Logistics and ecological sanitation in the city of San Fernando, La Union, Philippines

Dave Mateo[1] and Agnes Goze[2]

[1] Main author, Department of Technology and Ecology, Graduate School of Global Environmental Studies, Kyoto University

[2] Co-author, Center for Advanced Philippine Studies, Quezon City, Philippines

Abstract: Access to basic sanitation remains a grave challenge on both global and local scales. This paper examines the logistical aspects of a pioneering ecological sanitation initiative piloting the use of urine-diverting dehydration toilets in two low-income communities in San Fernando city, La Union, Philippines, from January 2005. The San Fernando city government currently faces two challenges. First, how to develop a system that will more efficiently serve not only the communities piloted in the project but an additional 1,000 households in the city to which ecological sanitation services are to be extended by 2010. Second, how to ensure that the system employed manages waste from the separation stage up to the treatment and re-use stages — thus confirming San Fernando city's commitment to providing fully sustainable ecological sanitation. The logistics system presented in this paper is the result of a six-month assessment study carried out from August 2006 to January 2007, the aim of which was to create a replicable logistics system that could be used to extend effective ecological sanitation services not only to other communities in San Fernando outside the original pilot study, but to other cities in the Philippines and, by extension, the developing world. Throughout, the authors emphasize the importance of joint cooperation between local government, the people in the communities concerned and any other stakeholders in achieving local-scale sanitation targets that can be replicated nationally and internationally.

Keywords: logistics system, ecological sanitation (Ecosan), urine-diverting dehydration (UDD) toilet, Philippines

1. Introduction

1.1 Ecological sanitation as a new sanitation paradigm

The need for more effective and ecological sanitation systems increases as the human population in urban areas increases. The flush-and-discharge sanitation system is commonly used in cities all over the world to collect sewage from flush-type toilets in all building structures connected to the sewage system. A large proportion of the collected sewage is discharged partially treated, if not completely untreated, into bodies of water. The popularity of this system of collection and treatment rests on its believed capacity to effectively reduce the potential hazards posed by the massive volume of sewage generated in the world's cities. Its capacity to do so is now under question, on the grounds that rather than solving the problem of waste, it merely shifts the problem to bodies of water that become the ultimate 'sink' for disposal.

There is growing consensus among sanitation experts in the Philippines and other developing countries that the flush-and-discharge method can no longer meet the sanitation needs of the world's most rapidly expanding urban societies. The effectiveness of current sanitation systems used in the new urban centers fall far short of widely acceptable treatment standards and high levels of investment are needed to construct a fully fledged and well-managed sewerage system if standards are to be improved. Other pressing issues include the massive waste of water integral to the flush-and-discharge sanitation system — unsustainable in countries where there may be severe limits on the water supply — and the continued spread of waterborne diseases.

What other methods might be available, if the flush-and-discharge system is inadequate to meet the growing sanitation needs of the world's most rapidly expanding cities? Individual septic tanks are commonly used in many semi-urban and even urban areas in developing countries, where there is an absence of a technologically advanced and properly managed sewerage system. Satisfactory performance of septic tanks relies on their technical design, installation, maintenance, and mode of operation (Butler and Payne 1995). Routine maintenance to remove the sludge (residual semi-solid fecal material) that accumulates at the bottom of the tank is particularly important. The desludging process presents particular difficulties in many urban areas of developing countries (Asian Development Bank 2001; Strauss et al. 2003) because it is costly — for low- and even middle-income families — and desludging services are not always available at the time of need. Poor location, sporadic desludging, inadequate design, additional maintenance costs and a lack of regulatory compliance and monitoring are just some of the factors that make the septic tank-based sanitation method a less than perfect answer to the needs of the world's rapidly growing cities, despite its widespread use in developing countries.

Ecological sanitation, dubbed Ecosan by its proponents, is a sustainable sanitation approach based on the idea that urine and feces are resources in the food chain. It is an approach that saves water, protects water quality, prevents pollution, and returns valuable nutrients into the loop. As such, it offers a valuable solution to the present sanitation crisis being experienced in developing countries. Methods of ecological sanitation emphasize the possibilities inherent in the on-site treatment and recovery of nutrients in human fecal and urinary waste, particularly for reuse in agriculture. For this reason, they involve processes that first render human excreta safe. The methods, technology and concept of Ecosan work towards two primary goals: to make sanitation sustainable and contribute towards the dignity and health of the communities in which they are used.

1.2 Sanitation in the Philippines

The Philippines is undergoing rapid urbanization as rates of population growth soar high above those of the country's neighbors in South East Asia: the population of the Philippines is expected to reach 94 million by 2010 (Philippine National Statistics Office 2006). Vast numbers of people migrating from rural areas into often-congested cities and rapidly urbanizing areas across the country present city governments with the daunting task of providing basic sanitation needs to ever larger communities. Lack of access to adequate sanitation has negative impacts on the Philippine economy and environment, as well as the wellbeing of individual Filipinos. It is reported that the Philippine economy loses an estimated 67 billion Philippine pesos (1.3 bn US dollars) every year because of water pollution (World Bank 2003). Three billion pesos of this total is spent on health costs resulting from contaminated water: diarrhea is commonplace among the Filipinos as a result of waterborne diseases exacerbated by a combination of poor sanitation and hygiene. Together, waterborne diseases accounted for an overwhelming 31 percent of all reported illness from 1996 to 2000.

The origin of these figures is not difficult to trace: although a mere 7 percent of the country's population is connected to sewerage systems, 48 percent of organic pollution generated annually — some 2.2 million metric tons — is domestic sewage. As in many developing countries, conventional and centralized sewage systems are too expensive to be implemented in rapidly growing urban areas. When introducing a capital-intensive sewer system into an urban context, cities must have the financial capacity and technical expertise to expand sewer lines and ensure that sewage treatment is adequate (Medilanski et al. 2006). In the Philippines, the provision of only the most limited sewerage services has led to the proliferation of on-site systems, such as septic tanks, to partially treat domestic sewage (World Bank 2003). These may be of poor design and construction in areas where local authorities are less stringent about health and safety regulations. Most, for example, merely serve as storage chambers where excreta may be kept for years, depending on the size of the tank. The bottom of many tanks may be unsealed and their construction is rarely watertight. Desludging is carried out irregularly in most cases because septic tanks are not serviced for desludging until they are full. More often than not, the waste stored in them may be simply stored without ever receiving treatment: it is common practice to build secondary septic tanks or concrete-walled chambers when the first tank is full — rather than desludge those tanks that have become full — largely on account of the unavailability or cost of desludging services. Where desludging is carried out, moreover, septage is frequently dumped directly and illegally into bodies of water, on land or into existing public sewers without proper treatment.

Figures state that 86 percent of Filipino families have access to sanitary toilets, as of 2004. The breakdown of this figure shows that 93 percent of families from the top 70 percent of the income stratum and 70 percent of the lower 30 percent of the income stratum have access to sanitation (Philippine National Statistics Office 2005). These figures do not necessarily reflect access to satisfactory sanitation. The Asian Development Bank calculated that a total investment of 256.37 bn pesos is needed if the basic sanitation needs of even half of the Philippine population (46.32 million) expected to be living in urban and rural areas by 2015 (the culminating year for the UN Millennium Development Goals) are to be met (World Bank 2004). Although ranked as a high priority in the Philippines Agenda 21 of 1996, spending on sanitation and sewerage remains low in comparison to water supply investments, which cover 97 percent of the country's annual budget for the water and sanitation sector.

The above highlights severe deficiencies in the provision of sanitation services in the Philippines. Conventional sanitation systems alone cannot provide a solution to these deficiencies. Development and construction of low-cost sanitation facilities must be prioritized if the Philippines is to meet international sanitation commitments by 2015. It is now believed that the adoption of an ecological sanitation approach may offer a complementary if not an alternative approach by which the country's sanitation goals may be met.

1.3 Ecological sanitation in the Philippines

Recent changes in regulatory frameworks have created a favorable environment for the implementation of ecological and sustainable sanitation systems. Ecological sanitation was accepted as a viable sanitation option in the implementing rules and regulations (IRR) appended to the Clean Water Act of 2004, in which the concept had not been mentioned. In a similar way, the IRR of the Philippine Ecological Solid Waste Management Act of 2000 called for the increased use of composting toilets and biogas plants, which treat and separate waste at the source, on the grounds that subsequent recycling, composting and reuse of any waste thus collected would reduce the amount of solid waste requiring disposal (Fruh 2003).

Ecological sanitation pilot projects carried out in the Philippines typically make use of urine-diverting dehydration (UDD) toilets that are typically built some 0.6 m above the ground. Elevation makes it easy to access the chamber beneath the toilet where containers to collect feces and urine are kept. Users of UDD toilets are required to throw a small amount of dry additive material down the toilet after defecation. Wood ash, sawdust, carbonized rice hull, dry soil and lime are all popular additives. Adding them mitigates odors, promotes the dehydration of the fecal material and — in the case of sanitizing additives such as wood ash — destroys pathogens (Winblad et al. 2004; Morgan 2007). Many UDD toilet models feature separate washbowls or floor washbasins, as shown in Figure 1, as most Filipinos wash after defecating or urinating.

