Taanka:

A Rainwater Harvesting Tank

Hedya Ferdjani [redacted]

Alice Lefebvre [redacted]

Alice Perié [redacted]

In collaboration with

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Abstract

Several regions in India do not benefit from easy access to water. Every day, women and young girls have to walk several hours in order to reach the nearest water source. One Prosper, an NGO founded by Raju Agarwal, began in 2017 the construction of rainwater harvesting tanks in the Thar Desert. These tanks give the opportunity for girls in villages to save time and use it to get an education. Raju Agarwal believe empowering girls is the key to transforming societies. However, construction time and costs are two important constraints that One Prosper try to minimize. The construction of a prefabricated tank was found to be a solution in order to optimize these criterias. With the collaborative help of the local Indian NGO Gravis, the design of the optimal rainwater harvesting tank to answer to the client's criterias is developed. The Environmental, Social and Financial aspects of the design are taken in consideration leading to the selection of the final steel tank : almost 100% renewable of a cost of 677 $ and that can be built in less than 3 days.

Introduction

The Thar desert also known as the Great Indian Desert is located in the northwest region of India. This region is arid and suffers from extreme high temperatures which can become a burden for its inhabitants. Indeed in May 2016, a temperature of 51°C was reached and corresponds to the highest temperature ever recorded by the Indian government. Two hundred kilometers north of the city of Jodhpur are located several villages that do not have an easy access to water source. Everyday, young girls from 8 to 15 years old have to walk up to 5 hours to the nearest water source and do not have the opportunity to get an education by lack of time and family revenues (OneProsper, 2018). The NGO One Prosper with the collaboration of the Indian NGO Gravis, tries to fund the construction of rainwater harvesting tank to allow these girls to get an education. This project globally cost 1800$USD, including 520$USD exclusively to the tank and its construction (Agarwal, 2018) . However, One Prosper would like to have a bigger impact on the village community by decreasing the price of the tank and by decreasing its construction time. It would allow them to reach their donations goal faster and to provide, in a shorter amount of time, more families with an access to water.

Therefore, the design team had for mission to design the optimal prefabricated tank that would reduce the time of construction for the lowest cost.

This report is explaining the steps followed for this design process to the finalization of the design starting with external researches on the Tankaa, its impact on the community and the quality control of drinking water reservoirs. The previous part is followed by the explanation of the concepts selection leading to the final design of the Tankaa. Subsequently, the Tankaa's components, materials selection and their functionality as well as the construction of the tank are described. The Life Cycle Analysis and the different design considerations from social, environmental and financial aspects are also inspected.

Vision Statement

The vision statement of the design team is the construction of a reliable and sustainable system of rainwater harvesting to help families in the Thar desert.

2.0 External Search

2.1 Background history of the Tankaa

Tankaas are a traditional rainwater harvesting method in India, and used to be considered as a religious component of the population's everyday lives. The first tankaa was built in region of Jodhpur in the year of 1607A.D., and became, over many decades, one of the most common rainwater harvesting technique (Goyal; Issac, 2009). A tankaa can be defined as an underground cistern, which will store rainwater during the dry season, and is designed to procure water to individual households or small group of the same community. The water stored in the tank is used for everyday drinking purposes, but is also used for livestock (Vangani; Sharma; Chatterji, 1988).

The water gets from the catchment area to the tank passing through an inlet made on the walls of the tank. Dimensions may vary; a tank can hold from 1000L to 500,000L of water in the Rajasthan, depending on its location and the amount of people it is for. The storage tanks are mostly found in circular shape, but rectangular shape is also possible. Traditionally, the access to a certain number of tankaa was symbol of the status of the family in the society (Goyal; Issac, 2009). With the evolution of urban areas in India, the development of a water supply system was needed. However, this system was highly in demand and was under a lot of pressure to provide water to the population, increasing the need to find other alternatives in rural areas. Today, rainwater harvesting is the primarily source of water in the rural areas of India, and Tankaas represent the most common way of doing so (Prasad and al, 2017). In the past decades, the government of the Rajasthan State worked considerably to increase the amount of Tankaa available to families of smaller communities of the region (Vangani; Sharma; Chatterji, 1988).

2.2 The Traditional Tankaa

The most common material for the construction of the tank is cement. Indeed, the fabrication of the tank is completely done on site. The process of construction can take up to a month, to allow the cement to cure properly. The cylindrical shape is generally more used than the rectangular shape, for the simple reason that it takes less material for the same tank volume than a rectangular tank, which is more economical (Vangani, Sharma, Chatterji, 1988). Also, the rectangular tankaa is more likely to develop cracks in its corners over time. Cement is more prevalent for the construction of bigger tanks, with a volume higher than 100,000L. For smaller tanks, masonry work is a viable option and requires less trained workers. Indeed, cement needs to be cured for at least 28 days, and requires to be wet at all times (Goyal; Issac, 2009). If the tank is made out of cement and well maintained throughout the years, its lifespan is around 20 years (Vangani, Sharma, Chatterji, 1988).

The catchment area of the tank is crucial to the design. The catchment area can be defined as the area where the rain first strikes. This area will directly affect the amount of water that the tank will store, and that will be available for use. Many different options for this parameter are available. In India, two types of catchment area prevents. The first one is when the tank is close to a house. The catchment area can be the house's roof. The runoff will therefore be routed to the tank by a pipe system. The second type, prevalent in the Thar Desert, is the ground itself (Prasad; Purohit; Sharma; Ameta, 2017). The runoff coefficient of the area, which represents the ratio of rainfall to runoff, will directly affect the amount of water that will be harvested in the tank. A higher runoff coefficient is recommended for a maximized water storage. Many different options are available to increase the runoff coefficient of the ground surface, and therefore increase the quantity of water entering the tank. After removing any vegetation of debris, a thick layer of material is added to the whole catchment area. Many options are available in regards to the material, although the most common is murrum, a gravel-like matter. However, pond silt, woodcoal ash and gravel are also prevalent choices. With the material, an artificial slope of 3 to 4% is created towards the inlet of the tank. The use of a roller is then needed to compact the material on the ground (Vangani, Sharma, Chatterji, 1988). However, when the budget allows it, cement can also be a choice for the catchment area, bringing the runoff coefficient to 1.0 (Michaud, 2015).

The quality of water can be affected by environmental conditions. The use of pesticides and fertilizers from surrounding agricultural lands can potentially contaminate the runoff. Also, the livestock waste and dirt can contaminate the runoff (Prasad; Purohit; Sharma; Ameta, 2017). The addition of a thorn fencing helps to increase the quality of water, as well as iron bars in the inlet hole to stop debris from entering the tank.. However, in the past decade, GRAVIS, an NGO based in India, responsible for the fabrication of tankaa in the country, added a component, desilting gutters, to the design of the tankaa that considerably increased the quality of stored water. This new addition to the inlet consist of a container with a depth below the ground deeper than the inlet itself, and acts as a desilting chamber (Garcha, n.d.). The principle of this system is that once this compartiment fills up, the sediments will drop to the bottom. The fact that the desilting inlet is below the inlet of the tank prevents a high quantity of sediments from entering the tank. The quality of the water outflow of this desilting chamber is higher than the inflow. Indeed, this system is able to decrease the amount of sediments entering the tank, considerably increasing the overall quality and cleanliness of the stored water (Lee, 2005).

Roof rainwater harvesting system

Another commonly used method to collect rainwater is the rooftop rainwater harvesting system that are installed in houses for domestic usage. As for the taanka, this structure consists of three basic elements: a catchment area, a conveyance system and storage tank. The water is collected from the roof, then goes through the gutters to channel to water into the pipes. The water is then stored in cisterns or tank.s This method is one the most used self-supply of water worldwide.

In south India, Tamil Nadu is the first state to make rainwater harvesting mandatory for every house to prevent groundwater depletion (TNN, 2017). In this region most of the house are equipped with rainwater tank that catches water from the roof.

2.3 <u>The benefits of the traditional Tankaa for the community</u>

Tankaas represent an important aspect of water security in the region where it is most prevalent, the Thar Desert. Indeed, these rainwater harvesting tanks can prevent people from having to collect water from a distant source (Pal, 2016). Tankaas represent a considerable time saving, because of the proximity of the water source from the house. While providing a secure source of water, tankaas brings many other social advantages to the rural community of the Thar Desert. The time saved by these families allows young girls to get an education in schools. With the tanks construction, maintenance and repair, the employment in the rural area is more stable. As mentioned earlier, the access to water represents the status of the families in this region. The access to a tanka decreases the gap between the lower and upper cases, as people become self-reliant. The water from the tanka is also of better quality than from other sources, the taste and cleanliness of the water is enhanced (Garcha, n.d.).

Furthermore, the tankaas represent a much cheaper water source than the piped water system, which becomes expensive in times of drought and water shortage (Goyal; Issac, 2009). Money is saved since the need of purchasing water is lower. Given the cleanliness of the water from the *tanka*, the risk of contracting diseases decreases, which entails that the health of the beneficiary population is increased, and savings come from the no necessity to reach health care (Garcha, n.d.).

