Prefabricated Septic Tank Kit for Emergencies

Pre-Feasibility Study

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Table of contents

Acronyms & Abbreviations

BOD	Biochemical oxygen demand
BORDA	Bremen Overseas Research & Development Agency
COD	Chemical oxygen demand
HRT	Hydraulic retention time
TCOD	Total Chemical oxygen demand

Table of Pictures

Rationale

In rapid on-set of emergencies where large numbers of people are displaced agencies first set up communal latrines. Where there is space and the ground allows trench latrines are still the cheapest and quickest option. However, with increasing number of displacements happening in situations where it is impossible to dig trench latrines due to rocky or water logged ground, lack of permission from landowners lack of space or lack of access for desludging it is becoming more frequent that raised latrines have to be used. After the Haiti earthquake Oxfam and other agencies had to build huge numbers of raised latrines in the urban areas, at each cubicle had 50+ users, the slabs were direct drop and people took in containers of water for anal cleansing. Each cubicle had around 1 m^3 containment beneath it and had to be desludged once every 4 days.

The cost of a desludging tanker is typically around US$150 for $4m^{3.}$ Therefore, if the desludging frequency can be lowered to once a month for a block of four then US$ 750 is saved each month. Finally, completion of the proposed effort would lead to a waste collection and pre-treatment option which may aid many of the ongoing TT projects focused on Omni-ingestion and processing in reducing their per unit cost and overall complexity.

There have been previous attempts to address the “where it is not possible to dig latrine pits” problem statement before such as using compact treatment units which are vastly expensive, an unsuccessful attempt to make a flat packed septic tank which was too fragile, adding additives to the sludge to decrease the solids, and some bladder type anaerobic digesters or biogas units which require a large amount of space and often complexity that is not viable in most emergency settings. These options were most recently investigated under the Emergency Sanitation Project (ESP) with Oxfam, IFRC and Waste Netherlands funded by OFDA. Recent advances in Tiger worm toilets and UDD Toilets (identified as best options by the project) are still not appropriate for 1st phase communal toilets in emergencies where a rapid set up is required and the users are between 50 and 100 people per toilet.

OXFAM approached BORDA to develop jointly modified and easy deployable septic tank design to address the above mentioned constrains in emergency camp.

Objective

The project aims to produce an improved septic tank involving new approaches and energy generation techniques, to provide an affordable, practical solution to the need for rapid communal fecal sludge management in emergencies.

For the purpose of this project a septic tank is defined as a sewage disposal tank in which a continuous flow of waste material is decomposed by anaerobic bacteria and the effluent disposed of by means of a soakaway. For this project two options must be considered for discharge of liquid effluent:

a. Option 1: the effluent can be discharged from the septic tank to a soak-away or vegetative leach field;
b. Option 2: the effluent can be discharged directly to a sewage drain;

If successful, this project could provide a rapidly and widely deployable option, significantly improving on current practices in a wide range of locations.

General Criteria for the system

During an initial design workshop on the 14th of November 2017, OXFAM and BORDA agreed on key design features and criteria to be considered in the design as follows:

- Small storage space:
    - Pre-production is essential to guarantee a fast reaction time in case of an emergency. Therefore, the storage footprint should be as small as possible to reduce the required storage capacity.
- Fast set up:
    - No complicated and time-consuming set up should be required, the best would be a "droop and use" solution.
- Suitable for airfreight:
    - System should be packed as small as possible and have to fulfill size and weight requirements for international airfreight.
- Suitable for all regions
    - The system should be suitable in all climate regions and for different sanitation cultures (washers and wipers) without requiring modifications and adaptations.
    - The treatment system is only designed for treating the fecal matter and, the water used for flushing and cleaning water[1]. In case the toilets should also be used as showers, the resulting grey water needs to be separately treated.
- Non-permanent structures
    - To prevent legal conflicts the system should only consist of non-permanent structures, which can be easily removed when they are no longer required.
- Costs:
    - The price per unit is expected to be beneath US$ 999 if produced in quantities. Prices for prototypes are expected to be higher.

