THE USE OF HUMAN URINE AS CROP FERTILIZER IN MALI, WEST AFRICA

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Figure I: Gemma Kite, with a completed urine collector. Gemma took most of the photos used in the figures for Chapter 4.

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ABSTRACT

People have used animal and human feces to fertilize crops for centuries because manure contains many vitamins that plants need. What most people do not know is that the majority of beneficial nutrients leave human and animal bodies through urine rather than through feces, and the majority of urine is pathogen-free. People in the developed and developing world are beginning to use this untapped nutrient potential to fertilize crops with great success.

Waste collection systems in the developed world are often centralized and are difficult and costly to upgrade to a urine separation system, but most sanitation systems in the developing world are on site. Moreover, while many development organizations are focusing on expensive composting toilets to replace existing latrines, these organizations are missing the intermediate step of urine fertilizer use to ease communities into nutrient recycling ideas in a sustainable way. Small adjustments in behavior can be made and inexpensive systems can be designed to collect urine, which can then effectively fertilize most crops. This can lead to increased food production and simultaneously increase the overall effectiveness of on-site sanitation systems.

This report explores current research on urine fertilizer and several aspects of urine fertilizer projects done by Peace Corps volunteers in Mali, West Africa. Peace Corps volunteers in Mali, West Africa are using a pilot project approach (based on the development philosophy outlined in *Two Ears of Corn* by Roland Bunch) to propagate the use of small urine collection systems in a sustainable way. The urine fertilizer trials teach people about small-scale experimentation. Trials also teach people about the value of urine as a fertilizer and the value of closed-loop sanitation. These urine fertilizer projects can easily be adapted to other communities and have the same effect. As communities accept the urine fraction of their waste as a valuable resource, they can begin to embrace the more complex and expensive aspects of closed-loop sanitation.

For Peace Corps Mali urine fertilizer projects, volunteers work with a small group of participants who try urine fertilizer on a small portion of their fields or gardens. Urine is collected in a jug and funnel system made of locally available materials. The urine is collected and diluted in a safe manner to avoid pathogen transfer and nitrogen losses as ammonia. Urine is applied at doses based on locally recommended nitrogen needs for specific crops and estimated nutrient values. Strong nitrogen doses are applied to increase the visible effect that urine fertilizer has on crops.

Participants join projects through a series of mutual agreements decided on by community leaders, project leaders, and by the participants themselves. Participants are encouraged and aided throughout the trials. Each participant is encouraged to work closely with and encourage others to build a support system. Success with urine fertilizer has been high, and participants are encouraged to show other community members and leaders the successes they find. The participants then become the teachers and project assistants and the use of urine fertilizer slowly begins to spread throughout the community. Participants also gain confidence in their ability to work with new technologies, experimentation, and community development with less and less outside help. In this way, the urine fertilizer projects lead to capacity building and to improved sanitation.

1. INTRODUCTION

Human waste removal is an important part of daily life, and it is an important factor in human health (Esrey et al, 2001: 33). The goal of most modern day sanitation systems is to prevent exposure of humans to the harmful pathogens that are found in excrement. Most systems in the developed world seek to carry away waste, remove pathogens and pollutants in an energy-intensive treatment system, and then release the contents back into nature, often in large volumes of diluted waste that can cause eutrophication. In the developing world, latrines are often used in various ways that concentrate the excrement and still pose a health risk (though this is better than excrement left out in the open). In addition, when sewer systems are used in the developing world, they often focus more on carrying away waste than adequately treating the waste, discharging pathogens that will contaminate the food and water of people downstream (WHO, 2006: 16). Also, sewers may not be an appropriate technology in areas of the world that are water stressed (Fry et al, 2008).

Beyond these very real concerns, there is also a growing awareness of the valuable nutrients being lost in human waste streams. A new paradigm is forming in the water and wastewater management sector to focus on the resources that can be recovered from wastewater rather than the constituents that must be removed (Guest et al, 2009: 6127). Current human waste collection systems do much to minimize human contact with the pathogens in excrement, but little to ensure that those nutrients will be returned to natural systems in a way that benefits food production soils. "[O]ur modern society separates food production and consumption, which limits our ability to return nutrients to the land. Instead, we use them once and then flush them away" (Vaccari, 2009: 55).

