sweet Corn					🟫	🟫				🟫	🟫	
Tomato						🟫	🟫	🟫			🟫	🟫
	🟨	🟨						🟨	🟨			🟨
				🟩	🟩	🟩				🟩	🟩	🟩

main source: http://krishisewa.com/calander/veg.html



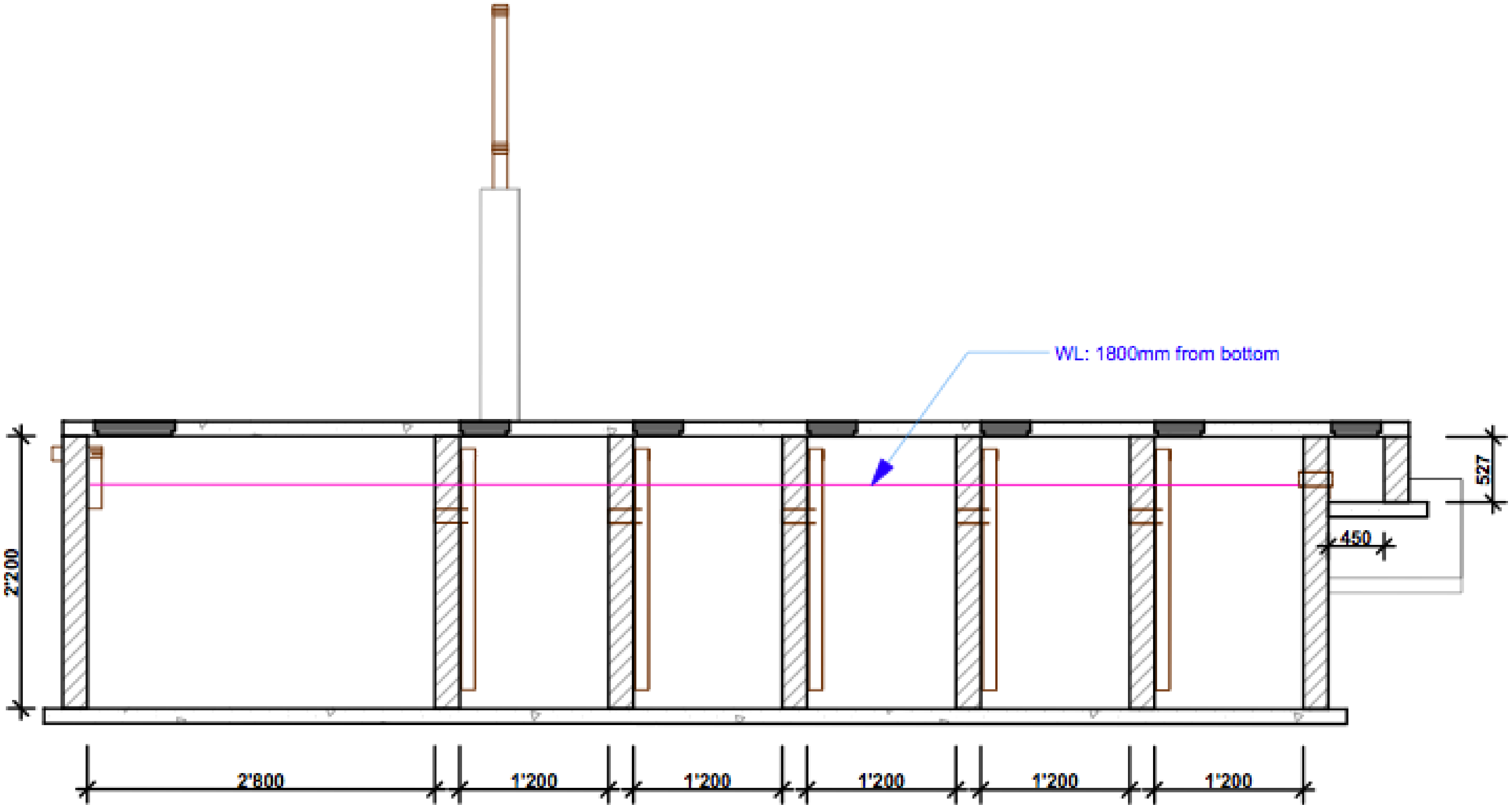
(source: N. Zimmermann)