- Capacity for up to 500 people daily

[1] Up to 2.5 liter per user and day

Primarily Design Consideration

Taking the project background and aims into consideration design objectives are:

a) Reducing desludging intervals, thus the operation cost and
b) Simple logistics with respect to procuring, storing and installation

First objective – optimizing of reactor volume, performance and desludging intervals

Parameter	Explanation	Impact
Hydraulic sludge retention time	With increasing the retention time of the sludge biodegradation increases and hence the sludge accumulation rate decreases	Increasing the reactor/tank volume
Separation of grey and black water	Only fecal matter and water for cleaning and flushing enter the septic system	The user interface design within the toilet needs to be designed and constructed in a way that in any case no water from bath or toilet cleaning enters the septic tank. With less water coming in and out of the septic tank less infiltration area is required a soak-a-way
Biological enhancement	The biological reproduction rate of anaerobic bacteria are 30 days and depends on a complex metabolism. Adding industrially extracted packed septic tank bacteria as powder, tablets or liquid during start-up phase would help to decrease the time until the biological system is established	Potentially reduced of odour during the start-up phase and higher investment cost.
Temperature	Below 15°C methanogenic bacteria start to hibernate and become inactive. With increasing the temperature up to 36°C the activity and hence the treatment performance increases	Installation of solar heating system or at least exposing blackish tank surface to sun radiation. First option would increase the investment cost enormously.

Second objective – effectively transportable and storage, durable and a handy kit solution

Parameter	Impact
Material	Weight, durability, reparability, joining method, availability, price
Joints	Easiness during assembling and dismantling, spare parts, tools
Size	Weight during transport, storability, excavation depth, sludge retention time
Shape	Storability

Considered materials for the system

To fulfill the agreed requirements, the following materials have been considered for the design:

- **Glass reinforced plastic**: Two-component plastic with fabrics for reinforcement. The material is laminated layer by layer onto a mold, which is removed after hardening of the plastic. A coat of paint is applied as a final layer.

Picture 1 Example of a Tank made

Picture 2 Lamination process from fiber enforced plastic

- **Rota molded structures**: This technology requires a hollow mold. Granular plastic is inserted into the mold, which is heated up under constant rotation. The melded plastic crates a layer inside the mold. The structure can be removed after cooling down.

Picture 3 Examples of rota molded structures

Picture 4 Rota-mold Machine

- **Membrane based structures**: Reinforced membranes similar to tarpaulin used for trucks is welded into the required shape.

Picture 5 Example of a tank made from membrane material

The following matrix was used to identify the optimal material from the considered options:

	Glass reinforced plastic	**Rota molded structures**	**Membranes**
Strength	Strong but will crack if dropped to hard.	Strong and more flexible as glass reinforced plastic	Strong, but must be protected from sharp structures which could puncture it
Weight	High	High	Low
Production time	Long due to hardening time of the layers	Medium	Medium to low, compared to the other options
Required tools	Mole, plastic, hardener, glass fibers	Rota molding machine, mold and plastic	Welding machine, glue, membrane
Transportation volume	High: cannot be folded or glued together.	High: cannot be folded. Gluing is possible, but requires experienced workers	Low: can be folded.
Reparability in the field	Possible but requires training and material	problematic	Patches can be applied with special glue, requires experienced worker
Recycling potential	Little to no	High, through shredding and granulating	Membrane can be cut and used for other purposes

Baseline Data

The proposed design base line data:

Chosen / given Parameter		Unit	Explanation
Number of Users per septic Tank	500	People per day	This is the typical number of users in the first emergency phase. Numbers might reduce in later stages.
Number of Toilets	10	No.	One toilet block contains 10 separate toilets, which are sharing 1 treatment facility.
Urine per Person and day	2,0	l/P*d	Values found in the literature have a range between 1,4 to 2 l
Feces per person and day	0,4	kg/P*d	Poor nutrition increases the volume of the feces
Max excavation depth	1,2	m	Value given by OXFAM, to ensure universal applicability of the system.
Min retention time of liquids	1.5	h	Design parameter, influencing the liquid solid separation, might be reduced to 12 hours.
Flush and cleaning water	2,5	l/P*d	Estimated number for washers might be lower in case of water shortages or in cultures, which use toilet paper.
BOD per Person and day	60	g/d	Literature value
COD (Assumed 2:1)	120	g/d	Literature value
Desludging interval	9	months	OXFAM asked for a 6-12 month interval, the length of the interval influences the size of the unit due to higher storage capacity.

