LOW COST TOILET FOR RURAL HOUSEHOLD

PRODUCT DESIGN PROJECT II
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Low Cost Toilet for Rural Household

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Master of Design

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I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/ source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Approval sheet

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Abstract

According to the 2011 Indian census 68.84% of the population are living in rural and 31.16% are urban dwellers. If we change the life style of the 68.84% population, obviously the urban areas will be positively affected, because the urban life is depending on rural resources. But majority of the people in rural area particularly in developing countries use an open field as "every man for himself" latrine.This is because most of the people in rural areas do not have knowledge on the negative impacts of defecting on open field. Miss understanding of toilet use and poor disposal of waste materials in rural areas leads to affect major health problems such as cholera, dysentery, diarroea, typho id and stomach complications. This problem is a serious issue especially in developing countries and it needs to be Improved from the base. It starts from changing the life style of rural areas using clean and controlled sanitation system in a safe and clean way by providing an affordable toilet for each household.

This project solves some problems related to toilet in rural areas in particular developing countries like Indian using the designed toilet pan which diverts solid waste from liquid wastes and providing sustainable sanitation, which is focused on closed-loop management of excreta and saving of other resources such as water. This is achieved by narrowing down to the toilet pan and the waste management system in the chambers to use as a compost making.

Objective

The objective of the project is :

1. To design a low cost dry toilet for rural household to those who do not get water supply for flushing.
2. Treat waste management in rural toilet and effective use of waste material as source of compost making.
3. To design durable, comfortable and easily accessible toilet pan that divert solid from liquid wastes.

Scope of the project

The scope of the project is limited to rural India where people use the toilet in squatting position and use water for anal cleaning. Since the toilet waste materials can be used for compost making, it needs to separate the solid waste (feces) and liquid wastes (urine and water for anal clean). This helps to get dry waste, which can easily dried in short period of time that can be used for compost making.

This project is aimed to develop(re design) the current dry toilet (Eco-San toilets) which currently used in India and other different countries which uses as compost making.

Chapter 1: Introduction

1.1 Synchronic and diachronic of toilets

Toilet is the part history of human hygiene which is a critical concern in the history of human civilization. It is a critical link between good and bad environments.

In 1738 J.F. Brondel introduced the valve type flush toilet and then Alexander Cummings further improved the technology and gave us a better device in 1775. In Cumming's design water was perennially there in the toilet so it suppressed odors. Still the working of the valve and foolproof inlet of water needed further improvements.

Joseph Bramah in 1778, substituted the slide valve with crank valve, it seemed then that the technology of pour flush was now perfected.

[According to Dr. Bindeswar Pathak, in India the institution of Gushalkhana (bathroom) was established by the Mughal Kings in 1556]. Oppressed by the heat and dust the Kings constructed luxurious bathing and massage facilities. But this was only for the rich. The ordinary citizens however lived in insanitary conditions.

In 1970, in India Sulabh International which is non governmental organization was established and realized that those sewerage facilities will remain out of the reach of the society at large and pioneering technology twin pour flush latrines and human excreta based Biogas plants. (Pathak May 25-27/1995)

1.1.1 Why toilet for rural household?

Most of the time rural people use an open field as toilet in deferent part of the world. This is because they did not have much knowledge

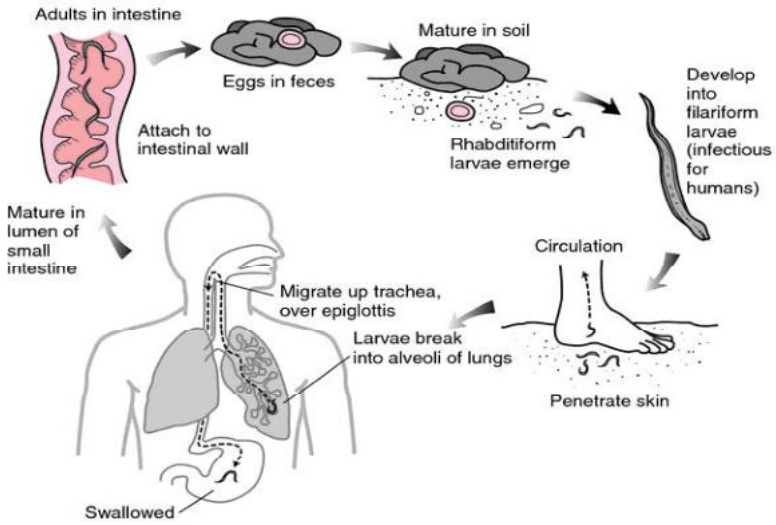


Figure 1: Hookworm development in human

(Source: - Dictionary.thefreedictionary.com as of Sep.18/2013)

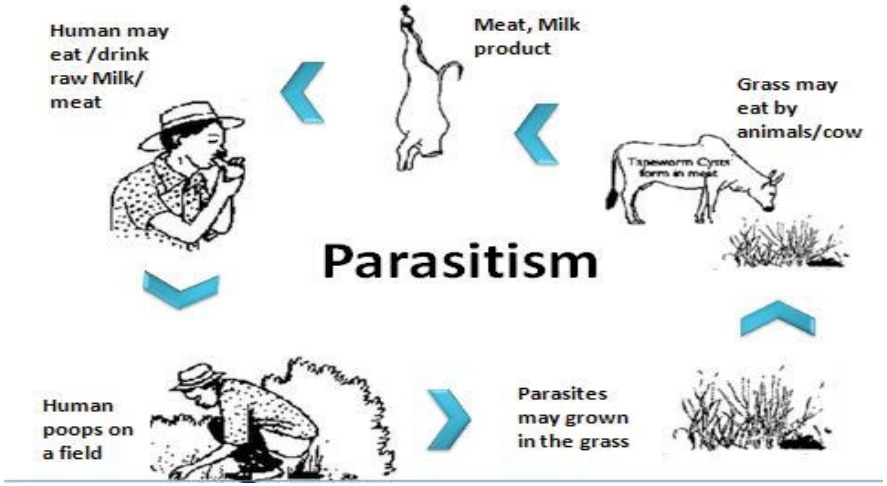


Figure 2 tape worm development in human

*(*Source: - www.cd3wd.com assessed in September.15.2013*)*

about the negative impacts of those wastes (how it affects their health). Now a days people became aware and are using toilets but it was not affordable for all because of the financial challenges.

Developing countries like India and Ethiopia, using of toilet is still an issue in particular rural areas where people use an open field. This affects negative impact on the health of people especially the users them selves in different aspects.

1. When they use an open field the fecal matter can develop worms that directly damages health of the users as shown in fig. 1
2. Indirectly the users may affected when they used raw meal (milk and meat) from cattle as in fig.2. The pictures (fig. 1 and 2) shows how hookworm and tape warm transmits from person to person when people uses an open field.

1.2 Design process

To start designing the problems the following processes are using to follow step by step.

1.2.1 Data collection

- Case study
- Market study
- Available products

1.2.2 Ideation

- Mood board
- Mind mapping
- Rough ideas for the problem

1.2.3Concept development

- Possible solutions
- Mock up models
- Metaphoric concepts

1.2.4 Finalize the concept

- Evaluation of concepts
- Final detailed drawings
- Final model

1.3 Techniques used for the design process

1.3.1 Observation: Observation helps to collect data like what type of products are in use?, How they are using it?, What type of materials have used for the system? And positive and negative impacts of the present technology etc and related questions are answered using this method

1.3.2 Asking (interviewing) users: Asking people what problem did they face in toilets and how they manage the wastes in the places/ what advantages and disadvantages they get from the waste matter? What were the previous problems in using toilet in an open field (if the people are using toilet)?

1.3.3 Photographic (images): Tacking images positive and negative sides of toilets which users use, critical problem especially in the current toilets as a references and bases to the design solution.

Chapter 2: Data collection

2.1 Toilet design for rural areas

When we talk about toilet there are three things which are evoked in our mind. Those are the toiler room, the toilet pan and the waste material in the toilet.

2.1.1 Toilet rooms

Toilet room design is not that much of an issue in most of the rural areas. It can be made with simple materials which are locally available. This is because low income of the people and less awareness on toilet rooms. They are simply built to cover the toilet seat and for the sake of privacy when they are using the toilet. It can be built using locally available materials like stone, brick, wood and bamboo.

The toilet room can protect the pit from external things flood, and non-dissolved materials like plastics and stones which may fall in to the toilet pit. In addition to this it also protected bad smelling coming out from the toilet. The room area in rural areas may depend on the users but it should contain the fixtures in it.

2.1.2 Human waste

Human waste contains feces and urine. One person produces the period of one year about 500 liters of urine and 50kg of feces. For flushing away those excrements a flush toilet uses in average 12,000litres of water per year. That mean, large amount of water is severally contaminated with fecal pathogens by rather small amount of water of human waste. To collect and clean the polluted wastewater, expensive swage and treatment are needed. (Anna Richert 2010). The urine has high content of ammonia which is important for plant and the feces contain

organism/ bacteria for compost making.

In general human wastes are used as raw materials for compost and bio-gas as a source of energy for cooking and lighting purposes in a closed pit (anaerobic reaction). This needs more wastes like cow dung, and any waste materials like vegetables, waste foods that make a methane gas which can be used for cooking food, and as a source of light. Urine is approximately 80% nitrogen, 55% phosphorus, 60% Potassium (Urine diversion February 2001)

[According to UNICEF, a gram of human feces has 10 million viruses, 1 million bacteria and 12,000 parasites. People walking on the urinated ground can catch the worms/Hook worm, which can enter through their foot and then enter the blood. So it needs control and managed by using organized waste management system].

2.1.3 Toilet pan

Current toilet pans in rural areas are not well designed and not comfortable to use, hygienically, ergonomically and the design focussed in some aged groups. The design is all about how to separate the faces and urine. In addition to this, there are some problems to be solved such as:

- Problems related to ergonomic design
- Hygienic issues
- Smell control
- Splash back (from the pit and on the pan when they are using it
- Accessibility for users/aged groups
- More activities have to done in the toilet, (poop, pee and wash) and yet separated the urine
- Ineffective separating solid waste/Night soil from urine.

Figure 3 Molded slab of the Arboloo toilet type
(Source: http://faculty-staff.ou.edu assessed in August 31/2013)

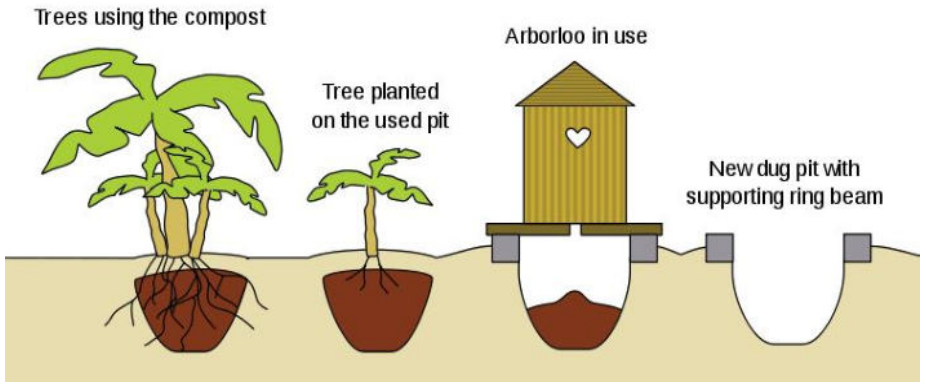


Figure 4 Arboloo toilet using as a compose
(Source; http://en.wikipedia.org/wiki/File:Arborloo-en.svg assessed in August 31/2013)

2.2 General Types of toilet seats and features

2.2.1 Arborloo

An Arborloo is a simple and ecological type of toilet. Its concept is to compost directly the feces in a pit, and to grow subsequently plants on this very fertile soil. This will happen after the pit is full. The process is preparing another pit and removes the concrete slab to use in the new pit (fig. 4). This is commonly used in east Africa/Ethiopia, Kenya, Sudan and Uganda and Tanzania/. It is simplest and cheapest toilet which is made up of four parts, (Eco-San foundation n.d.)

- The pit
- Ring beam
- The concrete slab
- Toilet house

Advantages

- Very cheap
- Can grow trees as a fertilizer
- No handling of waste

Disadvantages

- Require lots of spaces
- Flood can attack easily
- Slab is heavy to transport
- Footrest is not comfortable to squat
- Polluted the ground water where place reach in ground water

Figure 5 types of UDDT
(Source: http://www.wecf.eu assessed on August 8/2013)

2.2.2 Urine Diversion dry toilet (UDDT) Eco-San toilet

Urine diverting toilets do not mix urine and feces by using a separating pan. Urine is collected and stored in a reservoir. Feces, which are collected underneath the toilet, must be directly covered by dry materials such as sawdust, soil, ashes, or a mixture of those. The toilet products, urine and fecal compost, can be used as organic fertilizers. Urine is an excellent liquid fertilizer containing nitrogen, phosphorus, potassium and many micro nutrients. The urine can be diluted with water (3-5 parts water per part urine) and used as a fertilizer, or it can be added to a backyard compost pile dissatisfaction with the pit latrine. The fertilized plant will grow faster, develop more leaves and produce higher yields. Fecal compost is an excellent soil conditioner and fertilizer. (Clean water compost 2013)

This has some draw backs

- Discomfort in using it (cold, windy, smell and flies)
- In areas with high groundwater level, there is a lot of smell and the need to move the latrine frequently.

Advantages of UDDT

- More hygienic compare to other types of toilets
- Clean, can be built inside
- Can be built and repaired with locally available materials
- No water required for flushing
- Multiple designs possible (sitting/ squatting, Wet/dry cleaning);

Figure 6 Double vault toilet seat
(Source: - http://3.bp.blogspot.com assessed of August 31/2013)

Disadvantages

- Adequate training is needed;
- Maintenance required (cleaning, emptying urine tank at least 4 times a year and the chamber every second year)

Types of urine diversion dry toilet

I. Double vault toilet

- Each toilet seat has two chambers underneath
- The night soil/feces falls directly in to the chamber below it
- The night soil/ feces is stored in the first chamber until the second chamber is full(time span is depend on the size of the chamber and number of users
- After the first chamber is filled the second chamber will be used

Advantages

- Infrequent waste handle
- Long lasting design

Disadvantages

- Expensive
- Difficult to empty

I I. UD toilet with drum:

- This toilet is earth quake resistance
- It is used 15 gallon plastic drum. When the drum is full it is re-moved and replaced
- The system requires less handling of wastes.
- This system works particularly well when there is extensive usage of the toilet and when offset composing is required.

(A) movable on a cart

(B) movable by loading

Figure 7 Portable toilet room

(Source: www.rentabathroom.com.au assessed in September. 28/2013)

Advantages

- Less contact with waste because the waste is in side the drum
- Easy to empty that can be done by moving the drum to the remove the waste

Disadvantage

- Regularly removing of waste

III. Portable UD toilet:

- Portable toilets are extraordinarily expensive to service and maintain.
- Portable toilets to serve as UD toilets by installing the separating seat and placing a 15 gallon drum beneath the seat.
- Urine can be collected or diverted into an underground soak away
- They are good for communal toilets in camps
- Have low space requirements and lock easily

Advantages

- Space requirement low
- Easy to transport

Disadvantages

- Urine clogs easily
- Bucket close to seat

Figure 8 Sample of humanure toilet design
(Source: http://plantingmilkwood.files.wordpress.com assessed in September. 28/2013)

2.2.3 Humanure toilet

- Consists wooden box with 15 gallon receptacle toilet below the toilet seat (fig. 8)
- Low cost and can be made with local materials
- This toilet dose not separate urine and feces
- Very good for children and handicapped /disable users

Advantages

- Very cheap
- Conserve urine
- It requires low space
- Easy to use for children

Disadvantages

- Fill quickly
- Heavy to transport
- Increased cover needed

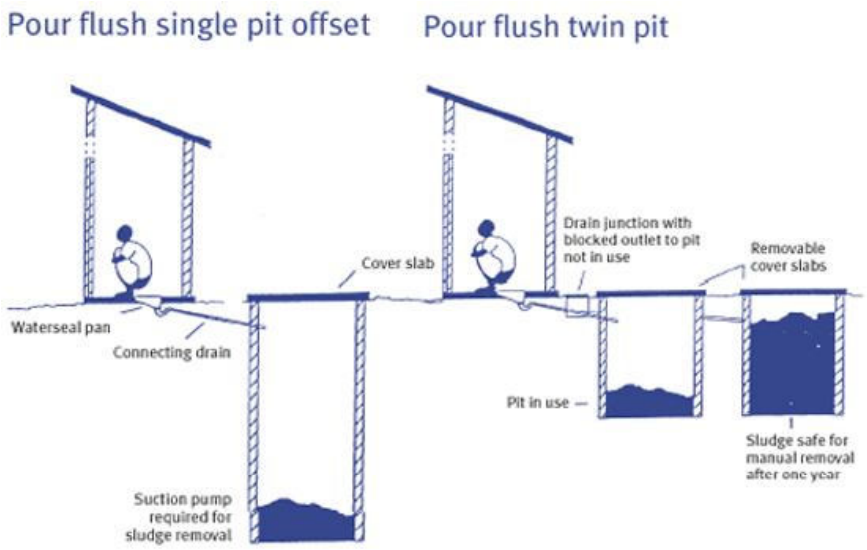


Figure 9 Pour flush single pit and twin pit
(Source: www.wateraidaustralia.org assessed in September 14/2013)

2.2.4 Pour flush Water Seal Latrine

The water and gas of the excreta gets absorbed through the pores of the leach pit and solid gets decomposed into manure. It is a desirable technology where contents of the pit are not visible due to water seal. It needs water for flushing but with the use of rural pan the consumption of the toilet can be minimized.

Advantage

- Since it uses two pits, it can be use the second pit until the dry waste in first pit is used for compost making

Disadvantages

- It uses water for flushing which is a problem to those who have scarce water
- It is difficult to empty the pit
- It may polluted the ground water
- Urine, water for flushing and feces are collected to gather in same pit

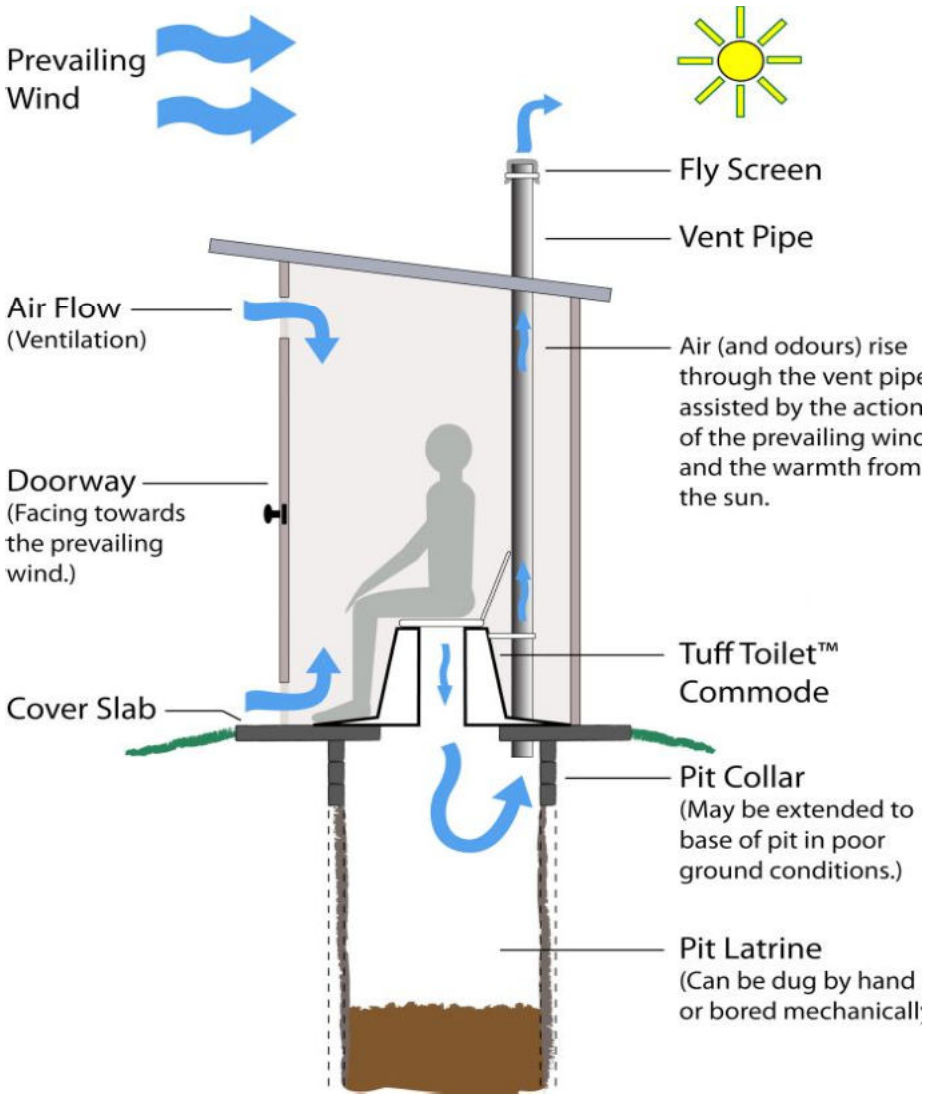


Figure 10 Ventilated Improved Pit Latrine
(Source: www.bellatrines.co.nz assessed in September.14/2013)

2.2.5 Ventilated Improved Pit Latrine (VIP)

VIP is more suitable for water scarce areas where people do not use water for flushing. In this technology, solid excreta directly get deposited in the pit and gas gets evaporated through pipe as shown in fig. 10.

