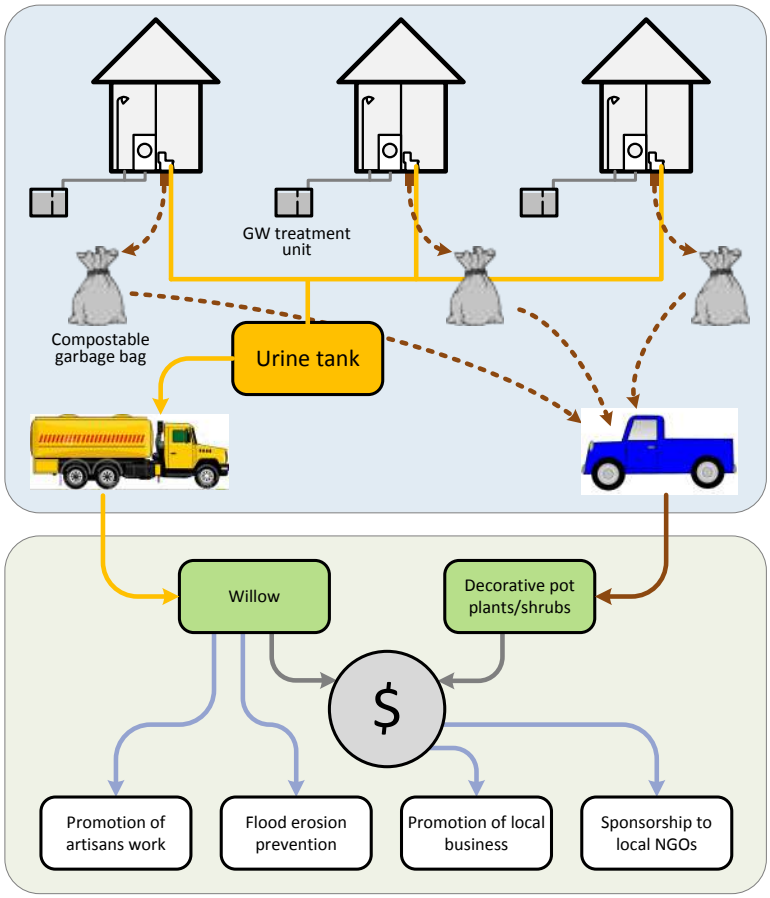
Terra preta sanitation as a way to improve sanitation and agriculture for an informal community of peri-urban area of Chisinau, Moldova



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ABSTRACT

The current proposal provides a sustainable sanitation solution to a peri-urban community of Moldova, while generating value chain from excreta and other organic waste and trying to create social assets by improving local landscape and preventing soil erosion. The area represents formally allocated plots for urban dwellers meant for agricultural purposes and building of summer houses. The increase in price of living in Chisinau has forced many residents to move to this area for a permanent residence. Along with lack of recognition from the local authorities the population in the area is faced with serious problems such as water shortage, lack of sanitation infrastructure and/or poor public services for empting the septic tanks. The proposed sanitation system is an urine diverting dry toilet , with a centralized transportation and treatment via terra preta sanitation approach. The urine will be diverting via a pipe system into collecting tanks, from where it will be transported via track to a storage tank to terra preta demo garden for further treatment via lacto-fermentation. The faeces along with kitchen/green waste will be collected by the users in compostable garbage bags and transported periodically to the centralized facility for their treatment via combined lactic acid fermentation and thermal composting. The business model elaborated suggests that the use of terra preta sanitation approach for growth and marketing of willow cuttings and decorative pot plants/shrubs fertilized with human excreta processed could be profitable. In the long term the project can contribute with some money return to solving of many environmental and social problems such as soil and flood prevention, rainwater harvesting and reuse, promoting of local artisan work.

