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Sustainability of a sanitation program in flooded areas of the Brazilian Amazon

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ABSTRACT

Riverine populations that dwell in flooded forests (*várzea*) require suitable solutions for sanitation. An experimental project was started in 1998, using double-vault toilets in seasonally flooded houses in the Brazilian Amazon. The objective was to improve the health of inhabitants using adequate sanitation technology and health education. The focus of the present study was the assessment of that intervention. We compiled information from reports, local assessments, and interviews with users. In 2012, 14 years after the beginning of the project, 44% of the double-vault toilets were still in use. The main benefits noticed were awareness of the importance of toilets for reducing outdoor human waste and providing comfort, privacy, and safety for families. The sanitation project succeeded in reducing open defecation and raised the interest and demand for toilets. However, there is still a need for improving the construction of toilets and to better adapt them to flooded environments. We also include suggestions for improving the toilets and their use in flooded areas.

Key words | Amazon, Brazil, double-vault toilet, flooded area, riverine populations, sanitation

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INTRODUCTION

According to the last report by the World Health Organization (WHO/UNICEF 2014), in 2012 1 billion people (14% of the world's population) defecated in the open. Worldwide, sanitation is worse in rural than in urban areas: 9 out of 10 people that defecate in the open live in rural areas. In Brazil, 6 million people have no access to sanitation, and among them 5 million people live in rural areas. As socio-environmental movements became stronger in the 1980s, several NGOs developed low-cost, alternative technologies, which used scientific knowledge to meet the population's needs.

Since 1998 a non-profitable organization, the Mamirauá Institute for Sustainable Development (MISD), based in the Brazilian Amazon, has been conducting an experimental project that built double-vault toilets in riverine communities. The chosen site was a protected area in the Amazon, which is yearly flooded by the waters of the Solimões River. For over 14 years, positive results have been obtained. It is already possible to discuss issues related to technology customization for flooded ecosystems and its

use by riverine populations. By publicizing this experiment, we may contribute to the development and successful implementation of other sanitation projects in the Amazon.

We describe the experience of building double-vault toilets in a riverine community. The focus of the present study was the assessment of the intervention. We investigated the challenges of implementing sanitation in a flooded ecosystem, locally known as *várzea*, as well as aspects of the transition from open defecation to the use of toilets.

Challenges of building toilets in flooded areas (*várzea*)

Flooded areas cover 800,000 km² or 14% of the Amazon River Basin. Flood occurs in unimodal, predictable, wide pulses (Melack & Hess 2010).

In the Mamirauá Sustainable Development Reserve (hereafter Mamirauá Reserve), the land remains flooded for 1 to 6 months a year (Ramalho *et al.* 2009). Houses are built on piles (pile dwellings) or on hard floating logs, in

order to be protected from rising water (Moura 2007). The sanitation infrastructure must be suitable. The main challenges of building a traditional sewage treatment system in communities living on floodplains are soil soaking and instability, as well as the vulnerability of exposed pipes (Borges Pedro *et al.* 2011).

Pit latrines (a hole dug in the ground and covered by a shelter) are the most common type of sanitation system found in those rural communities. This type of system causes water contamination by pathogenic agents and biochemical compounds.

Health conditions and the sanitation initiative

In the 1990s, severe helminth infections were frequent in rural communities, according to technical reports. Eighty-two percent of the children under age five were infected by parasites and 32% had more than one parasite (Peres & Moura 2001). Due to distances and transportation difficulties, and mainly to the lack of public health policies, healthcare in riverine communities is based on homemade remedies and prayers (Moura 1996).

The lack of health care units was common in these rural areas (Jatene *et al.* 1993). In the Mamirauá Reserve, recommendation by Catholic missionaries on the use of pit latrines was the only initiative to improve sanitation in riverine communities at that time.