UDD toilet ecological sanitation projects are taking place today all over the Philippines. Their use was first piloted in 2003, in the municipality of Tingloy Island, Batangas, under the auspices of the global Urban Waste Management Expertise Program (UWEP), coordinated and financed by the Dutch non-governmental organization WASTE, and facilitated by the Center of Advanced Philippine Studies (CAPS) and the Philippine Center for Water and Sanitation's International Training Network Foundation (PCWS-ITNF). Other ongoing projects are sponsored by the German Technical Cooperation (GTZ), currently supporting ecological sanitation initiatives in the southern islands of Bohol and Cagayan de Oro. Many recent initiatives have taken their inspiration from a particularly successful WASTE/CAPS and local government sponsored pilot project, which brought 20 UDD toilets to two low-income communities in the city of San Fernando, La Union, in January 2005. Success in the early stages of the project has encouraged the city to expand ecological sanitation to other areas of the city. Plans in the short term will bring the number of UDD toilets to 154 in the near future: these are to be installed predominantly in low-income coastal neighborhoods of the city. San Fernando's long-term commitment to ecological sanitation — articulated in the city's Strategic Sanitation Plan of 2007 to install an additional 1,000 UDD toilets across the city by 2010 — has attracted the attention not only of neighboring municipalities but of many other local governments in the Philippines.

With support for ecological sanitation initiatives growing across the country, the Philippines is ready to incorporate past experience into the implementation of ongoing and future ecological sanitation projects. Some of these learned lessons form the basis of recommendations proposed in the conclusion of this paper,

Fig. 1 (Clockwise from top left) Schematic drawing of urine diverting dehydration (UDD) toilet; a UDD toilet in barangay San Agustin; a ceramic UDD toilet bowl and floor washbasin; and a UDD toilet with optional ceramic bidet (right) and ashbin (middle)
(Source of schematic drawing: Center for Advanced Philippine Studies)

which summarizes a number of ways in which logistical aspects of ecological sanitation management may be improved in San Fernando city. It is the authors' shared hope that the projections and recommendations described in this paper will be useful not only to San Fernando city, but the Philippines in general and the rest of the world.

2. Logistics and ecological sanitation implementation

2.1 Introducing San Fernando city, La Union and the pilot project

The city of San Fernando, La Union (current population 112,316) is a coastal city located 240 km north of Manila. Concurrently the capital of La Union province and the administrative capital of the entire Ilocos region, which incorporates four provinces, namely Ilocos Norte, Ilocos Sur, La Union and Pangasinan, San Fernando city spans portions of the shoreline of the Lingayen gulf. The city's location with respect to the Philippine archipelago and La Union Province is shown in Figure 2: San Fernando Bay lies to its west, the municipalities of Bagulin and Naguilian, La Union to its east, the municipality of Bauang, La Union, to its south, and the municipality of San Juan, La Union, to its north. The city is made up of 59 *barangays* (the smallest unit of local government in the Philippines[1]), the total land area of which is 10,526 hectares. They are geographically clustered into 14 coastal barangays, 31 inland barangays and 14 upland barangays (see Figure 3).

UDD toilets were installed in two barangays in San Fernando in January 2005: 10 in San Agustin, a coastal barangay on San Fernando bay, located 4.5 km

Fig. 2 La Union province in the Philippine archipelago (shown left) and San Fernando city in La Union province (shown right)
(Source: Wikipedia)

Fig. 3 Map of San Fernando city, La Union (SFLU), clustered according to coastal, inland and upland barangays
(Source: City Planning and Development Office, SFLU)

southwest of the city proper, and 10 in Nagyubuyuban, an upland barangay in the northeastern reaches of the city. Their enthusiastic reception from local people prompted further efforts by the city government to expand its initiatives in ecological sanitation: most prominently, in Fisherman's Village in barangay Poro, the location of a city government housing project currently under construction, soon to provide 95 homes for fishing households relocated from barangay Ilocanos Sur, an area prone to flooding. Poro, like San Agustin, lies on San Fernando bay. The residents of both barangays depend upon fishing and aquaculture for their livelihoods. For this reason, neither community has an immediate agricultural or horticultural use for treated feces and urine redeemed for reuse via the UDD toilet system. Poro and San Agustin contrast starkly with Nagyubuyuban in this respect: Nagyubuyuban's upland location provides ample agricultural opportunities for the use of so-called 'humanure'.[2] Developing an effective collection system for the residents of San Agustin and the future residents of Fisherman's Village is therefore of prime importance if ecological sanitation is to be fully sustainable in either of these coastal urban barangays.

2.2 Method and aims of the logistics study

The primary objective of the study presented in this paper was to create an effective and efficient logistics system for the city of San Fernando with regards to its current and future implementation of ecological sanitation. The system was the result of the four-part logistics study outlined below, which set out to:

(1) determine accurately the volume of feces and urine generated at a local scale and use the resulting data to predict future volumes that will be generated under planned expansions of ecological sanitation in San Fernando;
(2) identify possible sources of ash, carbonized rice hull and other substances for use as additives and/or drying materials in the process of dehydrating feces;
(3) design a collection and transport system for hauling urine and feces for households currently using UDD toilets, which is replicable for future use as the number of UDD toilet-using households expands in the city;
(4) develop other logistics management steps for use in further expanding the use of ecological sanitation, both in San Fernando and elsewhere.

Section 3 examines each step of the study in detail. Context for the study is provided by a brief overview of the logistics set-up implemented in San Agustin to deal with the haulage of feces and urine collected from each UDD toilet-using household in the first year of the initial pilot project.

2.3 San Agustin in the first year of the pilot project

The collection and haulage of accumulated feces and urine was overseen by four parties in the project's first year: (1) an Ecosan Technical Working Group (TWG), made up of members of San Fernando's City Environment and Natural Resources Office (CENRO) and officials from other city government offices,[3] (2) members of the Barangay Council of San Agustin, (3) the Barangay Ecosan Committee (BEC[4]), tasked to oversee project implementation at the barangay level and consisting of the chairman and councilors of the barangay and some of the heads of the households in which UDD toilets had been installed, and (4) project staff from the Center for Advanced Philippines Studies (CAPS). The BEC established which cooperating households had full containers that needed emptying and hauling by coordinating with members of the Barangay Council. This was particularly important as the barangay did not possess its own means of transportation in the first year of the pilot project. The BEC relayed any information it collected to CENRO, which then set a schedule for immediate hauling. The BEC and CENRO also worked together in the provision and distribution of carbonized rice hull in order to ensure a steady supply to the barangay, with CENRO delivering to the barangay at the BEC's request.

The haulage process depended upon the cooperation of the UDD toilet-using households in the project. Members of each cooperating household were required to carry containers filled with their collected feces to a designated staging area in barangay San Agustin, where a vehicle (a small pick-up truck) would be waiting on scheduled hauling days. One to two people (depending on the weight of the feces or the strength of the household member making the delivery) would carry their household's accumulated feces to the loading dock in containers or plastic garbage bags, tied at the neck. Barangay *tanods* or watchers were on hand to assist with carrying and loading where necessary. Once loaded up, the sacks or containers of feces were transported to a secondary storage facility known as the EcoPits: these are three pits, 2 m long and 1.5 m wide, dug by hand to a depth of 1 m in grounds belonging to the city abattoir. The contents of the containers were emptied into the pits and covered with soil. The dried feces would be kept here for six to 12 months, for further sanitization and dehydration.

The procedure for urine was somewhat different. Households with no immediate use for urine as a fertilizer in their gardens were encouraged to bring their urine containers to the staging area whenever necessary for disposal. The contents could be emptied into a communal storage tank kept at the staging area, from which urine would be harvested periodically by the BEC of barangay San Agustin for use as a fertilizer. This was applied in the evening to city ornamental flower beds along Pennsylvania Avenue, a graceful boulevard located near the barangay.

Three haulings were carried out at three, four, and five-month intervals during the first year of the project. These irregular hauling intervals can be attributed to the following factors:

a) Transportation and drivers necessary for hauling were not always available at the times scheduled for haulage;
b) Initially unscheduled follow-up collections were required for hauling the accumulated feces containers of those households that did not cooperate during the first hauling activity;
c) Households lacking either containers or the space in which to keep filled containers were obliged to request an early and unscheduled hauling;
d) The onset of the rainy season suspended a scheduled hauling; and
e) With insufficient information about the haulage schedule or the volume of excreta that they could be expected to generate, some households stored their feces and urine in small or light containers that would be easier to handle manually when full. These containers filled up quickly

and required emergency hauling in some cases.