1.1 Background information and justification

The proposed sustainable sanitation and agriculture solutions are to be applied in a rapidly growing peri-urban community located near the capital of Moldova, Chisinau. The newly established community is near Tohatin village and occupy land formerly allocated for urban dwellers that live in Chisinau to spend their summer time in the area. The plots were meant for gardening and vegetable growing in order to support the urban food supply as well as to build summer houses where people can spend their vacation. Due to considerable increase in the cost of living in Chisinau, many people moved to reside in the area. The current population of the Tohatin commune[1] accounts for a total number of 2730, while that of informal community is 2500 – hence almost equal in population to the commune, and rapidly growing. In spite of these facts however, there is no recognition from either the municipality or the local authorities on the concern over the issues the peri-urban community is facing. While electricity is provided on a more secured basis, the issues of water, sanitation and waste is not addressed at all by the local authorities, the solutions being sought only on an ad hoc basis by the residents themselves and no long term commitment is foreseen with regard to building of sanitation infrastructure. Water supply in the area is provided either from the central aqueduct, private wells, rainwater or transported by tracks from Chisinau. Pit latrines and flush toilets connected to a septic tank are the main forms of sanitation in the area. According to a survey carried out by an NGO WiSDOM association and informal discussions with the residents, the poor service of sewage collection along with high prices for septic tank emptying forced people to build unsealed septic tanks which allow infiltration of residual waters into the soil or they allow them to flow on the street during heavy rain fall. The solid fraction is disposed of on vacant land. Introducing and promoting of urine diverting sanitation system would be appropriate for the area, considering the limitations of water supply, lack of sewerage infrastructure and low quality services for emptying of septic tanks. Urine diverting toilets were implemented in several schools and households of Moldova. The current proposal provides a comprehensive sanitation approach based on urine diverting dry toilets, which function on terra preta sanitation principles; also, it designs the main stages of excreta storage and on-site pre-treatment, transportation and processing at a centralized facility for the creation of terra preta-like soil improvers. The separated urine will be collected via a pipe system into tanks, from where it will be pumped each month and transported to a bigger storage tank, where it will be treated adequately and applied for irrigation of willow plantations. As the quantity of faeces will be much smaller, they will be collected in compostable plastic bags along with kitchen/green waste. Terra preta like soil improvers will be created from collected excreta/kitchen waste and biochar via combined lacto-fermentation and thermal composting. Terra preta sanitation approach in UDDT systems will contribute to the smell reduction and will create value chain out of human excreta. As compared to other types of soil conditioners, terra preta-like soil improvers are unique as they are more stable than normal compost, owing to the biochar component, contain a higher quantity of nutrients (as less nutrients are lost via volatilization) and can be obtained in shorter period of time. The final end-products will be used for horticulture (growing of decorative pot plants/shrubs) as well as planting of willow (Salix). The willow cuttings will also be sold to local artisans (for basket, fence and furniture making). As the free area proposed for Salix growth is prone to some erosion it will add to reduction of the environmental impact of soil destruction. The demonstration area designed for application of terra preta-like soil improvers may act as a point of social connection and communication. In the long term, some of the profit could be invested as

[1] Commune is the lowest level of administrative subdivision of a county in Moldova. Each commune is administered by a Mayor, being made up of one or more villages which do not themselves have an administrative function.

sponsorships for local NGOs for installing rainwater harvesting facilities, which will prevent further erosion and offer free water for the residents to be used in irrigation.

1.2 Technical description

The technology is based on terra preta sanitation approach which assumes a specific excreta treatment via combined lactic acid fermentation and thermal composting and addition of wood biochar, which ensures a safe treatment and reuse as well as obtaining of high quality agricultural fertilizers. Main system used is a common urine diverting dry toilet system which have some technical adaptations. The urine will be collected via a pipe system into cluster collection tanks (5-6 households), pumped once per month and transported to terra preta demonstration garden. The greywater will be treated on-site via a two chamber septic tank. Faeces will be collected in plastic containers and pre-processed on-site by each user separately and then delivered every month, along with kitchen and green/waste in compostable garbage plastic bags to be transported to terra preta demo garden (Figure 1). The kitchen/green waste before being placed in plastic bags could be pre-fermented by adding lacto-bacilli and storing it in closed vessels.