figure 8: 3D-view of treatment system comprising ABR, UF and HFCW



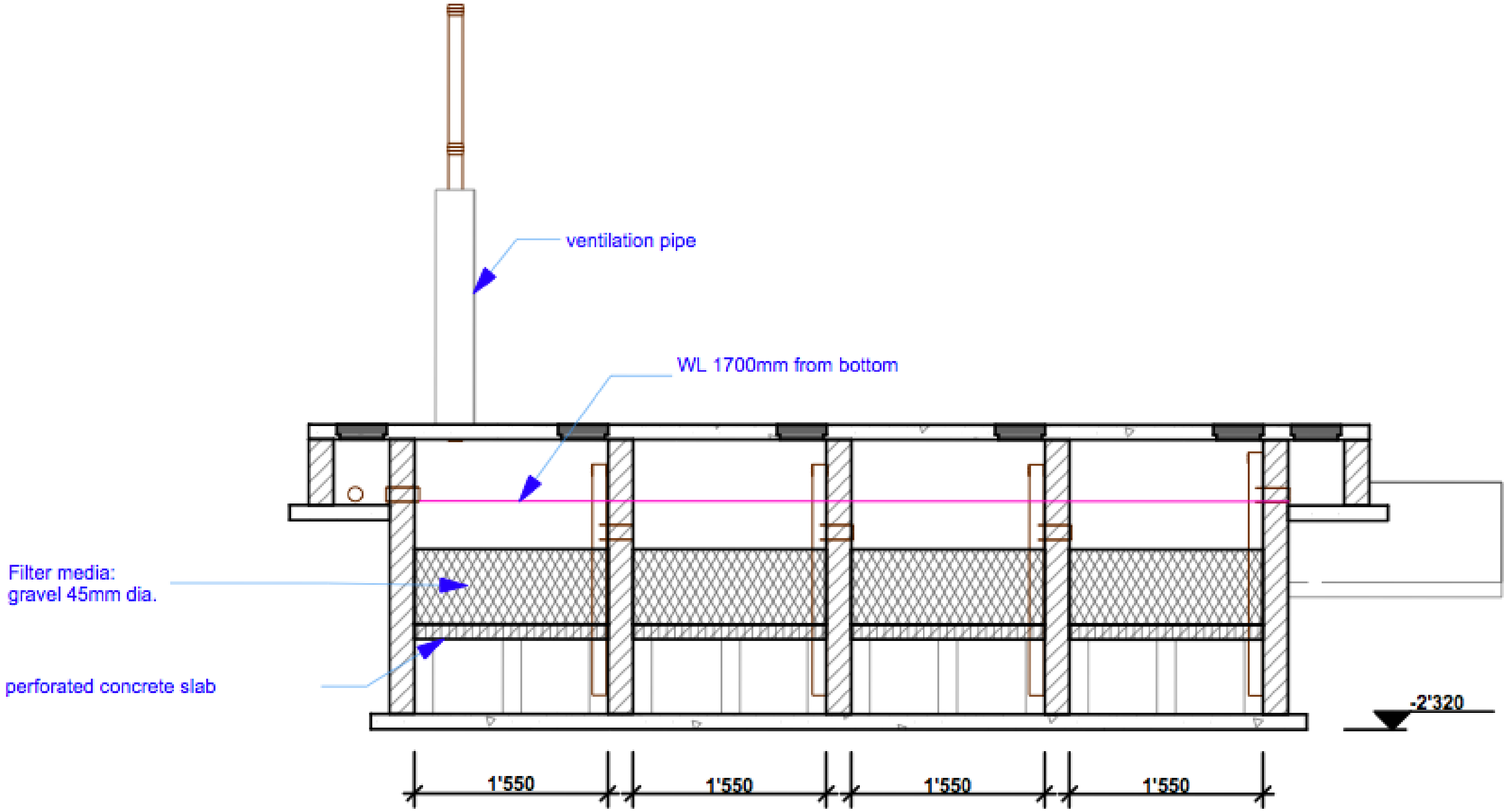
(source: N. Zimmermann)