Advantages

- Ventilation in VIP latrines is the action of wind blowing across the top of the vent pipe
- It can be constructed with minimum cost using local material and local skills.
- Do not require water for flushing

Disadvantages

- It is difficult to use when the pit is about to full because urine and feces are in same pit and splash back while using it
- Difficult to empty the pit

2.3 Case studies

2.3.1 Case study 1

Case study one was conducted in a village called Garade which is located at around 34km from Pune the west. In this village there are ten households, who are using the Eco-San toilet. The Eco-San toilet which was constructed by the Eco-San service foundation a non governmental organization promoting ecological sanitation. Before the introducing of the Eco-San toilet, the village community used to use the open field as "every man for himself" latrine. This practice causes a lot of health problems such as cholera, dysentery, diarrhea, typhoid and stomach complications.

To gazer relevant information regarding the Eco-San toilet, interview was conducted to randomly selected head of families who are currently suing the Eco-San toilet technology. Among the interviewees Mr. Popat and Mr. Shantaram expressed their satisfaction in using the technology.

According to Mr. Popat and Mr. Shantaram their family were affected by different diarrheal diseases and flies were coming to their house, the surrounding used to smelled bad and now this problem is solved with the Eco-San toilet.

The design of the Eco-San toilet is urine diversion dry toilet (UDDT) which the urine, feces and wash water stored in different containers.

According to the users of the Eco-San toilet, there is a droplet of urine and water going in to the fecal chamber and they add more ash/ saw dust or dry soil to get dry fats and to protect the smell.

From the case study which conducted in Garade, the following activities in the toilet room and out side the toilet room are happening.

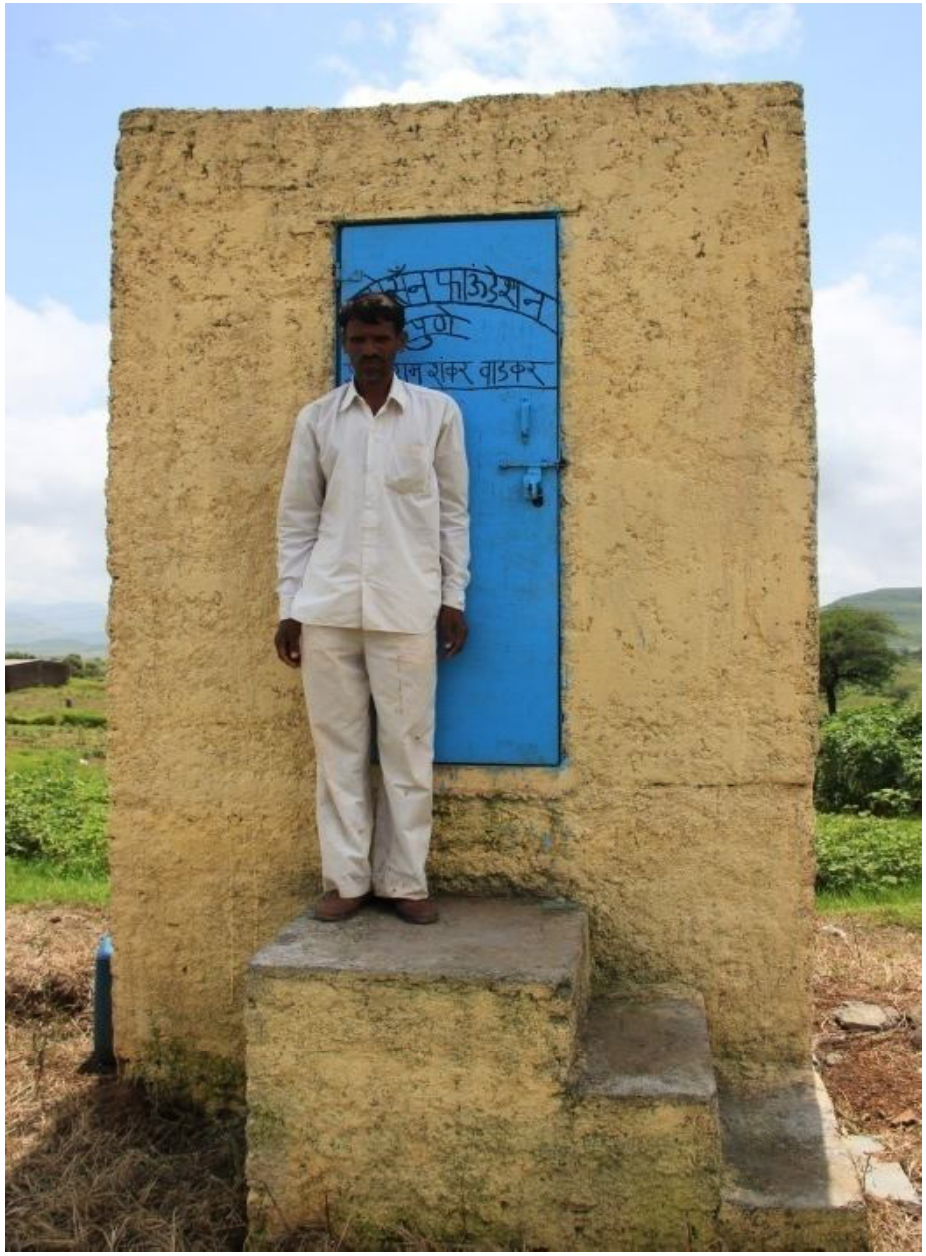


Figure 11 Toilet room in rural India at Gararde

I. Feces chamber

This designed has two chambers above the ground level by using brick and reinforced concrete. This is designed to be used for an average of five people in a family that they can use it for six months. After six months the first chamber will be filled and they use the second chamber. Now the first chamber is full and they keep it in side the chamber for six months till it finish the reaction and fully dried. Then they will open it through side of the chamber from the hole (Fig 12) provided for this purpose to remove the solid waste for next use. They use ash/saw-dust/dry soil to avoid bad smelling and accelerate the reaction to make the compost in the chamber.

The size of room which currently using by the people is 2m x1.2m which is divided in to two chambers. Each chamber has approximately volume of 0.4cubic meter that is 0.95m x 0.75m x 0.55m (length, height and breadth) respectively.

Figure 12 Back of the toilet room to empty the solid waste

(A) Urine tank (Jerry can) out side of the room

(B) plants grown by urine

Figure 13 Urine tank and plant by the urine

II. Urine tank

This is located outside of the toilet room in 20liter a Jerry can which is diverted by PVC pipe from the urine hole. Since this is kept out side, it is exposed for children reach and cattle may spill it. This Jerry can is filled in one month and pour it to the plant and is very important fertilizer for growing plants by the urine as shown in fig. 13 B

III. Water from the washing trap

This flows directly in to the ground/ plants. In the case study that I have done, the waste water that comes from anal clean is going in to peculation which is a small pit beside the toilet room diverted by PVC pipe. But as I have observed it is somewhat smelling and is exposed for children reach.

IV. Engineering works of the Eco-San toilet

I went to the village with Mr. Ganesh Kale, the project manager of the Eco-San toilet, who is supervising the constructions of the Eco-San toilet in Garade. Eco-San toilet is constructed using concrete and bricks. The mixing ratio of the construction is as given below.

- Plain Cement Concrete (PCC) is 1:4:8
- Reinforced Cement Concrete (RCC) is M15 and M20
- Mortar ratio is 1:4 and 1:6 (depending on the works and dimension of the toilet room 6.5ft x 4ft (2m x 1.2m))

The total cost of this construction is 36,000IRP. And construction up to slab level (till the plinth) is 20,000INR. They use diameter of 10mm bar reinforcement at a difference of 30cm. The Eco-San foundation gives 10% discount for the users. The toilet seat is made up of fiber glass and the price is around 1200INR..

V. Problems in distribution the Eco-San toilets

It was a problem to introduce the users to use an Eco-San toilet because it was new technology for them. But the Eco-San service foundation use an old people from the community and teachers from the village to teach them. After some time they understood the benefit of using Eco-San toilet, but still they have some problem while using the pan which is in convenient to go back and forth to use it.

Figure 14 Mr. Ganesh Kale in training how to construct the Eco-San toilet in Garade

(A) Compost collected to dry

(B) Garden area

Figure 15 Garden grown by using toilet waste

Benefits of the Eco-San toilet

The rural people in India use sufala and ugavala fertilizers for their farm land which is expensive. So this Eco-San toilet helps them as a source of fertilizer and it is a dual use for the users by protecting their environment and they got compost by re use the waste matter

VI. Current toilet seat in the village, Garade

Currently the Eco-San service foundation uses a toilet seat made up of Fiber glass. The image in fig. 16 shows the new toilet pan which costs 1200INR. The dimension of the seat is 90cm x 31cm.

(A) Eco-San toilet pan

(B) Eco-San toilet with footrest

Figure 16 New Eco-San toilet pan

(A) Toilet pan in cement floor finish

(B) Toilet pan in tiles floor finish

Figure 17 Eco-San pans in the room

(A) Stainless steel toilet seat

(B) Back side of the toilet seat

Figure 18 Toilet seat and room in IDC

Observations

There are some problem in using the Eco-San toilets. Those are;

1. Adding the ash/sawdust/dry soil spoils the toilet room because the container of the ash is not fixed
2. The urine tank and the peculation (the waste came from the anal wash are exposed to children reach and fly may grow on it which is risk for health.
3. Urine can mix with the fecal matter because of the length between the fecal hole and urine pan is long.
4. Ergonomics design problem in the footrest
5. Opening the top of the fecal hole which is unclean and unsafe
6. Evacuating the chamber is unsafe
7. Scratching of the seat during cleaning

2.3.2 Case study 2

The new fiber glass toilet room which is found in IDC is designed to separate fecal matter and urine using stainless steel seat. The seat is made by welding and bending sheet metal Fig. 18 shows the seats in IDC. The urine and fecal matter are stored in different chambers but the water for anal cleaning is collected with the fecal chamber.

2.4 Why low cost toilet for rural household?

Currently, the big gaps life style between the urban and rural people in developing countries is their income opportunities, living standards, education and health conditions, etc.

Farmers are limited to receive enough clean water supply and sanitation facilities as a social beneficiary. Furthermore, their living habits are directed toward the nature. It is difficult to break the thinking to defecate and urinate on an open fields in farmers and communities daily life.

Generally speaking, there are some reasons that have limited the numbers of toilet in rural areas such as:

- Low in-come
- High cost for a sanitation toilet
- Lack clean water (piped water supply)
- Poor awareness in hygiene
- Very scarce information and documents (books, guidebooks, manuals, ...)

2.5 How to design low cost toilet for rural household?

Low cost toilet for rural household can be designed by using and considering the following techniques:

- Using locally available materials which can make by local skilled people in such way that material durability and function of the product will be more effective and valuable.
- If it is manufactured in the industries, the product should supplied in a feasible cost for the users in price and/or more functional product compared to the existing product.

2.6 What to solve?

- Adding ash spoils the floor
- Since there is no fixed space for the ash bin, so that it spoils the floor as well as the pan when the users are adding it in to the chamber.
- Since the ash/saw dust is a powder it may blown by air and spoils the floor.
- Urine is collected outside the room which is exposed to children reach as well as cattle which can pour it easily
- Waste water which comes out from the wash area is flowing to a peculation around the toilet that allows to grow fly and mosquitoes.
- Squatting position is a best technique to use in toilets than seat but the footrest is not designed in such away that the center of gravity of the body during squatting
- Wastes are not flowing fully to the expected container, that few wastes stored over the wash area and urinals which allows to grow fly and mosquitoes and welcome you when using it
- The current material for the toilet pan is fiberglass which is light weight but it scratches when the users are cleaning. This scratching allows the ash to stick on it which look dirty and unhygienic.
- It is not hygienic to open the cap of fecal hole by hand
- No need to buy two pans for a single toilet which is costly
- Forcing men to squat for peeing, because urine may splash back

2.6.1 Critical issues and problems of toilet in current situation

1. Collecting urine outside the room and allowing to flow the wash water to the peculation
2. Foot rest is not comfortable to use in squatting position
3. Removing the dry waste from the chamber
4. Material used for the pan which scratches while they clean it because they use local available broom to clean
5. Using two pans in a single toilet room for same purpose inquire additional cost
6. Forcing men to squat for peeing

2.6.2 Problems which are not critical

1. Adding Ash/ saw dust or soil is not serious problems which can solved easily by using local available materials and putting a bucket on the floor to a right side of the user near to the fecal hole by providing cap to protects blowing by air.
2. Moving forward to clean your self is not an issue related to the benefited of the toilet as a compost making.
3. Urine and wash water are collected in a same container which may reduce the urine content used as fertilizer. But collecting urine and wash water in same container is much better to control toilet related problems that flows out side to the peculation. More over as per (clean water compost 2013)three to five liters of water is needed to dilute the urine to use as a compost. So it is not very serious problem.

Figure 19 Indian toilet seat
(Source: http://www.indiamart.com assessed in October 25/2013)

2.7 Who are the users?

The toilet is designed for:

- Those who did not have water for flushing because of water scarcity but they use water to clean themselves from an external container.
- Mainly rural India, who are in between the age of 14 to 60 years old. Because old people (60 year and older) have Loss of muscular strength, Postural balancing problem and related problems because of their ages. So it may difficult to squat and use this type of toilets. Since this design is in an Indian context they can use this type of toilet by providing bars to lift up because the main problem is lifting up. This also be a problem for children (13years and younger) to use it because children like fun and may sink in to the hole. So children can also use this toilet by providing

2.8 Market study

The current price of the Indian toilet ceramic seat (fig. 19) in Mumbai malls (Home town and R-city) is 2499INR. This uses water for flashing and does not separate the urine and fecal matter. The current cost for the Eco-San toilet pan(fig.16) is 1200Rs which is currently using by the user in the rural areas.

2.9 Design Brief

Design a low cost dry toilet for rural household with hygenic Facilities which is convinent for people between the age of 14 to 61 years and that separate soilid and liquid (feces, urine and wash water and) to use them as a source of energy and/ or compost.

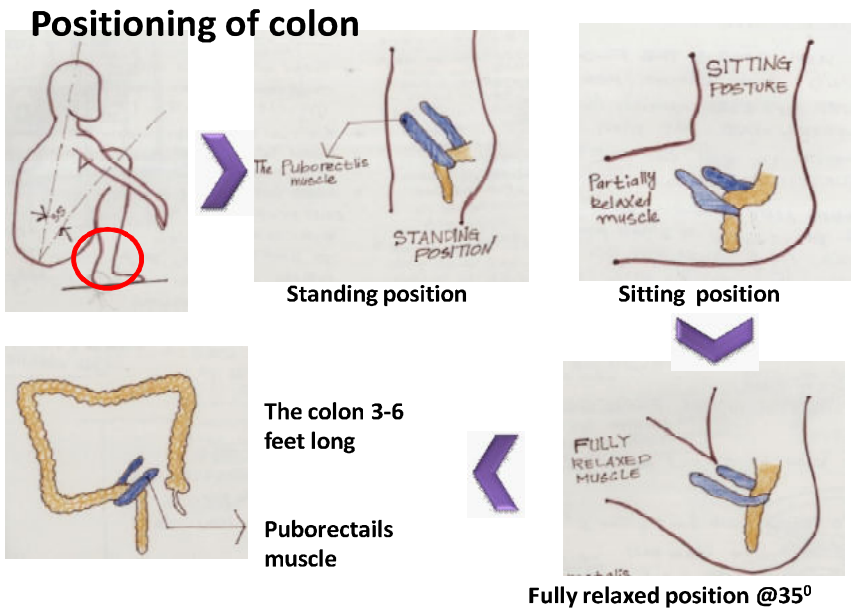


Figure 20 Colon structure

2.10 Why squatting position?

There are some advantages of squatting position while using the toilet. (REB 1966) Those are:

1. Makes elimination faster, easier and more complete. This helps prevent fecal stagnation, a prime factor in colon cancer, appendicitis and inflammatory bowel disease.
2. Protects the nerves that control the prostate, bladder and uterus from becoming stretched and damaged.
3. Securely seals the ileocecal valve, between the colon and the small intestine. In the conventional sitting position, this valve is unsupported and often leaks during evacuation, contaminating the small intestine.
4. Relaxes the puborectalis muscle which normally chokes the rectum in order to maintain continence as shown in fig. 20.
5. Uses the thighs to support the colon and prevent straining. Chronic straining on the toilet can cause hernias, diverticulitis, and pelvic organ prolapsed.
6. A highly effective, noninvasive treatment for hemorrhoids, as shown by published clinical research.

2.11 Design consideration for rural toilet

I. Safety

The toilet must safe for all users in the family. They must feel safe when they are going to use the toilet. The way should be clean that

Children can use it without having risk and fear of reptiles, and other ghost things. So routs should be cleaned/without long grasses and bushes if the toilet is built outside the house.

II. Privacy

Facilities must offer privacy when entering and using the sanitation services especially for girls.

III. Environmental degradation

Hygiene and sanitation facilities are often brought together with other unwanted activities, such as waste collection which causes nuisance, such as bad smell, flies and other pests. This wills de- motivates people to use the facilities.

IV. Risk of ground water contamination

To avoid contamination, sanitation facility should be constructed away from ground water sources.