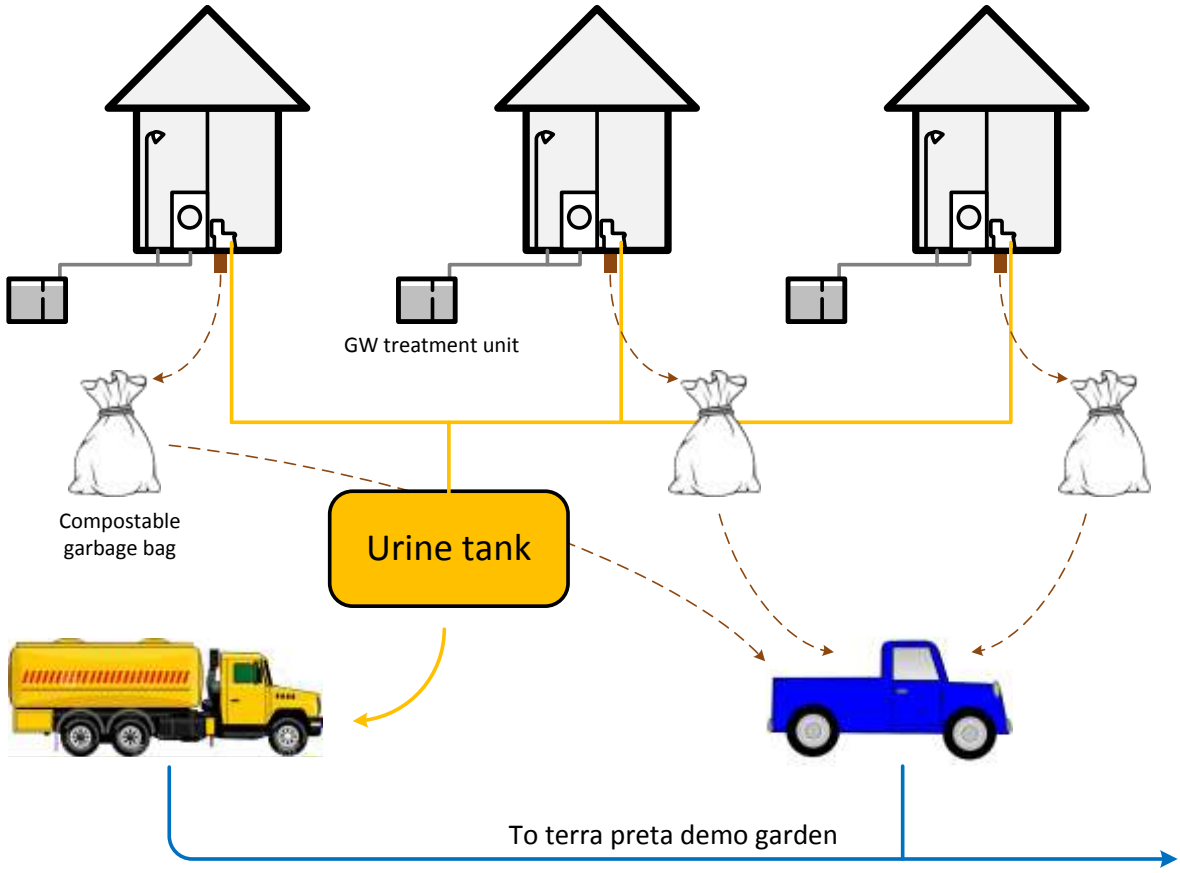

Figure 1. Collection and potential treatment of human excreta, greywater and other organic waste streams (kitchen waste, green waste)

At terra preta demo garden, urine and faeces treatment will be based on terra preta sanitation approach (TPS), that will lead to a minimization of the loss of carbon and nutrients (N, P, K), 0 waste generation, reuse of carbon, nutrients and water in agriculture and the creation of value chain from excreta. Excreta will be treated by integrated lactic acid fermentation and thermal composting (Figure 2).

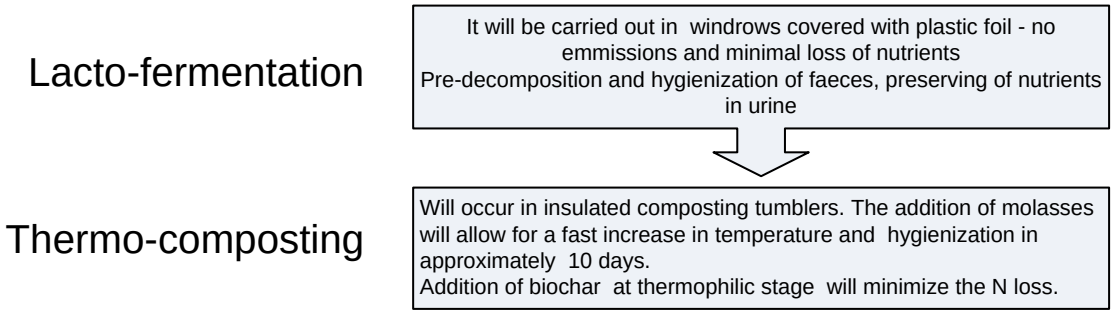

Figure 2. The main stages involved in excreta treatment

By adding of lactic-acid bacteria and sugar source there will be an intense growth of these microbes and consequently to an inhibition of the pathogens and putrefying bacteria (Wang et al., 2001). At lacto-fermentation stage faeces will be mixed with other organic waste such as kitchen waste, animal manure and green waste. Under the influence of enzymes released by plants as well as by bacteria, the non-digestible compounds such as cellulose, hemicelluloses, polygalacturonic and glucuronic acids will be transformed into simpler compounds (Kalantzopoulos, 1997). In order to have an intense microbial growth, a source of easily fermentable carbonaceous material such as molasses will be necessary to be added. This component will hasten the decomposition during the thermal composting by boosting the development of microbes and increasing in temperature above 55 °C during first or the ensuing days (Ma et al., 2010; Ong et al., 2001). From our personal experiments, exposing lacto-fermented material composed of human faeces, cattle manure, fruit waste, molasses and bacterial inoculate (at a proportion of 40:30:17:8:5) to thermal composting in an insulated composting box leads to a fast increase in the temperature. Already during the third day, it exceeded 55 °C, without need for turning or considering the C:N ratio (Andreev et al.2013). Such a temperature can be maintained for a period of more than 10 days, thus meeting the sanitization requirements of waste treatment for pathogen destruction (55° C during 5-7 days) (Ma et. al., 2010). Therefore, the lacto-fermentation contributes to an efficiency of composting and shortening of the sanitization time.