2.4 <u>Applicable Patents for the Prefabricated tank</u>

Prefabricated water tank is a system used by many NGO to provide a safe access to water in developing countries. Oxfam, an international confederation of 20 NGOs based in England (Oxfam International, 2018), is aiming to eradicate poverty and provide all the countries with a sustainable livelihood. Among their numerous project, Oxfam has designed a demountable water tank composed of three components: a cylindrical water tank made from steel sheets, EPDM liner and a PVC roof (Evenproducts, 2018). The tank is easily assembled on site and can provide safe water for populations located in arid or conflict regions. Oxfam builds tanks of all sizes ranging from 11 m^3 to 70 m^3. The tanks are ISO 900 certified, there represent a safe storage for drinking water, and be used for agricultural and horticultural purposes as well. (Oxfam International, 2018)

2.5 Potential expansion of the project

This rainwater harvesting tank is designed for the NGO One Prosper and its mission. Therefore all the dimensions and risks taken in consideration in this report are to fit the design criterias given by the client. However, this design and its dimensions can be modified to fit any other sites for any other clients. Other NGO like Engineers without Borders, devoted to international development could be potential clients interested in the design of this rainwater harvesting tank for some of their projects in Africa for example ("Investing in People-EWB Canada", 2019).

3.0 Concept Selection

3.1 Calculations for Design Feasibility

Estimation of water demand

This project required the design of a water catchment tank with the capacity to hold enough water for a family of 5 people over a period of 7 to 8 months. The average annual rainfall in the region is around 200mm per year (Phalodi averages, 2018). In rural part of India, the daily water consumption needed per person in around 20L (WHO, 2018). The water is used for domestic usage including cleaning, cooking, bathing and washing of clothes.

$$\begin{aligned} \textit{Water demand} &= \textit{Water use} \times \textit{Population} \times \textit{8 months} \\ &= 20L \times 5 \times 8 \times 30 \\ &= 24000\ L\ \textit{for 8 months} \end{aligned}$$

The tank would need to contain a volume of at least 24000L to be able to provide enough water for an entire family over 8 months. Since the tank is located in a arid region, it is important to take into consideration the evaporation rate. The take will be sized in order to receive a volume bigger than 24000L to make sure that there will be enough water available for the families. To do so, it was decided that the final tank would have a capacity of 25000L while taking into account the portion of water that would evaporate.

Estimation of water harvested

The quantity of water that can be harvested depends directly on the catchment surface. For this project, the catchment surface is build artificially with murrum soil on a sloped ground ("Home", 2019). Murrum is a type of soil that be easily compacted to make an impervious soil, so the water will not infiltrate into the soil and will keep running off to the inlet of the tank (Muley, 2010). Murrum is mostly made of clay, which has a high runoff coefficient (WWS, 2015). Runoff coefficient is the ratio between the quantity of water running off over the quantity of water precipitated. The higher the coefficient is, the less water is infiltrated into the soils and more rain will be harvested.

For this project, the diameter of the circular catchment surface is 20m. The catchment area would have a value of 314 m^2 . The quantity of water can harvested per can be computed through the equation below (Thomas, Martinson,2007).

$$Q = RC \times R \times A$$
$$= 0.70 \times 200 \times 314$$
$$= 43{,}982 \text{ L/year}$$

Where Q is the quantity of water run off
RC: Runoff Coefficient
R: Rainfall (mm)
A: Aera (m^2)

Per year, around 43,982 L of water can be harvested. Thus, 120 L of water can be captured per day. The monsoon can last up to 8 months, the volume of water harvested over this period would be :

$$120 \times 30 \times 8 = 28800L$$

Those are estimations; average precipitations can vary more or less depending of the years. However, according to the calculations, there should be a sufficient amount of water harvested.

3.2 Concept Development, Scoring and Selection

In order to determine which material material is the most suitable for the Tankaa design, a pugh chart has been conducted. This comparative analysis take into consideration the cost, longevity, recyclability and other technical criterias stated in the table below. Each criteria have been rated and weighted. After all the competing factors have been taken into account, it was decided that the most convenient material to use is the galvanized steel. The final cost, production and end of life steps are discussed later in the report.

	Weight Factor	Baseline	Concrete		Galvanized Steel		Fiberglass		Polyethylene	
Evaluation criteria			Rating	Weighted	Rating	Weighted	Rating	Weighted	Rating	Weighted
Strength	4	0	2	8	3	12	2	8	1	4
Resistance to Heat	4	0	3	12	2	8	3	12	1	4
Cost	5	0	2	10	2	10	-5	-25	4	20
Easeof Maintenance	3	0	-1	-3	2	6	2	6	0	0
Corrosion	5	0	0	0	0	0	3	15	2	10
Facility to assemble	4	0	-3	-12	2	8	2	8	3	12
Algae growth	3	0	2	6	1	3	-3	-9	-2	-6
Longevity	3	0	2	6	2	6	3	9	-1	-3
Recyclable	3	0	-1	-3	2	6	3	9	0	0
	Total			24		59		33		41

Table 1: Pugh chart

4.0 Final Design

The final design of the water harvesting tank is a 12ft over 10ft semi-buried cylinder. Before assembling the prefabricated tank, excavation works are required. Once the masons are done digging and the ground has been leveled, the water tank can be installed. The workers will receive a kit with the prefabricated water tank materials that include galvanized steel sheets, joints, flexible polypropylene liner and galvanized steel pipes. A handbook will be provided with the kit explaining the steps to assemble the tank. The galvanized steel sheets would have been cut into panels, perforated, corrugated and punched beforehand. Then, workers will have to assemble the sheets together with screws. A hole of the size of the inlet pipe diameter would also have been planned as well. Once all the steel sheets are joined together, Flexible Polypropylene liners will be added at the joints. Adding liners will make the tank more water resistant and will prevent from any cracks or leakage (National Poly Industries, 2018). Once the tank is completely assembled, the inlet pipe is fixed to the tank, the tank is closed and the rope pump is added.

4.1 Components of the Design

4.1.1 Steel Tank

The rainwater harvesting tank is made out of a cylindrical wall and a roof. The wall is made of 12 sheets of 1.3m of height and 2.6m of length. These sheets are joined together with screws, with a spacing of 0.15m in between them. The sheets are joined vertically with an overlap of 0.1025m, and horizontally with a 0.1205 overlap. The roof sheets are also fixed together with the help of bolts, creating a circle area. The tank is fixed on the concrete with L-brackets, which will hold the tank in a strong and firm position.

4.1.2 Desilting Inlet

A desilting system is integrated to the design in order to prevent as much debris as possible from entering the tank. Therefore, not directly part of the tank, the desilting inlet will be located at the entrance of the inlet pipe. The technique is simple and is the same as the one used for the Tankaa : lower than the inlet height will be excavated a small maze with vertical walls. The water before flowing in the inlet pipe will lose the debris while going through the maze. Maintenance of this desilting system will be required in order to ensure its functionality as it can fill up with debris very fast.

4.1.3 Inlet Pipe

An inlet galvanized steel pipe will be incorporated in the design. The pipe will act as a calming inlet, and will route the water from the inlet on ground level to the bottom of the storage tank. The inlet pipe is necessary to keep the sediments at the bottom of the tank. Water coming in without an inlet pipe could potentially cause the water to become troubled by disturbing the bed of sediments at the bottom (Texas A&M Agrilife Extension, n.d.).

The addition of an outlet at the ground level on the galvanized steel wall is a possibility that still needs to be evaluated in the next design process steps.

4.1.4 Rope Pump

In order to facilitate the usage of the rainwater harvesting system for the beneficiaries, a pump system is included in the design. The pump will deliver the water from the storage tank to the user. The design chosen for this system component is the rope pump. This pump systems suits the context the best in terms of environmental, economic, ergonomic and social aspects. The system requires simple pieces, made out of material that can be manufactured locally and from recycled material. Therefore, the recycling of the pieces will be easily done afterwards. In the case of a breakage, isolated components can be changed, instead of having to replace the whole pump (Erpf, 2005). Further, the fabrication cost of the rope pump is considerably low compared to other types of pumps. The cost of components and pieces for the fabrication of the pump, the maintenance and repair lower the total cost of the design, while promoting local work. The fabrication of the pump will therefore benefit the local economy (Wikiwater, 2018.).

To continue, as mentioned previously in this report, the ergonomic design of the pump only requires a force of 50 to 100 Newtons to use. Since the project aims to help young girls, it is necessary that the design allows them to collect the water safely and without any difficulty. This increases the social status and conditions of women and girls in the region, as any member of the family will be able to achieve the daily task of collecting water ("Rope pumps compared to Piston pumps", 2018). Additionally, due to the simplicity of the rope pump design, users can easily understand how to use it and can easily learn how to repair it, which gives the beneficiaries a sense of self-respect (Erpf, 2005).

The rope pump dimensions have yet to be determined. The dimensions and ways to assemble the pump system to the tank will be established further in the design process.

4.1.5 Polypropylene liner

In order to prevent leaks and the loss of water, a liner has been added to the design of the tank. The liner will add an extra layer of protection to the tank and therefore extending the life of the ank by creating a non-corrosive surface. It will also permit reducing the risks of reparation and maintenance. The liner used in the design is an flexible Polypropylene (FPP) liner. This material has excellent UV stability and is resistant to permanent sun radiation. This type of product is the most suitable for excavated water reservoir and to store drinking water. Flexible Polypropylene liner can last from 10 to 12 years (Evenproducts, n.d).

