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**39<sup>th</sup> WEDC International Conference, Kumasi, Ghana, 2016****ENSURING AVAILABILITY AND SUSTAINABLE MANAGEMENT  
OF WATER AND SANITATION FOR ALL****User perceptions and practical considerations  
for implementation of advanced sanitation technologies:  
a case study of the Nano Membrane Toilet  
from Kumasi, Ghana***P.H. Cruddas, A. Parker & A. Gormley, (UK)***BRIEFING PAPER 2492**

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*In response to the growing need for sustainable urban sanitation, technologies are being developed that will be completely novel to their target context. The successful adoption of such technologies will be dependent on their acceptability to end users and their adaptability to local settings. As part of the development of the Nano Membrane toilet, a design team conducted a field study in Kumasi, Ghana, to gauge acceptability of the design and to assess the perceived value of the designed outputs of the toilet. In addition, a physical survey was conducted of the residences of the interviews. Overall, the surveys provided information about site-specific attitudes and physical limitations which would need to be considered by designers. These types of survey can be used by technology developers to assist design or to identify areas that are appropriate for their technology. Conversely, similar surveys could be used as a community assessment tool to identify technologies that are best adapted for a specific circumstance.*

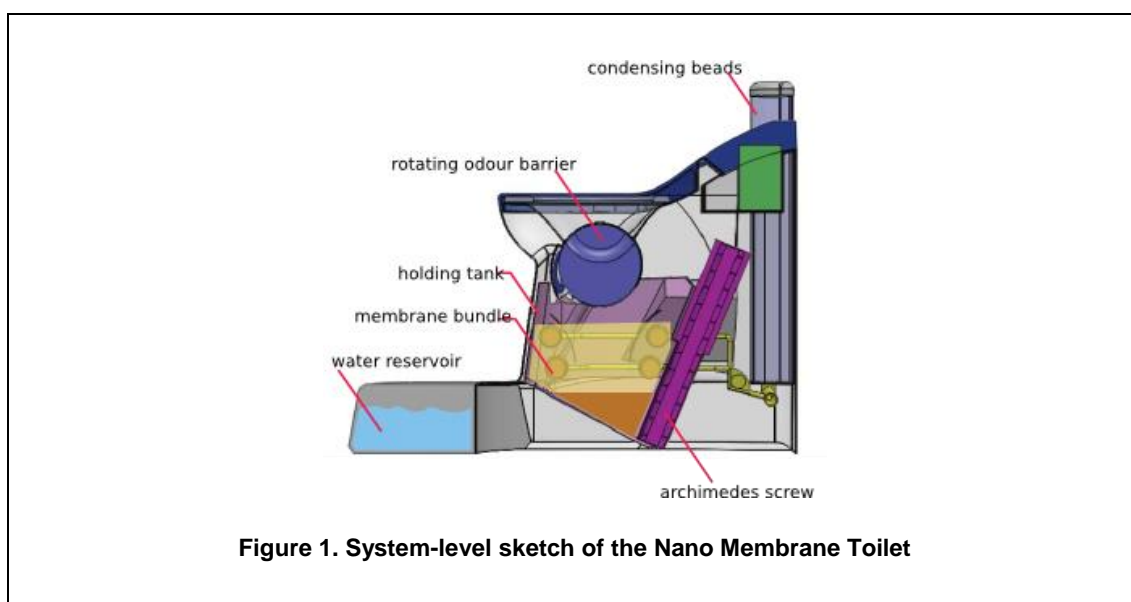
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**Introduction**

In response to the growing need for sustainable urban sanitation in low and middle income countries, the Water, Sanitation and Hygiene program of the Bill and Melinda Gates Foundation is funding the 'Reinvent the Toilet Challenge'. The challenge aims to develop novel sanitation technologies that: treat human waste and recover resources such as water, energy and nutrients; operate 'off-grid', requiring no water, sewer, or power connections; cost less than US \$0.05 per user per day; promote sustainable and financially profitable sanitation services and business in poor, urban environments; provide an aspirational product attractive to both developing and developed nations. In response to the challenge, and indeed through other funding channels addressing urban sanitation, new technologies are being developed that, if implemented, will be completely novel to the context they are being designed for. The successful adoption of such technologies will be heavily dependent on their design being considerate of end users and their communities, as well as physical constraints of urban environments. The Nano Membrane Toilet, being developed at Cranfield University, is one such technology being developed.