As the communities had no access to a technology compatible with local conditions, the Mamirauá Institute for Sustainable Development (hereafter Mamirauá Institute) started actions to develop and implement water pumping and toilets. Experimental double-vault toilets were installed in four communities to improve health conditions and reduce the occurrence of diarrhea resulting from open defecation. At that time, no sanitation models had ever been implemented in places with similar cultural and environmental conditions.

METHODS

The present study was conducted at Mamirauá Reserve (12,240 km²), a protected area within the Amazon and also classified as a Ramsar site: a wetland of international importance. The area is located within the floodplains of the Solimões River. The local population lives in communities of approximately 15 households. They are of indigenous origin and are under significant Catholic influence, especially in terms of social organization structure (Moura 2007; Queiroz & Peralta 2010). They make their living from family farming, fishing, extractivism, and community-based tourism (Mamirauá Institute for Sustainable Development – MISD 2011).

For data collection purposes, we conducted 11 interviews and visual inspection in two communities, as shown in Table 1. The interview and inspection were carried out only in the households with toilets in use, according to the statement of the interviewee. In the interviews, we addressed the following topics: maintenance and repairs performed, cleaning, users, sludge removal, odor, materials deposited in the toilet, suggested changes, toilet flooding level. For visual inspection, we considered: hygiene condition, odor, the condition of toilet structure, use of chambers, toilet access.

Furthermore, we used the analysis of technical reports (1997–2012). We also interviewed three technicians who worked on the project, focusing on their motivation for the work, relationships with stakeholders, community engagement, and difficulties in the project implementation. The information was analyzed qualitatively by period and topic. The topics included design and construction, use, maintenance, and changes due to toilet use. We also discussed sanitation systems in other developing countries.

The present study was approved by the Research Ethics Committee of the Mamirauá Institute (protocol 004/2011).

Table 1 | Number of households in communities and number of toilets of the study

Community	Households in 1998–2000	Constructed double-vault toilets in 1998–2000	Households in 2012	Toilets of the study (being used at 2012)
Jarauá	22	16	35	6
Nova Colombia	9	9	8	5
Total	31	25	43	11

RESULTS

The choice of the type of sanitation installed resulted from a partnership between the Mamirauá Institute and the Federal University of Pará (UFPA), who proposed the installation of a dry toilet (*fossa de fermentação*). The toilet design was created by government agencies for non-seasonally flooded areas.

The dry toilet proposed (Figure 1) is a double-vault toilet composed of a privy shelter (a small room) and two adjacent vaults (chambers) for containing excreta, without urine diversion (Cynamon type, Brasil 2006). The vaults must be built of brickwork and buried or semi-buried. It is an alternative waterless system, whose concept is based on taking turns in the use of vaults, i.e., using one vault at a time, while the other stays on hold. It is necessary to add dry organic matter, such as dry leaves, sawdust, and ashes, to the excreta every time after using the toilet. Water or other liquids must not be used. This procedure must be followed by users.

Adaptations to the initial project were made by the technical staff, such as adding ventilation tubes, using wood on the privy shelter walls, and adding window frames equipped with mosquito nets. All decisions on the technology were made without the participation of the community.

The building material was provided by the UK's Department for International Development (DFID), a British

government agency (Koziell & Inoue 2006). The greatest concern at the time was the financial sustainability of the proposed technology. The total cost per toilet was US \$718.00, six times higher than the minimum wage at the time (US\$117.00). This value was considered high and contrasted with the local income, which was, on average, US \$162.00/month (Moura et al. 2013). Government agencies were requested to provide bricks, cement, sand, wood, and roof tiles. The locals cooperated by providing volunteer work and part of the food supply for the field team.

The choice of communities that would receive the experiment took into consideration their involvement with activities taking place at the Mamirauá Reserve. Communities that were more strongly involved in conservation and handling of natural resources were selected. This criterion was used as a form of reward for the partnership with the communities and to complement the proposal of a new type of reserve based on sustainable development (Queiroz & Peralta 2010).