4.1.6 Biosand Filter

An important external contribution to the design is the presence of biosand filters in the villages home. Indeed, the water is not treated directly while entering the tank and water treatment for drinkable use is required. Therefore, the construction of a biosand filter by our client removes impurities providing water for drinking and cooking that is 98% pure (Pareek, 2014). Made of cement, sand and pebbles, the biosand filter can be used by everyone. The water is poured in a diffuser that will protect the top of the sand layer below it from being damaged by the water. Then going through the community of micro-organism that lives in the sand the water will be filtrate and all pathogens and suspended solids will be removed from it. Then the water will go through a separation gravel and drainage gravel, mostly present for support for the filtration and the separation process respectively before reaching the outlet tube and be used by its consumer

Our client is currently investing in this simple method at a cost of 80$ aside from the 520$USD of the tankaa. However, a canadian scientist named Dr. David Manz solved this water quality problem inventing a biosand water filter at a cost of Rs. 3,000, corresponding to around 40$USD or half the price of the current bio-sand filter being used by One Prosper (Clean Water Through Biosand Water Filters, 2018).

4.1.7 Concrete Slab

A concrete slab needs to be poured once the site has been excavated. The functionality of the slab is to support the Tankaa but it is also a component of the tank as it constitutes the base of the Tankaa. The Codes of Concrete Foundations by Canada Mortgage and Housing Corporation (CMHC) in consultation with the Canadian Home Builders' Association was consulted for the dimensions of the slab to ensure the safety and security of the design. (Concrete Foundations, 1988).

For greater strength, watertightness and prevent cracking from understrength or under design, and knowing that concrete is weaker in tension than in compression, a compressive strength of 20 MPa (2900 psi) is recommended for the slab.

Watertightness is very important as the water will be in direct contact with the slab.

Therefore, the dimensions of the concrete slab is to be of 12" (300mm) deep from the recommendations of the Codes and 12 feet long to sustain the Tankaa.

Moreover, it was recommended in the Manual of Construction of the Tankaa (Annexe 2) to place the concrete during the early morning or in the evening for hot weather precautions.

The Gravel, water, cement and stones are found on site as the workers use to build the traditional Tankaa using these materials.

If the finance of the project allows it, the use of reinforced concrete would be preferable, it will allow the design to have a thinner base that will be more resistant. A steel bar manufacturer close to the site will be required for the making of the reinforced concrete and to minimize the impact of transportation on the environment.

4.2 Instructions for maintenance

A manual of Instruction including the construction and the maintenance of the Tankaa is provided in the Annexe and is to be given to the owners of the rainwater harvesting tank.

Through a *Risk Assessment* (Annexe 1.A) several design considerations were pinpointed and preventions measures were taken. A list of different considerations and their risks rating were taken in consideration:

- Corrosion of the Tank Material (Low)
- Failure in the maintenance system of the tank (Low)

- Cloth of the filter by debris excess (High)
- Growth of Algae within the Tank (Average)

In order to ensure these risks related to maintenance are taken care of, a man working for Gravis will come every two weeks for the maintenance of the the tanks. However, the manual of instruction includes all the steps required for the family to do its maintenance.

For the Rope Pump, an individual *Rope Instruction Manual* is provided and also includes maintenance advices. The situation where the rope of the pump would break or would get stuck in the pumping site are thought of in the manual in order to ensure that the Tankaa is always functional.

A written report from the man in charge of the maintenance of the Tankaas will be sent directly to Gravis. This report will be used to improve the instruction manuals and to find other ways, if needed, to solve potential issues with the tank in order to make it last longer and as ergonomic as possible.

4.2 Assembly steps

For the construction of the Tankaa several steps are required and a precise order need to be follow.

The following list of materials is required for the building team in order to make the Tankaa :

- 12 galvanized steel sheets for the walls
- 6 galvanized steel sheets for the roof
- 622 Screws for the tankaa but 650 will be provided to account for the risk of losing the screws or replacement
- 5 Galvanized Steel Pipes
- Wire Mesh for the concrete slab
- FPP Liner
- 24 L-type Brackets (12 for the roof and 12 to fix the tank to the concrete slab)
- Trap

All the materials required for the making of the concrete slab are found on site by the building team as they are reusing the techniques they've been following for the construction of the older version of the tanks by One Prosper.

First Stage : Preparation of the site : Excavation , Concrete slab

The first stage of the construction starts with the selection of the site and its excavation. To optimize water recollection the lowest point of the field is preferable. Once this location is found, a diameter of 30 feet and 11 feet deep is to be excavated.

The concrete slab is to be poured preferably at night or early in the morning for hot weather precautions.

Second Stage: Assembly of the sheets

Once the concrete is dry and all the materials are brought up on site, the galvanized sheets need to be identified to reduce the risks of errors during the assembly.

After the sheets are identified, the non-perforated sheets can be assembled and fixed one by one using the L-Type Brackets onto the concrete slab. The steel sheets are joined to each other through the help of screws. Once this first layer of sheets is done and the diameter of the rainwater harvesting tank is obtained the second layer of galvanized sheets can be added and screwed onto the first layer.

Third Stage : Isolation Coating

For isolation purposes, the FPP Liner is to be applied all over the inside of the rainwater harvesting tank. The liner need to be hanged over the edge of the tank and secured with a wire or a rope all around the top of the tank.

A hole in the liner at the level of the inlet pipe has to be made and the liner surrounding the hole is going to be ducked-taped to the sheet. The duck tape will be covered by the rectangular base of the pipe and won’t be in contact with the water.

Fourth Stage : Rope Pump and Inlet Pipe

The assembly of the pipes and of the rope pump will be done on the fourth stage of the Tankaa’s assembly. The inlet pipe is made of 5 different pieces that need to be fixed to each other to make the final inlet pipe. Once the pipe is screwed to the Tankaa and to the FPP Liner the fourth stage is done.

Fifth Stage: Closing of the Tankaa, addition of the Rope Pump and catchment area

Once the pipe and everything that has to be inside the Tankaa is applied, the tank can be closed with the two galvanized sheets left.

No liner has to be applied on the inside top sheet as water will never be above the level of the inlet pipe and therefore never in contact with the top surface.

Once the tankaa is closed the rope pump is to be fixed onto the tank using the *Rope Instruction Manual.*

Catchment Area

The prefabricated trap of diameter 43.2 cm is to be fixed onto the top sheet of the tanks.

Once the construction of the tankaa is done, the desilting inlet needs to be excavated. Then it is important to test the rope pump and ensure that the components are well fixed onto the tank and safe for use. The same technique used for the desilting tank in the older tanks is used.

When the tank is constructed and the space around the tank is filled with soil, the catchment area needs to be prepared in order to improve the quantity and quality of the runoff. The catchment area is 10 m of radius and goes all around the tank. The soil that is left over from the excavation can be used to compact the catchment area. A slope of 4% from the furthest point away from the tank to the inlet pipe needs to be created. On a length of 10 m, a slope of 4% represents a vertical increase of 0.4m compared to the initial point located at the inlet pipe. To do so, rollers can be used by the workers to compact the soil and therefore increase its runoff coefficient. The more the soil is compacted, the higher the runoff coefficient will be, and a higher quantity of water will be harvested (Vangani, Sharma, Chatterji, 1988). Also, since the tank is designed with one inlet pipe, a gradient on the soil around the tank needs to be created. The level of soil of the point across the tank needs to be 0.1m higher than the point at the inlet pipe. This is to route the water to collect the water into the tank and avoid water accumulation around the steel tank.

Recommendations

Due to the amount of screws that need to be fixed to the tank, an electric drill is recommended. However, from the *Environmental Impact Assessment* filled by Gravis, the electricity in the region is *Somewhat* available and fairly distributed. To ensure access to electricity at all times, a solar battery should be provided to the building team in order for them to charge their electric drill and be able to build rapidly every tanks.

