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Know your people: social research and water recycling system design with communities in the Amazon

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Abstract

This paper sets out to answer the research question: *What differences come about when water-recycling strategies are adapted to the local cultural context?* It is argued that water management systems should be circular metabolisms, where wastewater is mobilized as a nutrition source. The aim is to propose water-recycling strategies at a micro level that reflect this. However, water-recycling systems are dependent on a complex set of social factors as to their acceptance/refusal and correct/incorrect use by the end users. This is particularly the case in Ecuador, where a plethora of variations in climates and cultures means that each project is different. This study proposes a qualitative methodology for the development of water-recycling strategies, where semi-structured interviews are first carried out to determine the design parameters of the specific social context where the project is to be implemented. Based on this, a water-recycling system can be proposed that is more likely to be readily accepted by the end users. The paper works with four of case studies, where the methodology is applied in three rural communities and an urban suburb in the Napo province of Ecuador, located in the Amazonian region. The results show that there were distinct differences in the water recycling strategies that were considered most appropriate for each case study. As such participatory design approaches can be said to be of great importance in the design of water-recycling strategies, where further work would necessary in working with the community members for the final system design.

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1. Introduction

1.1. Sustainable water management and problems with sanitation in Ecuador

The Bundtland Report of 1987 defined Sustainable Development as: "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [1]. This was then further developed to be a synthesis between three spheres: "economic, environmental and social" or "ecology, economy and equity" [2]. Additionally, it is argued that for this to be possible linear processes need to be replaced by circular metabolisms. In linear economies a resource flow is given as an input, where the output is a waste stream that negatively affects the environment, society and the availability of resources [3]. This is in contrast to a circular metabolism, where waste becomes a nutrition flow that leads to growth [4]. This is further reinforced by the Royal Institute of British Architects (RIBA), whose definition of sustainable communities includes the effective use of natural resources in a manner that enhances the environment [5]. In terms of water-recycling systems, this paper argues that these must be circular metabolisms where wastewater is mobilized as a nutrition source. It is also argued that this needs to be done in a manner that is cohesive with the culture, preferences and desires of the end users. Overall, in Ecuador wastewater treatment is of great concern. In 2010 it was determined that only 53.6% of Ecuadorian households were connected to a public sewerage system [6]. Furthermore, according to national statistics of 2011, municipal sewerage systems discharged a total of 225 000 000 m^3 into the environment untreated [7]. In part this could be attributed to the high costs of wastewater treatment, which takes up 53.3% of the total average expenditure for national municipalities [7]. To further complicate matters, Ecuador faces a polarity of situations. For example, whilst the main cities of Quito and Guayaquil currently have next to no wastewater treatment plants, Cuenca (Ecuador's third largest city) treats 95% of its wastewater [8] and Tena has the most advanced plant in the Amazonian region [9]. 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, such as Quitumbe wastewater treatment plant located in Quito, Ecuador. The plant is set to cost $12.3 million [10] and will treat 108 litres per second [11] (compared to 4810 litres per second of wastewater currently discharged untreated into Quito's rivers [12]). 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 small-scale water recycling systems could play an important role in reducing wastewater discharges. However, working at a micro scale entails designing within a complex set of social factors as to whether the system will be accepted/rejected by the end users. To this extent, designs need to be developed hand in hand with the end users, thus mitigating the risk of the systems being rejected and going unused. This paper focuses primarily on water-recycling strategies, with the aim of reducing wastewater discharges. It also considers wastewater treatment prior to discharge back into the environment, but where this is not studied in depth at this stage.

1.2. The importance of participatory design and solving sanitation problems with water recycling systems

Reason and Bradbury [13] consider participatory processes to be both a methodology for research and an approach to applied project work. Additionally, they are argued to be effective in the generation of knowledge [14]. Liener and Larsen [15] add that innovative technologies are achieved through collaborating as closely with the end user as possible, where to achieve this the end users need to feel secure and able to express their true opinions to the designers [14]. To this extent a group of 29 undergraduate students of the Ikiam University of the Amazon, Ecuador, carried out primary research in three communities and one urban suburb of the Napo province. Conceptual water management systems were then developed based on the findings from the primary research. As such the first step in a participatory design process was carried out, where in the future it would be recommended to further develop the system designs through workshops with the end users. It can be seen however, how important it is to know the people the system is being designed for, given the large differences in the conceptual designs proposed.