At the same time, soils are losing nutrients at an alarming rate, especially in Africa[1] (Connor, 2006: 1). Chemical fertilizers of many kinds are widely used, but the materials to create them are becoming increasingly more difficult to obtain. The nitrogen, phosphorus, and potassium that make up the majority of these fertilizers come from finite resource pools. The majority of nitrogen is made from natural gas and is subject to price changes and availability of methane. And while global potassium mines should last several centuries, global phosphorus mines are set to run out in less than a century, and the U.S. may run out in a few decades[2] (Vaccari, 2009:54). The cost of making and buying fertilizer is further exacerbated by fluctuations in oil prices. From 2006 to 2008, spikes in petroleum prices

[1] "[T]hree-quarters of Africa's farmland is plagued by severe soil degradation caused by wind and soil erosion and the loss of vital mineral nutrients. This degradation can partly explain why agricultural productivity in Africa has remained largely stagnant for 40 years while Asia's productivity has increased threefold… African farmers must have access to affordable mineral and organic fertilizers if they are to stand any chance of reversing the decline of soil fertility." (Connor, 2006: 1).

[2] "The U.S. is the world's second-largest producer of phosphorus (after China), at 19 percent of the total, but 65 percent of that amount comes from a single source: pit mines near Tampa, FL… Meanwhile, nearly 40 percent of global reserves are controlled by a single country, Morocco" (Vaccari, 2009: 54).

helped cause fertilizer costs to nearly triple and food transportation costs doubled (FAO, 2008: 5). Buying fertilizers and/or importing foods from outside the community will become more and more expensive as these resources become less available.

Figure 1.1: Urine diversion for a compost toilet (Photo by Karin Ahlgren, used with permission) (Kvarnstrom et al, 2006: 7)

In recent decades, closed-loop sanitation has received attention as a way to reduce health risks while at the same time recover useful nutrients and return them back to food systems quickly, preferably at a community level. The idea is to use excrement collection methods to facilitate the decomposition of pathogens and other excrement material into materials that can be used directly for crop production, which can then help alleviate malnutrition and possibly increase income (WHO, 2006: 29). One important component of closed-loop sanitation is the separation of urine from the waste stream, keeping excrement dry and speeding up decomposition of pathogens (WHO, 2006: 85).

In the developing world, where most sanitation systems are self-contained on site, urine separation is relatively easy and inexpensive. Urine also contains a high proportion of important nutrients in forms directly available to plants, and because urine is usually pathogen-free and low in heavy metal concentrations, it can be easily turned into a plant fertilizer (Kvarnstrom et al, 2006: 3). If all the urine were to be collected from one person, the urine would have enough usable nutrients to fertilizer 300-400 square meters of crop per year (Jonsson et al, 2004: 1). The World Health Organization has stated that recycled excreta nutrients have the potential to ameliorate poverty through the following (quoted from WHO, 2006: 17):

- Improved household food security and nutritional variety, which reduce malnutrition.
- Increased income from sale of surplus crops (the use of excreta and greywater may allow cultivation of crops year-round in some locations).
- Money saved on fertilizer, which can be put toward other productive uses.

This research report will focus specifically on urine fertilizer projects in Mali, West Africa and how the discussed approach can be adapted for other developing world communities and other closed-loop sanitation projects. These projects are not solving all health and sanitation issues, nor are they yielding enough fertilizer to increase production on a large scale, at least not initially. Instead, the projects demonstrate the value of nutrient recycling, the value of experimentation, and the possibilities that could open up for communities.

Chapter 2 outlines the basics and benefits of closed-loop sanitation and urine fertilizer. Chapter 3 explains how urine works as a fertilizer to improve crops. Chapter 4 explains the thinking behind a urine collector, tells how they are made in Mali, and describes how this approach can be adapted to other communities. Chapter 5 addresses these concepts in terms of the making of urine fertilizer, and Chapter 6 does the same for the application of urine fertilizer.

Chapter 7 explains the development philosophy of the book *Two Ears of Corn* and describes how this development approach was used to design urine fertilizer pilot-projects. Chapter 8 provides case studies of some projects done in Mali. Finally, Chapter 9 tells what happens after initial pilot projects have been done and articulates ideas for future research on the topic of urine fertilizer.