Irregularities in the hauling schedule caused by factors such as those outlined above had a negative impact on households as feces containers already filled to capacity rendered the UDD toilets unusable until a hauling could be scheduled. This situation left residents with little choice but to return to old practices — sharing toilets with neighbors or relatives, or defacating outside. Remedying irregularities in the haulage system is clearly crucial if the city is to extend UDD toilet usage to larger number of households in the short and long term.

3. Implementing the logistics study

The logistics study was carried out between August 2006 and January 2007. Its first step, as described in the four-part process summarized in Section 2.2, comprised efforts to determine accurately the volume of feces and urine generated at a local scale.

3.1 The monitoring activity

Monitoring activities to measure the total volume of feces, urine, and ash collected in 10 UDD toilet-using households were carried out at barangay San Agustin, one of the two initial pilot sites. San Agustin was chosen over barangay Nagyubuyuban, the second pilot site, because conditions in San Agustin resemble conditions in the barangay into which ecological sanitation is to be extended: San Agustin's residents have little space, available wood ash, or immediate use for the excreta accumulated by UDD toilet use. The monitoring process involved two stages: 1) preparation and implementation, and 2) analysis of results.

3.1.1 Preparations for the monitoring survey

(i) *Meeting of all the stakeholders*

Preparations began with a consultation meeting among the researchers, officials of the Barangay Council of San Agustin and the heads of UDD toilet-using households cooperating in the study (hereafter, 'cooperators'). The council chairman (who is also the head of the Barangay Ecosan Committee) was informed by the researchers of the activities to be undertaken involving the logistics study. The study's objectives and proposed methodology were discussed. The research team requested a map of the barangay for use in locating a number of households which might cooperate in the study. The Barangay Ecosan Committee was able to advise the research team on which households might be suitable.

(ii) *Site reconnaissance*

The map was used to delineate the study area. To date, 49 households in San Agustin have been provided with UDD toilets but some were structurally unfinished at the time of the study or rendered unusable by storm damage. Others were incomplete in terms of storage equipment. The researchers visited all the households and marked on the map the location of households with existing and functional UDD toilets, along with the alleyways and pathways used to access them. Each toilet was inspected by the research team, which checked for structural soundness (the condition of the walls, roofs, lower chambers, toilet bowls and pipes) and equipment (whether or not they were furnished with containers for urine, feces and ash).

(iii) *Selection of participating households*

A set of criteria was developed to determine which UDD-toilet using households would participate in the monitoring activity. Eligible households must 1) be willing to participate in the study, 2) have access to a UDD toilet that is functional, 3) use the UDD toilet regularly, and 4) be able to participate for the duration of the study.

Ten households were selected to take part in the monitoring process. Each comprised three to five household members, with the head of the household (usually male) employed in the fishing industry. In two of the participating households, one person from each household was chosen to be the sole user of the UDD toilet and other household members were forbidden to use the UDD toilet for the duration of the study. In each case, the individual chosen was at home all day. He or she could thus be assumed to be using the UDD toilet on a regular basis. All members of the remaining eight households were instructed to use the UDD toilets on a daily basis, in accordance with their personal circumstances (employment, school, obligations outside the home), which would dictate how regularly they used the toilets. The monitoring process was organized in this way to allow the researchers to compare the quantities of feces and urine generated on a per-person as well as household basis.

(iv) *Preparation of materials and equipment*

The following equipment was provided to all households cooperating in the survey in order to standardize the procedure for measuring feces and urine: a) improvised urinals for male users who preferred to stand to urinate rather than sit, made out of 5 liter PET bottles, cut to take the shape of a male urinal and connected to a storage plastic container by a rubber hose; b) a three-day supply of carbonized rice hull in 100 g packs (the number of packs distributed to each cooperator was based on the size of the household); c) black plastic bags containing 500 g of carbonized rice hull to be used to line each feces container to enable the easy collection and weighing of feces, and d) a daily monitoring sheet.

(v) *Briefing of cooperators*

The heads of each participating household attended an orientation session before the study began, where they were briefed on a) the objective of the study, b) the duration of the activity, c) what time the research team would visit them each day to weigh the accumulated urine and feces generated by the household, d) how to use the carbonized rice hull, and e) how to fill in the monitoring sheets.

Participating households were instructed to request additional supplies of carbonized rice hull from the designated supplier as needed — one of the cooperating households would act as distributor for all the groups in the monitoring survey. They were instructed not to swill or wash down the makeshift urinals with water or to empty urine containers until they had been measured.

(vi) *Daily data monitoring*

The research staff collected monitoring sheets from each of the cooperators daily, as seen in Figure 4. These recorded the frequency of defecation and urination and the number of 100 g packs of carbonized rice hull used per person per day. Measurements were taken on a 24-hour rotation, timed to begin after nine o'clock in the morning and span a complete one-day cycle. The research team visited each household at the same time every day: the order in which households were visited was determined by their toilets' proximity to the staging area, to where all collected feces would be carried for transportation on haulage days.

The daily visits enabled research staff to monitor whether the UDD toilets were being used daily and how closely households were following the given procedures. Observations on both points were duly noted by the researchers.

3.1.2 Results of the weight-volume measurements

Table 1 records the average weight measurements of feces and urine collected over the duration of the study. It shows that each household member excretes an average of 0.13 kg/day of feces (wet weight), defecating on average at least once a day. Measurements for urine averaged 0.34 L per day and 1.51 L per day for household members who used the UDD toilet irregularly or regularly respectively. Urine averages were calculated in two sets because data provided by the monitoring sheets indicated that household members who were away from home for most of the day used the UDD toilets twice a day at most (morning and evening). This would naturally lower the quantities of urine measured for that

Fig. 4 Monitoring activities in barangay San Agustin, SFLU. Clockwise from top left: retrieving feces prior to taking measurements; daily consultation with residents on UDD toilet use; and measuring the weight and volume of feces (plus additives) and urine

Table 1 Average daily generation quantities per person in San Agustin

Excreta & additives	Quantity per type of user	
	Regular	*Irregular*
Urine (*L*)	1.51	0.34
Feces (*kg*)	0.13	
Carbonized rice hull (*kg*)	0.25	

individual, therein lowering the volume of urine collected for the whole household and resulting in an unrepresentative and inaccurate average for each household member. As the measurements for urine generation taken from regular UDD toilet users corresponded closely with the values recorded for the two individuals who had been assigned the sole users of the toilets in their households, it can be assumed that the data shown in Table 1 is representative. In fact, the measurements for both feces and urine generation for barangay San

Agustin fall within the globally known average measurements, which are 0.14 kg/person/day and 1.10–1.37 L/person/day).

The average amount of carbonized rice hull used as a drying material ingredient was 0.25 kg per defecation. The monitoring sheets showed that household members varied as to how much carbonized rice hull they used at each defecation. The researchers had estimated that a single 100 g pack of carbonized rice hull would suffice per defecation. However, users tended to use much more than this — apparently seeking to neutralize odor even when the feces were already completely covered with carbonized rice hull.

All weekly and monthly feces weight measurements calculated on the basis of the data shown in Table 1 include the weight of carbonized rice hull added at the time of defecation, and an additional 500 g of carbonized rice hull provided as an initial layer inside the container to aid dehydration and prevent sticking. Using a 110 L half steel drum as a feces container, it takes 19 days on average for a five-member household to fill the container with feces and carbonized rice hull. As most households keep two containers inside the chamber beneath their UDD toilet, the total filling time doubles to 38 days. This suggests that the schedule for hauling should be set at an interval of 38 days, at which time an estimated 73.20 kg of feces and carbonized rice hull will be collected from each household.

Most households used 20 L carboys as urine containers. The average volume of urine generated per household amounted to 7.55 L daily and 226.5 L a month. These figures can be derived from Table 1, by multiplying the urine generation rate per regular user by five, the average number of people in a household. It would take a typical five-person household 2.5 days to fill a 20 L household container. It would take the same household 198 days to fill the 1500 L high-density polyethylene drum stationed at San Agustin's designated staging area for use as a communal urine storage tank. The same communal container would be filled in 20 days, should all ten participating households empty their urine containers into the tank.

Table 2 summarizes the filling times for both household and communal urine containers per household, using the urine generation quantities that were measured during the survey. These figures indicate that the communal tank stationed in San Agustin would have been insufficient to accommodate the urine

Table 2 Filling times of urine containers in San Agustin

Type of user	Container filling times (*days*)	
	Household type (*20 L capacity*)	Communal type (*1500 L capacity*)
Regular	2.50	198
Irregular	11.5	882

generated by UDD-using households, had all 49 UDD toilets in San Agustin been in use in the first year of the pilot study. A per-household urine generation of 7.55 L per day would have filled the existing communal tank in approximately four days: this would necessitate collection every four days — an interval costly to the city. Section 3.3 of this paper describes one solution to this problem: the installation of additional communal tanks capable of accommodating the minimum volume of urine that 49 households can be expected to generate for 30 days — a collection interval much more acceptable to the city on the grounds of cost.