2. Methodology

As previously mentioned, the research question to be answered in this paper is: *What differences come about when water-recycling strategies are adapted to the local cultural context?* As such there were sub-questions that also needed to be studied, namely: i) *Do the end-users currently have access to water, and if so what type of access?* ii) *What is the current state of the water infrastructure in the household of the end-users?* ii) *What are the uses of water by the end users? iii) Are any water-recycling practices currently carried out by the end users?*

The research was carried out through a 4-day workshop on water and sanitation at the Ikiam University of the Amazon, in the Napo province of Ecuador. The workshop had 29 undergraduate student participants, who under the guidance of the authors of this paper carried out qualitative studies required to answer the research question. The students involved in the research are listed in the acknowledgement section of the paper. The first stage was to explore the research question and sub-quesitons, and define the interview schedule for the fieldwork research. The second stage consisted of carrying out the fieldwork in three rural communities of the area and an urban suburb of Tena. The first stage was necessary to familiarize the students with the research questions, which according to Bryman [16] is extremely important since ensures all the researchers know exactly what is being looked into. This was done through carrying out focus groups in accordance with Escobar and Bonilla [17], where it is suggested that the number of participants is between 6 and 10 people, with a wide range of experiences in the field to be discussed and where the activity lasts from 1 to 2 hours. The focus groups involved 29 students divided into four teams of 4 to 6 people. 72% of the participants were from the Andes Region (Sierra), 24% from the Coastal Region (Costa) and 4% from the Amazonian Region (Oriente). All participants were current residents in Tena city and surrounding communities however, due to their studies at Ikiam University. Some students come from big cities (such as Quito) and others from small towns (such as El Chaco). As a result, the students carrying out primary research for this paper came from a broad range of living conditions themselves, from places with a coherent sewerage system to those with no sewage infrastructure whatsoever. One of the products from the focus groups was the questions for the interview schedule for the fieldwork studies.

Regarding the interviews, a semi-structured technique was used in accordance to Bryman [16]. In this case the interview schedule provided guidance for the researchers for the points to be covered and where adjustments could be made to improve the flow of the conversation. This technique was also seen to be in line with recommendations from Bergold and Thomas [14], where they argue 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. The interviews were carried out in an urban suburb of Tena, and in three communities of the area: Muyuna, Atacapi and Chambira. These communities were selected based on: accessibility, familiarity with students carrying out the research (some students live in these communities) and previous participation in IKIAM University projects. Tena city and the three communities are all located in Napo province in the Amazonian Region, as shown in Figure 1.

Fig. 1. Map of the places studied

3. Results

3.1. Focus groups

An interview schedule was developed that covered: i) demographic info, ii) access to water, iii) water infrastructure, iv) uses of water and iv) water recycling habits.

3.2. Semi-structured interviews

A total of 88 interviews were carried out: 16 in Muyuna, 19 in Atacapi, 15 in Chambira and 38 in Tena. The disproportionally high number of interviews in Tena was due to it being an urban suburb whereby interviewees were more concentrated in the same vicinity. The results of the interviews are summarized in Tables 1 to 4 below. It is recognized that the fieldwork failed to identify whether any of the interviewees were from the same households, which would be necessary for future research.

Table 1. Results for Muyuna.

Section	Results
Demography	Of the 16 people interviewed, 12 were women and 4 men. All of the interviewees were adults.
Access to water	All of the interviewees had access to water from the municipal system. However, in order to ensure its being potable, 19% added chlorine, 31% boiled the water and 37.5% used it untreated from the tap.
Water infrastructure	All of the interviewees had taps, as well as connection to a sewerage system where the wastewater is deposited in a municipal septic tank located in Tazayacu (Figure 1). All but one of the households had a personal potable water storage tank. Almost all the interviewees had at least one bathroom equipped with toilet, sink and shower.
Uses of water	Showers were done twice a day. Clothes were washed everyday, where two of the household had a laundry machine and the rest a concrete hand-washing basin. Other uses included cleaning the house and washing pets.
Water recycling habits	One of the families collected and reused rainwater.

Table 2. Results for Atacapi.