With the increase in temperature during the thermophilic stage, there is an inhibition in the nitrification process and consequently a significant proportion of ammonia is lost via volatilization (Bernal et al. 2009). In order to reduce ammonia loss at this stage it is important to add biochar. For example, application of biochar during sludge composting contributed to a significant reduction of nitrogen loss and the mobility of heavy metals for example Cu and Zn (Hua et al.2009). Biochar has the capacity to absorb ammonia owing to surface acid groups.

The technology of lactic acid fermentation is simple as it does not require any sophisticated equipment and locally available materials could be used. For example for the creation of anaerobic conditions simple plastic foil could be used. Also, sauerkraut brine can serve as a low cost substitute to lactic bacteria inoculates. As can be seen in Fig. 3, during the collection of solid fraction, the main component for using as covering material will be sawdust, this will help to dry the faeces and reduce the smell, which will be important when placing it in compostable plastic bags for its transportation to TP demo garden. However, in order to initiate a more intense lacto-fermentation at the collection stage, also other components could be used as covering material for example chopped corn stover (mainly cob and

stalk), press mud, clay and rock flower (Bagar & Kavčič, 2013; Bottcher et al., 2010; Snyman et al., 1986, Partha & Sivasubramanian, 2006; Solaimalai et al., 2001; Xavier & Lonsane, 1994) as well as dry microbial inoculate. Corn stover proved to be a suitable component for ensiling, including animal manure silage (Anonymous, n.d, Martinez-Avalos et al.1998). Press mud could also be a suitable material as it may contain 5-15 % of sugar (Partha & Sivasubramanian, 2006; Solaimalai et al., 2001; Xavier & Lonsane, 1994). By mixing the organic waste with clay and rock flour stable components - organo-mineral chelated complexes, which contribute to organic matter protection and stability can be obtained (Bagar & Kavčič, 2013; Stevenson, 1994). These components as a cover mix can be bought by the users from the service provider at the centralized terra preta demo garden. It also can be added at lacto-fermentation stage by the service provider.
The urine will be treated on-site by adding a solution of lactic bacteria and EFOS (molasses, sugar or whey). After being centrally collecting from the urine containers, it can either be soaked on biochar or applied directly for willow irrigation. In order to avoid willow fertilization and soil pollution, a nutrient mass balance would be useful. At this stage such calculations are not made yet. During the first stage of the project, the willow from the upper side of the living hedge (as shown in figure 4) will be cut and used for planting the areas prone to erosion or sold to local artisans. The willow is a suitable tree for prevention of erosion as well as flooding effect, which are characteristic for the examined community. The extensive root system of the willow anchors soil together and their stems slow the velocity of flood waters and winds (Extension notes, Ontario, n.d.). The produced terra preta like soil improver will be used for growing of decorative plants in raised beds as well as in a greenhouse (Figure5).