3.2 Survey of possible sources of ash and carbonized rice hull

Wood ash is an excellent additive for dehydrating, sanitizing and controlling the odor of excrement, as described in Section 1.3. It is used extensively in ecological sanitation activities in the pilot project's upland site, barangay Nagyubuyuban, where location yields a plentiful supply of both wood and wood ash. A large supply of wood ash is not available for use in coastal or more urban locations, however. Carbonized rice hull — a good substitute for wood ash — was used in barangay San Agustin in the first year of the pilot project for precisely this reason. Rice hull is particularly abundant during the harvesting season of November to January and the vast majority of it is treated as agricultural waste, dumped and burned along roads and highways in urban and rural areas alike. Irresponsible disposal practices create eyesores, cause silting in rivers and streams and add to the environmental degradation of land and air quality. Optimizing the use of carbonized rice hull as an additive for UDD toilet implementation on a city-wide scale is both environmental and practical, in terms of the sustainability of San Fernando's ecological sanitation initiative.

(i) *Salt factories*

Carbonized rice hulls were received in large quantities by San Fernando city from a salt factory in Dalumpinas in the first year of the city's UDD toilet pilot project. The factory used rice hulls as fuel for huge ovens used in salt production, procuring them virtually free of charge from rice mills. Before it became the city's supplier, the factory buried carbonized rice hull as a filler beneath the soil to even up ground levels or composted it with soil as a conditioner for banana trees planted in the factory grounds. Smaller amounts of carbonized rice hull were distributed to farmers, who collected it for use as a soil enhancer. Supplying the city was beneficial to both parties, therefore, solving a crucial waste problem for the factory as well as answering the city's need.

The factory, which opened in 2000, was closed in June 2006 after nearby residents complained about smoke emissions. When interviewed by the researchers, the former owner of the factory estimated that it consumed 800 sacks of rice hull per 24-hour period of salt production in the first years of operation, producing approximately 400 sacks of carbonized rice hull over each 24-hour period (a rice hull to carbonized rice hull production ratio of approximately 2:1). Salt production was scaled down in the months before closure. Decreased production levels meant that only half as much fuel — 400 sacks of rice hull per day — were needed to power operations, naturally resulting in half the amount of carbonized rice hull produced.

Such was the situation during the period in which the factory furnished San Fernando with carbonized rice hull in the first year of its pilot project.[5] The salt factory has since been relocated to the municipality of Luna, La Union, where its production capacity is half what it used to be. The relocated factory's management has an agreement with San Fernando City Environment and Natural Resources Office (CENRO) to supply it with carbonized rice hull, at a fee of Php 10 per sack. Other salt factories located in San Fabian, Pangasinan, have offered to supply carbonized rice hull to CENRO on the condition that the city shoulders the cost of transportation, haulage and manpower. In each case, the cost of bringing supplies in from outside the city adds to San Fernando's costs at precisely the moment that the city is poised to expand its ecological sanitation activities. A better option for the city is to look locally for alternative sources not only of carbonized rice hull but of other substances that can be used as additives. In the following, the researchers propose a number of businesses as potential suppliers of wood ash, carbonized rice hull and other additives for use in the future as UDD toilet use expands across the city.

(ii) *A local farmer*

San Fernando's CENRO currently places orders for fixed quantities of carbonized rice hull with a local farmer for use as a soil enhancer in the city's nurseries. He uses a hand-built carbonizer to burn rice hull on an open-field site near barangay Namtutan's daycare student center — a location chosen for its proximity to the main road, which eases the delivery and hauling of rice hull to the site and carbonized rice hull from the site. The carbonizer, like all such hand-built burners (an example of which can be seen in Figure 5) produces acrid smoke in much the same way as the open-burning method used traditionally to carbonize rice hull. This smoke is environmentally hazardous to motorists, commuters and people living nearby. For this reason, the farmer can only carbonize rice hulls during weekends, when the daycare center is closed, or when there are no classes.

The researchers visited the local farmer to monitor the process by which rice hull is carbonized. It took the farmer eight hours to carbonize eight large sacks of

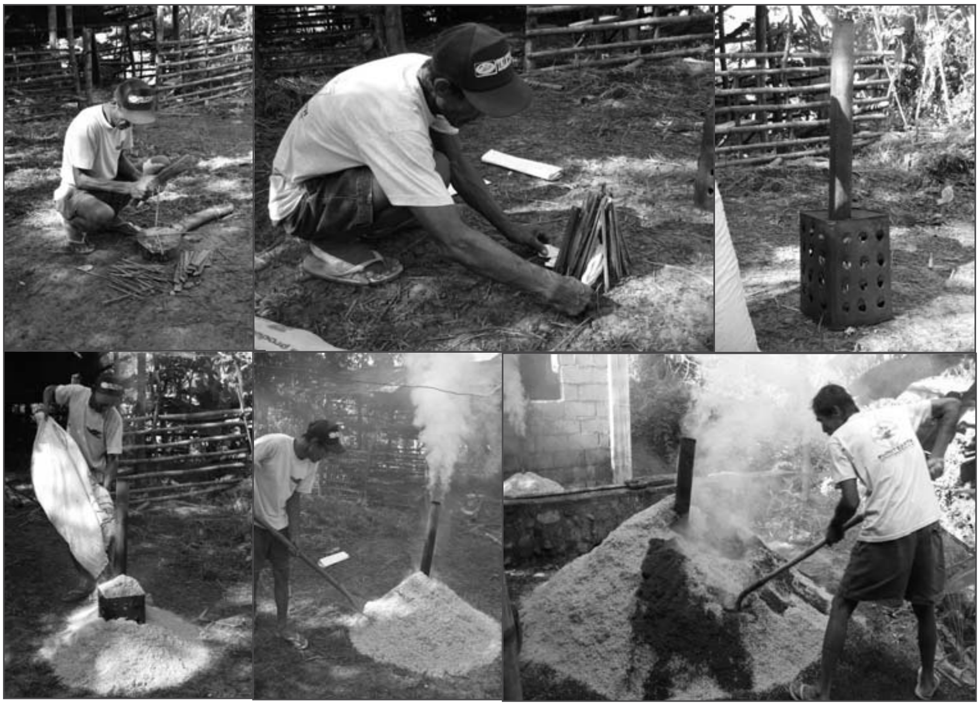

Fig. 5 Process of carbonizing rice hull. From top left: cutting small twigs as fuel and starting the fire; a hand-built carbonizer; pouring sacks of crude rice hull around the carbonizer; turning over the rice hull heap to ensure even heat distribution

rice hull (using the process shown from left to right in Figure 5). A total of 41.5 kg of rice hull was carbonized during the visit, resulting in 36 kg of carbonized rice hull — a weight reduction of only 13 percent. This translates approximately as a crude-to-carbonized rice hull ratio of 7:6, considerably higher than the 2:1 ratio claimed by the owner of the salt factory.

(ⅲ) *A local restaurant*

One local restaurant, which took part in the survey, uses rice hull to fuel its stoves for cooking soup stock to make congee (a type of gruel made from rice). It was observed during the site visit that the quality and condition of rice hull that was burned as fuel varied according to the degree of combustion to which it had been subjected. The end product was a mixture of carbonized rice hull and white ash. Further studies of the possible chemical effects of using the rice hull in white ash form as an additive should be carried out to determine if it is suitable for drying and sanitizing feces. There are, nevertheless, sufficient quantities of combusted rice hull in carbonized form stored in the cooking area to make the restaurant a possible supply source for the city.

(iv) *Bakeries*

The researchers located three bakeries within the city's boundaries employing conventional baking methods that used firewood as fuel. The researchers consulted the owners of all three establishments to assess the amount of ash being produced by each on a monthly basis in relation to the amount of firewood used. The results varied widely. The owners of all three bakeries explained that the volume of ash generated varies a great deal according to the scale of production on any given day or in any week and this determines how much firewood is consumed. Two of the bakeries estimated their ash production at between 3.5 to 7 sacks per week. Both businesses treat the ash they produce as general waste. A city-center location obliges one bakery to dispose of its ash together with other solid waste for collection by the city on a regular basis, while the other, which is located on the city's outskirts, is able to bury its ash in its own backyard. The third bakery was not able to approximate how much ash it produces: generally low production levels mean that the small amount of ash it produces is reused[6] and disposed of as ordinary garbage for collection by the city.

In all three cases, the ash being disposed of or buried can be used as additives in the city's ecological sanitation scheme. Coordination with the owners is the first step if the city wishes to persuade these establishments to be suppliers. The ash must be separated at source from other waste by the bakery owners and prepared for collection by either the UDD toilet-using local residents, collecting the ash directly, or the relevant city department, acting on the residents' behalf as distributor. Cooperation is the key to either of these set-ups, or indeed, any other method, if an agreement is to be struck that works for the bakeries, the city and its residents.

While other bakeries increasingly use liquefied petroleum gas as fuel for their ovens on the grounds that it is cheaper than firewood, all three bakery owners surveyed in this study expressed their intention to continue using conventional methods for baking — as long as their current production scale allows them to do so. Their cooperation, once gained, offers the city a continuous — if somewhat limited — source of good quality ash.