4.3. Design drawings

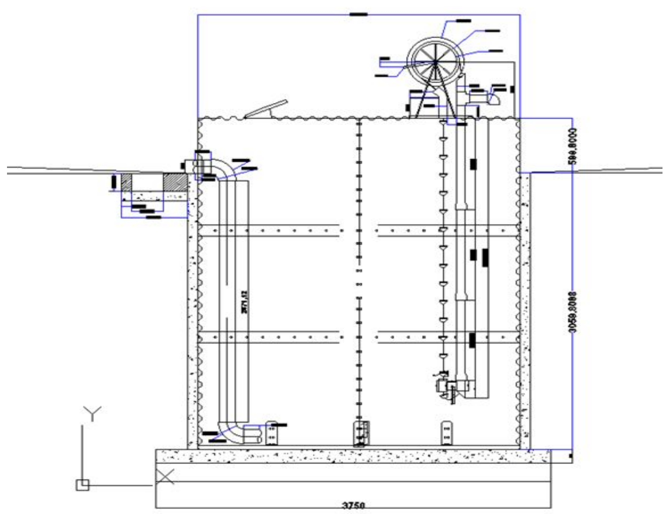


Figure 1: Plan of the Rainwater Harvesting Tank

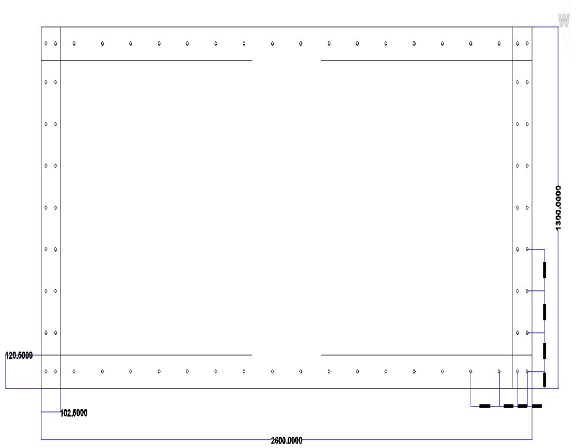


Figure 2: One Galvanized Steel Sheet

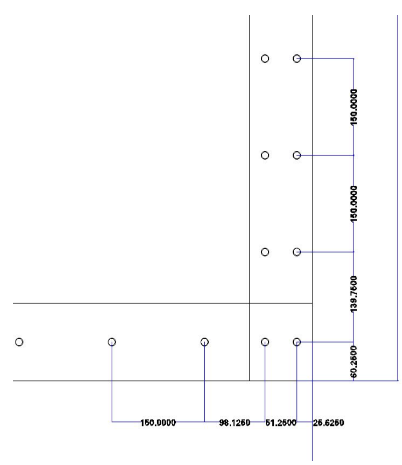


Figure 3: Right bottom corner of a galvanized steel sheet for dimension purposes

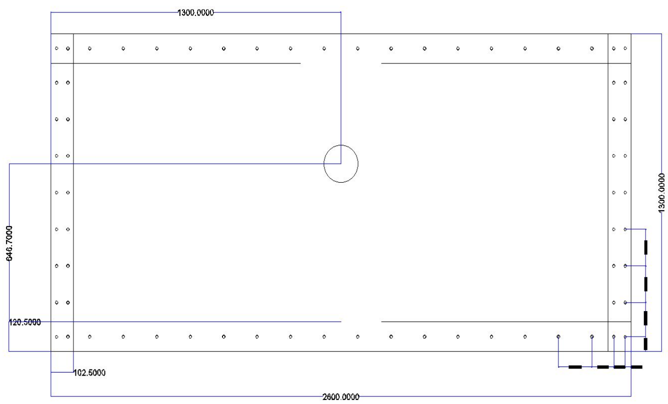
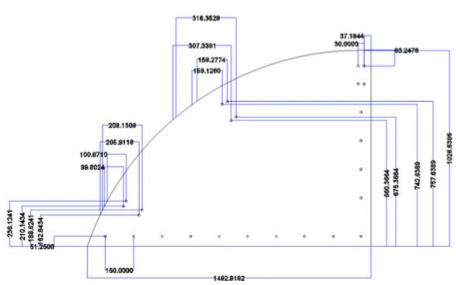
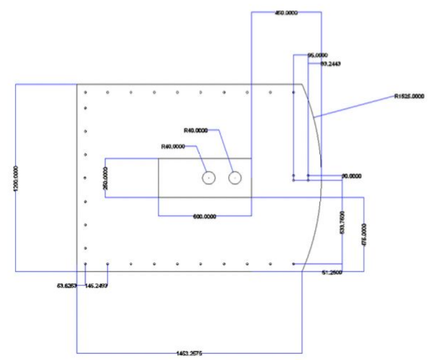


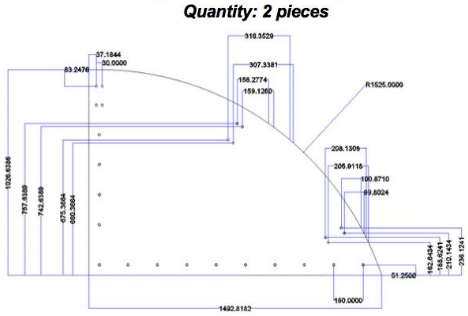
Figure 4: Galvanized Steel Sheet with the Perforated Hole for the Inlet Pipe Component



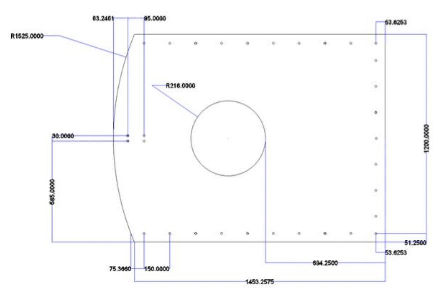
Top Left and bottom right of the roof of the Tank
Quantity: 2 pieces



Middle Right part of the roof of the tank
Quantity: 1 piece



Top Right and bottom left of the roof of the
Quantity: 2 pieces



Middle Left Part of the Tank
Quantity: 1 piece

Figure 5: Front view for the different roof sheets of the Tankaa

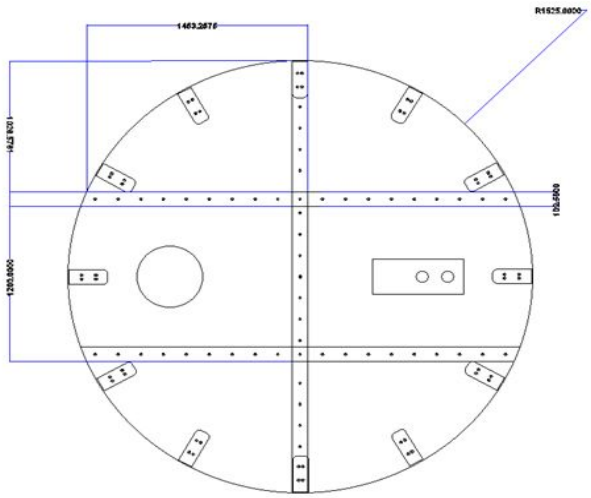


Figure 6: Assemblage of the roof of the tank

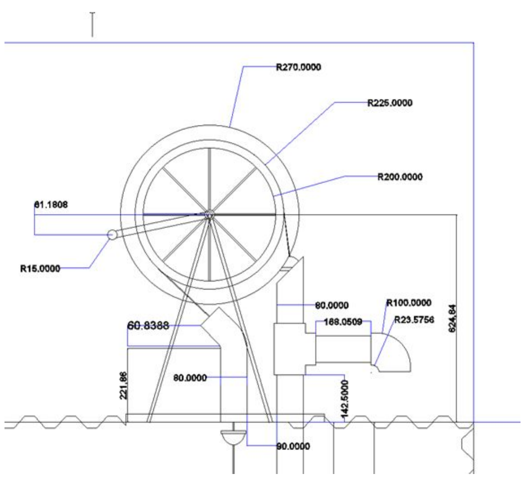


Figure 7:2-D view of the rope pump mechanism

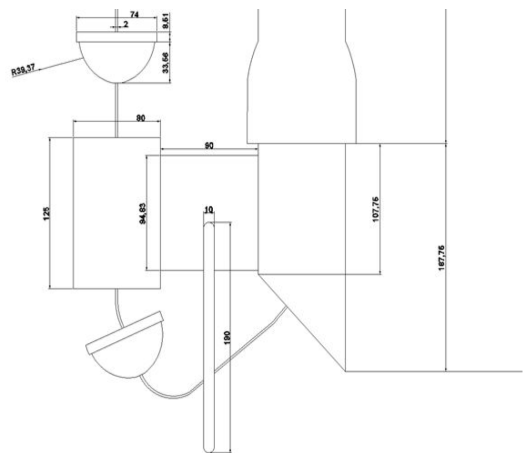


Figure 8: Guiding Block of the rope pump

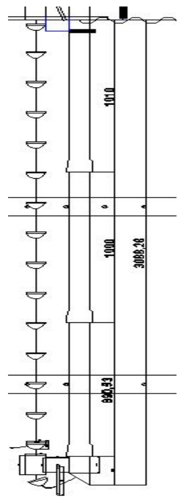


Figure 9: Pipe and rope components of the Rope Pump

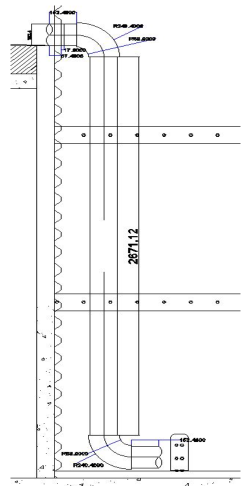


Figure 10: Complete view of the inlet pipe

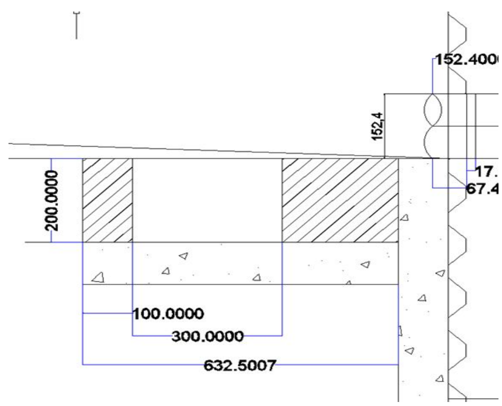


Figure 11: Desilting Inlet Component of the tank

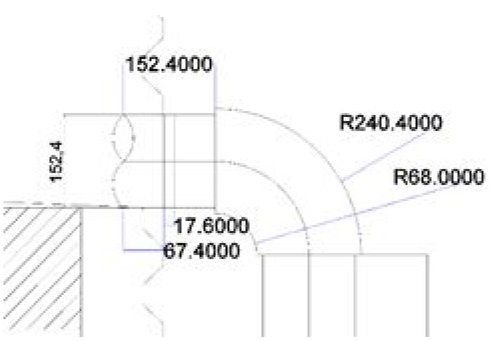


Figure 12: Inlet Part of the Inlet Pipe Component of the Tank

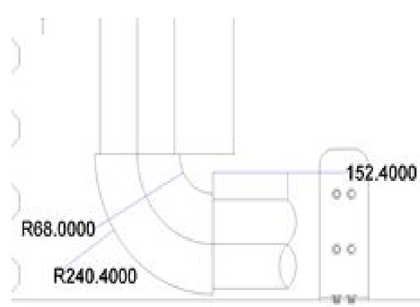


Figure 13: Outlet Part of the Inlet Pipe Component of the Tank

4.4 Design validation through test results and operating experience

4.4.1 Simulation

a. Forces included in the design

Hydrostatic force

An important force to consider for our design is the hydrostatic pressure. Indeed, the tank needs to be able to withstand the pressure of the water it holds, without breaking ("Hydrostatic Pressure", 2019). The hydrostatic pressure represents the pressure that is exerted at a given point because of the force of gravity, at equilibrium. In general, the hydrostatic pressure increases with the depth, or the height of the fluid column, since the weight of the fluid increases ("What is Hydrostatic Pressure -- Fluid Pressure and Depth", 2019). The following formula represents the hydrostatic pressure:

$$p_{hydrostatic} = \rho \cdot g \cdot h$$

Where:

ρ: the density of the liquid (kg/m3)

g: acceleration of gravity (m/s2)

h: height of fluid column or depth in the fluid where the pressure is measure (m)

For the design of our tank, the maximum capacity of the tank is when the water level reaches the soil level, which is 3.050m (10 feet). Hence, the maximum pressure that the steel sheets would have to withstand can be calculated as such:

$$p_{hydrostatic} = \rho \cdot g \cdot h$$

Where:

ρ= 1000 kg m3

G= 9.81 m s2

h= 3.050 m

$$p_{hydrostatic} = 1000 \ kg/m^3 \cdot 9.81 \ m/s^2 \cdot 3.050 \ m$$

$$p_{hydrostatic} = 29{,}920.5 \ kg/(s^2 \ m) = 29{,}920.5 \ Pa$$

$$p_{hydrostatic} = 29.92 \ kPa$$

b. Simulation on *Fusion360*

Since the rainwater harvesting tank was designed offsite, a simulation of the stresses that act on the tank needs to be conducted. This step is of major importance, as it relates to the safety of the users, as well as the feasibility of our design.

As explained previously in this report, many forces act on the steel tank. The simulation was done using *Fusion360*, a simulation software powered by AutoDesk which aims to help students and educators to model.

The first results are in response to the simulation of the hydrostatic force only. The simulation was set up with the design of our tank, the diameter being 3.050m and the total height of the tank 3.659m. The body, the water tank, was “split’’ in two in order to differentiate the surface above ground and underground, which are impacted by different forces and conditions. The height of the bottom part is 3.050m, and the part above ground is 0.659m long. The material chosen from the bank of materials of the software is ‘’Steel, galvanized’’, with a thickness of 3mm, as it represents the chosen material to construct our Tankaa design.

The following figure represents the results obtain when only a hydrostatic force is applied to the inside surface of the tank. The force simulated is the equivalent of the maximum level of water that the tank can hold, at 3.050m in height, starting from the lowest point of the tank. The results show that the tank undergoes a deformation at the bottom, representative of the hydrostatic force, which increases as the depth of the water increases. The height of the tank will also drop vertically to accommodate this deformation. The maximum point of stress is located at the bottom of the tank on the outside wall, which is expected because of the increasing gradient of the hydrostatic pressure with depth, and the minimum, around the middle of the bottom of the tank. Also, the highest points of the walls are not affected by stress, as the dark blue color shows on the simulation results.

The results presented in these figures are the von Mises stresses that act on the tank. This analysis is relevant to our design, since the von Mises stresses are typically used for ductile material, like metal, to see if the material will experience yield or fracture under certain conditions ("What is von Mises Stress? — SimScale Documentation", 2019).

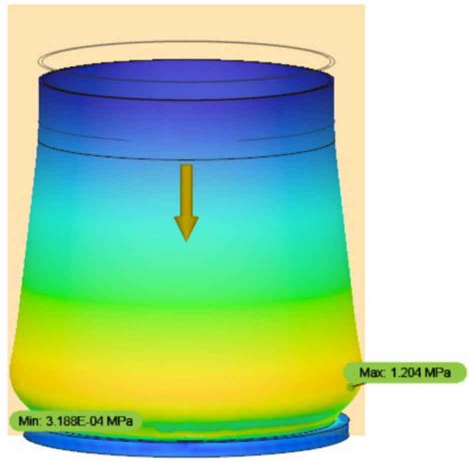


Figure 14: Von Mises stress of the rainwater harvesting tank under hydrostatic pressure applied to the interior surface

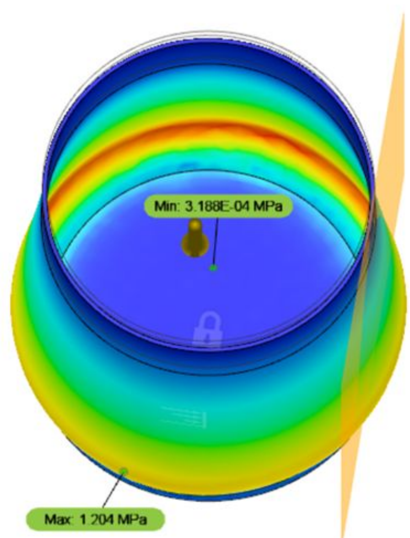


Figure 15: Maximum and minimum von Mises stress points acting on the tank under the hydrostatic pressure

The deformation seen in this simulation is explained by the fact that no other forces were added to the system. Indeed, the results of this static analysis are exaggerated and not accurate nor representative for our design. Since the tank is partially underground, the lateral earth pressure plays a role in the stress analysis, and will therefore respond to the deformation of the tank.

Even if this simulation shows that the actual tank would not break under the pressure of the maximum hydrostatic force, it is important to simulate other cases where other forces are taken into consideration.

The Thar desert usually experience monsoon wind during the rainy season. The wind load is an important factor to take into consideration when designing a rainwater harvesting tank. In addition, when taking into account the very high temperature of the region, the heat transfer inside the Tankaa is another important component to examine. Due to time constraints, the simulation of the Tankaa does not take into consideration the load of wind and the heat transfer to the tank. A more thorough research is recommended and should include the thermal radiation, the evaporation rate and the wind load.

4.5 Design Cost

One of the main challenges of the design is the final cost. Indeed, not only that Tankaa made from concrete take more than a month to be built, it has also a considerable price. The final design chosen made from galvanized steel will cost around 677$US. This price take into consideration the cost of labor work, the materials for the foundation, the steel sheets, pipes and polypropylene liner.

For the labor work, since the tank is semi-buried, excavation is needed and will cost 29$. Once the soil is excavated, two unskilled workers are required for the foundations and will have to work on it for two days until the base is ready to support the weight of the tank. To build the fundations, gravel, water, cement and stones are required. Since that a kind of raw material that can be easily find in the village and therefore will have a reduce price. In addition, wire mesh is required for the foundations at price of 3$. An approximation of 18$ has been made for the cost of foundations material.

As for the tank, 12 steel sheets will be needed to build a 25000 L tank. A steel sheet cost around 23$ per unit, and will require to be punched for holes beforehand which will be an extra cost at the discretion of the manufacturers. Moreover, the FPP liner used to add another layer of protection will cost 106$. There will 5 galvanized steel pipes inside the tank at 3$ per unit. In order to fix the steel sheets to the concrete foundation, L brackets will be used, 24 units will be required at a total cost of 5$.

After a discussion with Prakash Tyagi, the executive director of Graavis it was agreed that the final cost would only be an approximation that would tend to increase or decrease depending on the price of the raw materials on the Indian Market. The design team will send the final report including the building manuals for the tank and the rope pump to Graavis in India. Once they receive all the informations, review it and ensure the feasibility of the project, The Graavis team will take care of contacting manufacturers onsite and negotiate prices. The size of a design is specific to the requirements of each family therefore a fix priced can not be attributed.

Activities	Unit Cost Breakups (USD)		
	Quantity	Unit	Activity Cost
Labor Cost			
Excavation work	Lump sum		29
Skilled Labor - 2 person (11 USD $/day)	2	days	44
Unskilled Labor - 2 person (5.5 USD$/day)	2	days	11
Sub - Total			***84***
Raw Material cost			
Foundations (Gravel, Water, cement, stones)			15
Galvanized Steel Pipe	5	unit	15
Wire Mesh	1	unit	3
Steel Sheet	18	unit	414
FPP liner	1	unit	106
L type bracket	24	unit	5
Bolts	622	unit	35
Sub - Total			***593***
Total			677

Table 2: Cost Breakdown

5.0 Implementation of the Design

5.1 Social Acceptability

The implementation of a prefabricated tank will have several impacts on the community. Indeed, the decreasing time of construction for the tankaa from seven days to one day for the new tank will decrease the revenues of several workers of the rural area.

Moreover, the prefabricated tank does not require more than 3 people for its assembly, whereas the traditional Tankaa required up to 4 unqualified workers, therefore affecting even more the economy. However, the decrease in the total price of one tank should make their construction more recurrent, and thus slightly covered the loss in revenue with a recurrent work on the tanks. The design will affect some families who will not beneficiate from this 7 days of work salary. It was important for the design team and the client to find solutions to minimize the impacts of the water tank's implementation. A solution could be to gather a group of workers and ensure them that they will be the only group to be contacted for the construction of the tank. Both parties will beneficiate from this. The NGO will have more qualified workers and the workers themselves will have an insurance to be involved with the tanks.