V. Accessibility

It should be possible to reach facilities at all times and in all weather conditions during rain season

(Source of the above :- Technical Note Series, School and Anganwadi Toilet Designs, Norms and Options 2004)

2.12 Anthropometric Dimensions

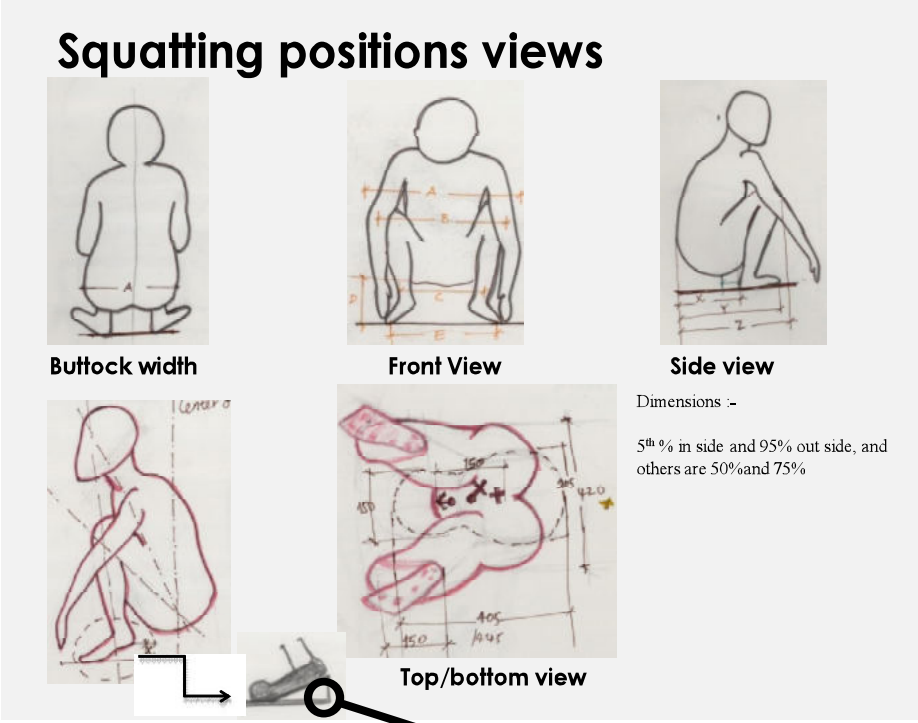
The following tables shows the anthropometric data (body dimension) of an Indian context in squatting position from the book "Indian Anthropometric dimension for Ergonomic design use by Debkhmar Chakrabarti, NID and Ergonomic Evaluation and Design Consideration for Indian Sanitary wares by GG Ray, IDC, IIT Bombay)"

Table 1 Antropometric data(dimension in mm)

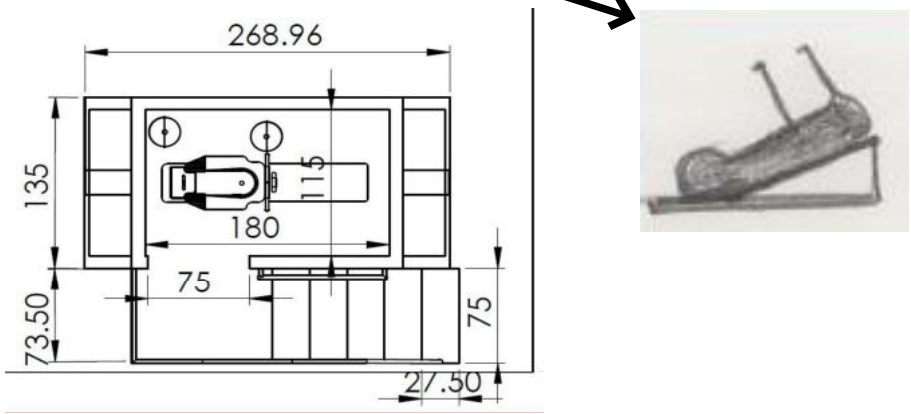
Squatting position

NO	Body part	Sex	Min.	5th	25th	50th	75th	95th	Max
1	Elbow to elbow distance relaxed	Male	300	354	419	459	519	599	780
		Female	260	279	369	419	489	642	700
		Com-bined	260	329	409	459	509	612	780
2	Knee to knee distance relaxed	Male	246	349	409	449	484	559	810
		Female	220	259	329	394	439	549	630
		Com-bined	220	329	404	434	479	559	810
3	Heel to heel distance	Male	90	99	153	204	233	297	366
		Female	62	63	99	150	198	202	210
		Com-bined	62	99	149	199	209	289	360
4	Crotch height	Male	21	28	44	63	94	136	170
		Female	25	52	73	79	109	159	160
		Com-bined	21	29	49	69	99	149	170
5	Big toe to Big toe dis-tance	Male	110	151	209	259	309	415	558
		Female	99	100	134	204	349	394	395
		Com-bined	99	132	199	249	309	401	558
6	Buttock to heel distance	Male	78	102	125	149	178	219	240
		Female	88	89	144	193	214	239	240
		Com-bined	78	102	125	149	183	229	240
7	Buttock to foot distance	Male	290	354	399	429	369	489	550
		Female	310	389	429	479	509	565	565
		Com-bined	290	354	409	439	479	565	565
8	Buttock to knee length	Male	390	409	439	469	494	554	835
		Female	370	370	354	476	529	569	690
		Com-bined	370	370	439	469	499	559	835
9	Hip width	Male	209	272	309	331	355	405	334
		Female	220	259	296	314	341	429	323
		Com-bined	209	269	304	326	353	406	331

(Source: (Chakrabarti n.d.) - Indian Anthropometric dimension for Ergonomic design use, Debkhmar Chakrabarti, NID and Ergonomic Evaluation and Design Consideration for Indian Sanitary wares, G G Ray, IDC, IIT Bombay)



(A) Squatting positions



(B) Squatting from top

Figure 21 Squatting positions and dimensions

From the Anthropometric data, above in table 1 internal dimension in squatting position is taken 5% that small users can use it and external dimension is 95% for those who have large body dimension. The following table shows the selected body dimensions for the seat design.

Table 2 Selected data for the design (dimension in cm)

Seat parts	Body parts	5%	95%
Foot rest	Toe to toe	13.2	41
	Heel to heel	9.9	29.7
	Lifted heel	3.7	12.37
	Foot length	19.4	25.81
Washing area	Heel width	4.48	6.2
	Toe width	9.42	11.5
	Buttock to urethra	20.01	28.81
	Buttock width	31.69	41.29
Fecal hole	Opening	3.46	9.7
	In side toe to toe	7.13	30.59
	In side heel to heel	7.68	22.9
	Buttock to heel	4.62	9.04
	Annul point to heel	-6.7	5.22

(Source: Indian Anthropometric dimension for Ergonomic design use, Debkhmar Chakrabarti, NID) , Ergonomic Evaluation and Design Consideration for Indian Sanitary wares, G G Ray, IDC, IIT Bombay, and the Bath room, Alexander kira)

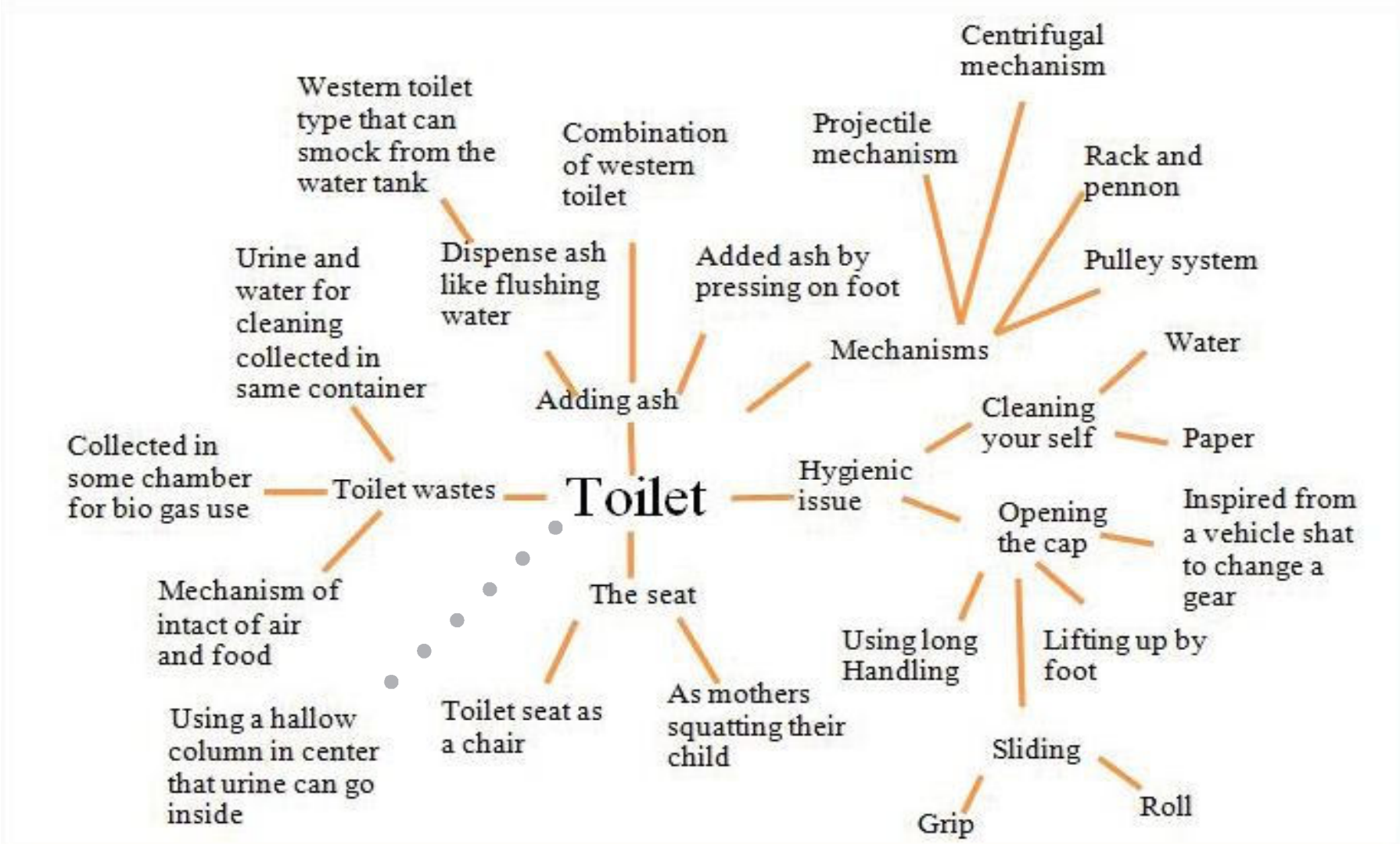
2.13 Why dry toile?

The design is a dry toile which separates fecal matter, urine and water for anal cleaning. This type of toilet is currently using by rural people and has the following benefits:

- It can be constructed any where like places with rich ground Water and those affected by flood
- Good solution for ground which are hard to dig
- It is permanent type of toilet
- It can be constructed near to the houses because it do not smell
- Best option for places in scarce of water
- It is good source of compost making

Chapter 3: Ideation and concept development

3.1 Mind mapping



3.2 Image Board

Figure 22 Image board1. Types of toilet seat and rooms

Figure 23 Types of toilet seats made from clay
(Source: http://www.indiamart.com/asia-diesel-exports/toilet-seats.html Assessed in August 31/2013)

3.3 Roll playing

The following steps shows that how rural people are using the toilet.

1. Lift up the cap of toilet pan
2. Tack down your pants
3. Sit on the toilet pan
4. Poop/ pee
5. Stand up
6. Wipe/clean your self
7. Put the wiper in the trash bin
8. Pull up your pants/put down your skirt if you are a girl
9. Tack same sawdust, Wood haven, lime, carbon or ash from the bucket and put in toilet
10. Close the pan
11. Wash your hands

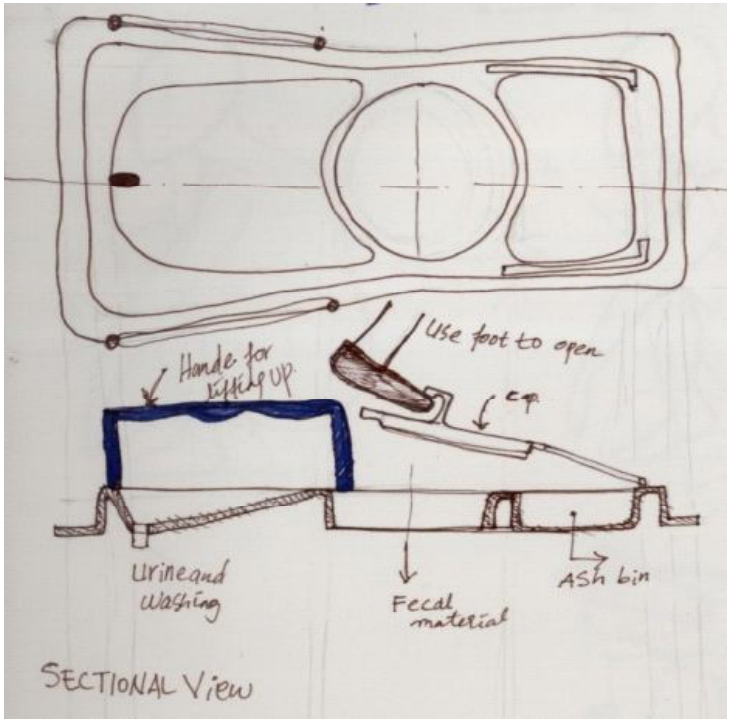
*In short Poop, pee, carbon, lime, ash or sawdust (Fig. 51) on page 46

3.4 Revised Design Brief

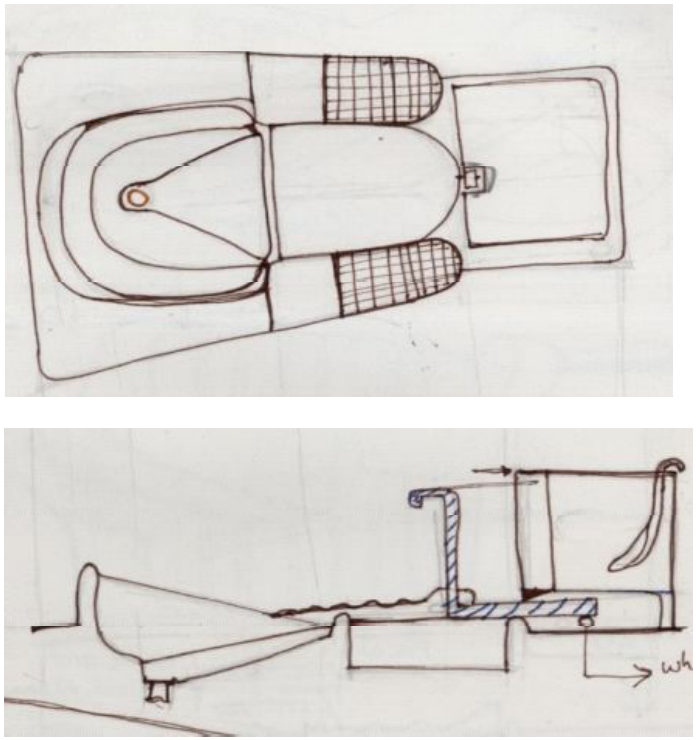
Design a low cost toilet for rural household:

- Which did not use water for flushing
- Separates solid waste from liquid wastes which uses as a compost making
- Enhance hygienic safety of users
- Easy to use and accessible for users

3.5 Concept development

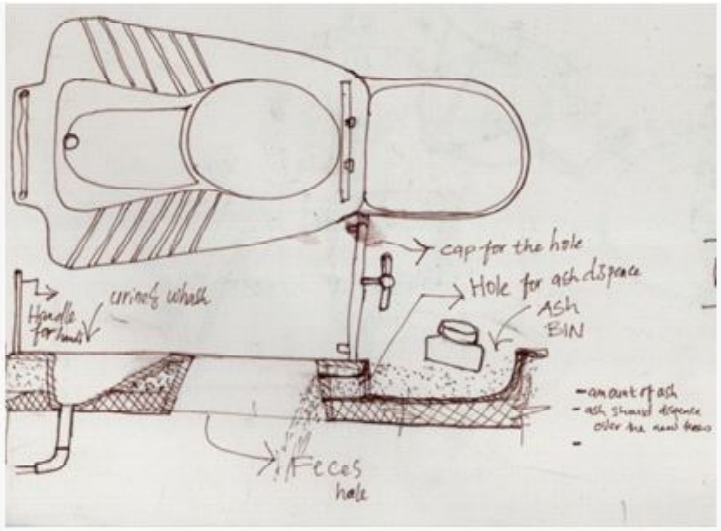


(A) This is an idea to Lift the cap by foot, handle for lifting up, Adding ash by scooping from the ash container

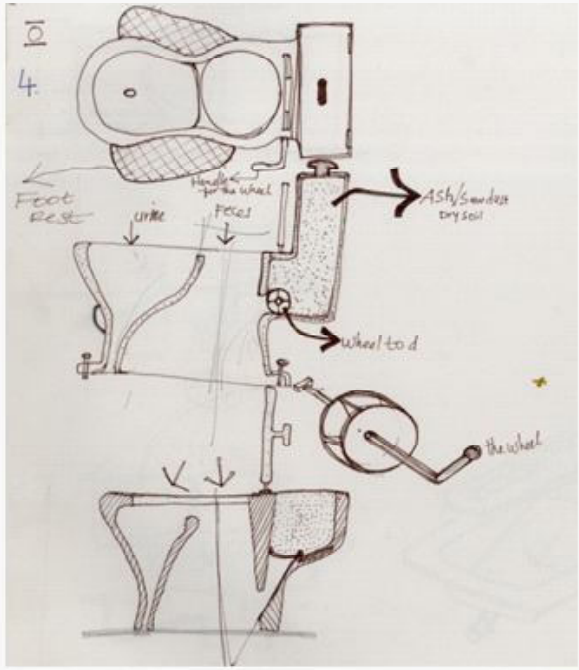


(B) An idea on how to opening the cap: pull/push the cap to close the hole, adding ash by scooping, move forward to clean yourself

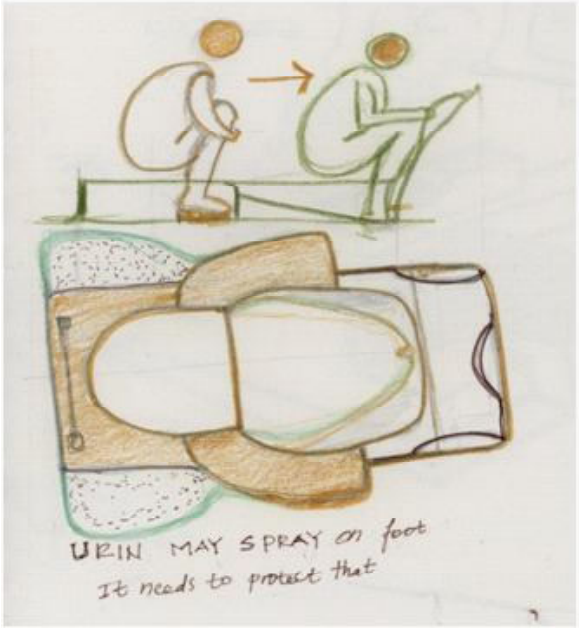
Figure 24 Ideas on how to add ash and open the cap



(A) Fixed cap to close the hole
Ash will be added by pushing from the back

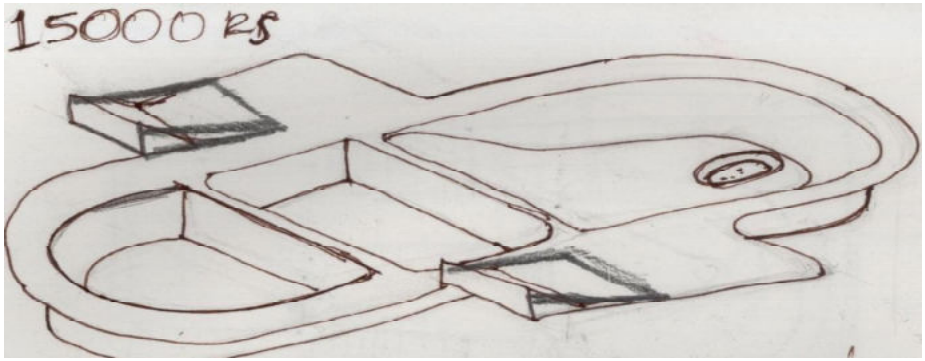


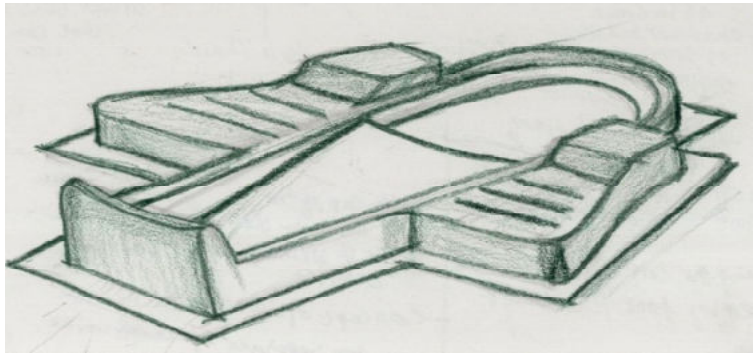
(C) concept of western toilet which flushes ash instead of water

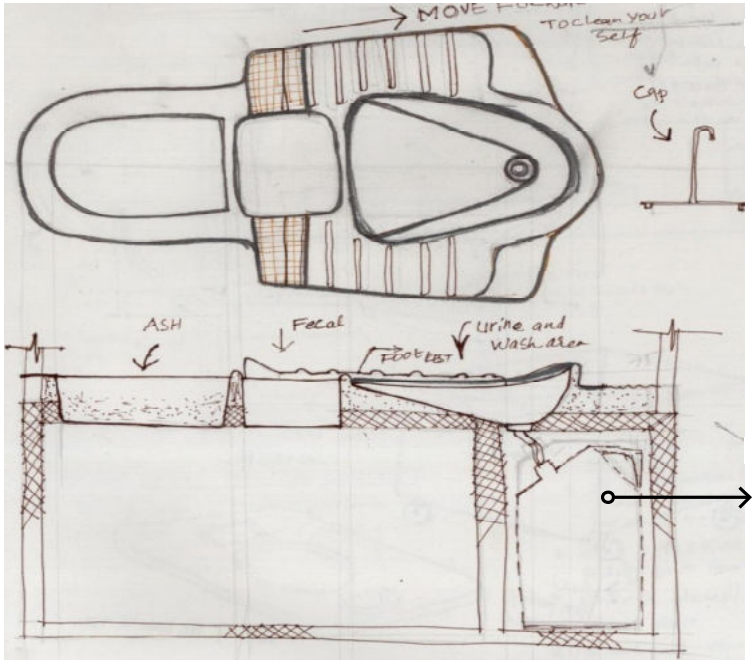


(B) Move forward to clean your self

Figure 25 Idea on seating position and adding ash, foot rest



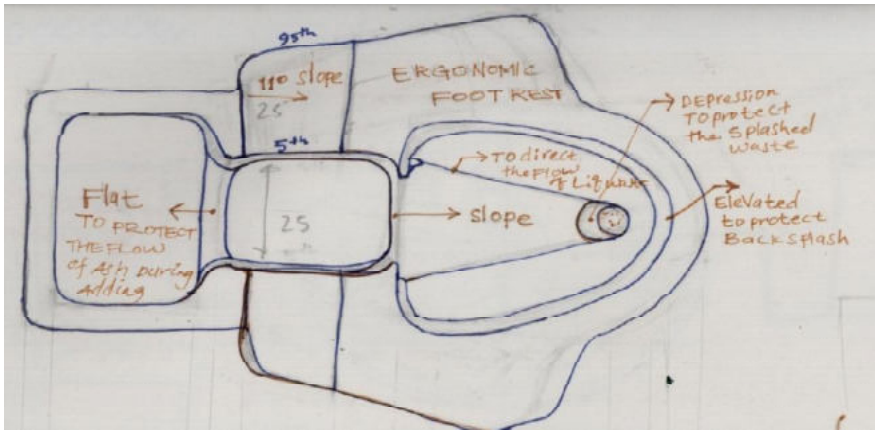




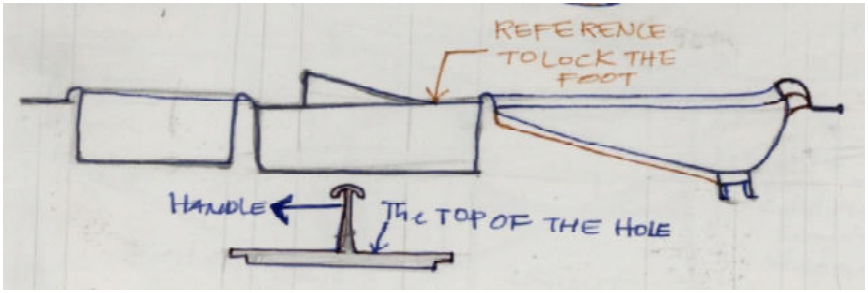
Providing some height to the handle of the cap to be hygienic