The Nano Membrane Toilet is designed for treatment and resource recovery from both the solid and liquid components of human waste. A waterless flush mechanism deposits human waste into a holding tank, from where liquids are extracted through a dense membrane bundle using a pervaporation process. The fluid is then condensed over beads with a super-hydrophilic nano-coating, with the resulting treated water available for re-use in the household (Figure 1). Solids are collected from the bottom of the holding tank and dewatered through an Archimedes screw, where they will be divided and dried before introduction to a small-scale gasifier unit. The Nano Membrane is being designed as a household-level sanitation system, and as such must be acceptable, and operable, by domestic users, as well as convenient to fit within households. As such, it was important early in the design to understand any potential limitations or restrictions that may be imposed on the design due to user perceptions on technology use, desirability of certain functions or

outputs from the system, and from the physical environment in which the toilet would be installed and would have to operate.



For this purpose, a design team conducted a field study in a target city for the Nano Membrane toilet. The purpose of the study was to interview potential users of toilet, to understand local attitudes to new technologies, specifically in the field of sanitation, and to assess the perceived value of the designed outputs of the toilet. The views of the local users would help shape the design of the toilet, by identifying components of the design that should be prioritised or emphasised in order to develop a system that was attractive to end users. In addition, a physical survey was conducted of the residences of the interviews, in order to obtain key design information that could restrict the design of the toilet. Of particular concern were the feasibility of installing a flue for gasifier exhaust fumes, and physical dimensions to enable the toilet to be installed, and potential moved around the home if desired by the user. Potentially, this combination of user interview and physical survey could be used to identify target cities or communities for the Nano Membrane toilet, or more widely as a tool for identifying suitable sanitation technologies for a specific community.

## Methods

A 43 question questionnaire was compiled to incorporate a number of aspects of the Nano Membrane toilet design that interfaced with the user, such as the gasifier, operation and maintenance, and technology acceptance. The questionnaire was conducted in Kumasi, the second largest city of Ghana, approximately 58% of the almost 2 million residents do not have household toilets. All of the residents surveyed were customers of Clean Team, a Unilever initiated sanitation project that consists of a simple toilet with a sealable bucket inside that stores waste in a chemical until Clean Team come to the user's house, seal the bucket and remove it for safe disposal before replacing the bucket with a clean one. Using Clean Team's customer base, 103 were selected houses to ensure a 95% certainty level that had the entire customer population been surveyed, the result would be within +/- 9% of our answer (based on confidence interval and confidence level calculations). A back-up list of 3 customers who were eligible for the survey but not selected, and can be met at home at any time of the day was also requested from each service area. The backup list became necessary because of the limited time for the survey, and the desire to survey 103 customers.

The customers' survey was carried out with Clean Team Service Associates (SAs). The SAs were familiar with the areas and could easily locate each nominee's home. Also, anticipating that some customers would not be able to communicate in English (as it turned out to be the case with 40-50% of the customers), the SAs were inducted on the questionnaires. Each question was explained to enable the SAs assist in interpreting in the native Twi language during the survey. This anticipation was borne from the previous researcher experience in Kumasi. To check that meanings were not lost during translation, the SAs were encouraged to develop key words that best replaced the English words and the interpreted answers were

compared with responses obtained from customers who could communicate in English. On arrival, the nominees were informed of the survey and asked if they were willing to participate. If the answer was affirmative, a participant consent form was administered and the questioning followed. Observations of the customer’s home were carried out alongside the administration of the questionnaire by viewing the sanitation facilities in the homes, particularly regarding the use and maintenance of Clean Team toilets. A total of 103 households represented by one individual were included in the study. Participant characteristics are summarised in Table 1.