Chosen / given Parameter		Unit
Number of Users per septic Tank	500	
Number of Toilets	10	
Urine per Person and day	1,5	l/P*d
Feces per person and day	0,4	kg/P*d
max excavation depth	1,2	m
Min retention Time of liquids	24	h
Flush and cleaning Water	1,5	l/P*d
BOD per Person and day	60	g/d
COD (Assumed 2:1)	120	g/d
Desludging interval	9	months
Sludge accumulation rate	4	Litre/cap*month
Accumulated sludge in 9 month	12	m^3
Average daily inflow		**Unit**
Urine	0,75	m^3/d
Faeces	0,2	m^3/d
Water	1,25	m^3/d
Total	**2,2**	**m^3/d**
BOD Load	30	kg/d
COD Load	60	kg/d

Dimensions

According to the base line data we propose a septic tank system with a total volume of about 16.5 m^3 consisting of two chambers. First chamber acting main as sludge holding and decomposing tank with a volume of 13,5 m^3 and second chamber for a final liquid/ solid separation of about 3,0 m^3.

Aiming a relative flat structure with an average of height of about one meter and a proposed width of 3,0 m would result a length of 5,5 m.

Proposed design concept – Septic Bag

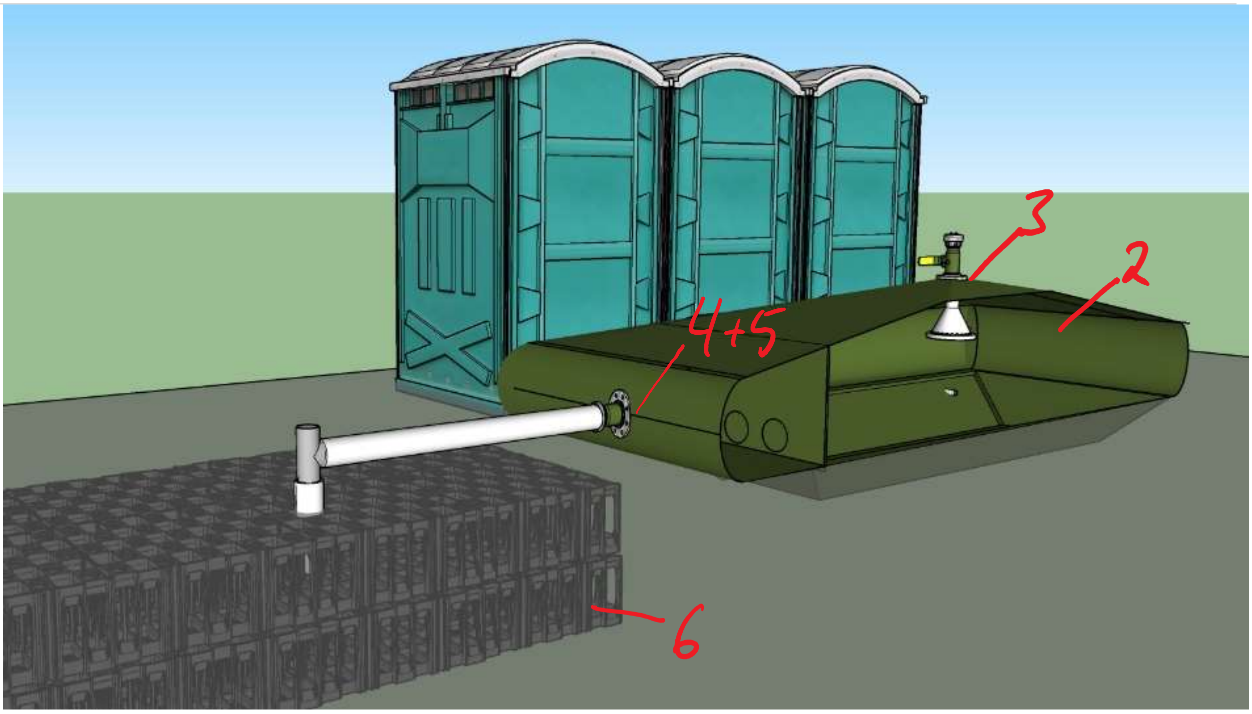
Concluding the pros and cons of the different materials, technologies, required dimensions and aimed product prize, we propose a so called septic bag system industrially manufactured out of high strength fabrics. A product with the following characteristics:

a) Moderate in weight estimated 20 – 30 kg
b) Can be folded with small storage and transportation dimensions
c) Best price volume ratio 50 – 100 Euro per m^3 total tank volume
d) Low building heights, hence less excavation
e) Potential exposure to sun radiation, hence increasing the treatment temperature increases the treatment performances
f) Durable material