Urine and wash water collects in some Jerry can

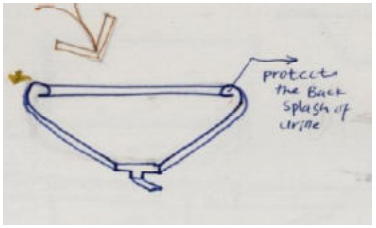
Figure 26 Idea on footrest and urine collection system

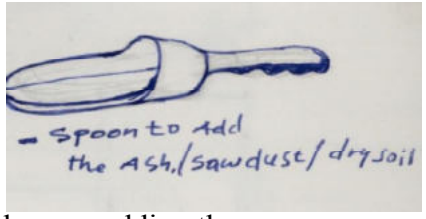


Ergonomically designed footrest,
Elevated height to protect splash back



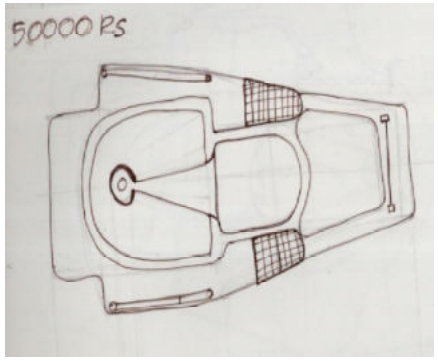
Ergonomic designed foot rest Protects urine splash back

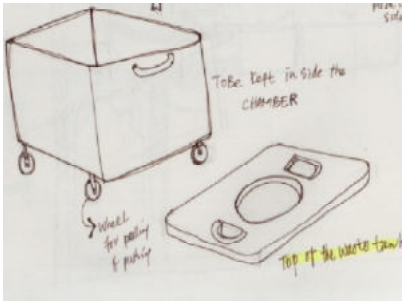


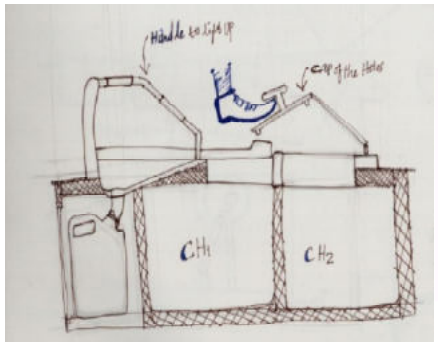


Scoop to add Ash/sawdust/charcoal.

Figure 27 Concept on opening the cap, adding the Ash, and squatting position

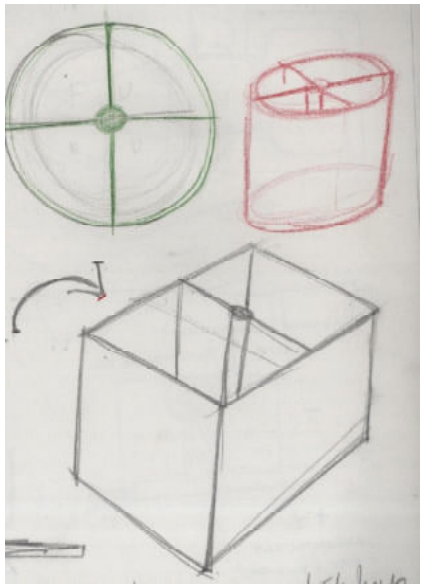


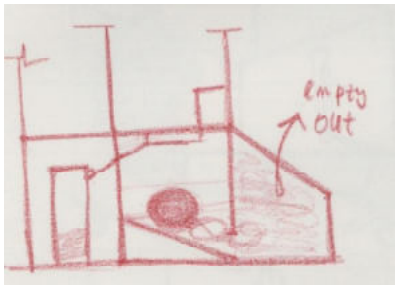




Using movable chamber
Open the cap by foot
Handle for lifting up

Figure 28 Concept on the chamber and ergonomic use of the seat





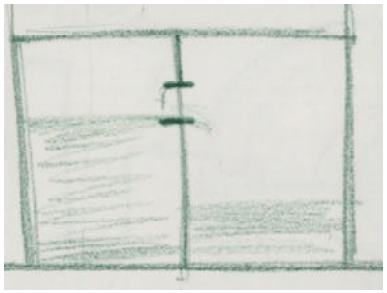


Figure 29 Possibilities of the chamber

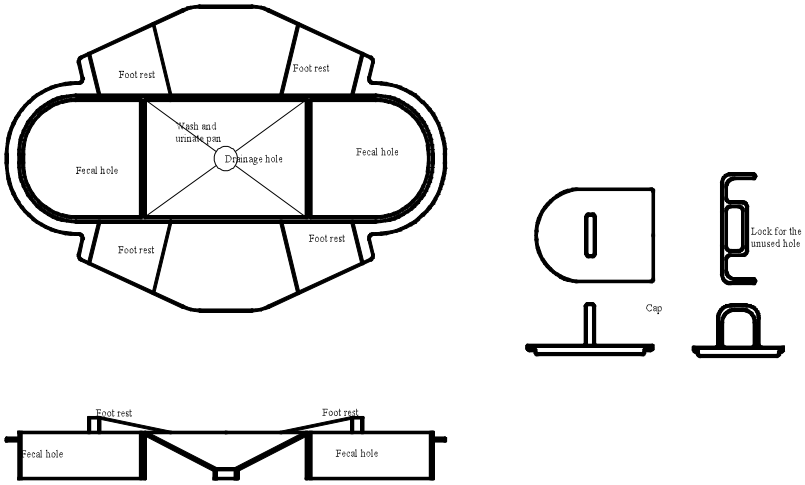


Figure 30 Two hole pan

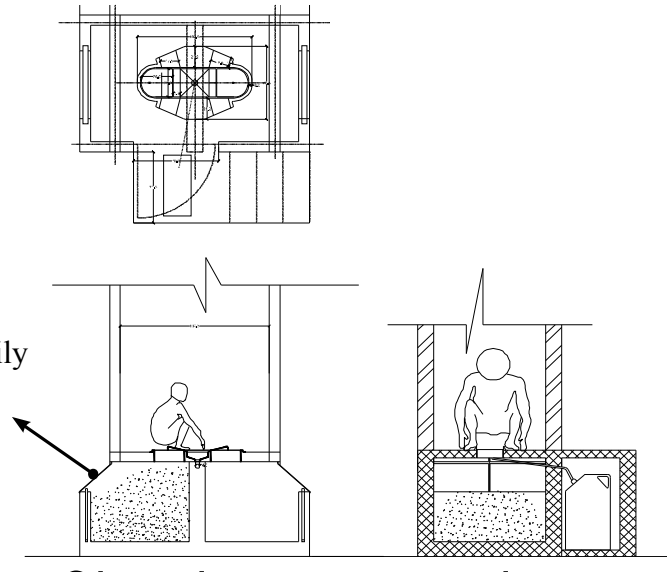


Figure 31 The product on the plan and chamber

3.6 Concept Evaluation

3.6.1 Concept 1

This concept has two fecal holes and fit each chamber(fig.30). Urinal and wash area cited at the middle for both sides of seating position which can protect splash back of liquid waste.

Advantages

1. It reduces number of pans (from two to one) which can minimize the cost
2. Comfortable footrest in squatting position and uses as reference point to seat in order to separate urine and fecal matter to fall in to the expected hole by locking the foot at the point where the angel of the footrest starts
3. Waste will not store over the urinated hole and wash area
4. Opening of the cap by foot is better than hand
5. Empty the chambers is relatively easy and safe

Disadvantages

1. Adding ash is still a problem
2. Since it has two holes the might be user interaction problem
3. Urine and water for washing are collected in same container so that it can full quickly
4. Men are forcing to squat for peeing
5. Fecal matter is collected at the corner because the hole is not in the center of the chamber

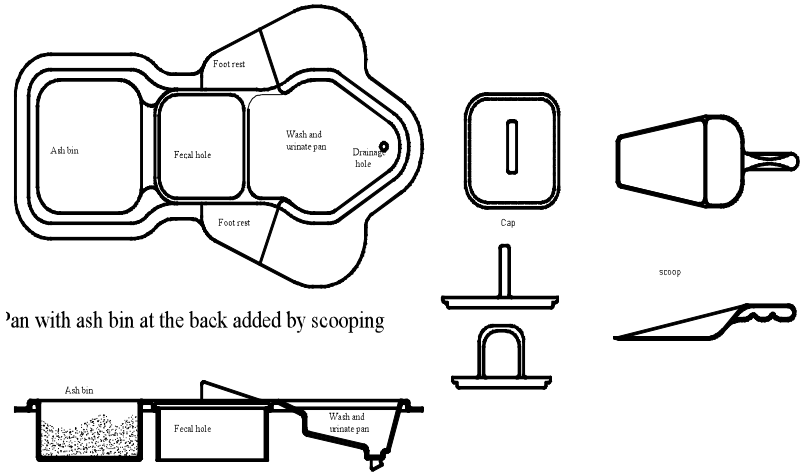


Figure 32 Pan with ash bin

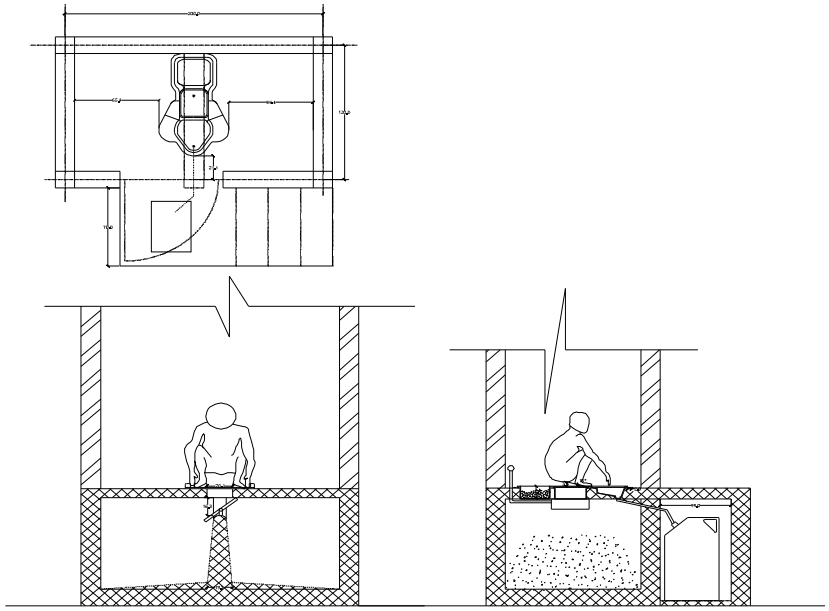


Figure 33 Sectional view of the plan

3.6.2 Concept 2

Advantages

1. It reduces number of pan (from two to one) in a single toilet which minimizes the cost
2. Comfortable footrest in squatting position and uses as reference point to seat in order to separate urine and fecal matter to fall in to the expected hole by locking the foot at the point where the angel of the footrest starts
3. Waste did not store over the urinated hole and wash area
4. Opening of the cap is better that it can open by foot
5. Ash can be added easily from the ash bin provided in the pan and no blowing ash over the floor

Disadvantages

1. Empty the chambers is unsafe and there is waste of space in the chamber
2. Urine and water for washing are collected in same container that it can full quickly
3. Ash may spoil the hand while adding in to the hole
4. Fecal matter is collected to one corner because the hole is not in at the center of the chamber
5. Ash may not added over the new feces because of the angle on the chamber.

6.

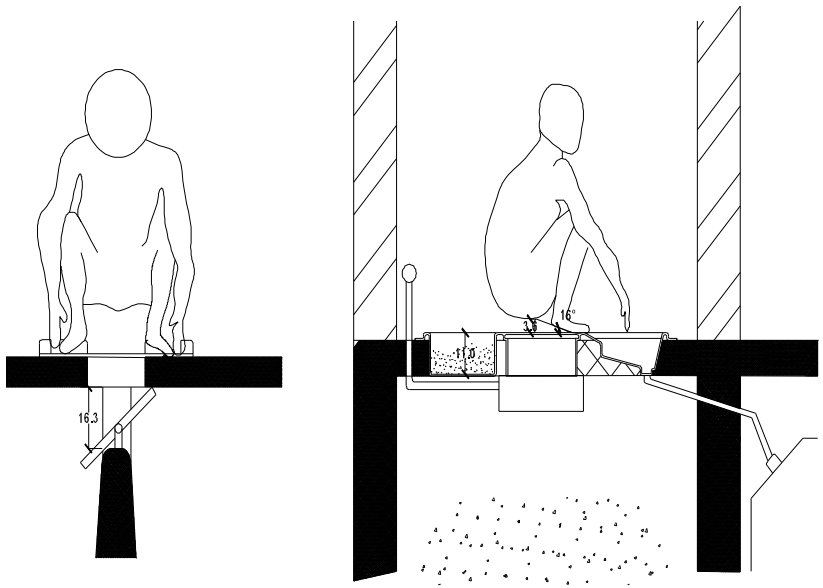


Figure 34 Sectional on the seat

3.6.3 Concept 3

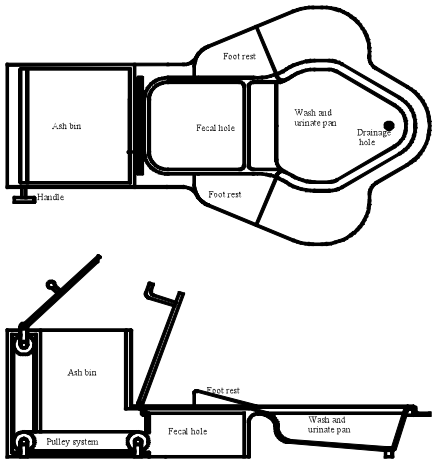


Figure 35 Toilet pan with pulley ash dispenser

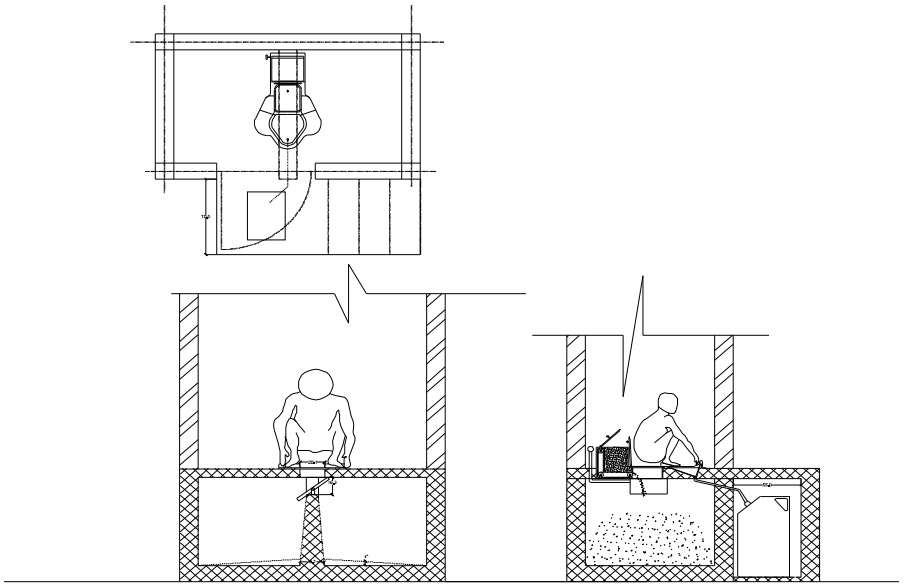


Figure 36 Sectional view of the pan in a room

Advantages

1. Men can pee in natural positioning of peeing (standing)
2. Comfortable footrest in squatting position and uses as reference point to seat in order to separate urine and fecal matter to fall in to the expected hole by locking the foot at the point where the angel of the footrest starts
3. No wastes are exposed outside (urine and waste water from wash area)
4. Waste did not store over the urinated hole and wash area
5. Opening of the cap is better that it can open using by foot
6. Ash can be added in to the hole by the mechanism without touching it

Disadvantages

1. Empty the chambers is unsafe and there is waste of space in the chamber at the top corners
2. Urine and water for washing are collected in same container that it can full quickly
3. Relatively expensive because of the pulley mechanism provided to add the ash
4. Fecal matter is collected to one side of the chamber because the hole is not in the center of the chamber
5. Ash may not added over the new feces because of the angle on the hole as shown in the section (fig 36)

3.6.4 Concept 4

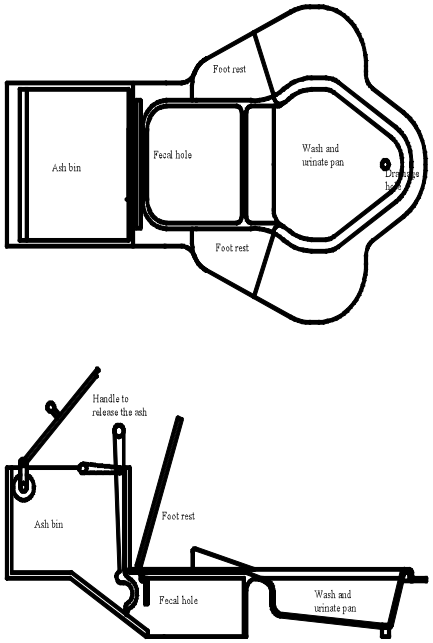


Figure 37 Toilet pan with gravity ash dispenser

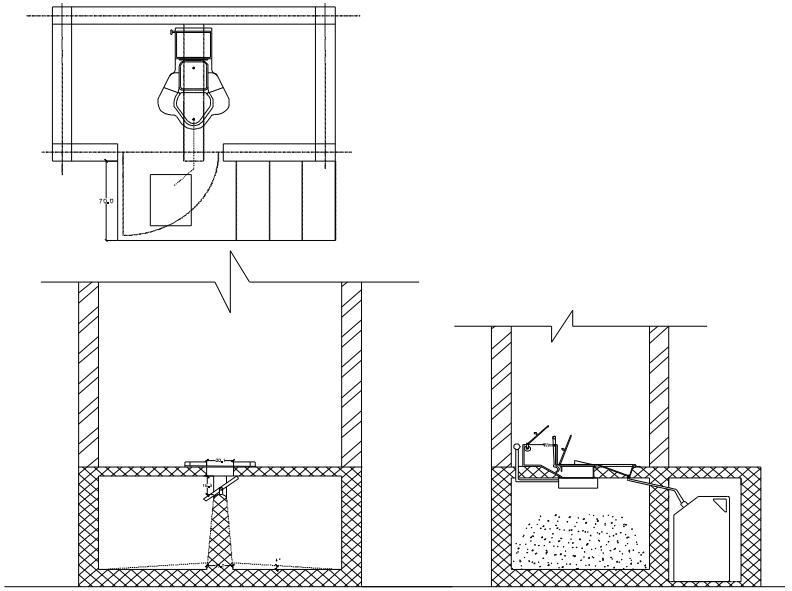


Figure 38 Sectional view of the room and pan

Advantages

1. No wastes are exposed outside the room
2. Comfortable footrest in squatting position and uses as reference point to seat in order to separate urine and fecal matter to fall in to the expected hole by locking the foot at the point where the angel of the footrest starts
3. Waste will not store over the urinated hole and wash area
4. Opening of the cap is better that it can open using foot
5. Ash can be added by gravity with out touching it