figure 9: Ground plan of treatment system comprising ABR, UF and HFCW



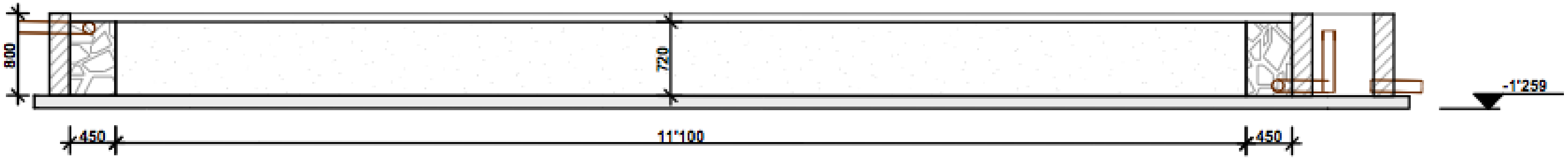
(source: N. Zimmermann)

figure 10: Longitudinal section ABR



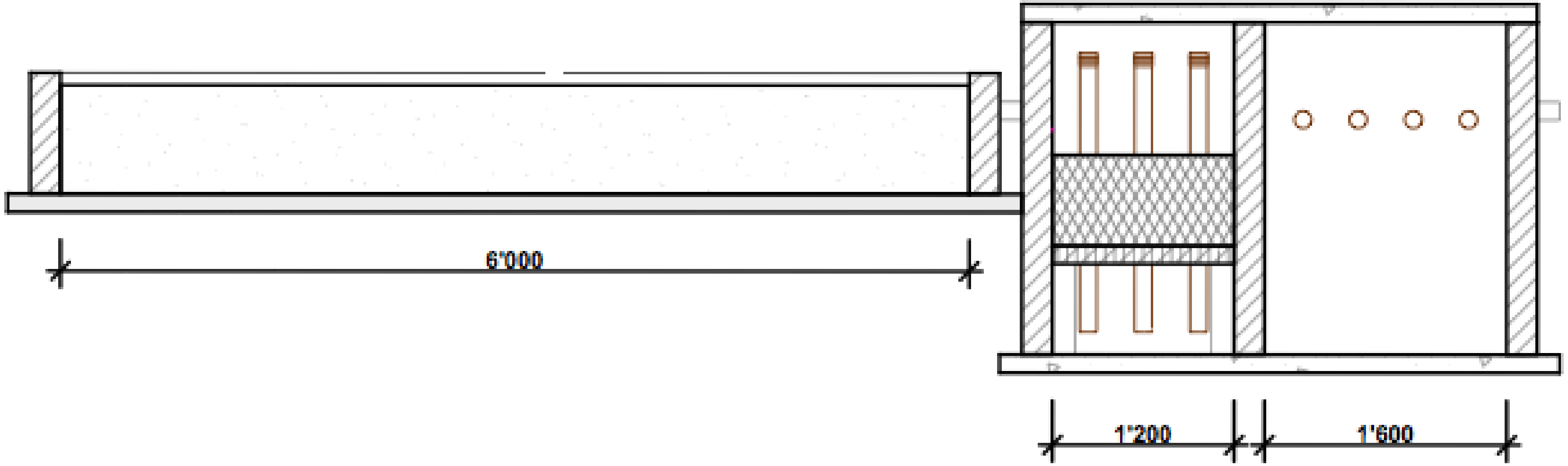
(source: N. Zimmermann)