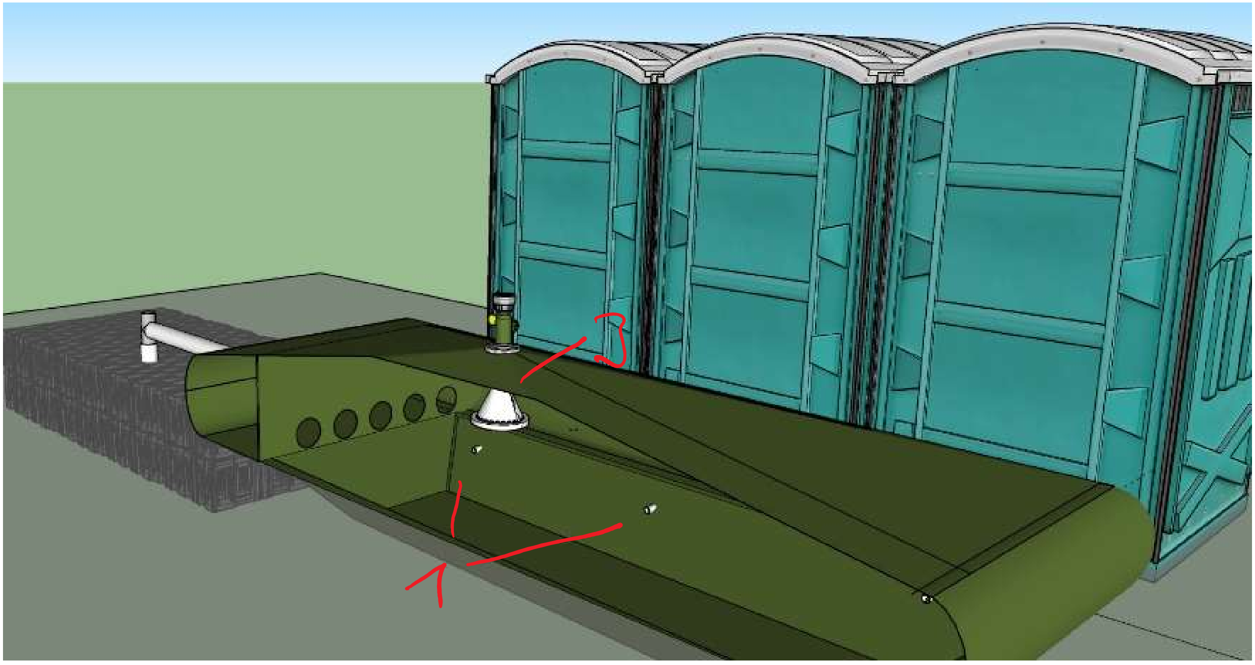
BORDA is contact with several internal membrane system suppliers for engineering such septic bags.

The proposed system consist of the main system components as follows:

Component	Function
1. Flexible connection to the toilet blocks	Connection with standard fast coupler to connect the toilet siphon at flexible height to the septic bag
2. Two chamber membrane bag with revision openings	Core treatment component where the incoming feces gets decomposed, liquid and solid fraction separated and sludge particle accumulated until emptying in period of 6 – 12 month
3. Desludging connector	To enable to desludge with means of a vacuum system the accumulated sludge without destroying or damaging the membrane
4. Overflow outlet pipe	Outlet for the separated liquid phase with integrated particle filter
5. Particle filter	Avoids that sludge particles or scum enters and blocks the infiltration system and to allow an easy cleaning
6. Underground soak-a-way	Infiltrates and disposes the effluent of the septic bag continually into the ground
7. Vent pipe or optionally biogas outlet	Digestion or biogas will be produced and can either released to the atmosphere or captured compressed to proposed pressure of 10 to 20 cm water column. Several bag can be connected to one biogas pipe network.