Disadvantages

1. Empty the chambers is unsafe and there is waste of space in the chamber

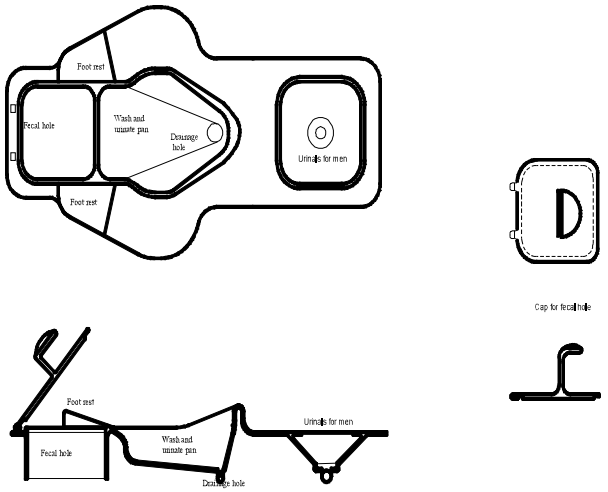


Figure 39 Pan with urinal for men and used by turn the position of the seat

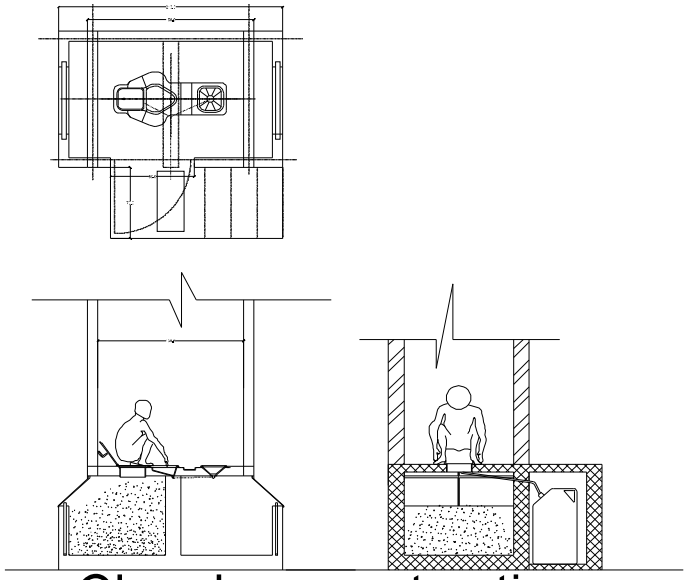


Figure 40 Sectional view of the pan and room

2. Relatively expensive because of the mechanism to add the ash
3. Urine and water for washing are collected in same container that can full quickly
4. Men forced to squat on the seat for peeing
5. Fecal matter is collected to one corner because the hole is not in the center of the chamber

3.6.5 Concept 5

Advantages

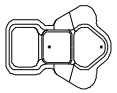
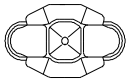
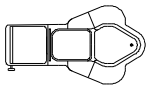
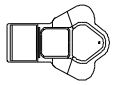
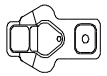
1. Simple and cost effective pan and it can be used by shifting the pan to the other chamber when the chamber in use is full
2. Provided urinal for men that can use in the natural peeing position (standing) as well as uses to cover the hole of the d chamber which is not in use
3. Chamber is relatively simple to empty and allow to see the wastes in the chamber
4. Comfortable footrest for a squatting position and reference for the urinal and fecal hole by locking on toe during squatting
5. No wastes are exposed outside for children reach and cattle
6. Waste will not store over the urinated hole and wash area
7. Opening of the cap is better that can open using foot
8. No space wasting in the chamber

Disadvantages

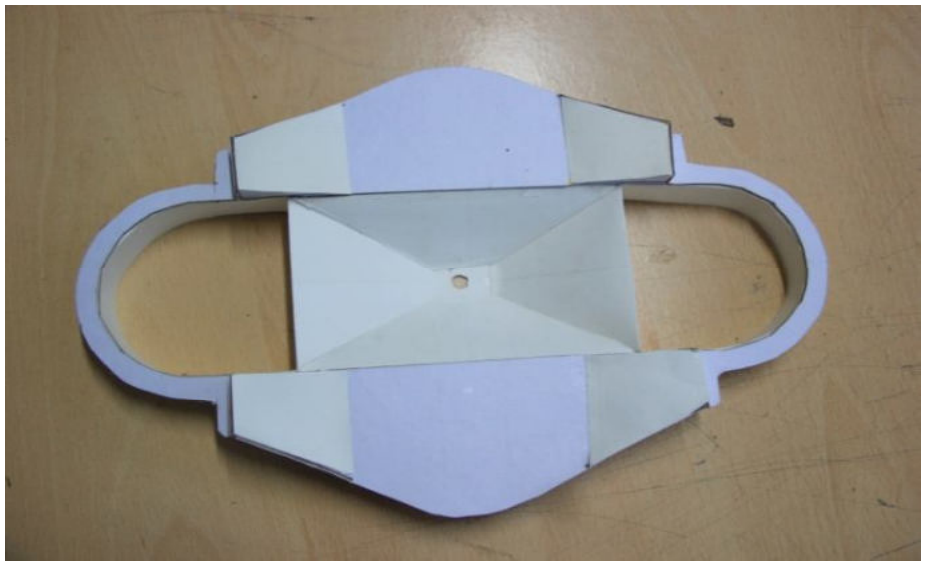
1. Urine and water for washing are collected in same container that it can full quickly
2. Adding ash to the chamber is still a problem
3. Shifting the pan when it needs to change to the empty chamber

3.7 Ranking of concepts

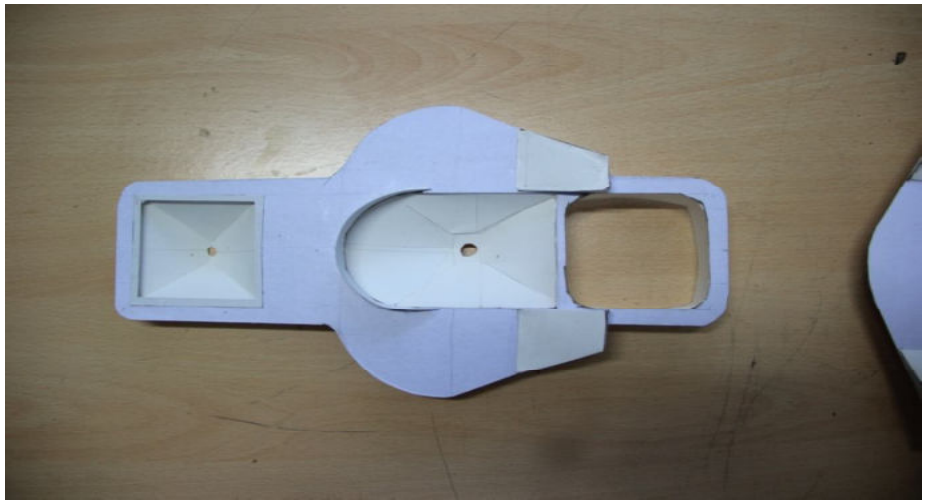
Table 3 Concept evaluation

Concepts	Adding ash	Place for the ash and scoop out process	Protec-tion of Ash from blown by air	Safety of Urine storage	Protection of Waste water which comes out from the wash area	Footrest is not ergo-nomic in squatting position	Wastes did not stored over the wash area and urinals	Opening the top of the fecal hole/cap is unhygienic	One seat in a single toilet room	Men pee in natural posi-tion	Low cost	Addi-tional func-tions	Diverting urine and fecal	User interaction of the seat
Concept 2 	Yes/2	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes/2	No	Yes/2	Yes/2
Concept 1 	No	No	No	Yes	Yes	Yes	Yes	Yes/2	Yes	Yes	Yes	Yes	Yes/2	Yes/2
Concept 3 	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	Yes/2	Yes/2
Concept 4 	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes/2	Yes/2
Concept 5 	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Mock up models



(A) Mock up model of the two hole pan



(B) Pan with urinal

Figure 41 Mock up models of the seat

This ranking is giving by listing the problems shown in table 3 how much problems can solved.

Note that:

Yes = problem is solved

Yes/2 = it is better solution but still needs more work

No = the problem is not solved yet

- Concept 5 got 3 No's and 11 yeses(1st rank)
- Concept 3 got No's and 3 half yeses and 8 yeses (2st rank)
- Concept 2 got 4 No's and 8 yeses 3 half yeses (Rank 3rd)

3.8 Finalizing the pan dimensions

The dimension of the fecal hole is equal to Buttock to urethra (20.1cm of 5th percentile) as show in table 2. Thus, in order to compromise the problem the smaller size (5th percentile) is considered. The foot rest in squatting position starts from the edge of the fecal hole (20.4cm of 50th percentile of the heel to heel dimension) plus 95th percentile of foot width. Foot length is 27cm which is 95th percentile. The footrest is designed 95th percentile; 7cm heal breadth and 10cm foot breadth. The angle of foot in squatting position can be calculated maximum toe to toe dimension, 41cm (95th percentile). The footrest is lifted to a maximum height of 12cm (95th percentile) and 3.7cm (5th percentile). This adapts as 4cm high (5th percentile).

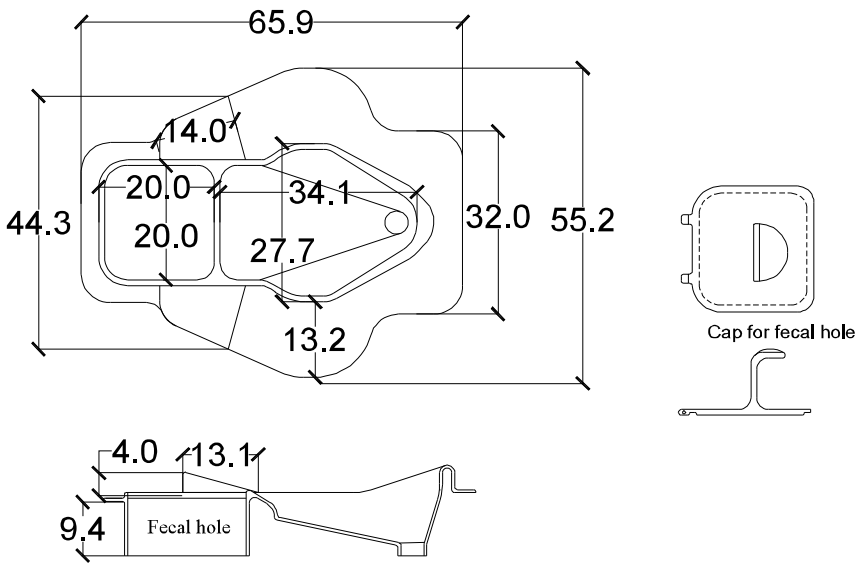


Figure 42 Dimension of the toilet pan

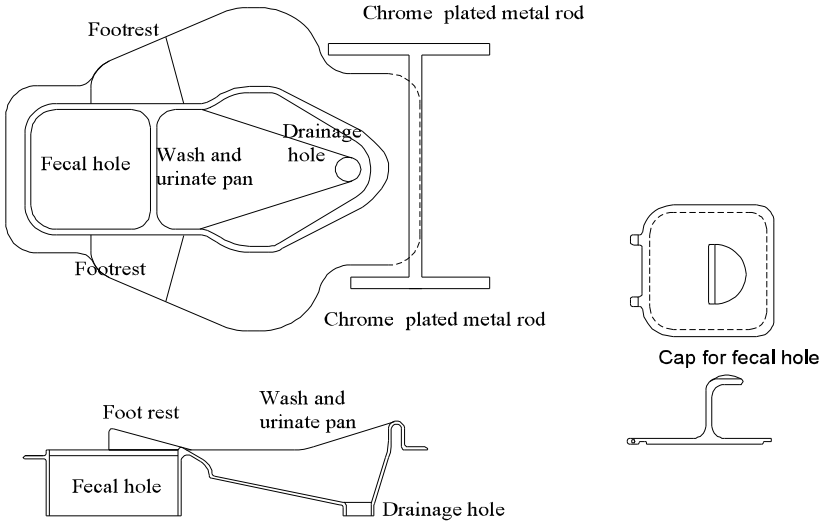


Figure 43 Toilet pan with supporter handle for elderly

3.8.1 How to use the toilet pan

This pan is used only in squatting position in an Indian tradition. Solid and liquid wastes are diverted on the pan. The Night soil (Feces) falls perpendicular in to the center of the chamber and urine is collected in a Jerry can below the stair case as shown in figure 47. Move forward to clean yourself in the wash pan and wash water is collected in same Jerry can with the Urine. The pan is used for the two chambers by shifting after the first chamber is full. This is simple process that lifting up and changes the position of the pan to the next use. The pan is fitted on to the floor through the footrest which can protects unwanted movement of the pan.

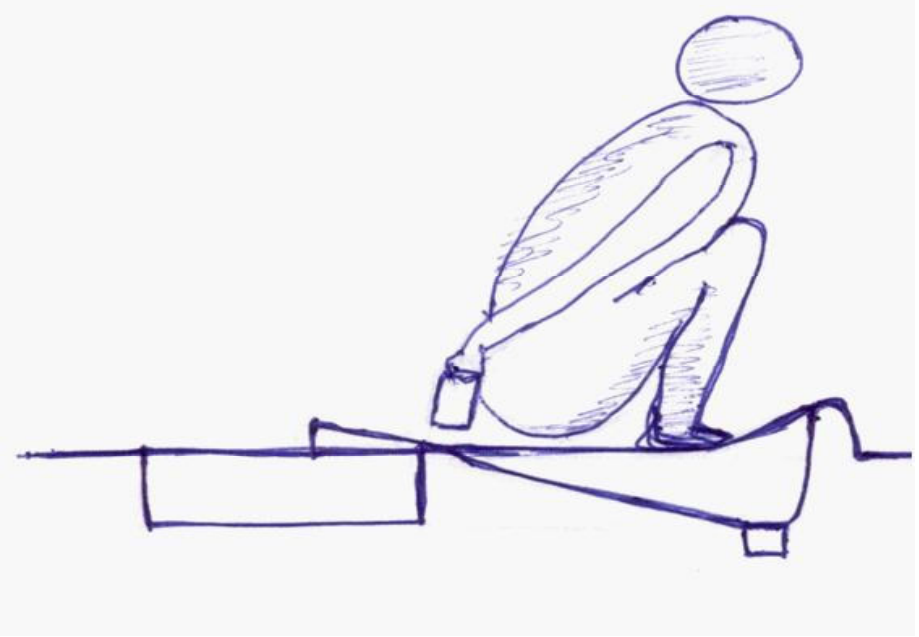


Figure 44 Self cleaning

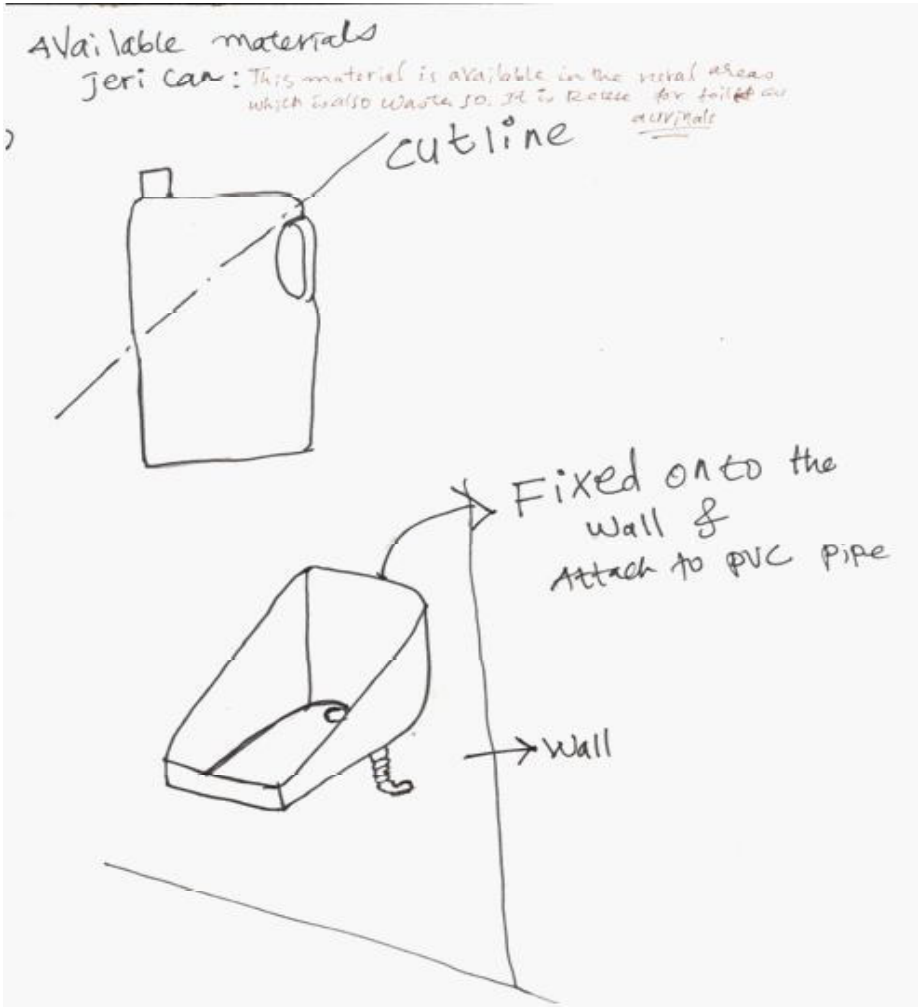


Figure 45 Cut Jerry can for Urinal use

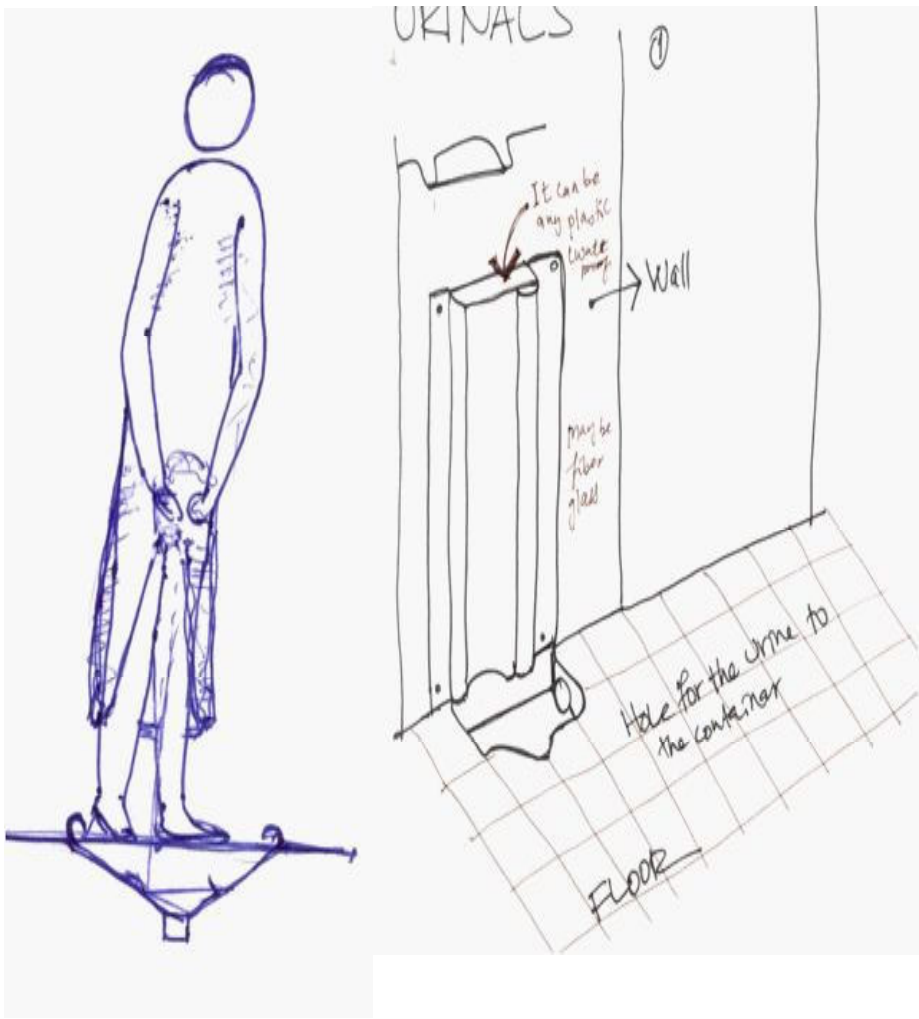


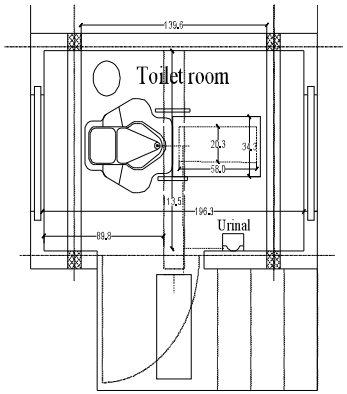
Figure 46 Wall Mounted urinals

The following urinal is also used by fixing on the wall which is drained by a PVC pipe to the Jerry can through the slab.