Several initiatives were done by the Indian government to aim women empowerment through education (Channan, 2018). However, girls still seem to be missing education. Through the NGO, the girls are guaranteed to go to school and have their tuition fully sponsored. This will allow the women to be more independent and likely to get married older.

5.2 Environmental Aspect

5.2.1 Impact of the Traditional Tankaa on the Communities

All the applicable constraints for the prefabricated tank were considered through the Environmental impact assessment of the traditional Tankaa . This Assessment can be found in *Annexe 1.B* and was filled by the executive director of Gravis. Through this survey, the design team wanted to ensure that the implementation of the design would not be the cause of discord within the village and the families. The executive director of Gravis, who is really familiar with the region, confirmed through the survey that the presence of violent conflict and the lack of law and order within the villages are very little. No land acquisition is required for the project or that would require resettlement. Moreover, since some of the questions asked were directly directed to the impact of the traditional tankaa (that is currently built in the Thar desert), the answers should also reflect the impact of the prefabricated tank. Questions such as if the projected impacted farming positively, or if the project has affected positively the health and the well-being of the community were all answered with "*Very much*". Therefore, through theses answers the design team is confident of the good impact of this new Tankaa on the families.

5.2.2 Life Cycle Analysis

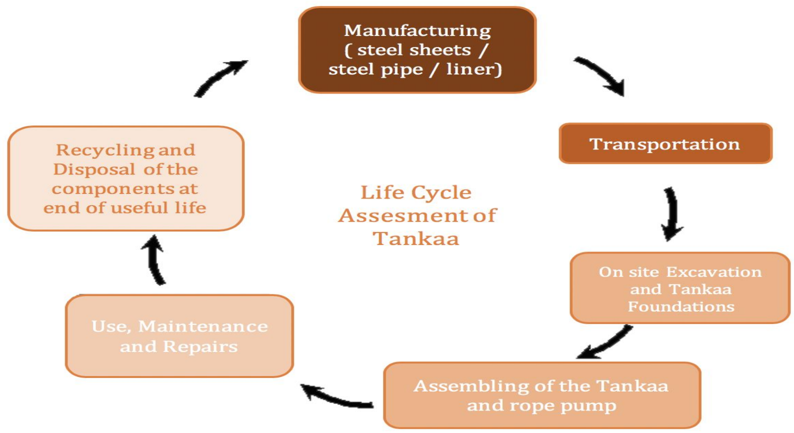


Figure 16 : Life Cycle Assessment of the Tankaa

This section is an attempt to a preliminary of a Life Cycle Assessment (LCA) since there were no thorough LCA that has been done with this kind of prefabricated tank. The LCA has been conducted in order to assess the different environmental impacts of the design from the stage of raw materials to the end life of the Tankaa while taking into considerations the transport of raw of materials, the production stage and the distribution on the market. The LCA takes into consideration the energy needed required at each stage as well as the waste and emissions to air and water produced. The LCA is an important component of this design since is was a determinant element to help the team choose which material would is the most suitable for the design of the tankaa. Indeed, the team debated between choosing galvanized steel or high density polyethylene (HDPE) plastic since they are both suitable materials. Before choosing which material would fit better, we looked at the price, at the fact that it would be recycled but also the energy needed and emissions produced.

Cradle to gate

For this LCA, the emphasis is put on the step of the steel sheets manufacturing. Indeed, since the galvanized steel sheets will be manufactured onsite at a local shop, the emissions and energy used for transportation are quite negligible and will not be taken into consideration for this design.

First, the Primary Energy Demand (PED) has been compared for the steel and the HDPE. The PED is referred as “the direct use at the source, or supply to users without transformation, of crude energy, that is, energy that has not been subjected to any conversion or transformation process” according to the 2019 definition of the Organisation for Economic Co-operation and Development (OECD). To produce galvanized steel, coal, natural gas, oil and electricity is required (Worldsteel association, 2018). For 1kg of steel that is being produced, around 25MJ of PED is required. As for HDPE, it mainly requires oil fuels and electricity to be be produced which gives a total of 76 MJ for 1kg of HDPE (Boustead, 2005). Through these results, it shows that steel is less energy demanding than HDPE and will require less raw materials to be produced.

Moreover, the gas emissions of the two materials have been compared. As shown on the figure below, when comparing carbon dioxide, sulfur dioxide and carbon monoxide emissions of both products it is possible to see that there are really little variations between the two materials and overall there emit approximately the same amount of gas into the atmosphere as shown on the figure below.

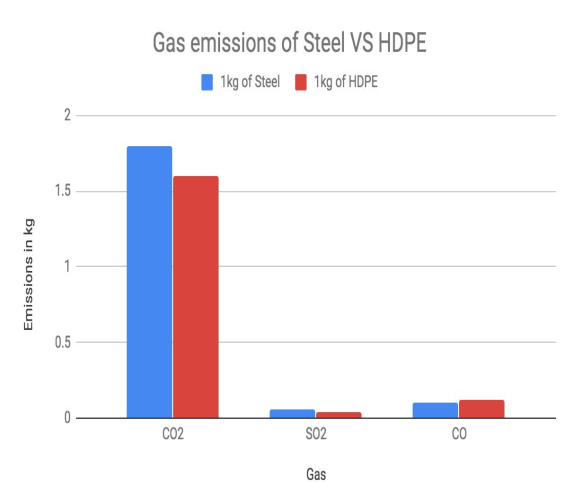


Figure 17 : Steel and HDPE greenhouse gases emissions

End of life

Steel saves energy through the fact fact that it is almost 100% recyclable and durable (American Galvanizers Association, 2019). Indeed, even with the zinc coating that is added to the steel during galvanization, galvanized steel stays a type of metal that is easy to recycle. Once the tank arrives at its end of life, the galvanized steel sheets can be brought back to the refinery which will recycle scrap metal. Then, the gravis team will have the possibility to sell their scrapple metal and buy other galvanized steel sheets made from recycling at a reasonable price.

However, recycling plastic is not as much practical. Since several types of plastic exists, sorting plastic depending of the type, reisine dye or additives that have been used, can therefore become a difficult task, especially in a country like India where recycling plants are still in progress and need to be accommodated to different materials.

Plastic will most likely end up in a landfill where it will not decompose or in incinerator where it will release harmful chemicals once burned.

Circular economy

The principal of a circular economy is an economic concept that fits into the framework of sustainable development. Such an economy operates as a loop, avoiding wastes and keeping the resources in use for as long as possible. The objective is to produce goods and services while strongly limiting the consumption and waste of raw materials, and non- renewable sources of energy.

The design of the prefabricated steel tank falls within the circular economy as it aims to minimize waste by making the most of the resources, regenerating the steel at the end of the tank life for another tank. Indeed, using steel, a material that has a rate of recycling going from 80 to 90% (recycling international,2012), the majority of the sheets will be reused to design another tank. Moreover, the rope pump is made from recycled material and will therefore not require new materials for its fabrication.

HDPE is the only material that will hardly fit within the circular economy as it has a recycling rate of only 30% (EPA, 2018) , therefore it will probably not be reused to “close the loop” for the reasons explained in the *End of Life* section and will consequently represent a waste.

Study limitations

Due to a lack of available information , the study only focused on one stage of the LCA whereas a complete analysis would talk into consideration each stage of the product life from raw materials, production, distribution, use, maintenance and end of life. Therefore the LCA gives a limited overview of the global environmental impacts and could ignore other important environmental considerations.

Moreover, the data used for the LCA are taken from developed countries that are using more modern methods for steel manufacturing. Those factories would probably emit less greenhouse gases than the one in India.

6.0 Conclusion

Working on this project represented a real challenge for the design team. Indeed, the scope of the project was very large and the resources available were limited. However the design of a tank that can be built in less than 3 days at a cost of 677$ and with a low environmental impact is presented in this report.

There is still work to be done in order to achieve the ultimate goal, more stress and strength tests need to be executed on the tank before it is actually built to ensure the safety of its users. However the report has set the foundations for this project to become reality.

The team hopes that more NGOs like Gravis or One Prosper will raise awareness to the situation of girls in rural area of India or elsewhere in the World and incite more people to look at other alternatives for a better developpement of the local communities.