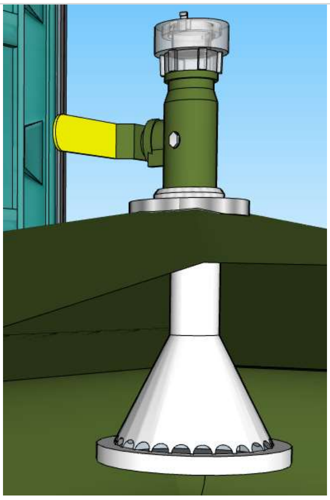


Picture 6 Draft drawing of the proposed system



Picture 7 Detail view

For desludging, a vacuum truck can be connected to the valve on top. The desludging head can be pushed in the sump by stepping on the tank to improve the emptying process. The membrane would be strong enough to allow the operator to step onto it in order to push the sludge out of the bag.



Picture 8 desludging head

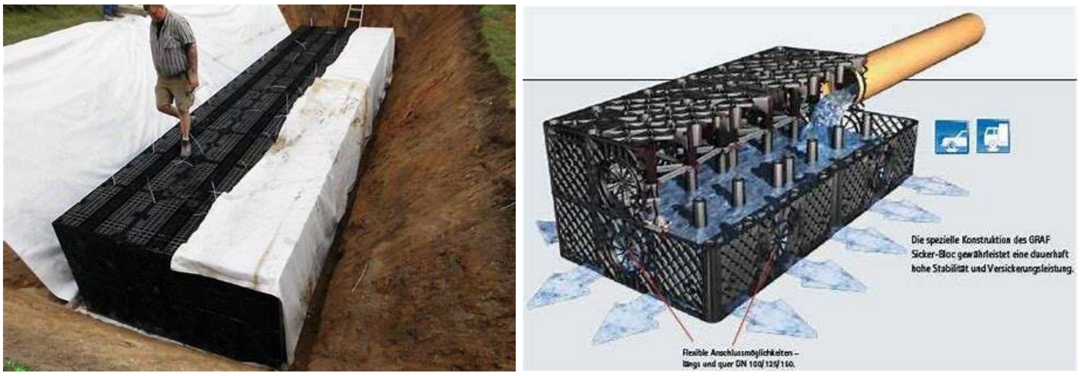
Picture 9 Quick coupling components

Picture 10 Particle filters to protect the infiltration system.

According to the estimations, daily up to 2.2 m³ effluent (liquid phase) needs to be disposed safely either via a sewer network or via so called Soak-a-Way infiltrating it into the ground if soil condition allows.

The proposed soak-a-way system consist of pre-fabricated polyethylene structure or boxes industrially manufactured for urban rain water infiltration. Such structures or boxes are wrapped in geotextile and installed in the subsurface, provide mainly water storage capacity during flow peaks without overflowing. New products on the market where the individual box gets assembled out of panels very quickly, that makes the logistics much easier. Such products are designed and supplied by the company 3P Technik Filtersysteme GmbH www.3ptechnik.com and other companies.

Picture 11 Components of a foldable prefabricated infiltration unit



Picture 12 Filter boxes installed to a infiltration system in size depending on the required infiltration area and buffer capacity

Next steps

If the proposed overall concept solves the need of OXFAM, the following steps are going to be undertaken:

Activity	Time line
1. Detailing and pricing the septic bag concept with more than one membrane bag supplier	Until end of February 2018
2. Preparation of an assembling and operation manual	Until end of April 2018
3. Manufacturing and factory testing	Until end of April 2018

Appendix 1 – suitable fabrics

Genap
waterproof solutions

Technical Datasheet

Genatex® 850

Data	Norms	Units	Specification
Material			reinforced PVC (Polyvinylchloride)
Woven			100% PES (1100 dtex)
Coating			PVC-P (two-sided)
Color			grey
Total weight	DIN EN ISO 2286/2	g/m^2	900
Tensile strength (L/T)	EN ISO 1421	N/50 mm	3000 / 2800
Tear resistance (L/T)	DIN 53363	N	300
Temperature resistance	DIN EN 1876/2	°C	-30 / +70
Flammability	ISO 3795	mm/min	< 100
Remarks			Kiwa certification according: BRL-K 519; MB (slurry resistant)