(v) *Barbecue and grilling stands*

Lechon manok (barbecue and grill food stands) are a common sight along all the major roads of San Fernando and use wooden charcoal as fuel. The amount of ash generated daily depends on the amount of charcoal consumed, which is directly proportional to daily sales. Before grilling starts — usually in the early afternoon — the ash produced on the previous day is taken out and disposed of as ordinary garbage. Some vendors — including the vendor visited by the researchers — grill meat on skewers placed above the charcoal and use metal pans to collect the dripped fat. The quality and condition of the resultant ash — shown in Figure 6 — is sufficient for it to be used as an additive — as long as it is stored separately from other kinds of garbage to enable it to be collected by the city. Before ash of this nature can be deemed suitable for use, further investigation is necessary to ascertain the effect potentially large fat deposits in the ash could have on the process of sanitizing and dehydrating feces.

(vi) *A noodle factory*

Wood ash and carbonized rice hull were found in relatively large quantities at the storage area of a factory, where they are produced during the process of manufacturing "pancit canton" noodles. Figure 7 shows the open storage area where the factory stored all kinds of ash and carbonized rice hull. The common practice of mixing the ash with garbage generated inside the factory can also be seen in the figure.

The factory disposes of its waste once a month, using one or two 7 m^3 capacity dump-trucks. The exact volume of waste thrown out depends upon the quantities of fuel consumed (ie. combination of sawdust, firewood and rice hull) to produce noodles in a given month. A staggering 90 percent of the factory's waste is composed of ash. This was the main reason, perhaps, why during a visit from the researchers in October 2006 its owners expressed their willingness to supply ash to the city. Factory management has agreed to separate carbonized rice hull and ash from garbage at source and coordinate with the city on matters such as collection, should the city request ash from the factory in the future.

(vii) *In-house carbonized rice hull production*

A final option for maintaining a sustainable supply of carbonized rice hull for use in the city's UDD toilet expansion is for CENRO to centralize the manufacture, handling and distribution of carbonized rice hull by producing its own. This could have an additional environmental benefit: CENRO is currently experimenting with the use of a smokeless carbonizer installed with a condenser to eliminate smoke emissions.

The city cannot afford to rely on clean technology alone, given that its need for drying additives for use in UDD toilets is set to rise dramatically. The results of the weight-volume measurements survey described in Section 3.1.2 show that each household uses 1.25 kg of carbonized rice hull per day as an additive and 1 kg for every 38-day haulage schedule as a liner for the container in which feces are collected. From this, it can be calculated that 1,154 households — the number into which UDD toilets should be installed by 2010 — will require 55,969 kg of

Fig. 6　Potential source of charcoal ash from local roadside grills

Fig. 7　Potential source of carbonized rice hull and wood ash (left) disposed of with waste noodles (right)

carbonized rice hull in total for a 38-day period. A single hand-built carbonizer can produce 36 kg of carbonized rice hull over an eight-hour period, as shown by the researcher's field experiments summarized in Section 3.2(ii). A total of 41 such carbonizers would be needed to meet demand, were the city to rely wholly on in-house production.

It would be impossible for San Fernando to use smokeless carbonizers in these numbers, given their cost. It is equally impossible to accept the potential environmental cost to residents of 41 old-style carbonizers emitting smoke in the city's barangays. In-house production is, therefore, unlikely to provide a solution in itself. It can be part of the solution, however, if supplemented by other sources of carbonized rice hull and new sources of alternative drying additives, such as those described in the above sections. Together, all these sources could go a long way towards meeting the city's current need to find drying additives locally, without incurring expensive transport and distribution costs. Other possibilities, such as the use of rice hulls that have not been carbonized, should also be explored to ascertain if they are suitable for drying purposes. Rice mills exist in city barangays such as Abut, for example, and these might be tapped as local and abundant sources of rice hull.

3.3 Financial assessment of the options for transporting feces and urine

The following sections examine the capital, operation and management, and running costs of transporting feces and urine by three different transport options. Costs to the city are calculated on a per household basis and worked out in accordance with the serviceable number of households per haulage schedule for each transport option. Feces and urine are collected and transported at different intervals: 38 days, in the case of household feces containers, (for reasons already introduced in Section 3.1.2), and 30 days, in the case of communal storage facilities for urine, for reasons discussed later in this section. The cost of transporting feces and urine are dealt with separately in this assessment because of differences in the timing of haulage schedules and the equipment required for haulage.

3.3.1 Transporting feces

The same vehicle used to collect San Agustin's garbage is currently being used to transport feces from the designated staging area to the EcoPits (the city's secondary storage area), where they are buried for a prolonged period as part of the sanitization process. If the city's aim to expand UDD toilet usage to 1,000 additional households by 2010 is successful, it will be obliged to procure additional means of transport to effectively manage the logistics of its ecological sanitation program. A simple financial assessment was carried out to estimate the capital and operation and maintenance (O & M) costs for three road-based transport options: a system based on the use of one, two or three motorized tricycles,[7] a system using a small pick-up truck (the current method), and a system employing a large truck. All estimates were calculated on the basis of the inputs derived from the weight-volume survey discussed in Section 3.1.2 and the following basic assumptions:

1) *Duration of one hauling schedule*. Feces haulings take place for an eight hour period (the length of a normal working day in the Philippines), every 38 days (the optimum service hauling frequency);
2) *Duration of one hauling/service trip*. The average travel time to complete one round trip between the staging area and the secondary storage area is one hour (including time for loading and unloading the feces). This allows eight service trips in one hauling schedule;
3) *Aspects of location*. The locations of all households serviced are similar in aspect to UDD toilet-using households in San Agustin, with respect to (a) easy access to the designated staging area, and (b) the distance between the staging area and the secondary storage area.
4) *Daily generation quantities*. The weight of feces generated by an average household of five people will total 0.65 kg of feces per day, plus an additional 1.25 kg of carbonized rice hull, used as a drying additive, added at the time of defecation and a further 0.50 kg of carbonized rice hull used to line each feces container.
5) *Labor force*. A hauling team of three people was assigned for each haulage schedule, irrespective of the vehicle(s) used. All team members are able to drive and assist, switching roles according to the mode of transport being used in each hauling schedule.

A. Motorized tricycle system, based on the use of one, two or three tricycles

Each motorized tricycle has a haulage capacity of 825 L. Table 3 shows the optimum number of households that one, two or three tricycles can serve in an eight-hour period if each tricycle makes eight service trips: 40, 80, and 120 households respectively.

(i) *Initial investment*. The capital cost of a system using a single motorized tricycle includes two items: a tricycle unit price of Php 75,000, and the cost for

Table 3 Optimum number of serviceable households for each mode of transport used to move feces

Options	Haulage capacity (*L*)	No. of trips *per day* (a)	Serviceable no. of households *per trip* (b)	*per day*＝(a×b)
1 tricycle	825	8	5	40
2 tricycles	1,650	8	10	80
3 tricycles	2,475	8	15	120
Small pick-up truck	2,500	8	15	120
Large truck	18,000	8	113	904

Table 4 Cost of transporting feces based on the optimum number of serviceable households for each mode of transport

Options	Optimum no. of serviceable households	Capital cost (*Php*)	O&M cost (*Php*)	Running cost per household (*Php*)
1 tricycle	40	79,000	1,744	44
2 tricycles	80	158,000	3,024	38
3 tricycles	120	237,000	4,303	36
Small pick-up truck	120	12,000	1,824	16
Large truck	904	465,400	11,631	13

providing a bamboo basket or tiklis (Php 100/basket) to each UDD toilet-using household (Table 4). The baskets are made of very light bamboo, equipped with handles and will be provided by the city to aid the manual transportation of feces from each household to the staging area by household members: the metal drums used as feces containers in the first years of ecological sanitation in San Agustin are heavy and awkward to haul.[8]

Note that the capital cost varies as the number of serviced households changes. Variations occur even where the number of tricycle units used remains constant owing to variations in the costs incurred by supplying bamboo baskets to different numbers of households.

(ii) *Operation and maintenance cost.* These include an estimated monthly unit maintenance cost of Php 1,100 for servicing the engine and tricycle upkeep (tricycle parts wear out quickly), the cost of gasoline consumption, a small remuneration for the labor costs of three persons (including at least one driver and one helper), and the cost of personal protective equipment provision for each person involved in the hauling. O & M costs increase in line with the number of tricycle units because of the costs incurred in maintaining them.

(iii) *Running cost per household.* A simple calculation of the running cost per household is obtained by dividing the total O & M cost by the number of households serviced by each tricycle option (Table 4). Running costs ranging from Php 36 to 44 were computed for each tricycle system by dividing the O & M costs of each by the optimum number of households. The projected running cost for the three-tricycle system is cheaper than both the one- and two-tricycle options as long as it services the optimum number of households at which it is most cost-effective, that is, 120 households.