Acknowledgments

The design team would like to truly thank the following individuals for their guidance, support and assistance:

- Professor Adamowski
- Professor Madramootoo
- Mr. Agarwal
- Mr. Tyagi

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Annexe I

	Potential Hazard	Existing Control Measures	Risk Rating	Preventive Measures
	Design Consideration			
1.1.	Water contamination by the soil/ debris	Man comes check the tanks every 2 weeks	Average	Man comes check the tanks every 2 weeks
1.2.	Failure in the Maintenance system of the tank	Man comes check the tanks every 2 weeks	Low	Man comes check the tanks every 2 weeks
1.3.	Cloth of the filter by debris excess	Man comes check the tanks every 2 weeks	High	maintenance training for the women
1.4.	Corrosion of the tank Material	None	Low	Add a protective coat
1.5.	Loss of Heat Resistance by the tank	None	Low	Use of Steel
1.6.	Growth of Algae within the Tank	Opaque tank	Average	Opaque underground Steel
1.7.	Rope for the pump breaks	N/A	Low	Use of a support rope and the Instruction manual for the rope
1.8.	Rope stuck in the pumping site	N/A	Low	Instruction Manual and directives
1.9.	The well dried up	N/A	Low	Instruction Manual and directives
1.10.	Temperature of the steel rises to high	N/A	Average	Cover the tank with the soil used during the excavation
	Communities			
2.1.	Failure to be used by women	None	Average	Human pump
2.2.	Problem with the families that did not received a tank	Village commitee organizes a meeting to decide who gets the tank	Low	Village commitee organizes a meeting to decide who gets the tank
	Environment			
3.1.	End of life of the tank : not recycled	None	High	Create an " End of Life" plan with our client

A. Risk Assessment Analysis

1. Identifying the Underlying Sources of Risk

The Prefabricated rainwater tank in galvanized steel sheet is to be implemented in the Thar desert, 200 km North of the city of Phalodi. This tank will allow girls to get an education by saving the time from walking up to 5 hours to the nearest water source. It will be attributed to one girl

Answer with an X

		Very much	Somewhat	Very Little	Not At All
Think about the local communities nearby your project.		X			
1.01.	Is there a significant level of poverty and relative economic disadvantage?	X			
1.02.	Is there noticable disparity in income and wealth -- a large gaps between "Haves" and the "Have Nots"?			X	
1.03.	Are public services, such as schools, available and accessible to everyone in the community?			X	
1.04.	Is healthcare available and accessible to everyone in the community?			X	
1.05.	Is drinking water easily accessible to everyone in the community?			X	
1.06.	If electricity is available in the area, is it fairly distributed?		X		
1.07.	Are there existing social issues such as alcohol or drug abuse, gambling, or prostitution?		X		
1.08.	Are there noticably high levels of unemployment and/or "people hanging around with nothing to do"?	X			
Think about both the country as a whole, as well as local communities near your project.					
1.09.	Is there a perceived lack of law and order?			X	
1.10.	Is there a perception of widespread corruption?			X	
1.11.	Is there a perception of equal access to justice?		X		
1.12.	Do minority groups feel generally discriminated against?			X	
1.13.	Is there widespread violence or abuse of women?		X		
1.14.	Are rights and freedoms of citizens respected?		X		
1.15.	Are natural disasters, such as hurricanes, floods, earthquakes or other similar events common?			X	
1.16.	Is there any presence of violent conflict?			X	
Think about the relationship between your project and local communities.					
1.17.	Was any land acquisition required for the project, and if so, did it require resettlement?				X
1.18.	Has the project impacted traditional livelihoods, such as farming ?	X			
1.19.	Is there a perception that the project has affected or polluted the environment?				X
1.20.	Is there a perception that the project has affected the health or well-being of the community?		X		
1.21.	Are there disputes with the labour force?				X
1.22.	Is there a perception that the project has provided benefits to the community unequally?			X	
1.23.	Is there a perception that employment opportunities provided by the project have been unequal?			X	
1.24.	Does the community have expectations of the project that they feel are not met?			X	
1.25.	Is there general opposition to the project within the community?			X	
1.26.	Has the project been responsible for the introduction or increased presence of public security forces?				X

B. Environmental Impact Assessment filled in by Prakash Tyagi, general director of Gravis

Annexe II

TANKAA INSTRUCTION MANUAL

OneProsper International

Gravis

By Alice Perié, Alice Lefebvre, Hedya Ferdjani

Tankaa Manual

Table of contents

Introduction

This manual can be used for the installation of the prefabricated Tankaa. The Tankaa is to be used by One Prosper and Gravis in order to help the families located in the villages of the Thar Desert. The climatic and hydraulic. conditions of the region were taken in consideration for the making of this manual and the selection of all the components. Therefore, if this manual was to be used for a different site location with different climate characteristics it is important to review the material selection.

In order to build the tank each step need to be followed carefully and in the given order. The design has for goal to be the least energy consuming and minimizes the carbon emissions of its production. Therefore, if a closer manufacturer was to be found, it can be used for the construction of this tank in order to minimize transportation greenhouse gases emissions.

Security and Maintenance Contact Information

In the case of an emergency or if this Manual does not provide an answer to the design situation the user is confronting, or for any additional information the following persons can be contacted:

Handyman- XX (to be completed)
Gravis- XX (to be completed)
One Prosper -XX (to be completed

Materials for the Tankaa

- 12 galvanized steel sheets for the walls
- 6 galvanized steel sheets for the roof
- 550 Screws for the Tankaa
- 5 Galvanized Steel Pipes to be assembled to make the inlet Pipe
- Wire Mesh for the concrete slab
- FPP Liner
- 24 L-type Brackets (12 for the roof and 12 to fix the tank to the concrete slab)

Construction

On site Preparation

Before the installation of the tank and the reception of the materials several steps need to be followed.

To optimize the water recollection of the Tankaa, it is best to select the location with the lowest elevation to be able to collect more water from a rainfall. Once the site is found, the excavation for the placement of the tank is required. The excavation site needs to be of 11feet deep and 30feet large to allow freedom of construction for the workers. The excavation process will be coordinated by One Prosper and through the procedures/operations they have been using with their previous Tankaa.

A concrete slab needs to be poured in order to support the Tankaa.
The dimensions of the concrete slab are following the code of Concrete Foundations developed by Canada Mortgage and Housing Corporation (CMHC) in consultation with the Canadian Home Builders' Association.
In order to optimize our design strength and prevent cracking from understrength or under designed concrete the Codes recommends using a compressive strength of 20 MPa for greater strength and water tightness. The concrete slab is also used as the bottom of the tank, therefore being water resistant is very important.
Concrete is relatively inexpensive, and to ensure the functionality of the slab above every soil, it will be of 12" deep (300mm) and 12 feet long.

For hot weather precautions, it is recommended to place the concrete during the early morning or in the evening.

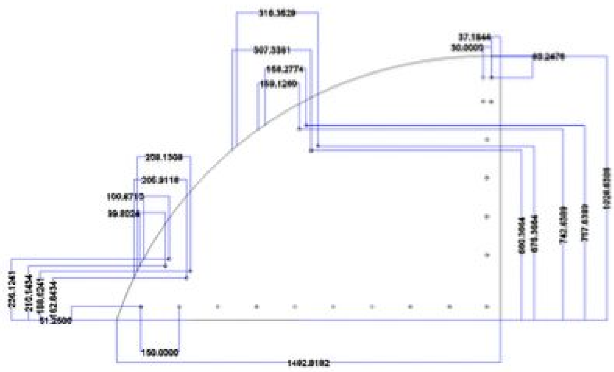
Installation

Assembly of the sheets

Before the assembly of the steel sheets it is important to follow the following steps:

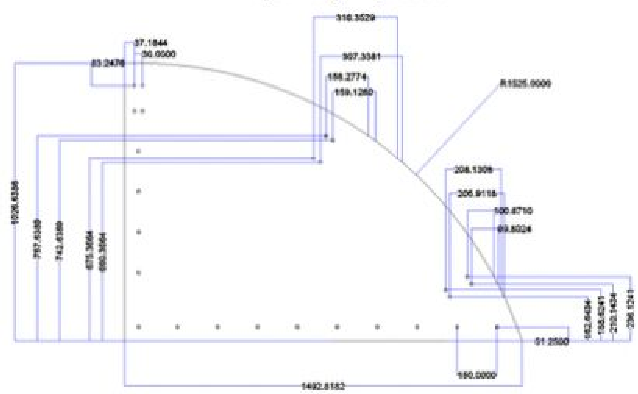
1) Identification of the galvanized sheets

   Roof of the Tank



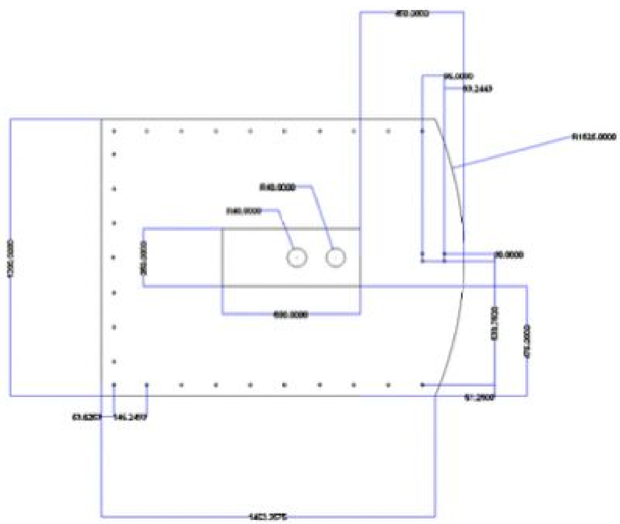
Top Left and bottom right of the roof of the Tank

Quantity: 2 pieces



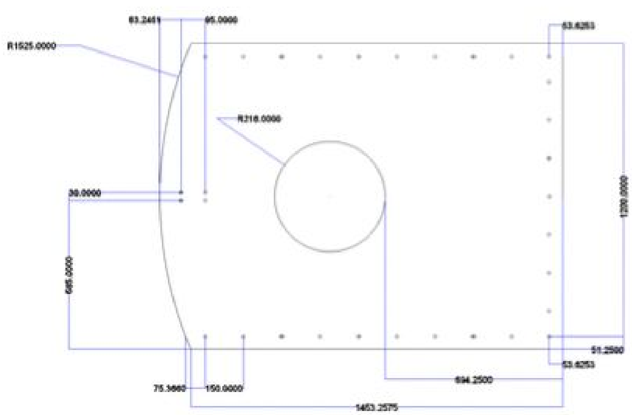
Top Right and bottom left of the roof of the