Building the toilets

During the project, 25 double-vault toilets were built in the households of two communities and three in public places (schools and meeting center), which benefited four small communities. On the building sites, there were at least

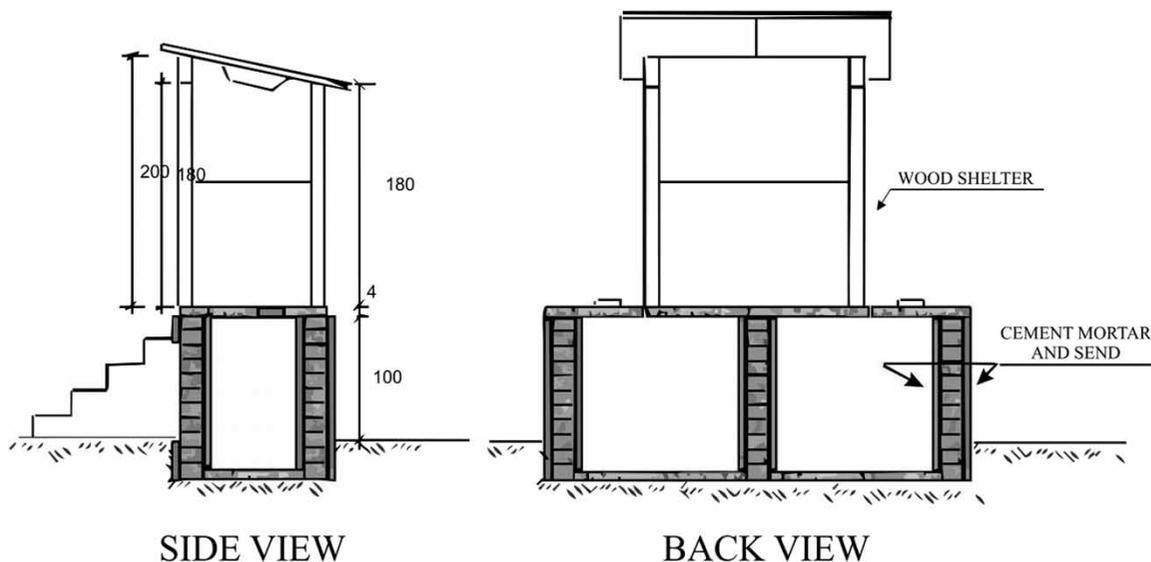


Figure 1 | Diagram of a double-tank toilet. Source: Brasil (2006).

three people: the person responsible for the project (a technician of the Mamirauá Institute), a bricklayer contractor, and a household member. According to the technical staff, the inhabitants had a positive reaction to the project: they expressed their happiness and gratitude.

In the region, most rural areas have no access roads. Therefore, passengers and cargo are transported by river on boats or canoes. Transport of materials from the river bank to the house during the dry season was usually via a long and tiring pathway. It was also necessary to transport water for the mortar, since there was no water pumping system available in the communities at the time.

According to a report on the construction, the population had great expectations about the use of toilets: protection from rain and insects, and significant increase in safety, mainly concerning risks of accidents with animals, such as snakes and caimans. As well, mothers felt safer allowing children to go to the toilet alone, mainly at night.

Location of the toilet

The houses in riverine communities are traditionally built facing the river (Moura 2007). The backyard of the house is the place selected for garbage disposal and evacuation, either in pit latrines or in the open. Open defecation usually happens on a special catwalk or footbridge locally known as *pau-da-gata* composed of a single log, where users defecate in the squatting position.

In respect to the local culture, the composting toilets were built behind the houses. The technician in charge made this choice together with the inhabitants. As it was a new technology, both the staff and locals did not know if this sanitation system would generate odor or not. Because of that, most households chose a place far from the house to install the vaults. Some families later added a *jirau* (external wooden floor used on these houses), to connect the toilet to the house.