B. Small pick-up truck-based system

Equipped with a haulage capacity of 2,500 L per service trip, a small pick-up truck is capable of servicing 120 households in one haulage schedule, as shown in Table 3.

(i) *Initial investment.* San Agustin owns a small pick-up truck used for transporting garbage and employed this for hauling feces during the early schedules in the first year of the pilot project. For this reason, the estimated total capital cost of the small pick-up truck system does not include the capital cost of a pick-up truck.[9] The only costs of this system, amounting to Php 12,000 shown in Table 4, are for allocating bamboo baskets to 120 households.

(ii) *Operation and maintenance cost.* The unit cost for maintaining a small pick-up truck is estimated at Php 1,000 per month. Gasoline consumption, remuneration for labor and allocation for personal protective equipment are also included in O & M costs. Remuneration for labor was calculated at a rate of Php 100 per helper and/or driver per day, in line with the rate awarded during past hauling activities in the first year of the pilot project (this rate of payment may be revised in the near future to bring payment in line with the minimum wage in the Philippines). Taking on average an hour to complete a single return service trip, the small pick-up truck-based system is capable of making eight service trips during one haulage schedule, serving 120 households in total. Its haulage capacity is equal to that of the three-tricycle system, in other words (Table 3).

(iii) *Running cost per household.* The running cost per household for servicing 120 households using a small pick-up truck would appear to be highly cost effective, coming to approximately half (Php 16/household) the cost of the three-tricycle system (Table 4). It is important to note, however, that 120 households represent the optimum haulage capacity of using a small pick-up system. If the number of households increases beyond this — to 154, for example — the benefits of decreased running costs will be offset by increased capital and O & M costs because the city would either have to increase the number of trucks used or supplement the use of a single pick-up truck with other modes of transport. Either option would affect its cost effectiveness.

C. Large truck-based system

A single large truck has a haulage capacity of 18,000 L capable of serving 904 households in a single haulage schedule, as shown in Table 3.

(i) *Initial investment.* The estimated capital cost for a large truck that can handle the transport of both feces and urine (it may be equipped for the latter with the simple addition of two stainless steel tanks) is estimated to be Php

465,400, as shown in Table 4. Additional investment costs in the big truck-based system include the cost of providing one bamboo basket to each household, as for both the tricycle and small pick-up truck systems used to transport feces.

(ii) *Operation and maintenance cost.* A monthly unit maintenance cost of Php 10,000, on top of costs for diesel consumption, manpower (Php 250 per day for the driver and Php 200 per day for two helpers) and personal protective equipment make up the O & M requirements for this transport system. The increase in haulage volume made possible by this system necessitates the payment of a higher wage to the driver and helpers. The increase in salary is offset by lower operational costs overall, which reflect the advantages of scale: this mode of transport is capable of serving a vastly larger number of households — 113 households in a single service trip — within the same time scale, thus lowering the O & M costs per additional household serviced.

(iii) *Running cost per household.* Completing eight service trips at a full effective hauling capacity of 18 m^3, the large truck-based system can serve a total of 904 households in one hauling schedule at an estimated Php 13 running cost per household (Table 4). With running costs as low as this, the large truck system is by far the cheapest of all the modes of transport assessed in the survey, making it the best option in terms of San Fernando's plans to expand its ecological sanitation program.

Remarks

The findings summarized in Tables 3 and 4 indicate that the appropriate choice of transport will depend upon 1) the optimum number of households being served, 2) the maximum quantity of feces that can be transported in a single hauling schedule, and 3) whether the best system is affordable. There are 49 UDD toilets currently in use or under completion in San Agustin. A one-tricycle system for transporting feces and additive is the most practical and efficient option at present in terms of running cost per household. (In this case, the hauling schedule must be amended to allow haulers to service the additional nine households as the one-tricycle-system is only capable of serving 40 households at the optimum, as shown in Table 3).

A number of variables undermine the assumptions upon which Tables 3 and 4 are based. It is important to note that the number of households that can be serviced by each option may vary, according to the distance between the designated staging area and the destination area (secondary storage area, treatment facility, or disposal/reuse area) in a given service trip. The estimates made in this section assume that service trips are an hour in duration but trips may become longer as UDD toilet use is expanded to new households in the city and new staging and storage areas are found. Longer service trips will affect how many service trips can be made in a given haulage schedule: if trips become longer and fewer, fewer households will be served. Haulage distance is as such just as important as the choice of transport in terms of the service that can be provided.

Conditions specific to the local community are another variable that should be considered in selecting the appropriate mode of transport for feces. The system that works well in one barangay may be totally unsuitable to another. For example, vehicles designed to operate in areas of high population density may be ill-equipped to handle the haulage of human excreta in urban areas with a lower population density, which have poor access and undeveloped roads.

3.3.2 Transporting urine

UDD toilets have been installed in 49 households in San Agustin. At present, not all of the households are using the toilets. Those that do are responsible for transporting urine to the designated staging area, where it is stored in a communal tank for harvesting (collection) by the city. This section focuses on the costs of harvesting the urine of 49 households (the maximum possible at present) from the communal storage tanks to an area of application, such as the ornamental flower beds of Pennsylvania Avenue, in the first year of the project. Table 5 shows the capital, O & M, and running costs for transporting urine using the same vehicle systems identified in Section 3.3.1 for feces transportation. The following factors are considered basic assumptions in making these calculations: 1) the mode of transport used to move feces and urine is the same, 2) the total urine volume per haulage schedule is equivalent to the volume of urine generated by 49 participating households, 3) the duration of a single round trip from the staging area to the urine destination is one hour, including the time for harvest and application, and 4) the urine is harvested at a 30-day interval to allow at least one-month for storing urine, to render it safe for application.[10]

Table 5 Overview of the costs for storing and transporting urine based on the 49 households using UDD toilets in San Agustin

Options	Communal storage tanks	Cost for urine harvest & application (*Php*)			Capital cost (*Php*)	Monthly O & M cost (*Php*)	Running cost per household (*Php*)
		Pump & hose	Harvesting tanks	Trailer			
	(a)	(b)	(c)	(d)	(a)+(b)+(c)+(d)		
Tricycle	90,000	14,500	6,000	30,000	140,500	231	5
Small pick-up truck	90,000	14,500	6,000	30,000	140,500	261	6
Large truck	90,000	33,000	350,000	0	473,000	520	11

(i) *Capital costs of urine transportation.* The respective capital costs of the unit of transport used is excluded in this assessment because the capital costs of transport mode are already calculated in the feces transportation system, being used here to transport urine.[11] Instead, only investment costs that are specific to urine transportation were considered in estimating the capital costs of each transport option, namely, the costs of investment for any equipment to be used in harvesting and applying the urine. These include the cost — the same in each case — of equipping tricycles and the small pick-up truck with a trailer carrying a harvesting tank, a pump and hose (used both to empty the communal storage tank and distribute its contents at the final destination). Initial investment costs are higher for fitting out the large truck with two stainless steel tanks equipped with pumps and hoses for transporting and harvesting urine.

The cost of additional communal storage tanks is also factored into the capital cost of all three transport options. Approximately eight 1,500 L communal storage tanks — each costing Php 6,000 — are required to store the 11,099 L of urine generated in a month by 49 households (calculated on the basis of figures presented in Section 3.1.2). This tank requirement was doubled, however, to allow the contents of the first batch of full urine tanks to be stored for up to one month before harvesting, the minimum storage time required to render urine safe for agricultural application.

(ii) *O & M and running costs.* These are minimal, comprising only the incurred costs of gasoline consumption and labor costs used to transport the urine from the communal storage containers to its place of application. As O & M costs are relatively low, running costs per household for all three transport options are also low: costs ranging from Php 5 for the tricycle option to Php 11 for the large truck. Cost effectiveness to the city changes, however, as the number of households being serviced increases. The tricycle system is cost effective in terms of serving the 49 households currently using UDD toilets in San Agustin, but it will become less cost effective and practical as the volumes of urine generated increase beyond current levels as more households join the city's UDD toilet initiative.

Remarks

Low O & M costs may open up more possibilities for promoting urine-diverting systems by gaining wider acceptance for ecological sanitation. Good household management is crucial, to keep these costs at a minimum. Households should ensure they keep the urine highly concentrated for further sanitization by not adding water. They should also avoid the use of excessive water for flushing to avoid adding to the volumes of urine to be transported. Storing urine in an undiluted condition inhibits the proliferation of the micro-organisms present and accelerates the rate at which pathogens die. It is particularly important that urine is stored in an undiluted state in tropical and hot climates because mosquitos — which spread disease — cannot breed in undiluted urine (Winblad et al. 2004; Schonning and Stenstrom 2004).

The incurred costs of ecological sanitation should be compared with any possible costs that may be recovered and the economic merits of urine diversion and application should be explored further at the local scale. The likely benefits to the city and its residents of a successful ecological sanitation program are twofold: a developed UDD toilet system will mitigate some of the costs of waste water treatment and septage management, and the availability of urine as a high-quality fertilizer for the agricultural sector will decrease dependency on expensive chemical fertilizers.