Section	Results
Demography	Of the 19 people interviewed, 9 were men and 10 were women. 15 were adult and the others under 18 years old.
Access to water	13 people had potable water connections, 3 people collected rainwater, 2 got water from the river and 1 from a stream. Regarding pre-treatment, 12 people boiled their water, 1 had a filter and 7 consumed without pretreatment.
Water infrastructure	There was no connection to any sewerage system. 15 people knew the water ended in streams, septic tanks or the river, whereas 4 were ignorant of the final wastewater destination. 5 people had personal potable water storage tanks and 7 said they had a connection to a common water storage tank. 3 people had a fully equipped bathroom (shower and toilet), 8 a partially equipped bathroom with toilet and sink only and 8 were without a bathroom.
Uses of water	Personal hygiene was carried out unanimously in the river. Most people also washed their clothes in the river. People also used river water to wash pets and clean the house.
Water recycling habits	It was common to use collected rainwater to irrigate plants. Otherwise, grey water was not recycled.

Table 3. Results for Chambira.

Section	Results
Demography	Of the 15 people interviewed, 10 were women and 5 were men. Additionally, 3 were teenagers and the rest adults.
Access to water	13 of the interviewees had pipe connections pumping water direct from the river. 11 people boiled water before consumption, with the others drinking straight from the tap.

Water infrastructure	All of the interviewees had a water storage tank. None had a connection to a sewerage system. Instead 7 had septic pits and for the other 8 the water went to a stream that was only used for wastewater deposits. Whilst 14 of the interviewees had bathrooms, 4 no had showers, 2 were without hand basins and 1 of the interviewees had no toilet.
Uses of water	Water was used for the preparation of food, with one interviewee boiling always before use. Clothes werealso washed daily and a shower taken twice a day by all. The grey waters produced were always sent straight to the Chambira river. Pets were washed once a week and half of the interviewees watered their plants.
Water recycling habits	Only one of the interviewees practiced water-recycling habits.

Table 4. Results for Tena Urban Suburb.

Section	Results
Demography	Of the 38 people interviewed, 26 were women and 12 were men. 26 were adults, 3 were elderly and 9 were adolescents.
Access to water	All of the interviewees were connected to the municipal water system. For drinking water however, whilst two of the interviewees pretreated their water (through boiling or chlorine), the rest bought bottled water.
Water infrastructure	All of the interviewees were connected to the municipal sewerage system. They were all under the impression that the water was discharged into the river. 6 of the interviewees had a water storage tank.
Uses of water	38 of the interviewees had a washing machine and 16 a concrete basin to wash clothes by hand or subcontracted to a launderette. 2 of the interviewees showered three times a day, 33 twice a day and 4 once a day. All of the interviewees had fully equipped bathrooms with shower, sink and toilet installed.
Water recycling habits	None of the interviewees had any water recycling habits.

4. Discussion of results

There are distinct differences in the water usage habits of the different locations studied. This in turn leads to different conclusions regarding the optimal water management systems that could be looked into. The key points the differences found and the subsequent impact in for the water-recycling strategies that were considered optimal are outlined below, where these are then shown in the flow diagrams of Figure 2. a to b. Overall, it can be said that there is no one-size-fits-all solution, and participatory design approaches are therefore of paramount importance for successful water management system design.

4.1. Muyuna

The need to pre-treat potable water could be further studied. The municipal water is of a good quality at its source: it is taken from Colonso Basin, located upstream of all communities listed in this paper. Colonso basin is a protected area. Therefore, human settlements are prohibited within the basin, reducing potential contamination due to human activities. The water is collected and goes through a complete potable water treatment process delivering drinking water [18] [19] [20]. This however, seems not to be known by Muyuna residents since some of the interviewees use alternative treatments (boiling water before using it, chlorine, etc.). The wastewater goes to a septic tank. In this case the objective would be to extend the life of the septic tank by recycling greywater. Water from the personal hygiene, dishwashing, and food preparation could be reused to satisfy the demands of the toilet cisterns and laundry. This could be done by pretreating the grey water to remove organic elements, oils and detergents. Also, there is a potential for rainwater collection, where this could be used for irrigation of plants and vegetable plots.

4.2. Atacapi

The main difference for Atacapi is the use of the river to satisfy various water demands. This paper argues that the custom of washing and personal hygiene in the river does *not* need to be changed. It is put forward that the custom be mobilized, but where improvements are made to reduce the risk of contamination of the river and of the

end users being exposed to those contaminants. It is suggested that in the absence of a potable water connection, rainwater collection be mobilized in favour of river water collection. This is due to there being less pre-treatment necessary of rainwater. The river water can be used for personal hygiene and clothes washing, but where the use of ecological detergents would mitigate the risk of contaminating the river water. The river could also be partially diverted through two biofilters or wetlands in order to: a) pretreat the water before being used for personal hygiene, and b) treat the water before its discharge back into the river. The river water could also be used directly to satisfy the water demand for toilet flushing, with the incorporation of a riverwater storage tank. Finally, the lack of wastewater treatment is of particular concern. It is suggested that micro wastewater treatment strategies such as biodigestors and constructed wetlands be looked into to safely discharge the treated water back into the river.