According to the assessment of 2012, toilets were located from 3 to 15 m away from the houses. These distances have not remained the same since the construction because some houses have been demolished and then rebuilt. During the flood season, the route from the household to the toilet had to be walked via a bridge or by canoe. Access conditions were worst where there were no

bridges available, and so the distance had to be crossed by canoe, which could hinder the access of small children, the elderly, and people with mobility problems.

Use and maintenance

Nine years after the construction, 88% of the toilets were still active (2008), and 14 years after it, 44% remained active (2012). During the period of planning and construction of the vaults in the community, new inhabitants arrived and built their homes. Due to the higher number of people, some neighbors started to share the same toilet, as there were not sufficient resources for the construction of additional units. In the following years, as new houses were constructed in the village, no double-vault toilet was included, as expected. Most new families did not use latrines, and some of them constructed poor latrines or flush toilets with soil disposal.

In 2012, abandoned toilets, which represented 56% of the total, were not surveyed and their former users were not interviewed. We can argue that they adopted the same alternatives as the new families in the community. However, we do not know how many people built a new toilet and how many returned to the old habit of defecating outdoors.

No guidance or continuous maintenance strategies for double-vault toilets were established because it was not clear or agreed between users and the Mamirauá Institute who would be responsible for maintenance. The explanation of how to use the sanitation system was transmitted to the inhabitants mainly during the time of construction. After that, the head of the household, his wife, and the older children were invited to a meeting about the use of the double-vault toilets. Afterwards, during staff visits, the locals were reminded of the instructions. Guidance also took place at events that aimed to prepare people responsible for health and welfare inside the communities, mainly healthcare agents and housewives.

From 1998 to 2002, an inhabitant who took the position of Community Health Agent and was a collaborator of the project was given the task of periodically monitoring the use of the toilets and vault cleaning. The monitoring included visits, conversations with inhabitants, and checking of some items considered indicators of a toilet's good

functioning, such as presence of a trash bin, materials added to the feces, and the dates of vault cleaning. From 2003 to 2008, the conservation conditions of the vaults and their use were checked by the staff and locals. Some damage was noticed by the bricklayer, such as cracks and infiltration, wood deterioration in privies, and the need for roof repair. Only one of the privies had its wooden shelter improved by the inhabitants.

According to local assessment, toilets were shared among one to three households and had a maximum limit of 15 users. Sixty-six percent of the privies were used by one household. Those used by more than one household were in a worse condition.

The most common problems were broken bricks and infiltration outside the vaults during flooding, due to permeability. Inappropriate health conditions were apparent in most toilets due to dirt on the floor, as well as the presence of disease vectors, such as flies, bees, and cockroaches. [Figure 2](#) shows a 13-year-old double-vault toilet during the dry and flood seasons.

Carelessness in alternating the use of the vaults was observed in all households. Each vault had a hole for the passage of excreta. The rest of the vault should remain shut, with a proper slab that could not be easily removed to avoid air and water entering the vault. As a proper slab

was not built or did not receive proper maintenance, both vaults were being used at the same time in most cases.

Users did not add dry material to the excreta or did not add it in the right quantity to maintain low humidity inside the vault. In addition, people used chemicals to try to stop the odor, such as burnt oil, detergent, and disinfectant, whose effects were temporary; they did not prevent the odor from being exhaled again.

Seven out of 11 families said that they threw paper and toilet paper in the vaults. Nearly half of the families stated that they usually threw ash or burnt oil to control the odor. Only 2 out of 11 toilets used dry leaves and sawdust, but only during the dry season, when these materials were available. The water used to clean the floor flowed inside the vaults. The simultaneous use of the vaults, along with high humidity and a mixture of chemicals increased the odor. Odor was reported in 64% of the interviews, together with the increasing development of vectors, such as flies and cockroaches.

The recorded reasons for abandoning the toilets were: bad odor, structures damaged by flood, lack of maintenance investments (for changing of wood shelter and roofs), and families leaving the community. The amount of money needed to repair the damage was estimated as US\$350.00, a value far beyond the average income of the families.