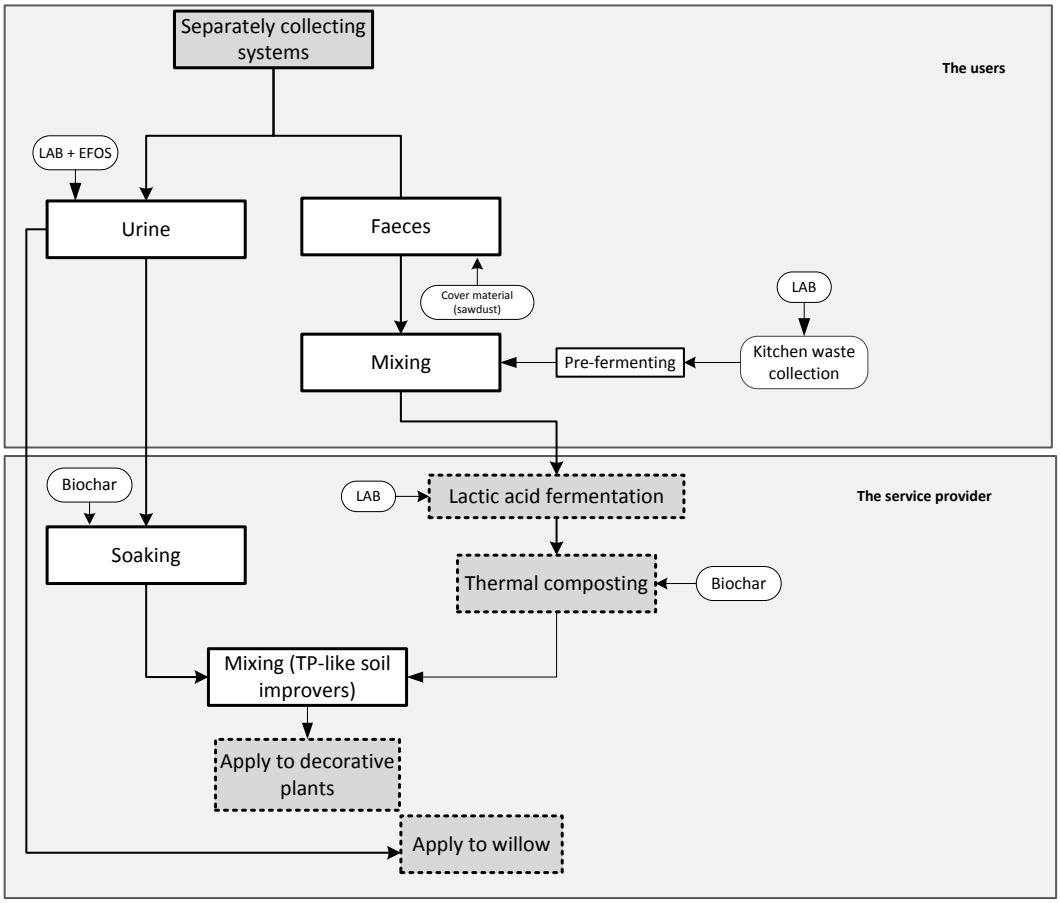

Figure 3. The process of treatment of human excreta and production of terra preta soil improvers.

LAB - lactic acid bacteria, EFOS - easily fermentable organic substrate (kitchen waste, molasses)

Figure 4. A potential way on how the willow living fence will look like

Source: Inspiration green, n.d. Green living willow hedges

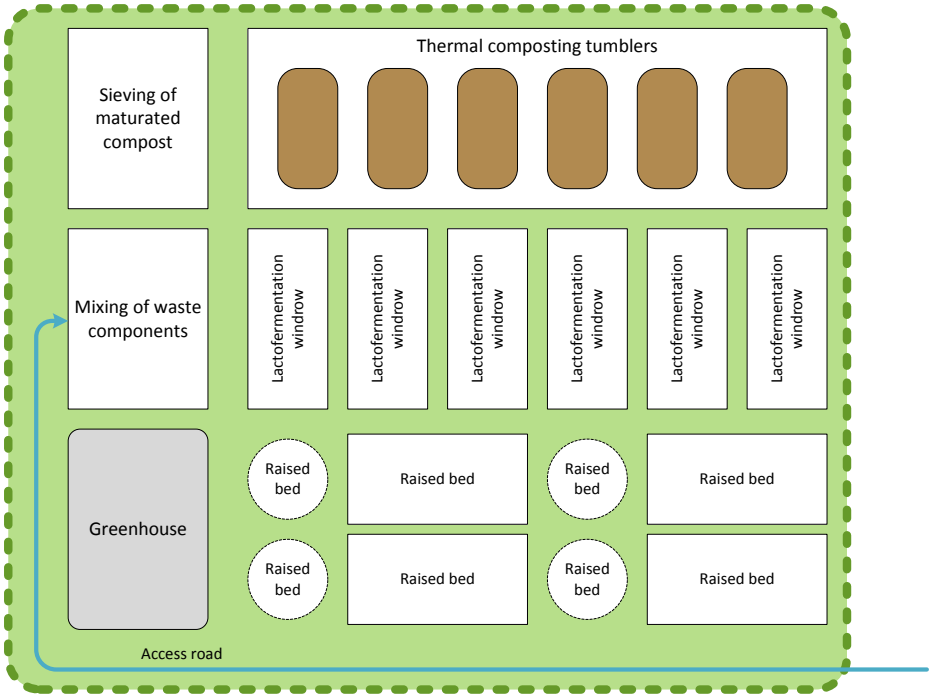

Figure 5. The potential scheme of TP demo garden

1.3 Business model canvas

1.3.1 Customer segments

As can be seen from Appendix 1, the main customers are the users who will accept the new sanitation system from the informal community as well as gardeners and artisans from the area and neighborhood communities (willow basket and furniture makers interested in buying willow twigs). As the sanitation system is new for the customers they need to be informed and educated on the technology.

