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HOW CAN WE STOP THE SEWAGE?

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In Ecuador 46.4% of households lack access to sewerage systems, and then much wastewater is discharged from sewerage into the environment untreated. On the one hand dry toilet systems present themselves as an optimal solution against this backdrop; they mitigate the production of black water, whilst having fertilizer as the end product. On the other hand, they tend to have a low acceptance level by potential end users. This problem of social acceptance is then further exacerbated in urban areas. In order to overcome this, the design of an ecological dry/semi-dry toilet was carried out in two phases. The first phase consisted of purely sociological research, where the aim was to determine the basic design parameters that should be used for ecological toilet prototype. The second phase is the development of ecological toilet prototypes, which are then tested in terms of their level of acceptance/rejection by potential end users. The overall aim is to develop toilet prototypes that on the one hand mitigate the production of black water, whilst on the other are accepted with open arms by end users, and even preferred over the conventional toilet common to urban areas.

Keywords: Dry toilet, Suction toilet, Manual suction, Wastewater treatment, Black water, Grey water, Water recycling.

1 INTRODUCTION

1.1 The Problem of Water Treatment in Quito, Ecuador

In Ecuador wastewater treatment is a serious problem. According to the census of the Ecuadorian National Institute of Statistics and Census (INEC 2010), only 53.6% of households have a connection to public sewerage systems. In addition, wastewater management makes up 53.3% of the average expenditure of national municipalities' budget, totalling 179 142 858 USD (INEC 2011). In 2012 49.8% of national municipalities carried out wastewater treatment, where a total of 128 000 000 m^3 of wastewater was processed. Despite this, 225 000 000 m^3 of wastewater was discharged untreated into the environment. The problem of wastewater treatment could be approached either at a macro or micro scale. A macro scale would involve large, expensive infrastructure works over a long time period. On the other hand, there is a possibility to consider the problem at a micro, or individual scale. In this case, it is suggested that every household would opt to change its toilet installation, to one that avoids the production of black water. The objective of this research project is to determine whether or not it is possible to mitigate the production of black water from

Ecuadorian households, whilst at the same time upholding a maximum level of comfort and lifestyle for the end users.

1.2 The Importance of Participative Design

In this research a participative design approach was adopted in accordance with Reason and Bradbury (2008), which is both considered a methodology for investigation and an approach to applied projects. In this sense, the researchers and end users worked together in order to reach solutions that are innovative and sustainable. It is considered to be a proven methodology in the generation of knowledge (Bergold 2007). In practise, to achieve this it is necessary to involve the end user at all stages in the development of the new product. In this manner it is guaranteed that the end result will be in accordance with the users' needs, given that they were involved in the entire design process. This is reinforced by Liener and Larsen (2009), who mentions how in current society innovative technologies are achieved by being as close to the end user as possible. In is worth mentioning however, that honesty from the end users can only be achieved by creating a secure setting in which the users feel comfortable in expressing their true opinions (Bergold and Thomas 2012).

2 METHODOLOGY

For this research, a series of sociological investigations were carried out: eight site visits to study homes with a dry toilet installed; twenty-eight semi-structured interviews with hypothetical end users of the prototypes to be developed; twelve focus groups with hypothetical end users of the prototypes to be developed. The results of the sociological investigations were used for the parameters of design for an initial prototype, which was given an initial evaluation through a preliminary social study with end users.

3 RESULTS AND DISCUSSION

3.1 The Series of Sociological Investigations

As was mentioned in section 1.2, in order to achieve participatory design it is important to carry out social research in such a manner that the persons being studied feel comfortable and able to express their feelings and opinions. For this reason the site visits were conducted in the homes of dry-toilet users. In addition, the interviews were semi-structured so that they could be adapted to the flow of conversation. Finally, the focus groups were carried out in an informal and familiar environment. The results were as follows:

Eight site visits: eight locations in Ecuador were visited that each had differing climatic conditions. Dry toilets with urine separation or with mixed faeces and urine were both used. A number of installations suffered from ventilation problems, which led to unfavourable smells and proliferation of flies. Sawdust was often used as a drying material and used toilet paper was thrown into the toilet (a practise that is not common in Ecuador). The mix would be left to decompose for a number of months for it to be converted into compost. The users of the dry toilets generally felt comfortable using dry toilet technologies, where the resulting fertilizer was used for ornamental plants and fruit trees. It is also important to note that every end user had had the dry toilet installed under his/her own initiative. In this sense they also had no qualms about mixing the residues of faeces/sawdust/paper/urine in order to produce an optimum compost and fertilizer.

Twenty-eight semi-structured interviews: the results showed the importance of cleanliness for both private and public toilets. On average the interviewees used the toilet four times per day, and tended to change their toilet installation every five to ten years. There was a consistent preference for white toilets, which were felt to reflect cleanliness. With regard to negative aspects, special mention was given to the need for constant cleaning of the toilet, bad smells, the noise made when flushing and the excessive water needed to do so.