Figure 2 | A 13-year-old double-vault toilet during the dry and flood seasons (photo by Maria Gomes).

Adaptations to the construction

The adaptations proposed are presented in Table 2. The local team adapted the original project design in order to make the construction of double-vault toilets possible in flooded areas. The project technicians believed that the use of more concrete in the structure, or the use of another material for the vault walls (instead of bricks) would have been the right choice in order to enhance vault resistance.

DISCUSSION

Benefits of toilets

The main benefits noticed were awareness of the importance of toilets for reducing open defecation and promoting the comfort, privacy, and safety of the families. The toilet was equipped with a privy shelter and a roof, which allowed people to use it even when it was raining, which was a fact that the inhabitants cherished from the beginning of the project. It also brought the desired protection against animal attacks. Protection against animals, such as snakes, is also noted by Jenkins & Curtis (2005) as a reason why people would like to be able to have a sheltered toilet. Black & Fawcett (2008) states that the

toilet also provides safety against violence. According to this author, woman and teenagers feel safe by having a sheltered toilet nearby. A toilet allows them to stay close to home, and they would not be seen by anyone, during the day or night. However, these issues were not reported by locals in the present study.

Insects were not expected to be present after the construction of the double-vault toilets as they were always around the catwalk or footbridge used for open defecation (*pau-da-gata*). With the new privies, some insects were drawn away. However, other insects, such as cockroaches, flies, and wasps, discovered the necessary conditions to grow inside the vaults (chambers) that did not possess a proper slab.

Since using the toilets, the inhabitants said they noticed a decrease in odor from excreta around the houses. The toilet was seen as a barrier against some animals, such as pigs, chickens, and vultures, which used to feed on excreta immediately after defecation, causing discomfort to people.

A reduction in the number of excreta-related diseases is one of the benefits expected from sanitation. Parasitological exams were applied to the communities studied during the construction of the toilets and approximately 1 year after it. The results (Peres & Moura 2001) showed that helminth and protozoan parasitism prevalence was above 80%, with no significant reduction in parasites after the construction

Table 2 | Initial concept and progress of a double-vault toilet designed for flooded areas in the Amazon

	Initial proposals by technicians	Adaptations made by technicians	Community's adjustments	Current opinion of technicians
Construction design	Double-vault toilet with brick walls	Addition of ventilation tubes, use of wood on the shelter walls, addition of window frames equipped with mosquito nets, semi-buried construction	No participation	Use of concrete, instead of bricks would make vaults more resistant. Use of waterproof vaults. Construction of better slabs for the vault not in use. Higher construction to avoid flooding
Toilet seat	No proposal	No proposal	In 2012, suggestion of a toilet seat with water discharge	Toilet seat needed, but without water discharge
Toilet location	No recommendation	At the back of the residence	At the back of the residence	Better access for people with mobility problems
Dealing with odor	Adding dry materials	Adding dry and local aromatic leaves, fruit peel	Burnt oil, disinfectant, dishwashing liquid	Addition of more dry materials such as ash, lime, and sawdust

of the toilets. The use of the toilets was probably not enough to break the transmission cycle of those diseases (Loneragan & Vansickle 1991). Even though health education actions were taken, people simply did not change their habits, such as drinking untreated water, not washing hands after using the toilet, and walking barefoot.

Simms *et al.* (2005) showed that the benefits of building toilets are not primarily related to health indicators. Implementing toilets in Gambia (in Africa) generated new demands for sanitation in a poor rural community. No educational campaigns were included in that project. The authors concluded that the positive aspect of family cooperation came from adjusting the technology to the local reality and from advancements provided by sanitation, such as better hygiene conditions, safety, and welfare.