figure 11: Longitudinal section UF



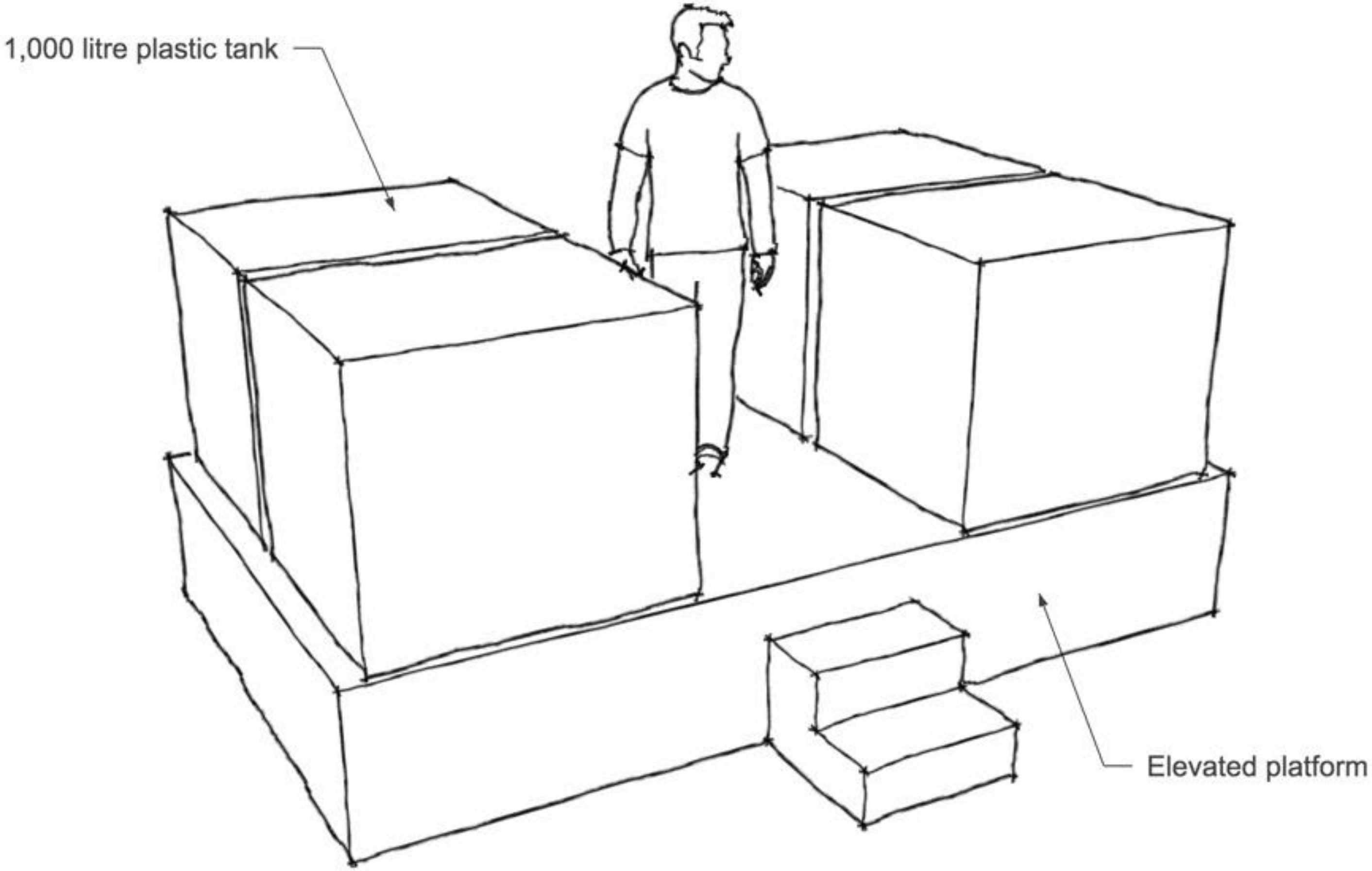
(source: N. Zimmermann)

figure 12: Longitudinal section HFCW



(source: N. Zimmermann)

figure 13: Cross section through ABR, UF and HFCW



(source: M. Wafler)

figure 14: Schematic diagram of urine storage facility

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gtz ecosan program
recycling oriented
wastewater management
and sanitation systems

Commissioned by:
Bundesministerium für
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