3.9 Removing and collecting the waste from the chamber

Dried fecal waste is removed from the sides of the chamber which is provided to get easy access and the fecal matter got dry faster because the cover is metallic which transfers heat in to the chamber. Addition-

ally is a door mounted to the chamber which helps to cover the fecal hole and helps as a protection of the fall of dry waste as shown in figure 47.



The design allows to get access and ventilation in to the dry waste n that solves the problem in invisibility of the new fecal mater during adding ash

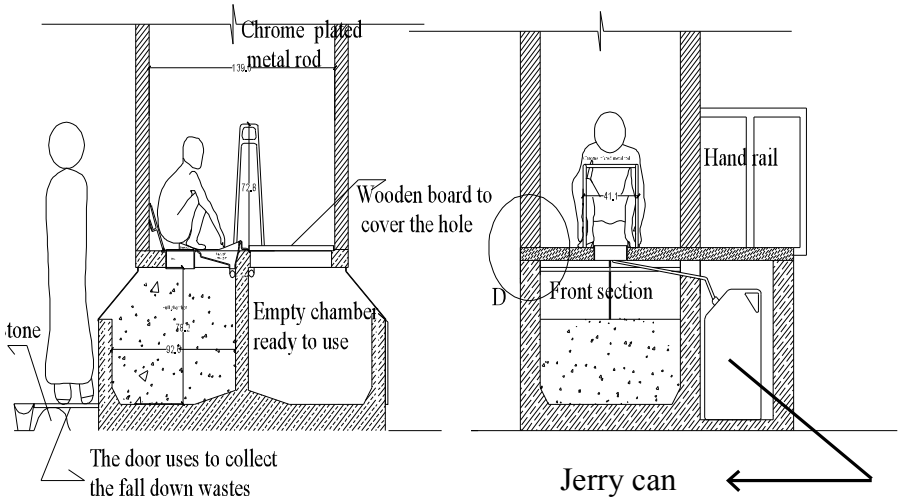


Figure 47 Chambers section

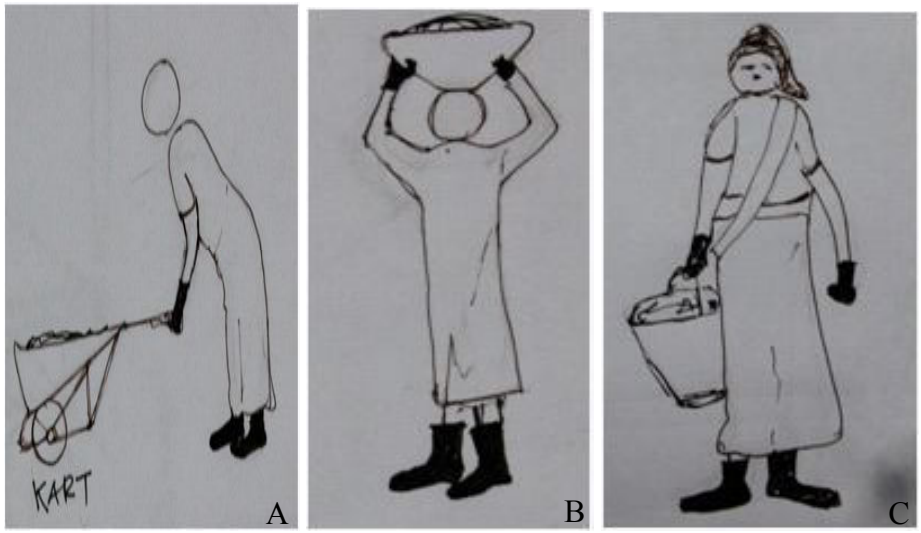
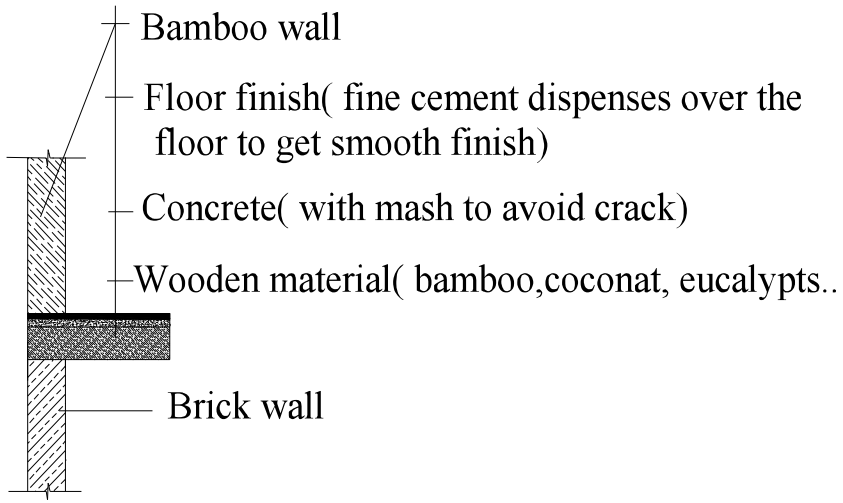


Figure 48 Transporting the waste



Wall, Slab and chamber detail(D)

Figure 49 Detail of the wall and slab

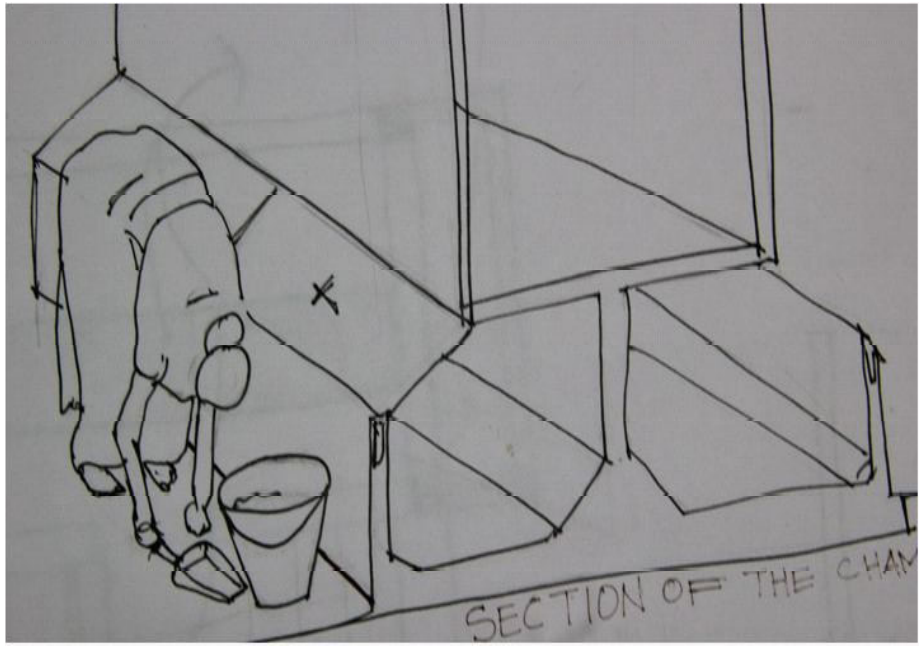
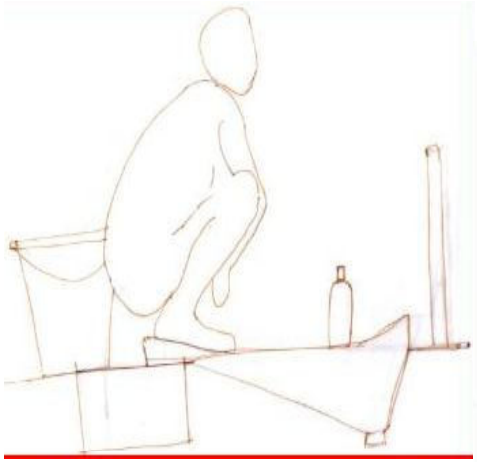
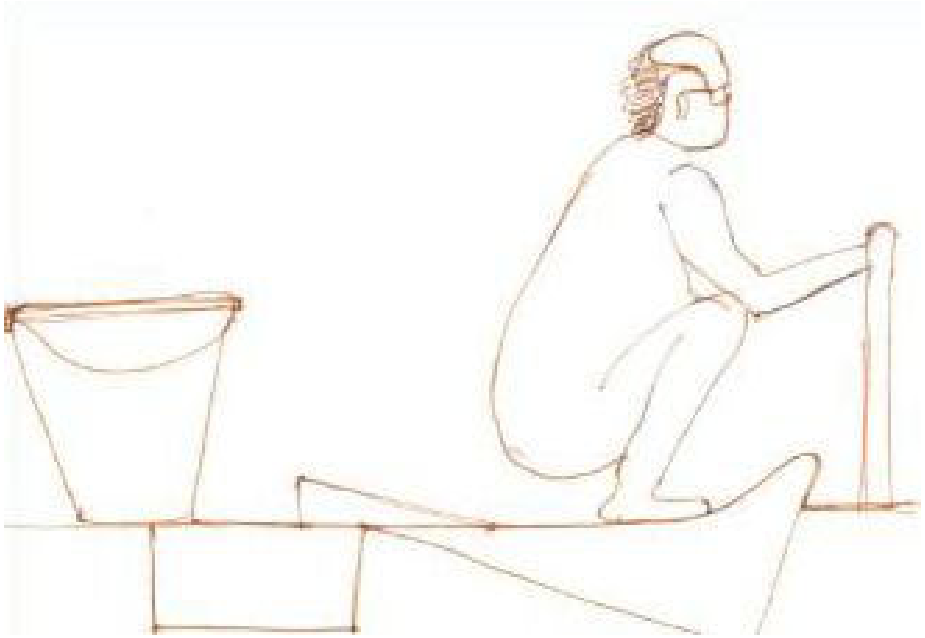


Figure 50 Cleaning the fall wastes around the chamber

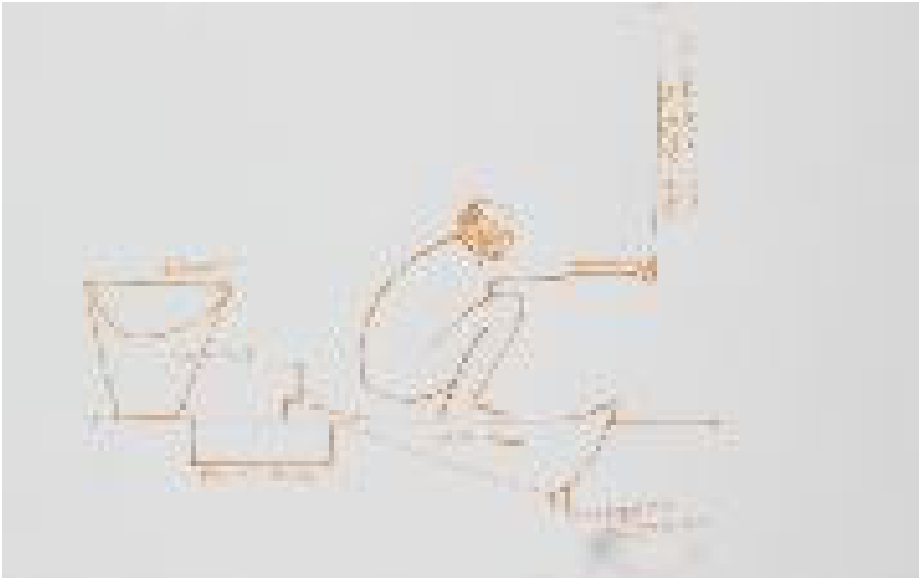


(A) Squatting

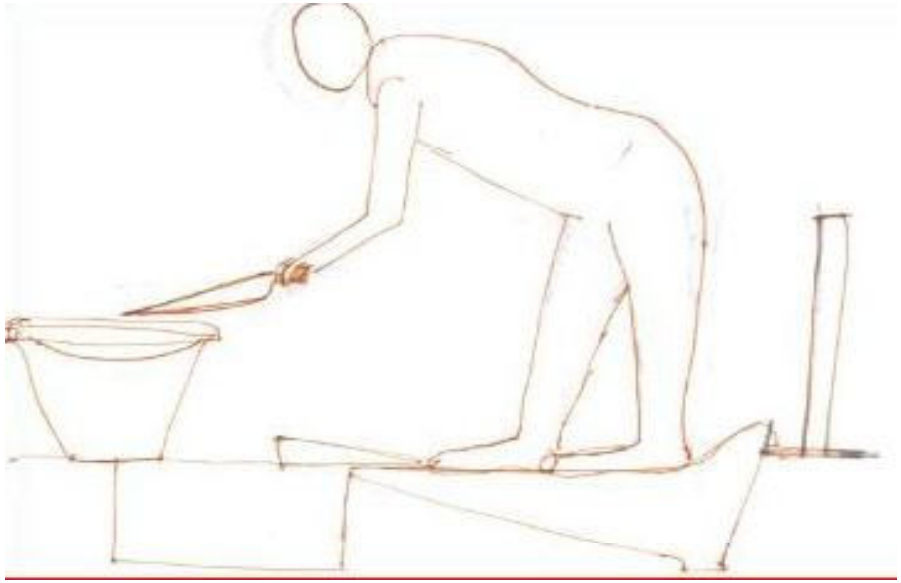
(B) Washing



(C) Lifting up using wooden bar (Elderly)



(D) Lifting up using ceiling hanging rope (Elderly



(D) Adding ash

Figure 51 Activities in the toilet

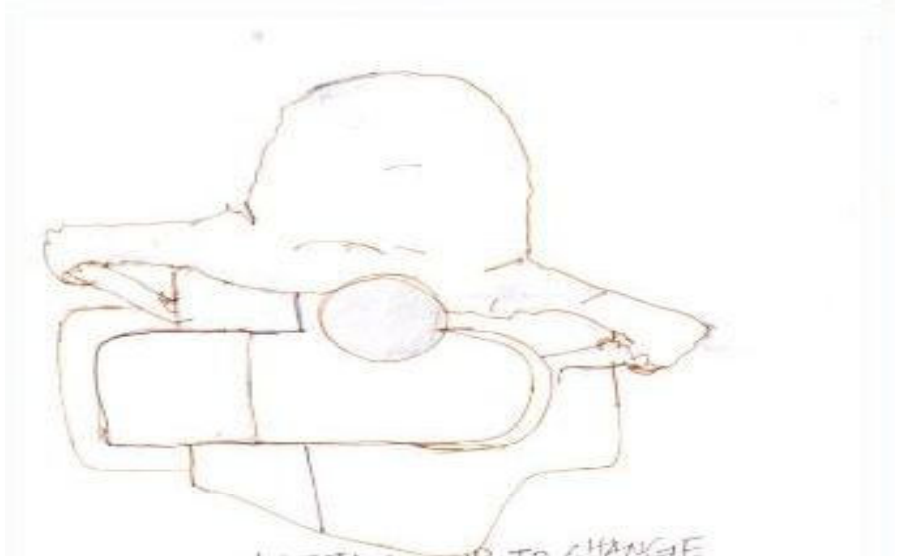


Figure 52 Lifting up the pan to change

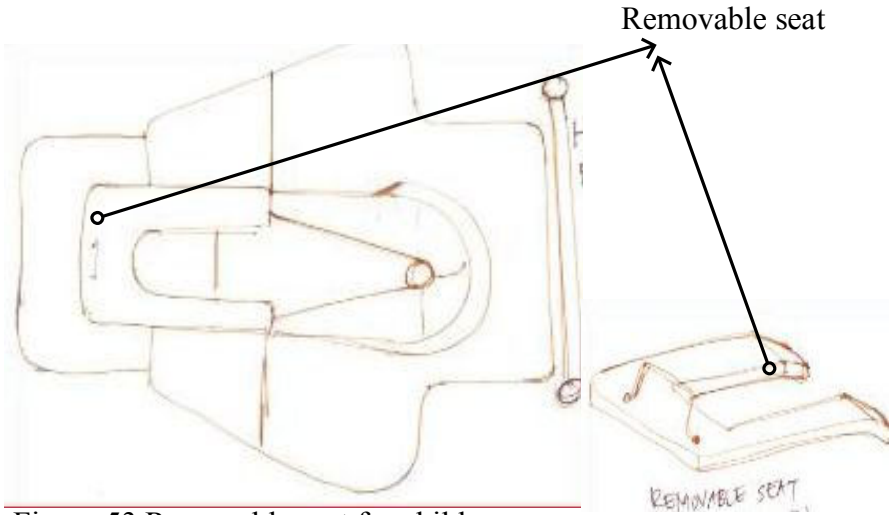


Figure 53 Removable seat for children

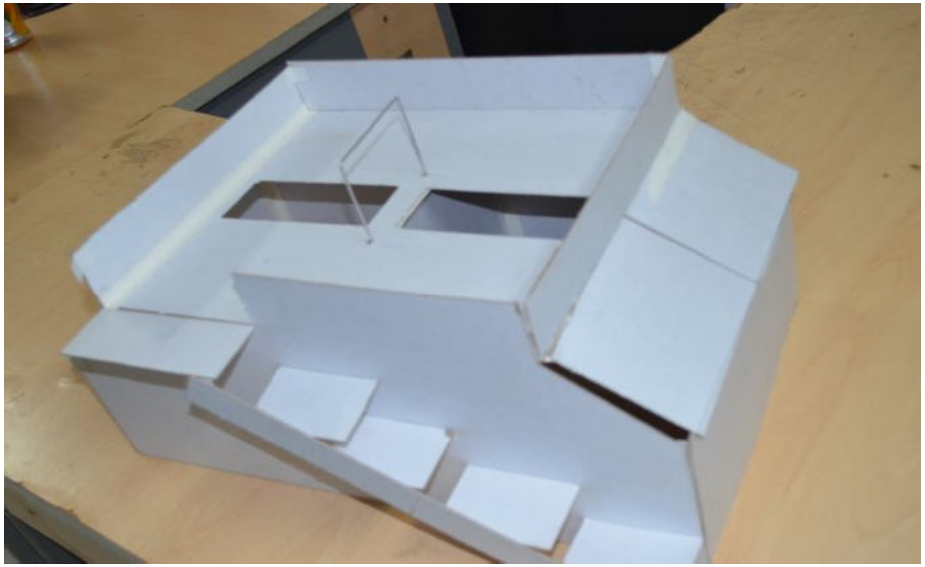


Figure 54 Mock up model of the room

Figure 55 Squatting position

Figure 56 Wooden bar to lifting up (elderly)

Figure 57 Ceiling hanging rope to lifting up (elderly)

The Images represented in figure 56 and figure 57 represents the way how old people standing up after they finished their staff in the toilet. Figure 56 is one method to lift up while the old people standing up. But this is very expensive and needs space in the toilet room.

Figure 57 is also an other method which is used a rope hanging in a ceiling. This is quit cheap and affordable for rural people and it is a typical Indian tradition where old people uses in their home mainly in their beds.