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1.3.2 Value proposition

Among the main problems the community is facing is the inappropriate system of collection and wastewater treatment as well as lack of continuous supply of drinking water, soil erosion and flooding problems. The current proposal promotes the sanitation system based on ecological sanitation and terra preta sanitation approach which may lead to a cleaner, safer and healthier community. The obtained terra preta-like compost will have a high hygienic and agricultural value owing to the addition of nutrient rich organic waste and biochar. The treated urine will be used for willow irrigation. Provision of willow cuttings is very important in the region as there are no suppliers of such material in Moldova, even though the work of artisans and furniture making is common. In the long term, extending of willow plantation will contribute to the reduction of soil erosion and flooding effects and improving the local landscape. The decorative plants (grown in the greenhouse and raised beds) grow easily and are widely used for exterior decorations. The current system can play as an example to other similar communities from Moldova faced with problems of lack of wastewater collection and treatment systems. In the case the element with faeces collection could fail (due to user inaceptance, problems with local authorizations etc.) the users could be thought to process this type of waste on-site via terra preta sanitation approach. The service provider could produce terra preta-like compost from kitchen/green waste and animal manure.

1.3.3 Channels

The residents will be informed about TP sanitation technology via different meetings and interactive demonstrations about the ecological sanitation system and the advantages of it over existing system (f.e. pit latrines require space or desludging, are less hygienic and smelly, also there is poor services for septic tanks emptying). Also there will be TP-demo garden and shop where customers will learn some steps in making TP compost and buy the decorative flowers/willow twigs. The price for decorative plants will be established according to the similar prices of the concurrent companies in the area. The production promotion (for example willow cuttings) will be made via living willow structures, for example living fence and baskets for plant growing available in the TP demo area. Additional information will be placed on boards available in the area. For bulk orders (willow cuttings and shrubs) the service provider[2] could offer discounts and free delivery. Permanent customers will get a regular update about the product via emails. Also bookings and reference orders via Internet could be possible.

[2] The service provider can be a local enterprise interested in the product or a social enterprise created by local NGOs

1.3.4 Customer relationships

The main idea of the current proposition is to create long term environmental and social benefits to a marginalized community in Moldova by introducing a sustainable sanitation, agriculture and business approach. The maintenance of the customer relationships will be kept via security, professionalism, innovation and quality (Appendix 1). Security would mean on time collection of excreta and its safe treatment through a maximum avoidance of user disturbance (such as smell nuisance). Professionalism is manifested via the fact that research support will be offerred from qualified specialists of Unesco-IHE Institute for Water Education, Delft, the Netherlands and Crop Research Institute Selectia, Baltsy, Moldova. The relationships will also be based on innovation as a relatively new approach in sanitation and excreta reuse. An important consideration is also the quality of the product - the hygienic and agricultural parameters can be tested at the National Centre of Public Health of Moldova and Institute for Crop Research Selectia.
The main points of interaction with the customers with the service provider will be via a contract system - monthly, annual and biannual contracts. The staff of service providers will contact them via phone or email for signing the contract. The beneficiaries of the annual and biannual contract will benefit from a discount. Also users can get some discounts for buying decorative flowers and purchase of toilet cover materials and/or bacterial inoculate. Local environmental NGOs WiSDOM and Renasterea Rurala who have implemented projects in the area may play an important role in preparing the market. Also the residents can take a participatory role in decision making as regarding the placement of the demo-garden, urine containers, waste collection strategy etc. via a Local Committee elected by the members of resident associations. A social survey would be important before project implementation.

1.3.5. Potential revenue streams (in euro)

The main potential revenue streams come from product sale/service provision (more detailed costs are presented in Appendix 2), user contributions, non-refundable grant and service provider investment (could be from a loan) (Table 1).

Table 1. The overall financial needs (euro)

Funding sources	**Year 1**	**Year 2**	**Year 3**
User contributions	106947	0	0
Non-refundable grant	68384	22790	20990
Service provider contribution	**5000**	**5000**	**10000**

1.3.6 Key resources

The main key resource of the proposition is the human excreta which can be reused safely for creating social and environmental benefits
Also secondary key resources are:

- Terra preta demo garden

- Sustainable collection and treatment sanitation system
- Products for sale (willow cuttings, decorative plants/shrubs)
- Qualified personnel
- Trustful partners

1.3.7 Key activities

- Land preparation and obtaining of the required permits
- Establishment of TP demo-garden: lacto-fermentation and thermocomposting facilities
- Establishment of greenhouse
- Excreta collection and pre-treatment
- Excreta transportation to TP demo garden
- Production of TP-compost
- Procurement of plant seeds/seedling material
- Establishing of raised beds, greenhouse
- Establishing of willow plantations and living structures
- Planting of decorative pot plants Petunia and shrubs Hortensia
- Promoting of products and TP based approach in organic waste treatment
- Selling of products (decorative plants, willow cuttings)