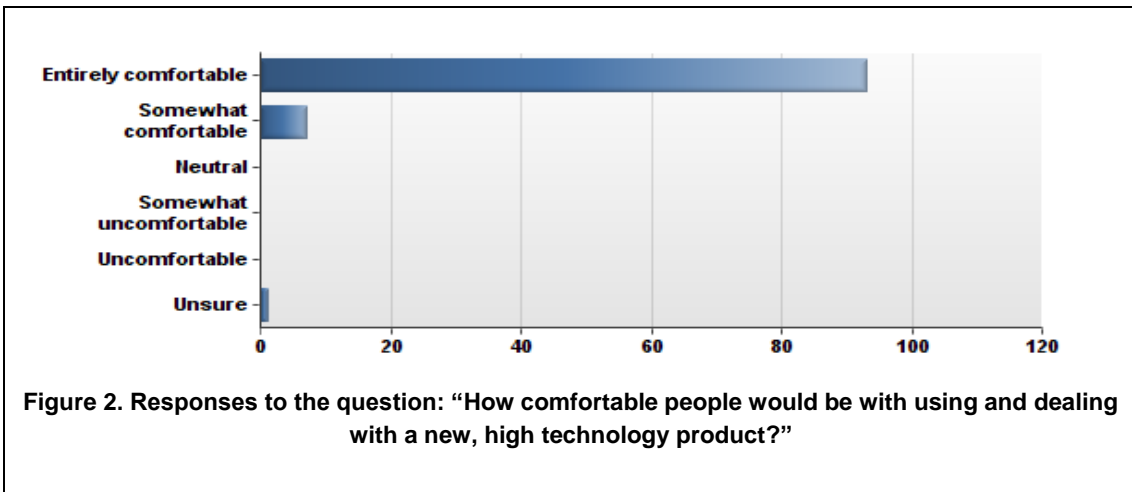
<b>Table 1. Participant characteristics of the 103 households survey respondents</b>									
		<b>Age bracket</b>							<b>Total</b>
		<b>16-18</b>	<b>18-24</b>	<b>25-34</b>	<b>35-49</b>	<b>50-64</b>	<b>65-74</b>	<b>75+</b>	
<b>Gender</b>	<b>Male</b>	0	3	5	9	4	4	2	27
	<b>Female</b>	0	2	17	35	15	5	2	76
	<b>Other</b>	0	0	0	0	0	0	0	0
	<b>Total</b>	0	5	22	44	19	9	4	103
<b>People older than 16-years living in household</b>	<b>0</b>	0	0	0	0	0	0	0	0
	<b>1</b>	0	0	1	12	8	4	2	27
	<b>2</b>	0	1	13	19	6	2	1	42
	<b>3+</b>	0	4	8	11	5	3	1	32
	<b>Total</b>	0	5	22	42	19	9	4	101
<b>People younger than 16-years living in household</b>	<b>0</b>	0	3	2	10	8	5	4	32
	<b>1</b>	0	1	5	11	2	1	0	20
	<b>2</b>	0	0	7	8	5	1	0	21
	<b>3+</b>	0	1	8	12	4	2	0	27
	<b>Total</b>	0	5	22	41	19	9	4	100

Building surveys were conducted on all interviewees’ houses, or on the outhouses if the current Clean Team toilet was kept external to the main residence.

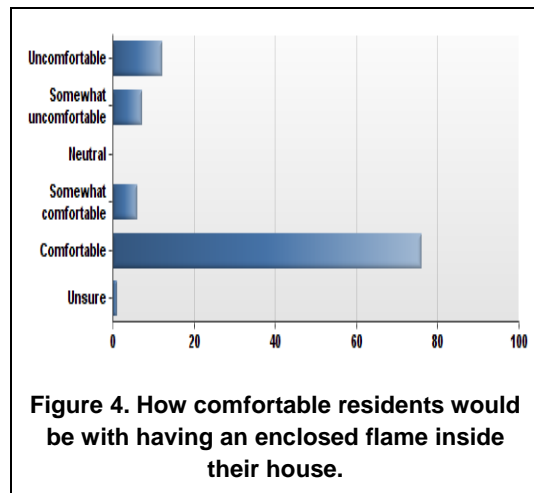
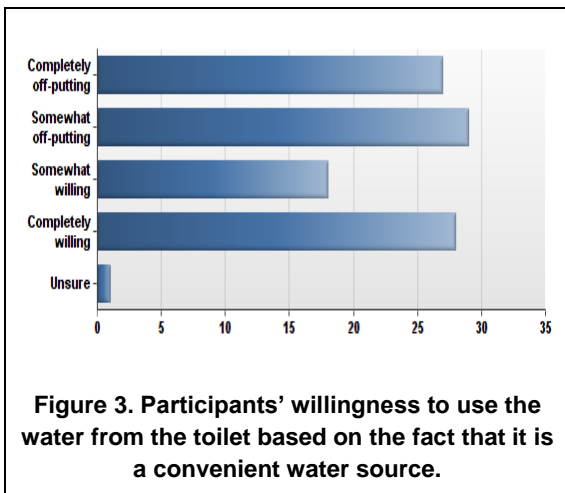
## Results