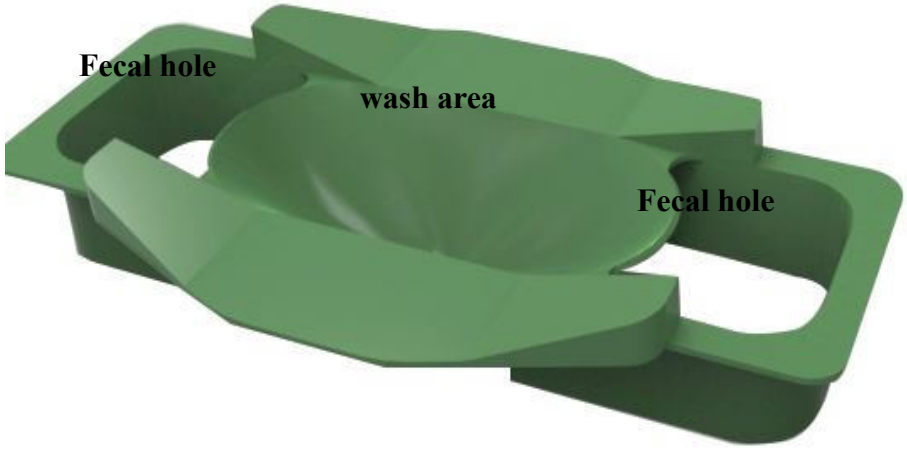


Figure 58 Concept 1 pan with two holes

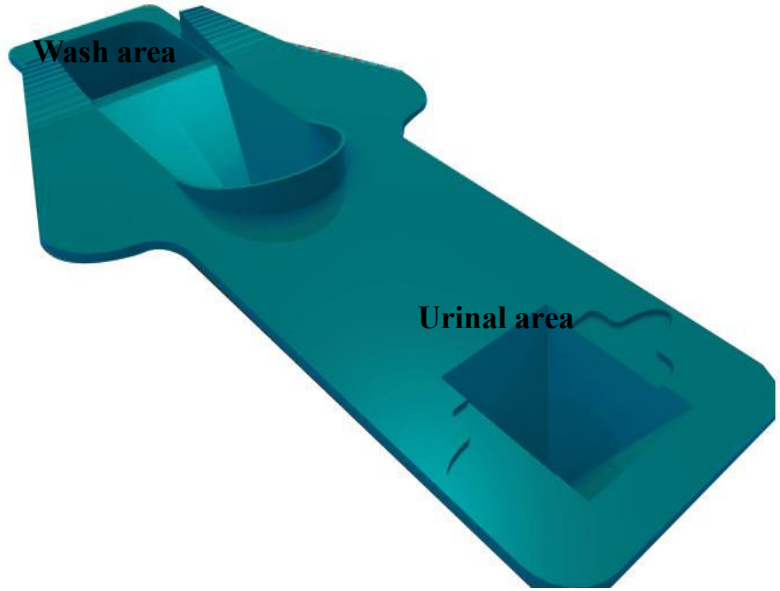


Figure 59 Concept 2 **Pan with urinals**

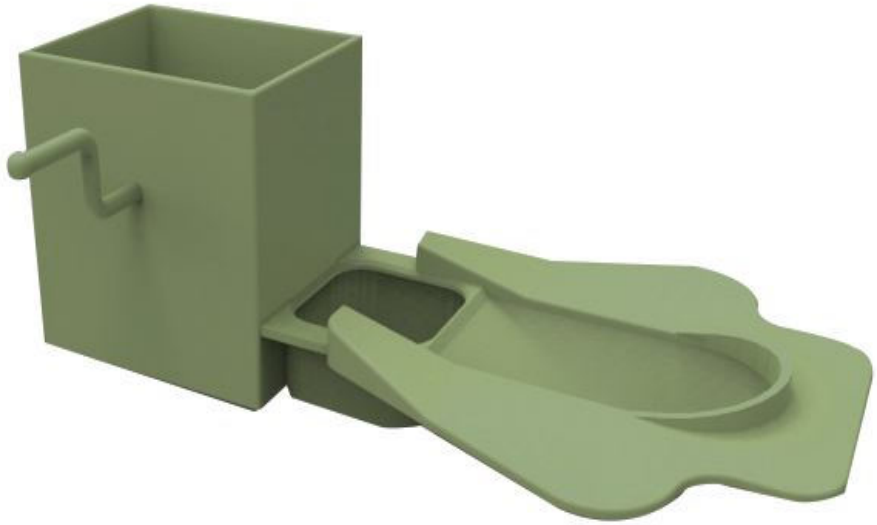


Figure 60 Concept 3 pan with ash container

Figure 61 Concept 4 pan with no additional function

Table 4 Final concept evaluation

Parameters

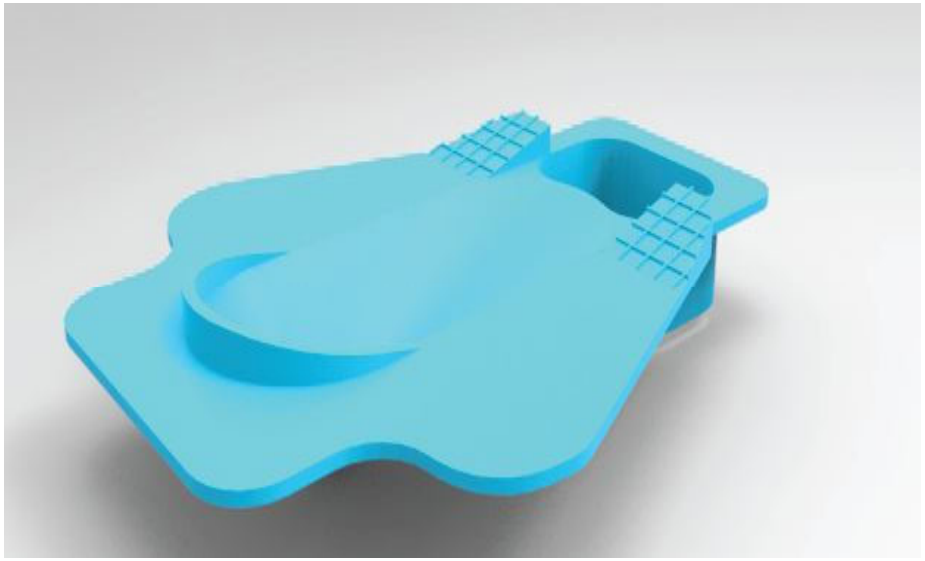
For evaluate	Concept 1	Concept 2	Concept 3	Concept 4
Portability	2nd	3rd	4th	1st
Low cost	2nd	3rd	4th	1st
User interaction	4th	3rd	2nd	1st
Simplicity	3rd	2nd	4th	1st
Functionality	4th	1st	2nd	3rd
Manufacturing	2nd	3rd	4th	1st
Compatibility	2nd	3rd	4th	1st

There for according to the given evaluation criteria concept 4 (Figure 61) is final concept of the pan.

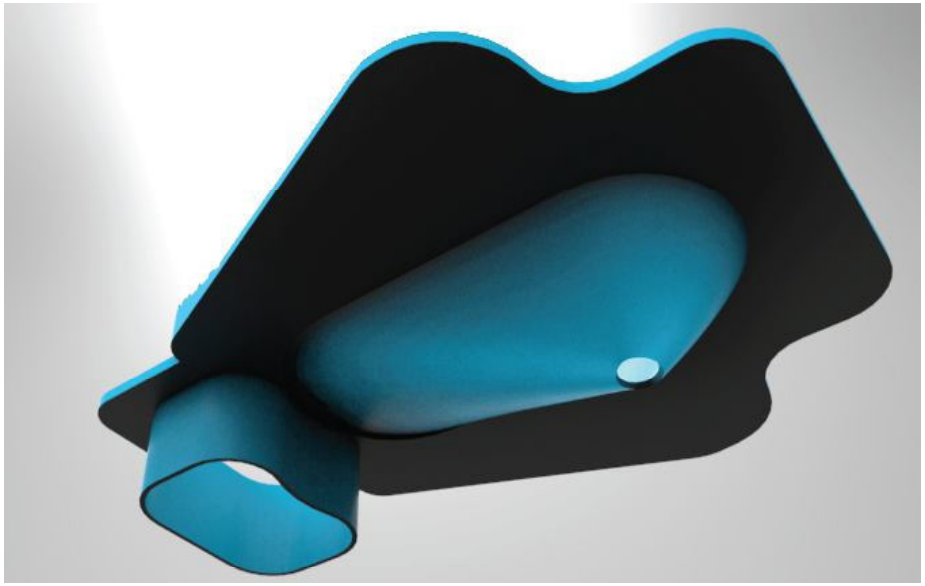
3.10 Form exploration of the Final concept

(A) Top in 3D

(B) Perspective view from back



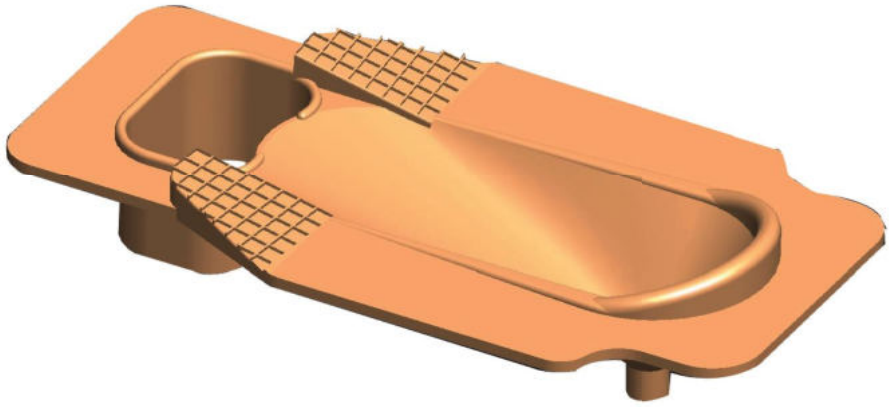
(C) Perspective view of the pan (front)



(D) Bottom view of the pan

(E) Perspective view of the pan (back)

Figure 62 Final design of the pan



(A) Isometric 3D view from the top

(B) Isometric 3D view from bottom

Figure 63 Final Design of toilet pan

Figure 64 Cap of the fecal hole

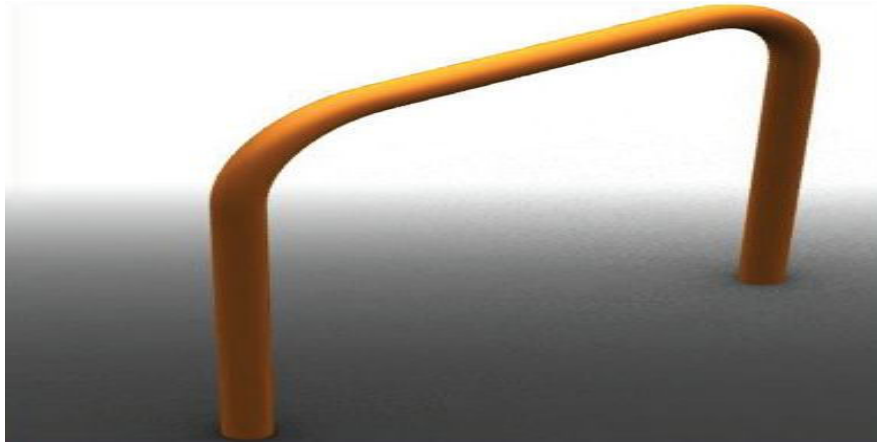


Figure 65 Wooden handle to lift up (for elderly)

Figure 66 Ceiling hang rope with handle to lift up (for elderly)

Figure 67 Wooden board Wooden board to close the unused hole of the chamber from the top