1.3.8 Strategic partners

- Local authorities - they are important as they will provide the land where TP demo garden will be designed and built. As the service provider may offer some services such as material for greening, decorative plants and also planting services the local authorities can grant land using for free or at a lower price. In addition the mayoralty will be interested in cooperation as the service provider, by planting willows will improve the landscape and also prevent erosion in the area.
- Research team from UNESCO-IHE (The Netherlands) and Selectia Institute (Moldova) will provide useful insights into the research aspects of sanitation and treatment/reuse of excreta
- Artisan association will be important strategic partners for acquiring material for basket and furniture making
- A business consulting company - can give useful consultation on elaboration of a detailed business plan and marketing strategy
- The users of UDDT systems - they are important partners as they will provide the organic waste for terra preta production.
- Local environmental NGOs WiSDOM and Renasterea Rurală who have experience in the area
- International partner NGOs (f.e. WECF, GWP)

1.3.9 Cost structure

As regarding the cost structure, it could be presented as the following:

Time requirements: minimum 3 years
Energy: Vehicles and fuel for excreta transportation. Running of treatment equipment will mainly require mechanical work (casual labour).
The financial costs can be distributed as following:

1) Equipment and supply costs: 216641 euro[3]
2) Renting of vehicles/land rent: 7890 euro
3) Personnel costs: 52080 (see Appendix 4 for a more detailed description)

The building of UDDT and septic tank will be done by the residents themselves according to a grant scheme (covering 20% of the construction materials) that could be implemented by a local NGO in cooperation with service provider. As can be seen in App.2 and 3, the business can be profitable starting from year 2, if considering the contribution from a non-refundable grant (as there are many social and environmental benefits) as well as 80% of user contribution in ecological sanitation systems and gray water septic tanks. Some costs could be reduced (for example those of septic tanks and ecological sanitation facilities the owners could build it from their own materials). The overall costs will be adjusted based on a market survey and in consultation with a local business consulting company.

1.4. Additional questions:

The current proposal is at its conceptual phase. It can be however be implemented as one or few grant projects with the co-funding from the service provider and the local beneficiaries. It will be developed further after the detailed business plan and social survey will be undertaken. The current contribution is based upon the work of different authors such as Otterpohl & Buzie, 2013; Factura et. al.2010 as well as own research contribution carried out within a PhD program carried out at Selectia Institute/UNESCO-IHE Institute for Water Education. What is different in this proposition is that based on a comprehensive literature review and experiments carried out within PhD program, thermal composting is used instead of vermicomposting as the second stage for faeces sanitization and organic matter stabilization. The addition of easily fermentable organic substrate (molasses) during lactic acid fermentation leads to a fast increase in temperature, without need for mixing. At thermophilic stage the addition of biochar will reduce N volatilization, thus increasing the agricultural value of TP-like compost. The lacto-fermentation of urine is important for preserving more nutrients (N and P) in plant available forms. The urine will be used for willow irrigation, which will be planted initially as living fence, thus reducing the transportation costs, while promoting the product (willow cuttings) for local artisans. The produced TP-compost from faeces, kitchen/green waste, molasses and biochar will be used for growing of decorative pot plants/shrubs.

1.5 References

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[3] Under this category were not added the compostable plastic bags as there it was not possible yet to obtain information on their supply/price for Moldova

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APPENDIX 1.

Appendix 3. The schematic business canvas model

<table>
<tr>
<td>Key partners

• Local public authorities of Tohatin commune
• Unesco IHE Institute for Water Education
• Business consulting company
• Local environmental NGOs WiSDOM and Renașterea Rurală
• International network organizations GWP, WECF</td>
<td>Key activities

• Excreta treatment and production of terra preta like compost
•
• Establishing of terra preta demo garden
• Excreta collection, pre-treatment and transportation of demo garden
• Excreta treatment
• Establishment of willow plantations, living structures
• Establishing of raised beds, greenhouse, planting of decorative pot plants Petunia/shrubs - Hortensia</td>
<td>Customer Segments

• 200 households of peri-urban informal community of Moldova
• Gardeners and artisans</td>
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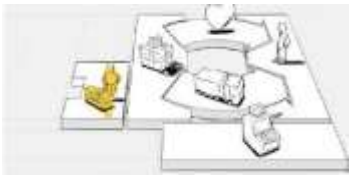
<tr>
<td>Key resources

• Human excreta treated via terra preta sanitation approach
• Terra preta demo garden
• Sustainable collection and treatment sanitation system
• Products for sale (willow cuttings, decorative plants/shrubs)
• Qualified personnel
• Trustful partners</td>
<td>Value proposition