### Acceptance of new technologies

Initially, researchers sought to identify any barriers to new technology adoption, at a broad level and subsequently with questions more focused on the Nano Membrane toilet. For the areas of Kumasi surveying, 92% of respondents were entirely comfortable using and dealing with (covering cleaning, operating and maintaining) a new, high technology product (Figure 2). This was true across ages and genders, and reflects the openness of most of the respondents to new technology – many own and use mobile phones, as well as other electronic goods such as televisions and fridges. In addition, the inherent bias of the survey must be identified as all respondents, as customers of the Clean Team enterprise, had already made a decision to adopt a new form of sanitation technology.



Respondents were asked more specific questions regarding acceptance of technologies found in the Nano Membrane toilet, focused around the membrane treatment for water reuse, and the inclusion of a small-scale gasifier for destruction of biosolids with heat and electricity generation.



When the water source from the toilet was explained to the participants, there were mixed responses in their willingness to use the water, knowing where it comes from (Figure 3). Some Muslim participants reported that under no circumstances could they use the water due to their religious beliefs. However, only a small number of respondents attributed their decision to religion. Figure 4 shows how comfortable people would be with having an enclosed flame and increased temperatures as a result of the flame inside their house. A total of 75% of respondents said they would be comfortable and 6% would be somewhat comfortable with the gasifier in their homes. In addition, a total of 51% said they would be unconcerned about the resultant raised temperatures in their house while 20% said that it would not really be a problem (data not shown). In this sense, the residents did not appear concerned about safety with regards to the flame or increased temperatures in their homes.

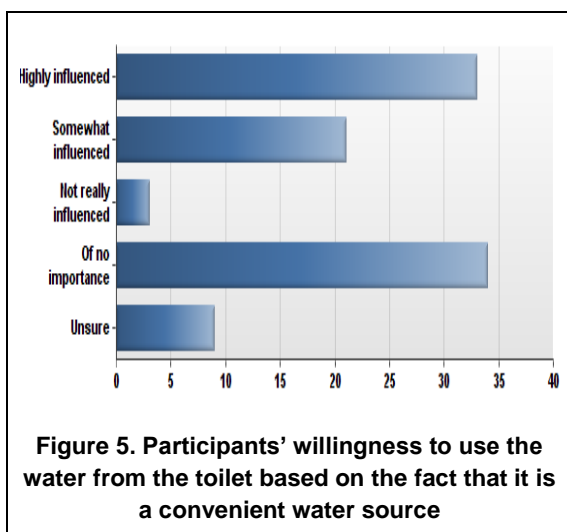
One concern the development team had during the initial design phase of the Nano Membrane toilet, was that the introduction of a high-value technological product into low-income communities could provide an increased security risk for those choosing to install a toilet in their home. To most respondents (81%), the toilet would be seen as a very valuable item in the household. However, 80% of respondents also considered there to be no increased security risk due to the perceived value of the toilet. These two components are cross-tabulated against each other in Table 2, and suggest that there is not a strong link between the addition of a high-value technology and an increased household security risk in the communities surveyed. Many respondents cited the closeness of their communities contributing to low crime rates between residents, and this may not be the case in all urban settlements.