4.3. Chambira:

One of the main concerns in this case is the use of the river to satisfy potable water demands. It is suggested here to separate potable and non-potable water demands, where potable water could be satisfied through the collection of rainwater. The riverwater could then be mobilized for toilet flushing and clothes washing. The lack of a coherent wastewater treatment strategy is here also of particular concern. As in the case for Atacapi, it is suggested that micro waterwater treatment strategies such as biodigestors and constructed wetlands be looked into as a manner by which the water could be treated to a level it could be safely discharged back into local streams.

4.4. Tena

Tena was distinct to the other communities studied. It was an urban area of the main provincial city, as opposed to a rural town or community. All of the residents had a connection to the municipal water system, which is considered to be of good quality [18] [19] [20]. It would be worth promoting the potable water plant to the residents of Tena however, in order to increase their awareness of this. In addition, the residents seemed to be unaware of the recently inaugurated wastewater treatment plant of Tena. The plant started functioning in November 2015, and uses the most advanced technologies currently available for wastewater treatment in the Amazonian cities of South America before discharging the water back into the Tena river [20] [21] [22]. In the future however Tena is set to expand, just like cities the world over. This is further influenced by the Ikiam university being located in the vicinity, which currently has 350 students and plans to expand to 3000 in the near future. It is unclear as to whether the design of the plant was carried out where the influence of the university in future wastewater loads was taken into account. As such, it is of importance the wastewater treatment plant is not overloaded with increased water discharges in the future. It is therefore recommendable to introduce grey water recycling systems similar suggestions for Muyuna. In this case the water used for personal hygiene, dishwashing, and food preparation could be reused for toilet cisterns and laundry.
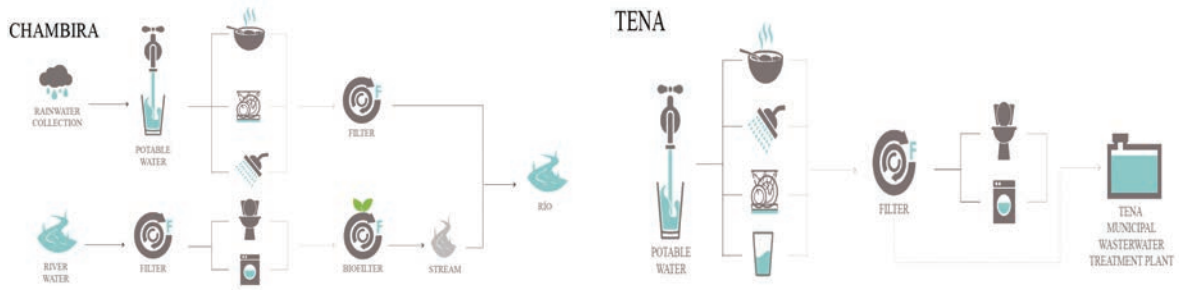
Fig. 2. Suggested water management strategies for a) Muyuna, b) Atacapi, c) Chambira and d) Tena

5. Conclusions

The research question for this paper was: *Is it possible to reduce potable water demands through water recycling systems that are adapted to the local cultural context?*

Overall it was found to be possible as long as a participatory design approach is adopted, given the significant variations in water recycling strategies suggested for locations not more than 2 km apart. There was a clear difference between urban and rural locations. It was also important to note the use of nearby rivers for potable water and wastewater discharges. It was also important to note that certain end users were unaware of Tena's high quality of potable water, or the municipality's highly advanced wastewater treatment plant.

6. Recommendations for further research

For the future it is recommended to test out the design proposals with further social research in the communities. To this extent key stakeholders would need to be identified to implement water reuse habits in Tena and surrounding communities. The level of acceptance of rainwater collection would also need to be assessed. Additionally, it would be interesting to study how water practices change with people's awareness of the presence of functional water treatment and wastewater treatment plants. Finally, it would be beneficial to run a cost-benefit analysis of changing water-usage practices (rainwater collection, grey water reuse, etc.) for the maintenance of the current wastewater treatment plant in Tena.

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