Quantity: 2 pieces



Middle Right part of the roof of the tank

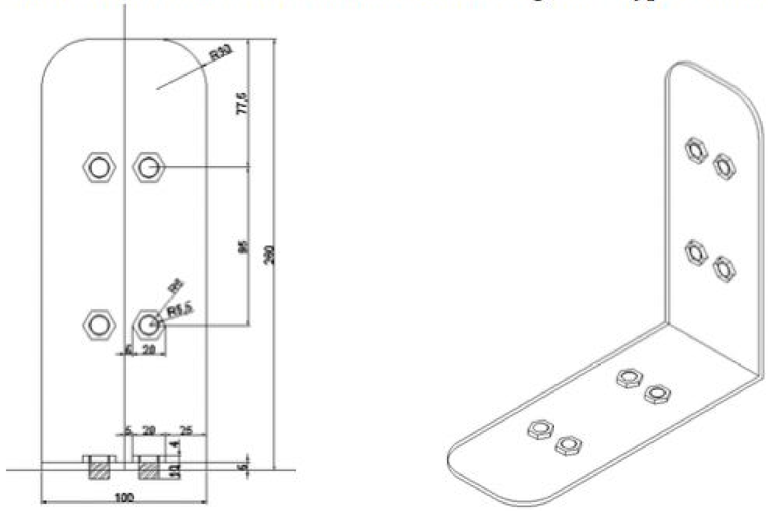
Quantity: 1 piece



Middle Left Part of the Tank

Quantity: 1 piece

2) Fixation of the sheets onto the concrete slab using the L-Type Brackets.



<u>Two views of the L-Type Brackets, screws and dimensions</u>

An electric drill is recommended for this step as it will ensure the tightness of the screws, ease of construction and decrease construction time.

<u>FPP Liner Coating</u>

1) Apply the FPP Liner starting from the bottom base of the tank (covering the concrete slab) and **fix it through the use of.** Then keep applying the liner on the inside wall of the tank.
2) Make a hole in the liner at the level of the inlet pipe and duck-tape the side in order to later on fix the pipe. The duck-tape will be covered by the sides of the pipe with a rectangular base.

<u>Rope pump and Inlet Pipe</u>

1) Assembly of the Rope Pump. For this section, please refer to the *Rope Instruction Manual*
2) Assembly of the pipes tube to make the inlet pipe
3) Fixation of the inlet pipe to the pre-perforated galvanized steel sheet using the provided screws.

Closing of the Tankaa and Rope Pump Addition

1) One Inlet Pipe and Rope pump are built, close the Tankaa using the 2 galvanized sheets left and the screws.
2) Fix the Rope Pump to the sheet with the hole designed for its diameter. For this section, please refer to the *Rope Instruction Manual*
3) Fix the prefabricated trap of diameter 43.2cm on the corresponding top sheet of the tank

Desilting Inlet

1) The excavation of the desilting inlet respects the traditional ways of the original Tankaa by One Prosper.

Catchment Area

Once the tank is built and the voids around the tank filled with soil, the catchment area needs to be prepared in order to improve the quantity and quality of the runoff.

- Use the leftover soil from excavation to compact a 10m radius catchment area
- Make sure a slope of 4% from the further point away from the tank to the inlet pipe is created

It is recommended for the workers to use rollers to compact the soil and increase its runoff coefficient.

Rope Pump verification

Before leaving the site, it is important to try the rope pump and ensure it is usable by the families.

Maintenance and Repairs

This section refers to the maintenance and the repairs of the Tankaa in case of failure. A skilled person trained by Gravis will be in charge of circulating in the different villages/families at a rate of once every two weeks in order to assist the families and help in the case of failure. A report will follow every intervention on the Tankaa do in order to continuously improve its design.

Cloth of the filter by debris excess

During heavy rainfall, a lot of debris and sand tend to accumulate in desilting inlet and to in the inlet pipe. It is important to optimize debris capture by the desilting inlet to keep the water capacity of the Tankaa. Therefore, the following needs to be done:

- Verify every day that the desilting inlet is free of debris in order to optimize debris capture.

Growth of Algae within

Using the trap at the top of the tank, visually inspect the tank and see if any green spots can be observed.

If Algae can be observed:

- Use the pole and open the trap
- Create movement in the tank with the pole in order to increase the level of oxygen in the water.

Water Contamination by the soil/ debris

If soil and debris are accumulating at the bottom of the tank use the pole to remove as much debris as possible.

Once the tank will be emptied the top of the tank can be removed and the bottom sandy layer can be entirely removed for the next season.

Corrosion of the tank Material

The FPP Liner applied on the inside of the water tank is already a measure of corrosion and its life expectancy is of 10-12 years.

End of life of the tank

To respect the values of the engineers that designed this tank it is important that the end of life of the steel tank is taking care of. Please make an agreement with the steel sheet manufacturer to recuperate the steel sheets in order to reuse the material and make new sheets.
The rope Pump is already made of recycling materials and the dissembling team should judge on the

Annexe III

Calculation of the number of bolts needed for the construction of the tank:

- To fix the sheets together for the walls of the tank

First, we need to compute how many bolts it takes to fix the sheets vertically with each other.

Height of sheet = 1.3m

$number\ of\ rows = \frac{1.3m}{0.15m} = 8rows\ approx.$

Each row has 2 bolts, so:

$$number\ bolts\ per\ junction = 8\ rows\ \cdot 2\ ^{bolts}/_{rows}$$

$$number\ bolts\ per\ junction = 16\ bolts$$

The circumference of the tank is covered by 4 sheets, hence 4 junctions of sheets.

$$number\ bolts\ for\ one\ row\ of\ sheets = 16\ bolts\ \cdot 4 = 64\ bolts$$

The height of the tank corresponds to 3 sheets of 1.3m fixed together. Thus, the total number of bolts to fix all the sheets vertically corresponds to:

$$total\ bolts = 64\ bolts\ \cdot 3 = 192\ bolts$$

Secondly, the sheets need to be fixed together horizontally. The length of the sheets without the overlap between them corresponds to:

$$length\ of\ sheet = \frac{circumference\ of\ tank}{4\ sheets}$$

$$length\ of\ sheet = \frac{9.58m}{4\ sheets}$$

$$length\ of\ sheet = 2.395m$$

The number of bolts per length of sheet can be calculated as follows:

$$number\ of\ bolts\ per\ sheet = \frac{2.395m}{0.15m} = 16\ bolts\ approx.$$

The total number of bolts to cover the circumference of the tank, which corresponds to 4 sheets is calculated as such:

$$number\ of\ bolts\ for\ 4\ sheets = 16\ bolts\ \cdot 4\ sheets$$

$$number\ of\ bolts\ for\ 4\ sheets = 64\ bolts$$

The design of the tank has two junctions of sheets in height. Therefore, the total amount of bolts will be the number of bolts for 4 sheets multiplied by two:

$$total\ number\ of\ bolts = 64\ bolts\ \cdot 2 = 128\ bolts$$

Therefore, the total amount to fix the steel sheets of the walls of the rainwater harvesting tank is calculated as follows:

$$total\ bolts\ for\ walls = 192\ bolts + 128\ bolts$$

$$total\ bolts\ for\ walls = 320\ bolts$$

- To fix the tank to the concrete slab

To fix the tank on the concrete slab, a total of 12 L-brackets were used. The L-brackets use 4 bolts on each part, for a total of 8 bolts per piece. Therefore, the total amount of bolts to fix the tank can be computed as such:

$$total\ bolts\ to\ fix\ tank\ on\ concrete\ slab = 12\ L - bracket\ \cdot 8\ {}^{bolts}/_{bracket}$$

$$total\ bolts\ to\ fix\ tank\ on\ concrete\ slab = 96\ bolts$$

- For the roof of the tank

The same number of bolts were used to fix the roof on the top of the tank than to fix the tank on the concrete slab. Indeed, 12 L-brackets were used, each one needing 8 bolts. Therefore, 96 bolts are needed.

The roof of the tank is made of 6 sheets of galvanized steel, cut in different shapes. The specific drawings for all these pieces can be found in drawings section of this design report. The following represents the number of bots for each sheet of the roof:

- Top left and right sheets: 14 bolts each
- Bottom left and right sheets: 14 bolts each
- Center left and right sheets: 27 bolts each

The total number of bolts needed to fix the roof sheets together is:

$$total\ bolts\ for\ the\ roof = (14\ \cdot 4) + (27\ \cdot 2)$$

$$total\ bolts\ for\ the\ roof = 110\ bolts$$

Therefore, the total number of bolts for the roof can be calculated as such:

$$total\ bolts\ for\ the\ roof = 96\ bolts + 110\ bolts$$

$$total\ bolts\ for\ the\ roof\ = 206\ bolts$$

Finally, the total amount of bolts for the assembly of the entire tank is:

$$total\ bolts\ for\ the\ tank = 320\ bolts + 96\ bolts + \ 206\ bolts$$

$$total\ bolts\ for\ the\ tank = 622\ bolts$$