**Table 2. The value of the toilet against the extent to which the security of homes would be threatened due to the perceived value of the toilet?**

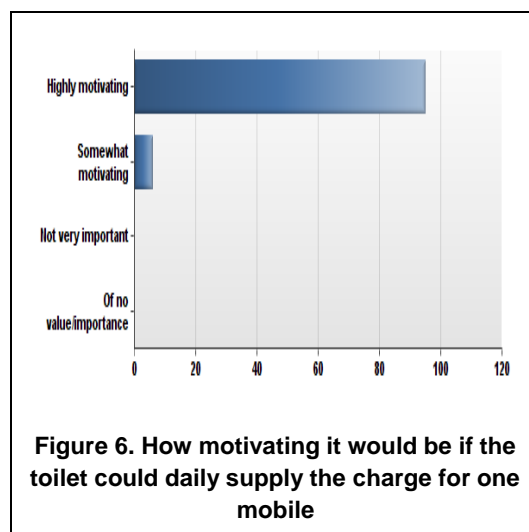
		How valuable would the toilet be in your home?				
		Very valuable	Somewhat valuable	Of little value	No value	Total
To what extent would the security of your home be under threat due to the perceived value of the toilet	High risk	1	1	0	0	2
	Medium risk	7	1	0	0	8
	Low risk	6	2	0	0	8
	No risk	69	10	1	0	82
	Unsure	0	0	0	1	2
<b>Total</b>		<b>83</b>	<b>14</b>	<b>1</b>	<b>1</b>	<b>102</b>

**Desirability of output resources from the toilet**

Further to acceptance of the new technologies, respondents were questioned on the attractiveness of the recovered resources, as a measure of their perceived value of the toilet in above solely sanitation.



**Figure 5. Participants' willingness to use the water from the toilet based on the fact that it is a convenient water source**



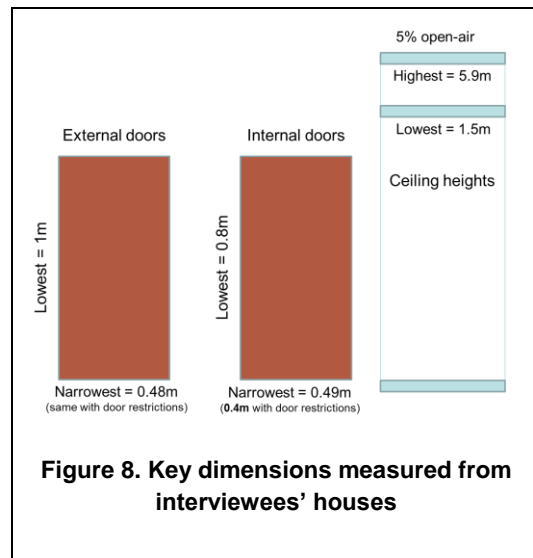
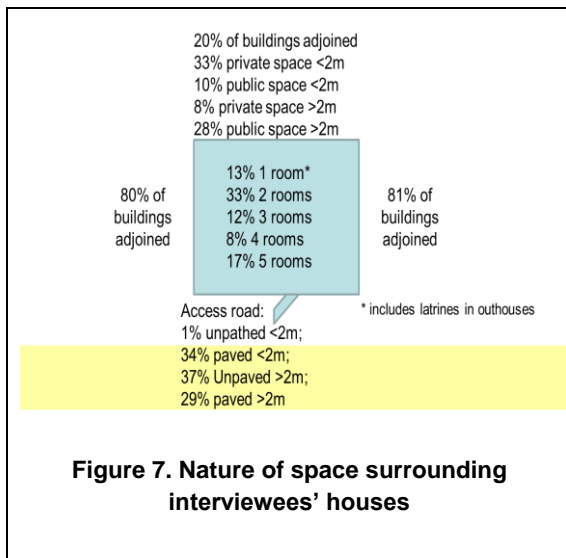
**Figure 6. How motivating it would be if the toilet could daily supply the charge for one mobile**