Creating a cleaner, safer and healthier community through terra preta sanitation approach</td>
<td>Channels

Interactive demonstrations

• Street demonstrations/meetings with customers
• Living willow structures/composting process at demo garden
• Regular product update via website/email, online bookings</td>
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Cost structure

- Time requirements: minimum 3 years for project running
- Energy: Transportation costs
- Financial requirements:
  Equipment and supply cost - 216641 euro
  Renting of vehicles/land rent - 7890 euro
  Personnel cost: 52080
  - Human resources: administrator, accountant, casual labour, research expertise

Customer Relationships

Offering long term environmental and social benefits to a marginalized community

- Security (on time collection of excreta and its safe treatment)
- Professionalism (research support from qualified specialist in the field - scientists from Unesco-IHE Institute for Water Education and Crop Research Institute of Baltsy, Moldova
- Innovation (new approach in treating and reuse of excreta)
- Quality (the quality of terra preta-like compost will be tested for hygienic and agricultural quality - National Centre of Public Health, Crop Research Institute of Baltsy, Moldova

Revenue streams

- Revenues from product sales/service provision
- Revenues from user contributions for building UDDT and septic tanks (106947 euro)
- Non-refundable grant (112164)
- Service provider investment (20000)

APPENDIX 2. Potential revenue streams

Name of product/service	**Month**												
	1	2	3	4	5	6	7	8	9	10	11	12	Total
Urine collection charges (calculated for 200 households)[4]	250	250	250	250	250	250	250	250	250	250	250	250	3000
Faeces/kitchen waste collection (calculated for 200 households	250	250	250	250	250	250	250	250	250	250	250	250	3000
Selling of willow cuttings (1 ha, from the second year)	3000	3500	3000	0	0	0	0	0	0	0	0	3000	12500
Selling of annual decorative pot plants (greenhouse, 150	0	0	0	500	600	500	400	300	300	0	0	0	2600

[4] The price is calculated as the average price/person for disposal of waste: Source: Chivruga V. & Panainte, P. 2013

m2)													
Selling of decorative shrubs, Hortensia (2000 m2, from the second year)[5]	0	0	0	4000	2000	2000	2500	3000	4000	0	0	0	17500
Total													38600

APPENDIX 3.

Cost/revenues (euro)

Monetary flux	**Year 1**	**Year 2**	**Year 3**	**Total**
Revenues from sales/service provision	6600	38600	49890	95090
Revenue Taxes	792	4632	5986	11410
Costs (supported by service provider)	5000	5000	10000	20000
Net revenue	**808**	**28968**	**33904**	**63680**

APPENDIX 4 Approximate cost structure (euro)

Type of cost	**Year 1**	**Year 2**	**Year 3**
I. Equipment and supply costs			
1. Plastic foil for lactic acid fermentation	500	300	200
2. Compost tumblers	250	0	0
3. Compost mixer	500	0	0
4. Chopper	500	0	0
5. Wood for raised beds	800	0	0
6. Greenhouse, 150 m2	3600	0	0
7. Microbial inoculate, biochar, molasses	1800	1800	1800
8. Microbial inoculate, biochar, molasses	1800	1800	1800
9. Irrigation system	500	200	200
10. Purchase of willow cuttings	2700	2700	2700
11. Seeds/seedlings	2500	1000	1000
12. Urine tank (5 m3)	9600	0	0
13. Concrete urine tanks (3 units@6 m3 - collection)	960	0	0
14. Concrete urine -storage tanks (1 unit@18 m3)	947	0	0
15. Urine diverting dry toilet systems (200 household units)	73684	0	0
16. Septic tanks for greywater treatment (200 households)	60000 (300*200)	0	0

[5] The fluctuations in revenue is related to seasonal preferance of customers for buying the product.

Subtotal	**160641**	**7800**	**7700**
II. Renting of vehicles/transportation costs/land renting			
1. Renting of track for urine transportation	360 15euro/day@24 days/year	360	360
2. Renting of track for faeces transportation	120 15euro/day@8days/year	120	120
3. Transportation costs (product delivery/purchases	1000	1000	1000
4. Land renting	850	1150	1450
Subtotal	**2330**	**2630**	**2930**
III. Personnel costs			
5. Administrator	4800	4800	4800
6. Research consultancy	5000	5000	5000
7. Accountant	2400	2400	2400
8. Casual labor for waste collection/compost processing	2880 72 days/year@2 people@20 euro/day	2880	2880
9. Watchman	1200	1200	1200
10. Driver	1080	1080	1080
Subtotal	**17360**	**17360**	**17360**
TOTAL	**180331**	**27790**	**27990**