In Benin (Africa), the reasons for the population wanting a toilet, as reported by Jenkins & Curtis (2005), were welfare and a feeling of increased prestige among neighbors, relatives, and visitors. It represented a connection to the urban world and comfort, and it also helped people with mobility problems.

The challenging change of behavior

The transition from the habit of open defecation to the use of a toilet demands a change in behavior. The first change noticed is the privacy offered by the toilet's shelter. However, the toilet is dark and it smells, which can be repugnant to some people, and it might be considered confining (World Bank 2012). In order to avoid discomfort, the toilet must be designed to be a clear, ventilated, easy to clean, and pleasant place (Tilley *et al.* 2008).

Another change in behavior is the treatment applied to the excreta. When there were no toilets in the communities, during the dry season people would defecate directly on the soil or use simple pit latrines. In a few days, the excreta would be decomposed, or at least would be in a different state, due to environmental conditions of heat and humidity or animal activity. During the flood season, excreta would be directly discarded on the surrounding waters, and therefore would be dispersed. With the double-vault toilet, excreta would be stored in a box, according to the inhabitants' point of view. Therefore, it would always be within people's sight, causing discomfort

to whoever uses the toilet. From their point of view, it is not good to have excreta concentrated in a dry vault, instead of simply being handled by the soil. The same was also reported by Nawab *et al.* (2006) in a study with a rural population in Pakistan.

Handling excreta, which is necessary for the maintenance of the vaults, was not a regular practice in the households. The proper procedure would be to empty the vaults when they are almost full. However, this extraction has not been done properly or with the necessary frequency. Because of that, the odor was intense and decomposition did not occur.

In order to remove matter from the vault, sometimes the inhabitants made an opening in the vault walls, instead of removing it through the proper slab at the top. Maintenance of the toilet involved some costs, such as changing tiles or fixing the chambers' brickwork. Other actions involved labor and could be accomplished with materials found in the community, such as fixing the wooden shelter. In both cases, with and without costs, maintenance was not properly conducted, as shown by the poor conservation status of toilets. One of the reasons for the lack of maintenance of the chambers is probably the lack of knowledge on how to work with mortar and masonry, as constructions in the region are traditionally made of wood.

People expressed the desire to have a conventional sanitation system with flush toilet bowl/seat and sewerage during interviews. According to Rosenquist (2005), the flush toilet possesses features that are closer to the human ideals of cleaning and comfort, such as elimination of odor and excreta immediately after flushing. In the case of the double-vault toilet, viewing the excreta could have been avoided by adding dry materials more frequently.

Visual contact with feces causes disgust, as does handling (Miller 1997). Jenkins & Curtis (2005) collected data from interviews and concluded that some people consider the use of toilets alone a health improvement. They believe that parasites, diarrhea, cholera, tuberculosis, and other illnesses are transmitted by air or the mere sight of the excreta. According to Curtis *et al.* (2004) and Winblad & Simpson-Hébert (2004), the human disgust for excreta is an unconscious response against the contamination risks of the environment. Therefore, it can be considered an evolutionary step towards protection against diseases.

Water-based flush toilets represent an evolution in terms of hygiene, because they draw the excreta away from the surroundings, but do not guarantee proper treatment. However, low-cost alternatives of black water treatment applied to flooded areas are currently being studied.

The double-vault toilets were built without a seat, as presented in Table 2. This choice was made because it was believed that using the toilet in the squatting position would be better accepted by the population, since it was the local habit. After a few years, the staff technicians changed their minds and realized that the seat would add comfort to the toilet, with no significant additional costs of construction. Taking that into consideration, we suggest that population preferences on this matter should be investigated using a larger and more diversified sample. Only then, would it be possible to know which toilet design would meet the community's expectations.

The lack of educational material containing instructions for users (written information and drawings), including recommendations for the maintenance of the vaults, was a fault in the project. The instructions were passed on verbally, which was not sufficient for the inhabitants to understand how to remove matter from the vaults when they were full, and what should be done with this removed matter, or even how to handle it safely.