Genap b.v. rev.0 0212

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Genap
waterproof solutions

Technical Datasheet

Genatex NW PP 20

Data	Norms	Units	Specification
Material			Polypropylene (PP) (non-woven)
Weight		g/m²	235 ±23.5
Thickness (at 2 kPa)	EN ISO 9863-1	mm	1.7 ±0.34
Tensile strength (L/T)	EN ISO 10319	kN	20/20 ±2.6
Elongation at break (L/T)	EN ISO 10319	%	50/50 ±11.5
Static puncture resistance	EN ISO 12236	kN	3.40 -0.68

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Appendix 2 – workshop minutes

Minutes of the project preparation meeting

Minutes of Meeting

Purpose of Meeting: OXFAM Meeting on Prefab emergency Sanitation and FSM options for Rohingya camps

Date/time: 14 November 2017, 09:00 – 17:00

Place of Meeting: HQ, BORDA

Meeting attended by:
- Andy Bastable, OXFAM
- Brian McSorley, OXFAM
- Dr. Jochen Scheerer, 3P
- Thorsten Reckerzügl, BORDA
- Ralf Knoche, BORDA
- Kristian Franzius, BORDA

Note prepared by: Kristian Franzius

Structure:

1. Round of Interdiction
2. Report on Rohingya camps, Bangladesh
3. Development of prefab septic tanks
4. Milestones for development of septic tanks

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1. **Round of Interdiction**
    - Brian: > OXFAM general Focal Point for this Project (Septic tanks are not his main expertise). His superior with technical knowledge on septic tanks is Andy.
    - - Thorsten Reckerzügl, BORDA: Represents BORDAS West and Central Asia (WESCA) BORDAs focal region for Emergency Sanitation
      - Ralf Knoche, BORDA
      - Kristian Franzius, BORDA: Water and wastewater engineer.

2. **Development of prefab septic tanks**
    - Information on used emergency Toilet Systems:
      - Phase 1 in emergency relief
        - Prefab Slabs from UK Warehouse
        - Cubicles are made from tarpaulin (Testing of Dunster House System)
        - Estimated lifetime of the structures 3-6 months

  - Pit of 4-5 x1m, unlined
  - Tests are done with Tiger Worm Toilets, UDS Toilets , Compost Toilets and a bucket system

In general OXFAM looks also for solutions suitable for problematic soil conditions:

- Price up to 999US$
- 500 users per septic Tank
- Users per toilet acc. to SPHERE: 20 long term | 50 in Emergency | up to 100 in reality at the moment
- Max depth: 1.2 metres
- Urine :1.5 to 2 l/P*d
- Faeces: 0.12 to 0.4 kg/P*d
- Min. retention time of liquids: 90 minutes
- Operation Time: 6 months to 1 year
- Flat packet | Airfreight (max. measurements?) to transport with passenger planes
- Discharge to soak away or river
- Efficient and robust
- Rapid digestion of solids
- Further work on the requirements for the system
- OXFAM would like us to reinvent the septic tank
- Long discussion on possible and impossible ideas like heating systems with solar, bio-fuel cells and or biogas, aeration of the tank, drying systems ….
- OXFAM: most important: it has to work, recycling of treated water and sludge for agriculture is a secondary benefit
- Regulations do not have to be considered during development phase
- In further discussions: the idea of a biogas digester made from Tarpaulin came up: fast setup, gas could be used for light.
- Lower part with all connections might be done with roto moulding, top could be flexible like to big biogas plants in Germany
- Prices for options should be compared, but the main focus was agreed to be on the Biogas option
- Another option discussed was a prefab. septicSeptic tank (with or without biogas use) which is collapsible for airfreight. One option discussed here was a bladder like septic tank.
- To improve sedimentation and therefore reducing retention time and size installing a lamella separator in the septic tank has been discussed.
- Size limit: 4*2*1,2m per unit
- Should be compared in price and efficiency with a standard containment.

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3. Milestones for development of septic tanks
    - Inception: October 17
    - Selection of sites: End of October 18?
    - 2 Designs: End January 18
    - 1st Prototype ready: End of March 18
    - Assembling |Testing Germany: April 18
    - Shipping (OXFAM): End of April 18
    - Testing 1st run : June 18

End of Project incl. Reporting: September 18