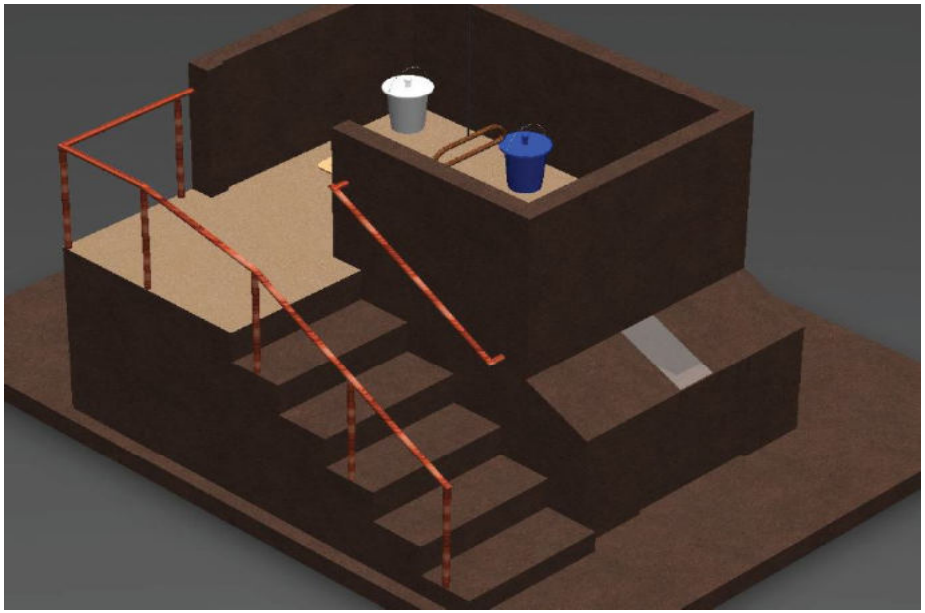


Figure 68 Toilet room

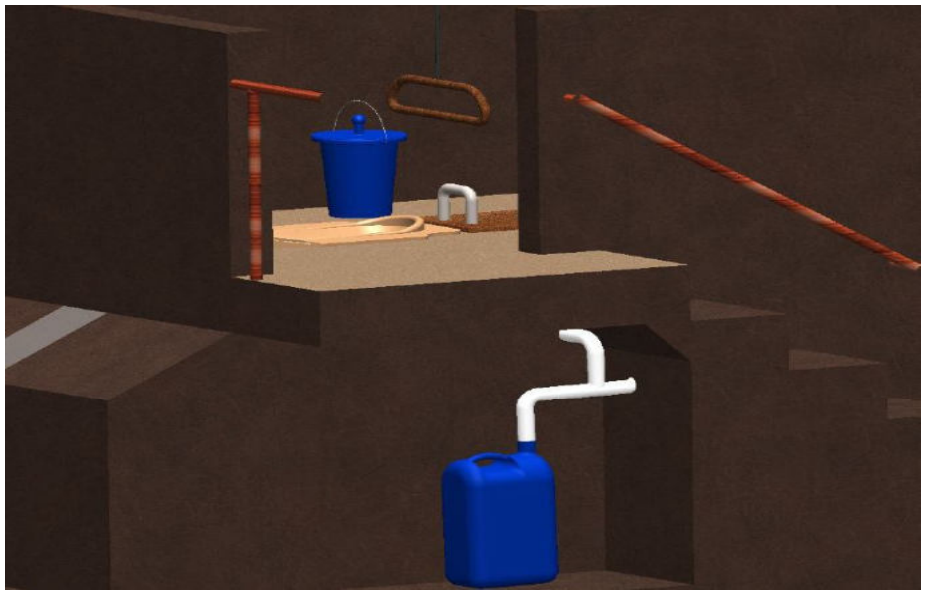


Figure 69 Suctional view of the toilet

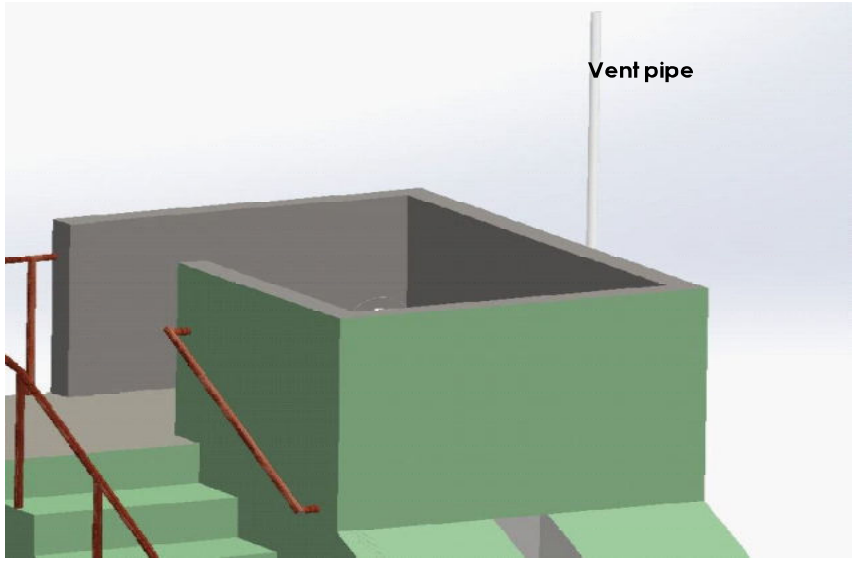


Figure 70 Elevated vent pipe to the rear side of the room

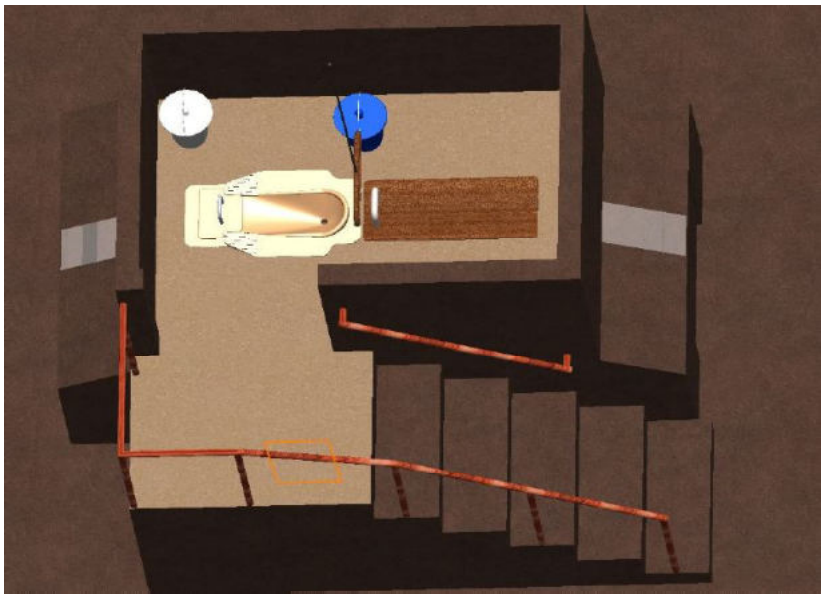


Figure 71 Furnishing room with the fixtures

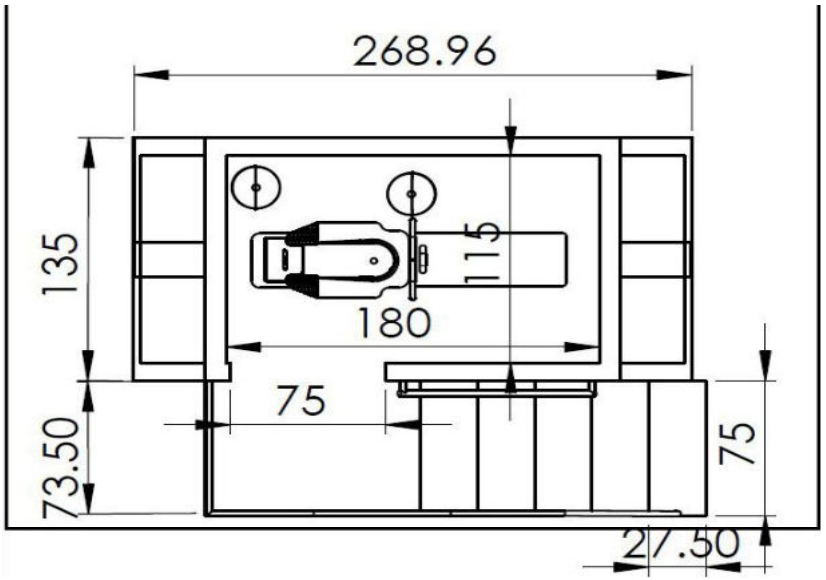


Figure 72 Dimension of the room

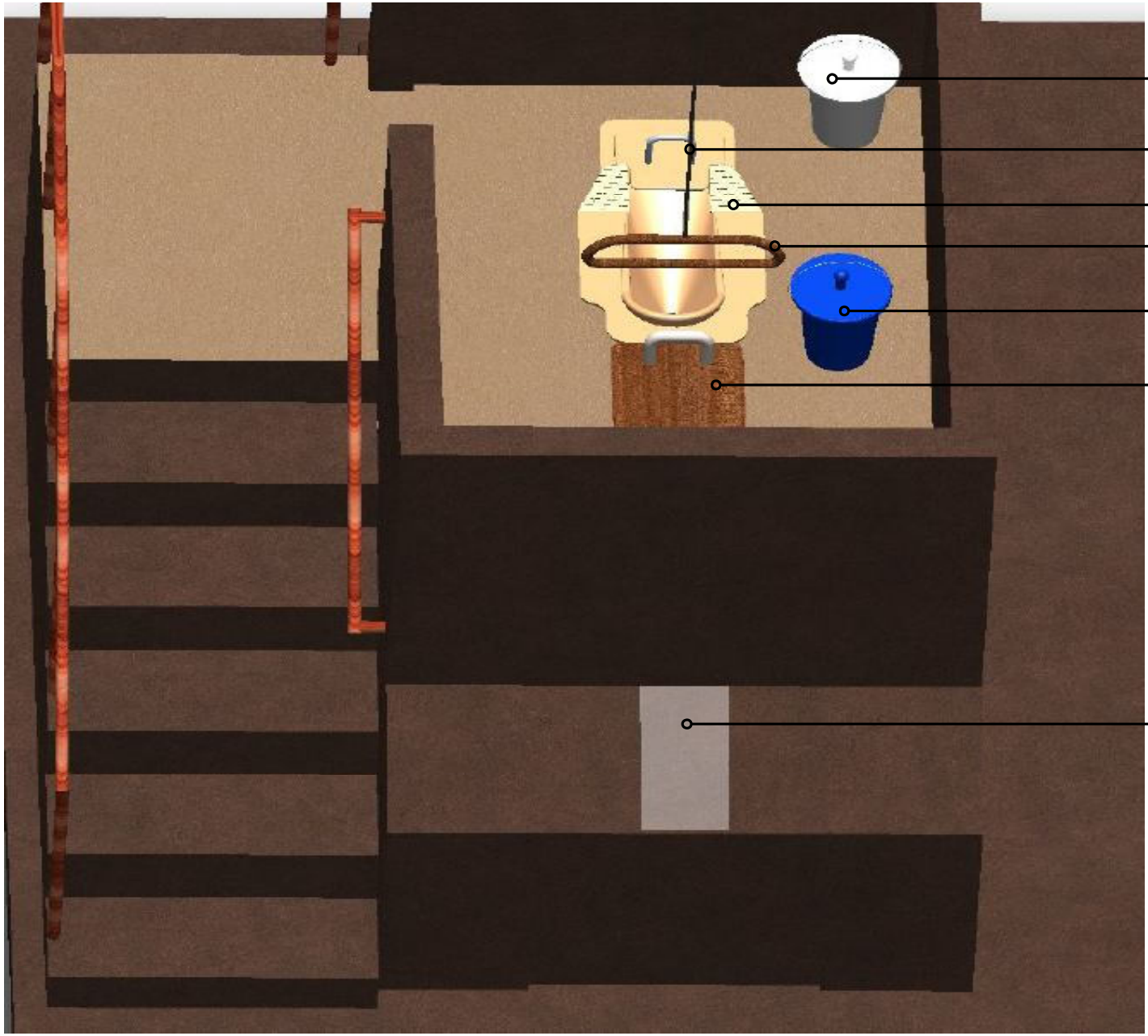
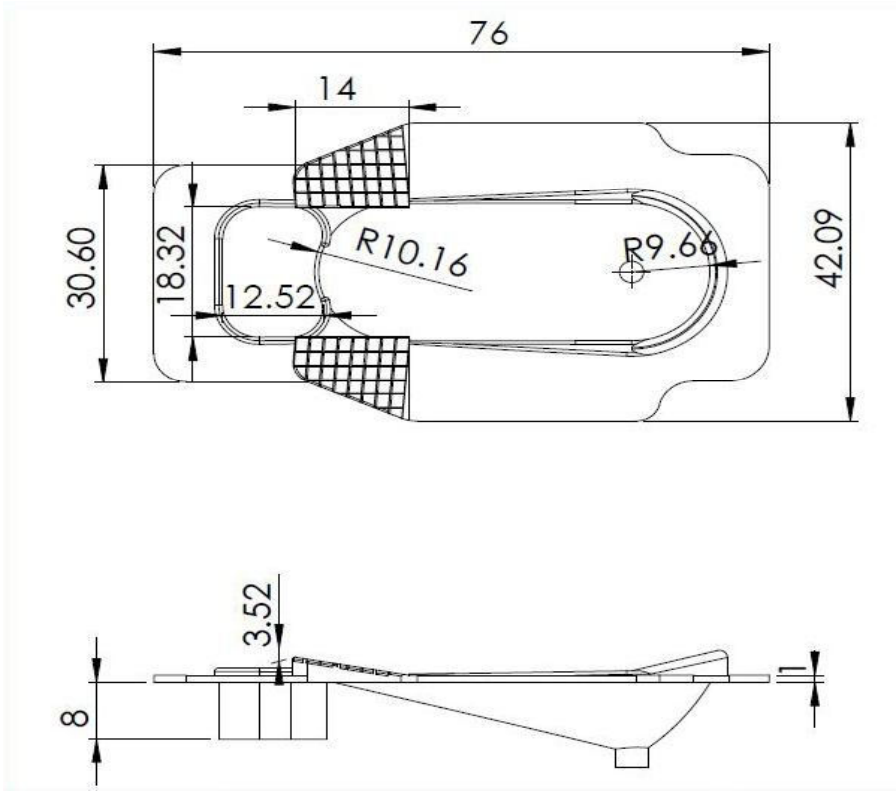
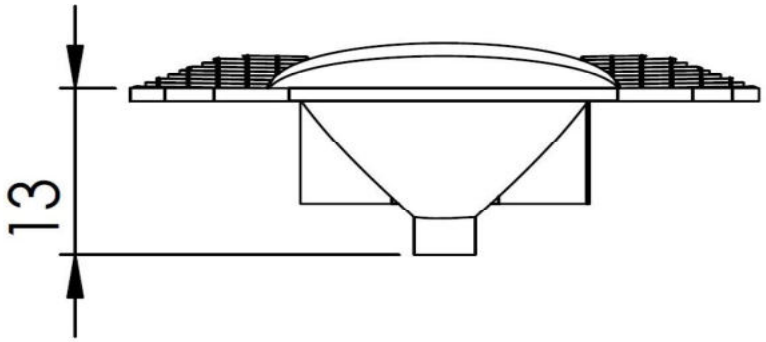


Figure 73 The products in the room



(A)



(B)

Figure 74 Final pan with dimensions

3.11 Material selection and consideration

Possible materials used to manufacture the toilet pan are listed below

- Gypsum and other materials for strengthen the seat
- Clay and gypsum by adding other natural materials to provide strength
- Concert toilet mostly used in rural areas
- Polyvinyl chloride(PVC)
- Hard wood (maple or birch)
- Fiberglass by adding good surface finish and scratch resistance materials like tooling resin Wood laminated
- Paper pulp with good surface finish
- Stainless steel/ sheet metal by coating **Vitreous enamelling**

This pan is designed to be made using stainless steel by coating vitreous enamelling which is durable, scratch resistance, free of corrosion and light weight to transport to rural areas.

3.12 Manufacturing process

After making the final mold of the product from stainless steel spray Vitreous enamelling on to the product and fired in to vitreous enamelling furnace(750- 850 degree centigrade) to form a permanent bond with the steel base. This cover coat is applied either by dipping or spraying to obtain a wide range of color. It is possible to use in any shape with out losing its property.

(A)

(B)

(C)

Figure 75 Final Model of the toilet pan

3.13 Product branding and logo design

Product name is “Netsi” which is an “Amharic” word, in Ethiopian National language and its meaning is free, clean. As you can see in the logo the letter ‘N’ reflects user in relaxed position. And the color Green represents the toilet is used as a compost making that is green.

References:

1. Anna Richert, Robert Gensch, Hôkan Jůnsson,. In *Practical Guidance on the Use of urine in crop production*, X. Stockholm Environment Institute, 2010.
2. Chakrabarti, Debkhmar. *Indian Anthropometric dimension for Ergonomic design use.* National institute of design (NID).
3. G.G.Ray. *Ergonomic Evaluation and Design Consideration for Indian Sanitary wares*. Mumbai: Department of Science and Technology, Govt. Of India, Industrial Design Centre., Indian Institute of Technology Bombay., 1990.
4. *Clean water compost.* 2013. http://www.cleanwatercomponents.com/education/composting-toilets (accessed September 2013).
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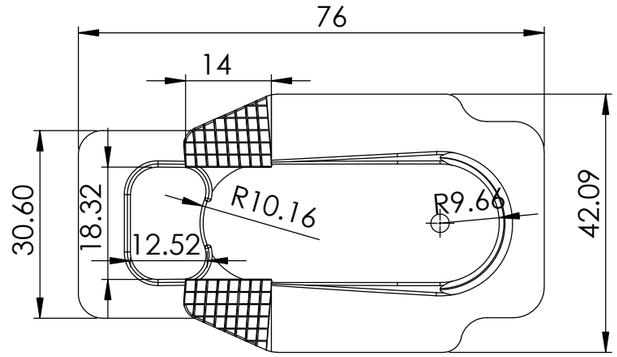
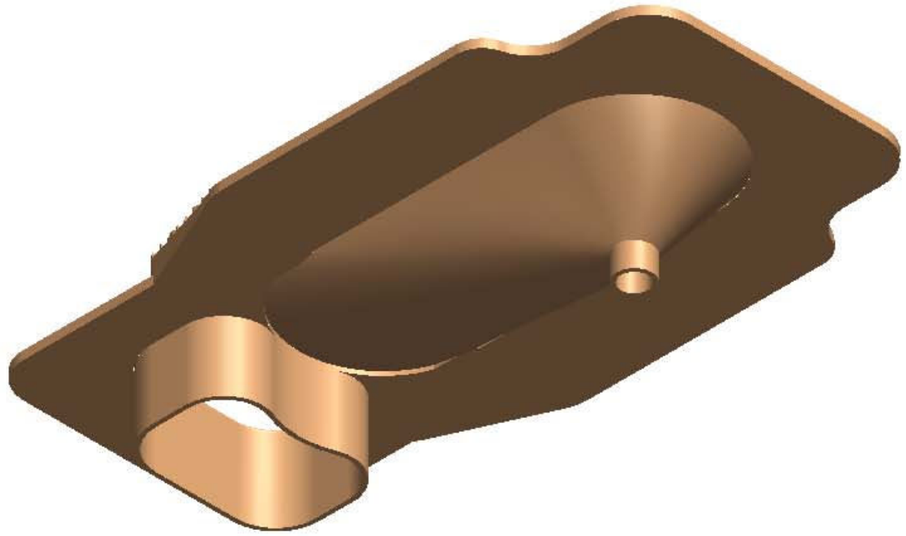
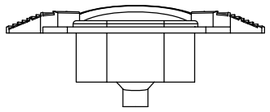
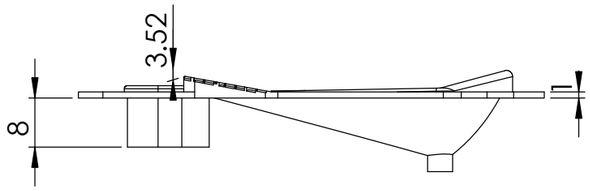
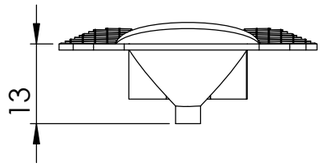
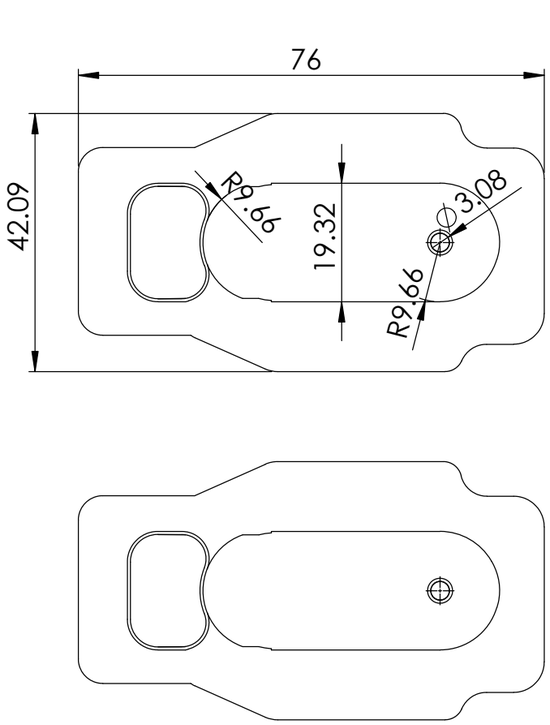


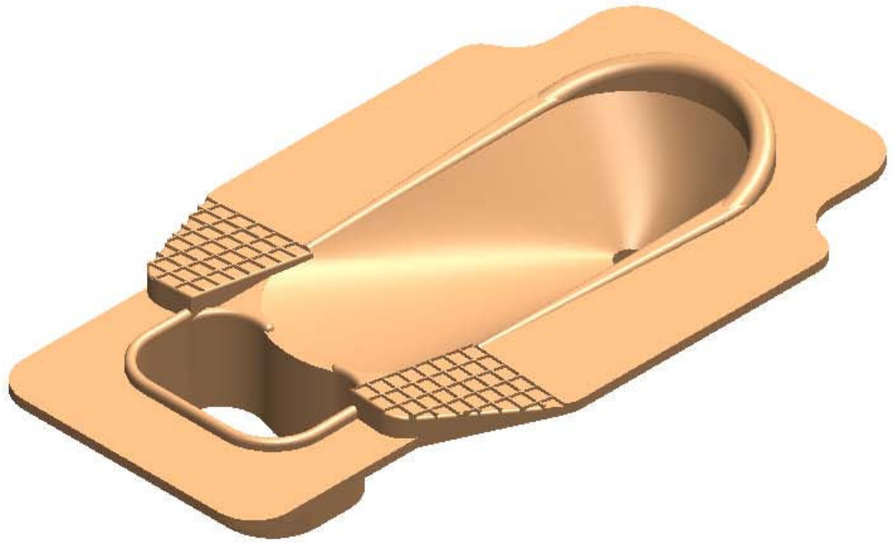




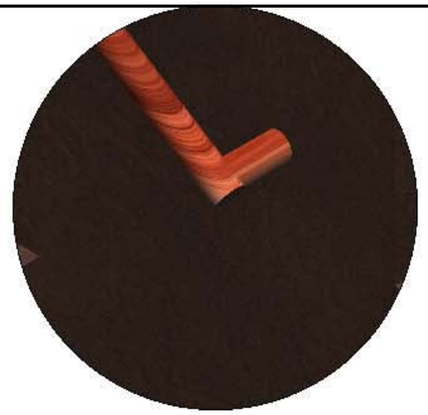








UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION
	NAME	SIGNATURE	DATE				TITLE:
DRAWN	Tuumay Allene						
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:			DWG NO. Toilet pan/seat / A3
				WEIGHT:			SCALE:1:10 / SHEET 1 OF 1



DETAIL D
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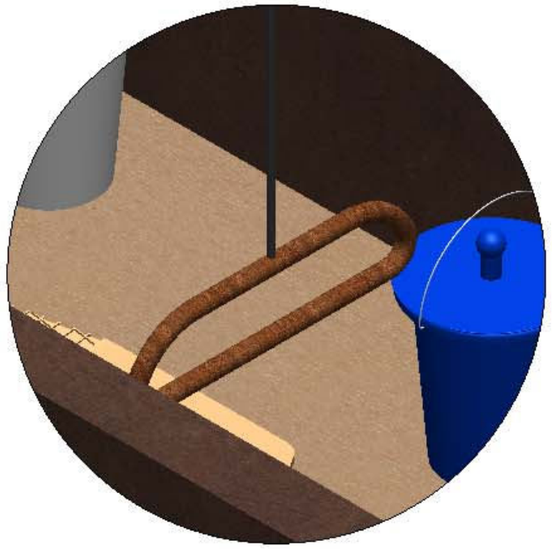
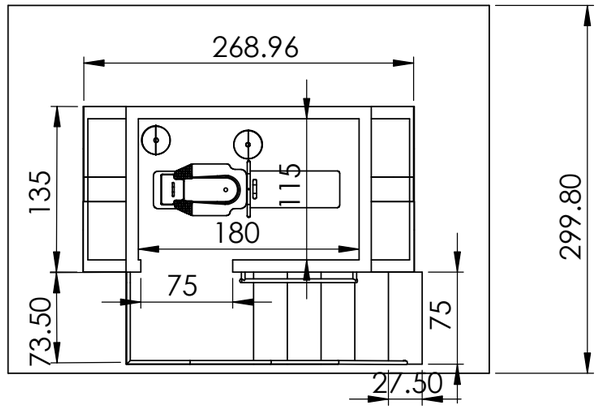
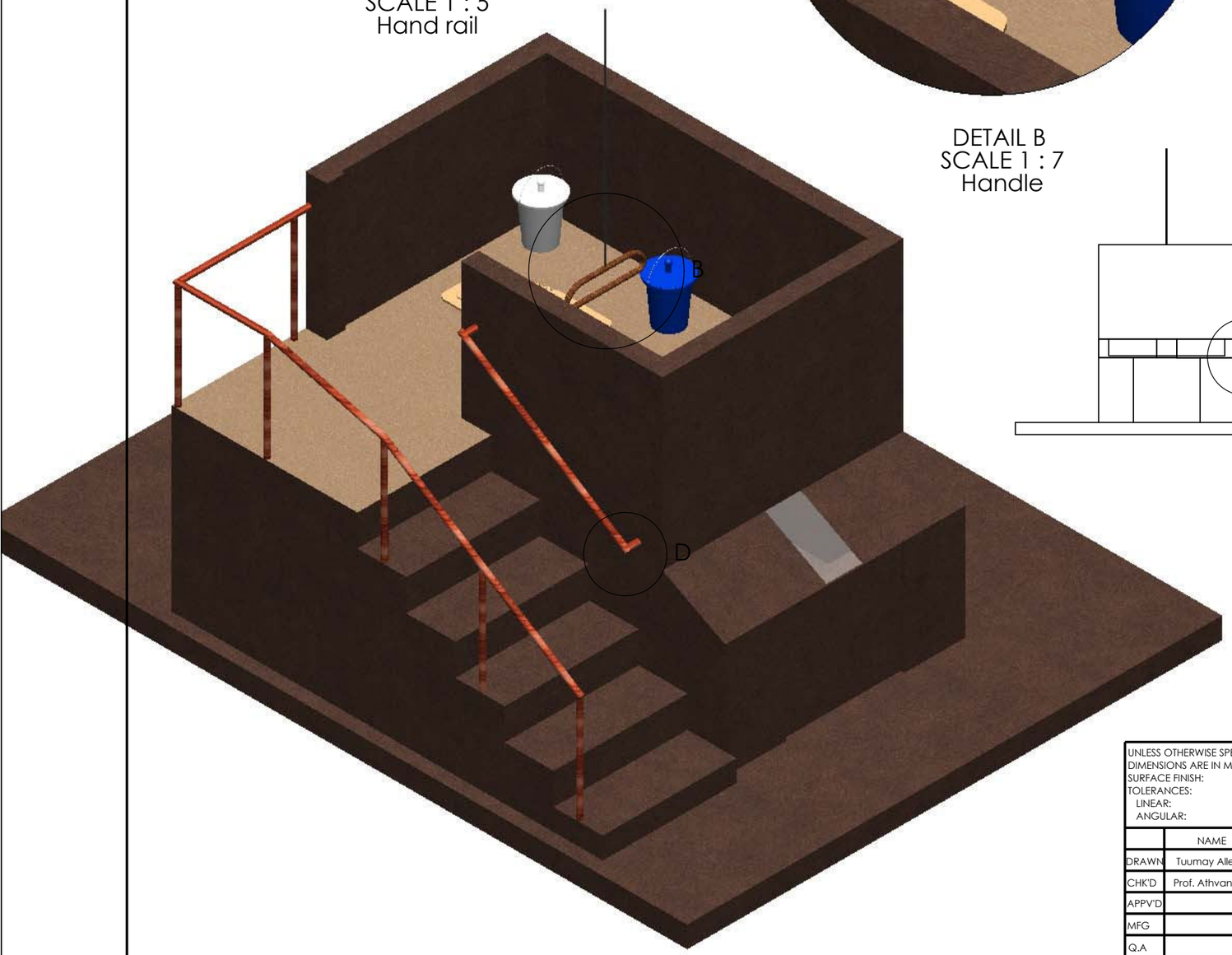
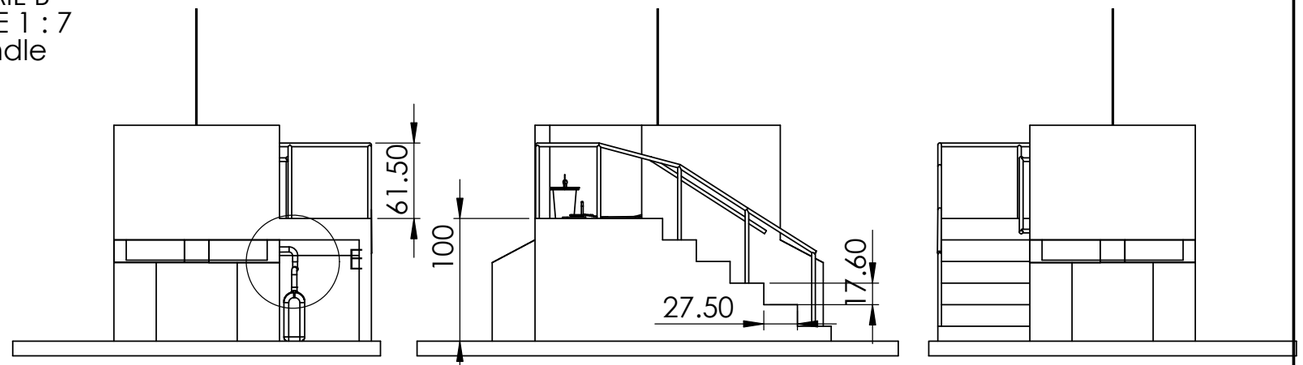
Hand rail



DETAIL B
SCALE 1 : 7
Handle







DETAIL E
SCALE 1 : 5
Jerri can

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:			DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE			TITLE:	
DRAWN	Tuumay Allene						
CHK'D	Prof. Athvankar						
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO. Toilet room	A3
				WEIGHT:		SCALE:1:50	SHEET 1 OF 1