4. Projections: using the data

This section uses the technical assessment for hauling collected feces and urine in combination with data from the San Agustin-based weight-volume measurements of urine and feces in order to make two sets of projections: the first, short term, with regards to the city's plans for Fisherman's Village, and the second, longer term, with regard to plans for the year 2010.

4.1 UDD toilets in Fisherman's Village

As introduced in Section 2.1, the city of San Fernando has initiated a resettlement program for families living in flood-prone areas in coastal barangays Ilocanos Norte and Sur. The city has identified 95 families for relocation to Fisherman's Village, a new housing project currently under construction in barangay Poro. Each housing unit within the new complex is to be installed with UDD toilet facilities, making Fisherman's Village the centerpiece in the city's ecological sanitation initiative.

(i) *Cost of urine collection and transport for Fisherman's Village*

The installation of centralized urine tanks in Fisherman's Village greatly simplifies the urine collection system for the community. All the UDD toilets in the housing units will connect to a main pipeline that empties into one of four communal urine concrete chambers, each servicing a specific number of households and each with a capacity of 6,000 L.

Table 6 shows an estimate of the daily generation quantities for each group of households connected to a chamber, if the values measured at San Agustin are

Table 6 Urine generation quantities and chamber filling times at Fisherman's Village

Chamber no.	Storage capacity (*L*)	No. of connected households	Urine quantity per connected household (*L per day*) (*based on regular users*)	Chamber filling time (*days*) (*based on regular users*)
1	6,000	28	211.40	28
2		22	166.10	36
3		25	188.75	31
4		20	151.00	39

applied to the housing project at Fisherman's Village. Twenty-eight housing units are connected through a main pipe to urine chamber 1, while chambers 2, 3 and 4 accommodate 22, 25 and 20 households, respectively. The table indicates that the chambers will be filled to capacity in 28 to 39 days if UDD toilets are used regularly, and average daily generation rates equal those of the residents of San Agustin, at 1.51 L per person. Haulage of urine will have to be undertaken before the chambers are filled because there are no spare chambers in place to accommodate changes in volume. Some of the families who will be living in the complex have fewer than five members. For this reason, the urine generation calculation (based on a five-member household) used to determine how long it will take to fill the chamber, should be adequate to offset possible overflows due to any sudden increase in the number of users or the use of excessive water to flush the urinals.

What are the projected costs for dealing with this amount of urine? Projections in the capital costs for Fisherman's Village exclude the construction costs of building the storage chambers because information on these costs was not available for computation in the study. Their inclusion would naturally have resulted in higher investment costs. The existence of in-built urine chambers renders secondary storage tanks, such as those allocated for San Agustin, unnecessary. Any remaining capital costs relating to the transportation of urine for Fisherman's Village are, therefore, made up solely of the investment costs of harvesting and application equipment (ie. harvesting tanks, pumps and hoses) shown in Table 7. With almost double the number of households to be serviced,

Table 7 Overview of the cost projections for storing and transporting urine in Fisherman's Village with 95 participating households

Options	Cost for urine harvest & application (*Php*)			Capital cost (*Php*)	Monthly O & M cost (*Php*)	Running cost per household (*Php*)
	Pump & hose (a)	Harvesting tanks (b)	Trailer (c)	(a)+(b)+(c)		
Tricycle	29,000	12,000	60,000	101,000	285	3
Small pick-up truck	29,000	12,000	60,000	101,000	369	4
Large truck	33,000	350,000	0	383,000	654	7

investments for harvesting and application equipment are twice as high as for San Agustin.

The monthly O & M costs shown in Table 7 for transporting urine from the chambers to their place of application are slightly higher than in San Agustin, for all three transportation options, as can be seen by comparing the results in Table 7 with those of Table 5. This is because larger volumes of urine are to be transported, a factor that directly influences the number of service trips that must be made, thus increasing gasoline consumption. Running costs per household are nevertheless lower in Fisherman's Village because the monthly O & M costs are distributed between 95 households — just under double the number of the households currently serviced in San Agustin.

(ii) *Cost of feces collection and transport for Fisherman's Village*

As discussed in Section 3.3, the specific haulage capacities of each mode of transport can serve an optimum number of households. Adopting the same conditions and assumptions, the San Agustin-based data shown in Tables 3 and 4 can be used to project the most appropriate and economical mode of transport for transporting feces for the 95 new households to be serviced in Fisherman's Village. The data in Table 4 suggests that a small pick-up truck can serve 120 households in a single haulage schedule at a running cost of Php 16 per household. Investing in a small pick-up truck is, as such, cheaper than acquiring three tricycle units, for which running costs would be Php 36 per household to serve the same number of households.

4.2 Longer term projections for the Year 2010: the city's commitment to ecological sanitation

The city plans to bring 1,000 more households into its ecological sanitation program by 2010, phasing them in gradually over a two-year period. Adding 1,000 new UDD toilets to those already in existence or under construction will bring the number of UDD toilets in the city to 1,154. Completion of this expansion plan can be expected to generate a massive 8,713 L of urine and 2,770 kg of feces plus additives per day (Table 8). Harvesting and finding a good use for urine and dried feces in these quantities is going to be a major challenge for the city in the years ahead.

(i) *Cost of urine collection and transport*

Table 9 sets out the estimated capital and monthly O & M running costs of servicing 1,154 UDD toilet-using households. The projections use the same conditions set for the San Agustin-based technical assessment described in Section

Table 8 Projected urine generation quantity for 1,154 UDD toilet-using households (by 2010)

Excreta & additives		Quantities Daily	Monthly	38 days
Urine (*L*)		8,713	261,381	331,083
Feces (*kg*)		750	22,503	28,504
Carbonized rice hull (CRH) (*kg*)	additive	1,443	43,290	54,815
	liner	577	1,154	1,154
Total CRH requirement (kg)		*2,020*	*44,444*	*55,969*
Total weight of feces & CRH (kg)		*2,770*	*66,947*	*84,473*

3.3. Investment costs amounting to Php 2,094,000 are for the provision of 349 plastic 1,500 L communal storage tanks in designated staging areas around the city, each at a cost of Php 6,000. This figure doubles the number of tanks actually required to store the volume of urine generated by 1,154 households in one month. Doubling the number of tanks allows urine to be stored for at least one month after the first batch of the tanks (175 in all) become full (a process that can be expected to take 60 days, if the urine generation volumes recorded in San Agustin in the weight-volume assessment study are accurate). The O & M costs incurred by the haulage, harvesting and application requirements of managing a monthly volume of 261.38 m^3 of urine (Table 8) are estimated to range from Php 5,239 to 7,194 (Table 9), depending on the selected mode of transportation: these include the gasoline and labor costs of an average eight service trips per vehicle type. A budget of Php 3.20 to 6.10 million in terms of capital costs will furnish the city with any of the following for use in harvesting and applying urine: (a) 22 trailers (including pumps, hoses and a harvesting tank) for attachment to either tricycles or small pick-up trucks, or (b) 11 stainless urine and water tanks (plus hoses and pumps) for installing in large trucks.

Based on the cost projections outlined above, 48 to 65 per cent of capital costs will have to be allocated to the facilities for storing urine. The O & M cost, however, when shared among the total number of households served, results in running costs per household that are within the same range as the running costs estimated for San Agustin and Fisherman's Village. The investment costs of storage may differ, however, if other types of storage system are used, such as

Table 9 Overview of the cost projections for storing and transporting urine by year 2010 with 1,154 participating households

Options	Communal storage tanks (a)	Cost for urine harvest & application (*Php*) Pump & hose (b)	Harvesting tanks (c)	Trailer (d)	Capital cost (*Php*) (a)+(b)+(c)+(d)	Monthly O & M cost (*Php*)	Running cost per household (*Php*)
Tricycle	2,094,000 (65%)	319,000	132,000	660,000	3,205,000 (100%)	5,239	5
Small pick-up truck	2,094,000 (65%)	319,000	132,000	660,000	3,205,000 (100%)	6,362	6
Large truck	2,094,000 (48%)	159,500	3,850,000	0	6,103,500 (100%)	7,194	7

concrete chambers similar to those constructed for Fisherman's Village. A Materials Recovery Facility (MRF), to be built near San Agustin's current staging area, is currently being planned as a viable secondary storage area for households not only in San Agustin but also Fisherman's Village and neighboring Poro.

(ii) *Cost of feces collection and transport*

As shown in Table 8, a combined mass of 2,770 kg per day of feces and carbonized rice hull will be generated upon the completion of 1,154 UDD toilets — a total of 84,473 kg for a 38-day hauling schedule. The breakdown of investment costs required to serve this number of households can be seen in Tables 3 and 4, which show the different costs of transporting feces to an optimum number of serviceable households by alternative vehicle options. The tables indicate that a combination of two modes of transport is economically feasible for transporting feces in these quantities: a large truck that is capable of serving 904 households plus a small pick-up truck that can serve 120 households, with respective running costs of Php 13 and Php 16 per household. The three tricycle system — cost effective for the same 120 households — incurs higher running costs per household compared with a small pick-up truck option.