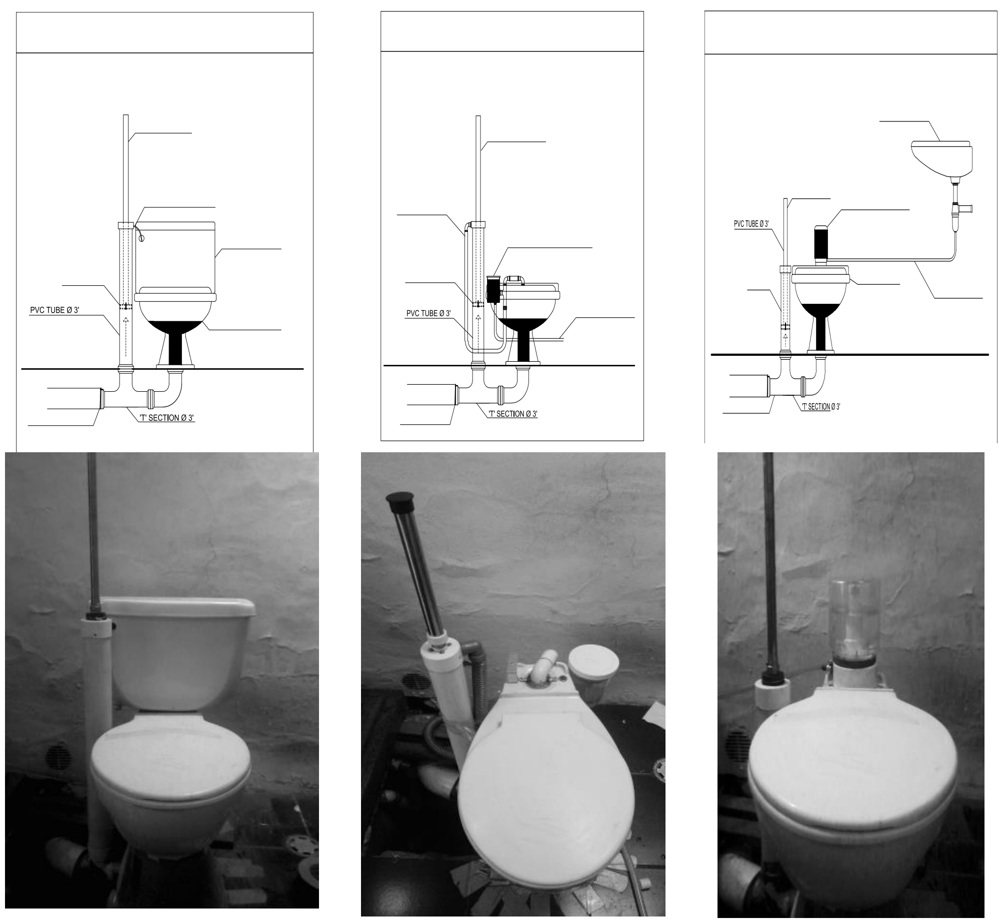
Twelve focus groups: various conclusions were reached. First, that the toilet is a basic tool of our everyday lives, and as such should always be in optimum working conditions (with little need for maintenance). Second, cleanliness was seen to be of fundamental importance, and to this extent white, modern toilets were preferred. Third, it was considered that the area in which the toilet is found must be clean, with a light and clear colour scheme to make the user feel at ease. Fourth, there needed to be an effective system to get rid of the waste products, given that there existed an aversion to any contact with them (even visual). Finally, in general there was little interest in knowing about the final destination of the waste products.

3.2 The Initial Prototype

Conventional toilets that are commonly available in the Ecuadorian market tend to be dual flush, using 4.1 litres for flushing urine, and 6 for solids (Viegener 2014). Given the results of the sociological investigations, the parameters used for the design of the initial prototype were to a) maintain the appearance of a conventional toilet, and b) use the least water possible to flush away the faeces, urine and paper. It is important to note that the initial prototype developed to date has drastically reduced the water demand for flushing to but one litre, thanks to a manual suction system. This in turn opens possibilities to a) recycle water from the hand basin used for washing hands to recharge for the next toilet flush, and b) reduce the size of the biodigestor that would be needed in future research, in order to pre-treat the wastewater prior to discharge to public sewerage systems.

Additionally, a further objective was to minimise the economic impact of changing toilet systems, and as such enable it to be easily replicated. To this extent it was of great importance to make use of the existing infrastructures of conventional toilet installations. The prototype was therefore developed using elements that were easily accessible in local stores, and which could be installed by the end user him/herself if necessary.