With respect to water reuse, the participants' willingness to use the water was not remarkably influenced by the fact that it would be a convenient water source – with 37 % reporting that it would be of either no or little importance. A total of 33% reported that they would be highly influenced by the water's source and 21% would be somewhat influenced (Figure 5). This may be explained by the high level of water service already enjoyed by many respondents, with 82 % of respondents having access to piped water supply and 73 % stating they were satisfied with the quality of their current water supply (data not shown). Figure 6 shows that all respondents would be either highly motivated (94%) or somewhat motivated (6%) to install the toilet if it was able to supply the charge of one mobile phone per day. Many respondents cited frequent electricity blackouts as impacting their everyday lives, which contrasted the regularity and quality of their water supply. This distinction could impact the potential value of electricity generated from the toilet gasifier, and suggests an electricity output function may be an important feature for customers in Kumasi.

**Building surveys**

A physical survey was undertaken on the residences of the interviewees, including key dimensions for toilet installation, the materials of the rooms where the toilet is situated, and the nature of the space

surrounding the house. The building surveys were designed to inform aspects of the installation of the toilet and its potential movement between rooms within a house.



With respect to installation, it was 66 % of residences had an access road greater than 2m, meaning delivery of units could be made by vehicle. Only 1 % of residences had unpaved access roads less than 2m wide. The narrowest external door was 0.48m wide, and whilst this is narrower than the dimensions of the Nano Membrane toilet, the current design would fit through 92 % of the external doors surveyed. Installed exhaust flues external to the house would require planning, as 80 % of houses were enclosed on either side. Although only 20 % of houses were connected at the rear, 38 % faced onto public space, and so the potential pollution in the fumes would have to be considered – in total, 99 % of walls surveyed were brick and plaster, mostly between 15 and 20 cm thick, so would require some masonry work to fit a flue. By contrast, 47 % of ceilings were corrugate iron and 17 % were wood boards, meaning 64 % of ceilings could be fitted with flues with only minor works. Of the remaining, 27 % were concrete/tile, with 7 % of residences having an additional level of building on top of them. Ceiling heights varied from 1.5m to 5.9m, meaning flues fitted through ceilings would need to be variable in height to be able to manage these large differences.

## Discussion

The results of the interviews demonstrated a willingness of end users in Kumasi to accept new technologies, even related to sanitation at a household scale. Whilst there were some reservations about reuse of water direct from a toilet, there was still general willingness to use the water. However, it was not seen as a particularly valuable commodity, probably due to the level of piped water supply. Respondents were also largely comfortable a small-scale gasifier within their house, and the problems of “doomsa doomsa” – regular power outages – in the city meant the potential to charge mobile phones from a power outlet was seen as a valuable component of the design. However, the interviewees were responding only on the basis of description of the technology, and these results will need to be validated once prototypes are available, as the attitudes may change when respondents interact with the actual technology. Fears amongst the UK-based design team that the addition of a high-value technology may present a security risk were not perceived by the end users, who mostly considered their neighbourhoods safe with respect to burglary of residents. Building surveys found the delivery of pre-fabricated units would be suitable for the large majority of households, with good access roads to most residences and sufficient door sizes for the toilet to fit through. If the gasifier required a flue for exhaust gases, the location of toilet would need to be careful considered, to avoid major masonry works or the expulsion of exhaust fumes at unsafe levels close to human habitations or thoroughfares.

Overall, the interviews and physical surveys were able to inform designers about site-specific attitudes and physical limitations which would need to be considered for a new technology to be implemented. Whilst the surveys are extremely esoteric, they can serve as useful insights into technology implementation into a specific city or community, or conversely similar surveys may be developed to help identify the optimal

technology to be selected for a specific set of cultural attitudes or physical environments, such as a local government or NGO considered the implementation of a new sanitation technology.

## Conclusions

A survey combining end user interviews with physical building surveys identified key design aspects that technology developers should consider when designing the Nano Membrane toilet, as well as areas to focus on for marketing when the product is brought to market – such as the desire for small-scale power sources for most households. These types of survey can be used for individual technology developers to assist in design, or to identify potential target cities or communities that are appropriate for their technology. Conversely, similarly designed surveys could be used as a community assessment tool to identify technologies that are best adapted for a specific cultural and physical environment.

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