It is important to note that the estimates given above are based on the same assumptions as that described in Section 3.3. With the expansion of UDD toilet provision to households all over the city of San Fernando, factors specific to different localities and communities will undoubtedly play a crucial role in identifying the best management system for transporting feces to the secondary storage area for further treatment in a given local context.

4.3 Conclusion: recommendations

Any effective logistics system for the city of San Fernando must integrate sanitization and reuse principles into the implementation of ecological sanitation. This study has shown that the best identified option does not only depend upon physical infrastructure and equipment, but also on local conditions, the cooperation provided by the households using UDD toilets and the commitment of local government. Active participation of the host communities is, therefore, an important component to the sustainability of the project.

The short- and long-term projections outlined in Sections 4.1 and 4.2 build upon the data collected in San Agustin over the course of a six-month assessment study, which measured the volume and weight of urine and feces generated by UDD toilet-using households. Average generation rates for a household of five members were found to total 0.65 kg of feces per person per day and 1.51 L of urine per person per day. Quantitatively, this adds up to an accumulated 38-day weight of 73.2 kg of feces and carbonized rice hull, and a monthly volume of 227 L of urine per household, ready for hauling every 38 days in the case of feces, or every month in the case of urine. The following recommendations are based on these results:

a) *Feces transportation in San Agustin.* Based on the cost of serving 40 households, the authors recommend the one-tricycle system as the most practical and efficient option for transporting feces in accordance to San Agustin's immediate needs. The remaining nine households currently installed with UDD toilets may be served by extending the hauling schedule period beyond eight hours. This extension may prove unnecessary if the haulage volumes for 49 households prove to be less than the quantities estimated for 49 five-member households (some households will have fewer members than five, the average number of household members calculated in the assessment study).

b) *Storage.* The city's current ecological sanitation needs already necessitate storage facilities that can accommodate a periodic amount equivalent to 38-day generation of feces and additives, and one month's urine volume, for the purposes of storage and sanitization. The feces and additives generated and collected every 38 days must be dehydrated and stored for six to 12 months, to render them sanitary for application in agriculture, and urine must be stored for at least one month before it is harvested for application. The existing single 1,500 L communal storage tank in San Agustin is already insufficient to accommodate the 49 households in which UDD toilets have been installed, if all toilets are used properly.[12] A per household urine generation of 7.55 L per day will fill the existing communal tank in approximately 4 days should all 49 households use their UDD toilets fully. It is therefore recommended that 14 more communal urine tanks should be installed immediately to increase holding capacity levels. In the short to mid term, the proposed materials recovery facility should allocate space to store urine for a period of at least one month and feces for a minimum of six months. The city's long-term expansion goals require a much larger area for storage. Two storage options are under consideration at present: the reservation of an area at a sanitary landfill currently under construction, and the construction of a new storage site at barangay Mameltac. In either case, the site will serve as the central treatment facility for the UDD toilet products for the additional 1,000 households.

c) *Additives.* The city should seek and organize additional suppliers of rice hull for use in carbonization, along with suppliers of carbonized rice hull, wood ash and other additives that can be used to dehydrate feces. Where possible, local suppliers should be used. The type of additives that are used to dehydrate and partially treat the feces should be varied in accordance with the city's re-use and/or disposal plan for sanitized feces. Ash, lime, sawdust, crude rice hull (non-carbonized), crushed dry leaves, peat moss and even dry soil are all good additives for absorbing odor and moisture and covering fecal matter. Feces dehydrated by the use of additives such as these make good compost. Wood ash (high in pH) sanitizes the feces not only with the aid of dehydration but by killing most of the pathogenic microorganisms.

d) *Carbonizing equipment*. Smokeless carbonizers should be used in place of the hand-built carbonizers being used at present if the city proceeds with current plans to produce carbonized rice hull in-house.

e) *Investigation of reuse options*. Further research on the reuse of treated feces and harvested urine from UDD toilets should be conducted by the city's Agriculturist Office. Reuse is crucial for the system's environmental and economic sustainability and will allow the city to recover the costs incurred in providing UDD toilets to ever-increasing numbers of households. Three methods of reuse merit particular consideration in the future: 1) the use of sanitized human excreta in agriculture for use by local farmers, 2) the use of sanitized feces as planting material along the periphery of the city's sanitary landfill area when construction is complete — this will condition the soil for the planting of vegetation in those areas of the landfill that will act as buffer zones between the landfill site and neighboring areas, and 3) the potential use of urine as a fertilizer for golf courses.

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Notes

1 *Barangay*, formerly known as *barrio*, is the native Filipino term for a village, district or ward.

2 It is assumed in this study that UDD toilet users in upland barangays maintain their own household level logistics system.

3 Heads from the following city offices sit on the TWG: City Environment and Natural Resources Office (CENRO),

City Health Office (CHO), City Planning and Development Office (CPDO), City Engineer's Office (CEO), *Sangguniang Panglungsod* (the city council) and the City Agriculturist Office (CAO). The Ecosan TWG was tasked to oversee, supervise, facilitate, and schedule activities in the two pilot barangays as part of the city's ecological sanitation project.

4 The Barangay Ecosan Committee (BEC) was created to oversee the implementation of the city's ecological sanitation activities at the barangay level. The BEC was legitimized through a resolution passed by the Barangay Council, which retained direct authority over the BEC. The barangay chairman enjoys executive power over the BEC.

5 These figures are rough estimates only: the researchers were obliged to rely upon the factory owner's recollections because no production records of any kind were kept during the period in which the factory remained operational. The factory's closure before the study was carried out naturally limited the capacity of the researchers to obtain accurate results regarding production volumes of carbonized rice hull.

6 This bakery stores ash inside the oven for a week or so as a heat retainer before disposing of it as ordinary garbage.

7 The motorized tricycles in question are actually motorcycles equipped with an improvized sidecar.

8 The use of *tiklis* or bamboo baskets to haul feces from each house makes the weight lighter for carrying and provides a welcome safety measure against unwanted contacts with the feces. Feces should be placed inside a sack or a thick plastic bag to prevent them from spilling or passing through the holes of the basket.

9 The researchers did not include the capital costs of purchasing a small pick-up truck in this assessment because the truck was already in use and the initial logistics study was conducted with a view to solving the city's immediate logistics problems rather than making long-term projections on the merits and demerits of different transport systems. The researchers acknowledge that this unit cost should be included in any future financial assessments that offer projections requiring the use of more than one small pick-up truck.

10 Urine contains less pathogenic bacteria than feces and is sterile when excreted by a healthy person. For this reason, no extra measures are needed to prevent disease transmission through urine products during handling and transport, beyond an initial period of storage (Slob 2005: 30). Winblad et al. (2004: 9) recommend that urine is stored for one to six months before harvesting and application. The period of time depends on how the urine is to be used: if it is to be used to fertilize vegetation in a tropical country such as the Philippines, a shorter storage period is possible than in more temperate regions. Where food crops are to be consumed raw, the experts recommend that urine is stored for at least one month before harvesting and mixed well with the soil, particularly if the edible parts of the plant grow above the soil surface (Winblad et al. 2004: 10).

11 This urine transportation assessment was made on the premise that the most appropriate and cost-effective transport system would be used to transport both feces and urine. A completely independent financial assessment should be made separately for feces and urine, if the real scale of cost effectiveness and appropriateness of the available options are to be explored in detail.

12 Fortunately, perhaps, in this respect, some households are not cooperating fully at present in bringing the urine they generate to the staging area for communal storage. In addition, some household users — most often men — use the UDD toilets only on an irregular basis. Both these factors mean that the single communal tank currently available in San Agustin is able to cope with demand — a situation that could change at any time as households become more efficient users of their UDD toilets.

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Dave Mateo is a PhD candidate in the Department of Technology and Ecology at the Graduate School of Global Environmental Studies, Kyoto University, Japan. He received a Bachelor degree in Civil Engineering and Environmental and Sanitary Engineering from Mapua Institute of Technology in the Philippines and a Master's degree in Environmental Management from Kyoto University. He specializes in strategic sanitation planning for developing countries, with a particular focus on the management of urine diverting dehydration toilets used in ecological sanitation initiatives in the Philippines. Dave presented recently on the management and construction of dry toilets in urban settings at the World Toilet Summit 2007 in New Delhi, India.

Agnes L. Goze is pursuing her PhD at the Institute of Environmental Science and Meteorology at the University of the Philippines, Quezon City, Philippines. She has a Master's degree in Environmental Science and Technology from the International Institute for Infrastructure, Hydraulics and Environmental Engineering in Delft, the Netherlands, and a Bachelor of Science in Chemical Engineering from Saint Louis University, Baguio City, Philippines. She worked with an NGO, implementing ecological sanitation in the city of San Fernando, La Union, from January 2006 to December 2007.