In Figure 1(a) the first prototype developed is shown, in which a bypass has been installed that through manual suction generates a vacuum to flush away the waste products. The system was tested using various fake faeces and toilet paper mixes. PVC tubing of a 3-inch diameter was used, with a range of heights tested from 90 cm (in accordance to someone standing) to 54 cm (in accordance with the end user sitting). The system was successful in flushing away all the waste products. The next developments of the prototype made were in relation to the water recharge system. The objective was that in the same action the toilet would flush, whilst also recharging the toilet bowl and water deposit in same action. In this manner the toilet was cleaned and left ready for the next user. This was all achieved whilst maintaining a water demand per flush of 1 litre. In Figure 1(b) the subsequent prototype developed is shown. In this case the conventional water cistern is replaced by a compact element that still uses the water float from the original toilet cistern. A pipe makes use of the air compression produced above the manual suction piston, pushing water to recharge the toilet bowl. Finally, in Figure 1(c) a further development of the prototype is shown where water is flushed directly from above the toilet bowl and the original cistern flapper is used, but where the cistern is replaced by a transparent container. The advantage of this option is that the working elements of the toilet flushing system can be clearly seen, which enables the end users to be conscious of how the toilet functions. For all of the prototypes, there is the possibility for them to be connected to either the household water mains or to use recycled water, given that they work independent of water pressure at the recharge point. To this extent successful trails were made in connecting the prototypes to the washbasin, thus mitigating the potable water demand from a toilet.



(a) (b) (c)

Figure 1. Manual suction toilet prototypes a, b, and c.

3.3 Initial Testing of the Prototype

This research is in the early stages of carrying out sociological studies to determine the level of acceptance from the end users. As an initial study to gauge this level of acceptance, five semi-structured interviews were carried out with members of the public from a middle-class background. Each person interviewed had previously had the opportunity to use the first prototype (Figure 1a). In general, the first reaction was one of some confusion when confronted with the vertical manual suction appendage, and where it was thought a didactic label might be of use. Otherwise, the prototype was considered to be a normal toilet. It was natural to pull the manual suction handle with force, and as such no discharge problems were encountered. It was also clear that the water demand for toilet flushing had been drastically reduced, which was perceived to be the main advantage. A disadvantage that was encountered was the noise made when flushing, due to the sound of the suction mechanism. Finally, it was noted that used toilet paper could be flushed with the faeces and urine. It was considered unusual however to do so, given that in in Ecuador it is common practise to throw the used toilet paper in a specially allocated dustbin adjacent to the toilet. To conclude, it can be said that the first prototype achieved to: a) drastically reduce the water demand for flushing; b) maintain the appearance of a conventional toilet; c) use readily available materials; and d) have an initial positive level of acceptance overall by the end users. For future research and prototype development, amongst the improvements to be made it is recommended to: a) make the design easier to comprehend regarding the operation of the vertical manual suction unit; b) reduce the level of contact the end user has with the flush mechanism (such as through the incorporation of a pedal-operated system) which was found to be of importance in the focus groups from Section 3.1.

4 CONCLUSIONS

This research project took on the challenge of looking at how to stop sewage (more specifically the production of domestic black water), taking the urban sector as its starting point. The aim is to bring about a mass-change at a micro, or individual level. To this extent it was put forward to design a toilet prototype in such a manner that the water demand for flushing was reduced drastically, and as such paving the way for a micro-biodigestor to be incorporated in the future for the wastewater to be pre-treated prior to discharge. In order to guarantee that end users accepted the prototype with open arms, a series of sociological investigations were carried out to determine the parameters for design. An initial prototype was developed, which used a manual suction system that brought the water demand down to a mere litre. Additionally, the prototype is made from a conventional toilet, making use of elements that are readily available in local stores and without the need for major construction works. Furthermore, by reducing the water demand to one litre, the doors are opened to use recycled water from the hand washbasin for toilet flushing. The initial reactions of end users of the first manual suction prototype were positive overall, where the initial social study shed light on improvements to be made in the future. Finally, the later prototypes that were developed did away with the water tank of conventional toilets. This also reinforced the didactic elements of the toilet, clearly showing the reduced water demand.

5 RECOMMENDATIONS FOR FURTHER RESEARCH

Amongst the suggestions for further research, it is recommended to: i) carry out further development of prototypes, included versions with a mechanized suction system; ii) develop a branding of the prototypes that leads to a positive first reaction and less confusion by the end users; iii) carry out an in-depth sociological study, where the prototypes are installed in a public area such as the Pontificia Universidad Católica of Ecuador; iv) develop a low-cost, micro biodigestor that can be easily incorporated into the toilet prototypes, in order to pre-treat the wastewater prior to discharge. Technical measurements can then be taken of the quality of the water being discharged in order to guarantee that sewage is indeed eliminated.

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