One of the indirect benefits from proper human excreta handling would have been the use of this compost for agriculture. This is a trend that has been discussed worldwide, as a form of ecological sanitation (resources oriented sanitation) (Winblad & Simpson-Hébert 2004). However, the idea of using human excreta in agriculture was not significantly encouraged by the project (considering the high prevalence of intestinal parasites); hence, this practice has not been adopted by the inhabitants.

The need for better design

The variation in environmental conditions was one of the factors that affected vault structures, especially during the flood season (up to 6 months a year). The first vaults were built in 1998, at approximately 1.20 m above ground, taking into account seasonal flooding. Uddin (2011) presented this recommendation as the main adaptation for

building toilets in flooded areas in Bangladesh. However, 1 year later a great flood was recorded in the Mamirauá Reserve (Ramalho *et al.* 2009) and flooded all households and some of the toilets. In order to avoid too much water going into the vaults, the staff sealed some vault slabs with cement.

With the vaults underwater, inhabitants had to stop using them and were forced to defecate in the open again, directly on the water. The flood caused infiltration to the vaults, which diluted all excreta. As the water level decreased, so did the level of the material inside the vaults, and contaminated water leaked through their permeable walls. When the land dried a few months later, families restarted using the toilets, although without doing any repair to the vaults or toilets.

After that, two other great floods (Mamiraua Institute for Sustainable Development – MISD 2013) left entire communities and vaults underwater. The worse damage occurred between 2008 and 2012, a period when most double-vault toilets were deactivated. No repair to the damaged structures was done. We believe that these are the main reasons for the abandonment of half of toilets that were in use.

The need for sanitation education

The high incidence of intestinal parasitoids was the main reason for the construction of the toilets. Hence, the project included educational actions focused on the use of toilets to improve healthcare. The educational instruments used were lectures with pictures and leaflets with information on disease prevention, importance of the vaults, how to prevent diarrhea, and boosting personal hygiene through washing hands and wearing shoes.

Although some toilets are still being used, no great change in hygiene has been observed. Despite the educational actions, it has been noticed that besides the bad hygienic conditions found in the toilets, the habit of cleaning hands has not been adopted by the families. There was no proper place for cleaning hands after using the toilet in 45% of the households, which, facilitates the transmission of diseases. Scott *et al.* (2007) presents several examples of projects that failed to promote hygiene by not considering local habits and beliefs.

According to Black & Fawcett (2008), only a few people associate the use of toilets with better health, but many

associate it with other benefits, such as comfort and privacy. Therefore, we believe that a motivational talk based mainly on the hope of reducing diarrhea is flawed. It is necessary to use more arguments during educational actions. Cleaning, raising children, and social acceptance are great motivations to promote hygienic behavior, according to Scott *et al.* (2007). This way, the role of sanitation education in transforming the local reality is promoted, through approaching methods fine-tuned with local habits aimed at promoting small changes in behavior and attitudes that would make people, houses, and public spaces much cleaner.

CONCLUSIONS AND RECOMMENDATIONS

This sanitation experience succeeded in reducing open defecation and in creating a growing interest and demand for toilets, although not necessarily the same sort proposed by the project.

The composting vaults contributed to the comfort and safety of households, as well as to reducing odor. However, there is still a need to adapt the construction to seasonally flooded environments. The technology must be water resistant and the toilets must be located even higher above the ground. It is also necessary to spend more time training users on how to use the double-vault toilet and other dry sanitation systems that could be installed. These technologies require greater effort in comparison to the solutions traditionally in use (open defecation and pit latrines).

We recommend a different approach to people, emphasizing the positive aspects of sanitation and hygiene from their own perspective, instead of simply exposing expected individual health benefits. We learned that the availability of an affordable and efficient technology, aligned with the social reality of a community, as well as motivation created through education in sanitation, may be key to promoting sanitation in the rural riverine communities of the Amazon.

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