2. UNDERSTANDING CLOSED-LOOP SANITATION AND URINE

2.1 Nutrient Cycles Concerning Human Waste

2.1.1 Nutrient Cycle: The Human Body

When a person eats plants, or eats animals that have been eating plants, she is ingesting all of the elements that once made up a perfectly good plant. Her body breaks down the plant and animal tissue and uses it to build new cells. Unless she is growing or gaining weight, these new cells are mostly just replacing old, broken down cells in her body (Drangert, 1998: 161). Even when children are growing, only a small portion of nutrients is retained in the body. For example, Swedish children between 2 and 17 only retain "approximately 2%, 6%, and 0.6% for N, P, and K, respectively" (Jonsson et al, 2004: 5). Old cells that have been replaced make their way into the blood stream and exit the body through exhalation, defecation, or urination.

While it is true that a person will exhale some of the plant-building elements she ingests, these mostly consist of carbon, hydrogen, and oxygen; elements that plants can get from the atmosphere. The remaining elements that are required for plant growth are entering the body and exiting the body at a fairly constant rate. In fact, if one could somehow harness every atom that exits a person's body, there would be almost enough atoms of each element to create enough protein, fat, carbohydrates, and nutrients to feed that person indefinitely (Jonsson et al, 2004, 5; Kvarnstrom, et al, 2006: 34). Of course, atoms from human waste are not procured and are not so easily rearranged into edible plants. In fact, the human body has a tendency to take these potential plant-building elements and turn them into, among other things, harmful germs that exit the body in feces.

2.1.2 Nutrient Cycle: Typical Food Systems

In the developing world, food systems usually operate in the manner depicted in Figure 2.1. Food is grown and harvested. It can then be fed to other animals, whose bodies build new cells using the same plant-building elements. Humans then consume the harvested plants or animals, digest the plant-building elements, and build new cells. Old cells are excreted along with other wastes, including some potentially harmful intestinal germ cells.

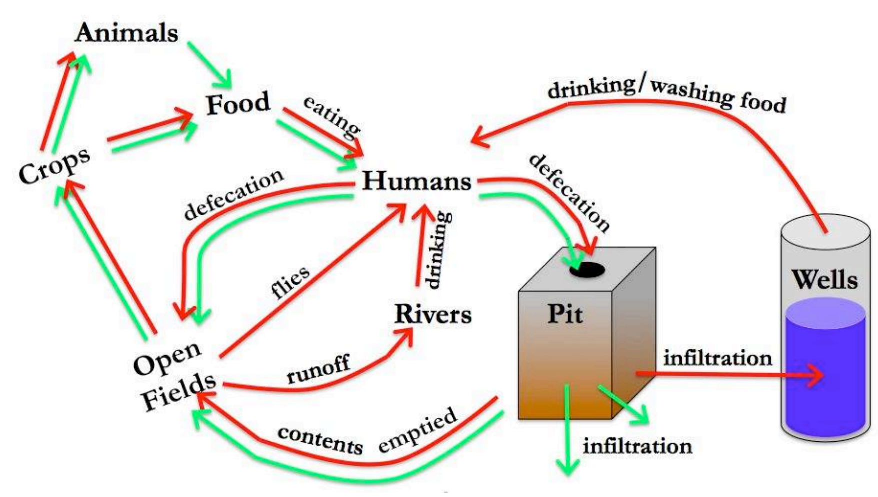

Figure 2.1: Nutrient and pathogen travel in typical developing world sanitation systems, with people defecating in pits or fields. Green arrows indicate nutrient travel; red arrows indicate pathogen travel.

This waste is often disposed of improperly or inadequately. Some cultures still defecate in open fields, leading to the contamination of food and water. Others build pit latrines, which are healthier than open defecation, but can still lead to the same contamination when left uncovered. Moreover, latrine pits are often dug near wells, near natural drinking water sources, or in areas where feces can contaminate groundwater, and it can take many years before these pits become pathogen-free. These pathogens work their way into humans and cause the diseases (mostly diarrheal diseases) that account for between two and three million deaths each year (Esrey et al, 2001: 8). In Africa, for example, diarrheal disease accounted for an estimated 707,000 deaths in 2002 (WHO, 2004: 120)

2.1.3 Nutrient Cycle: Closed-Loop Food Systems

The goal of "closed-loop" sanitation is to turn human waste back into plants as quickly, efficiently, and safely as possible. Rather than just dispose of the waste, closed-loop sanitation works to kill diseases and change valuable plant-building elements back into a form that can be put into soil to help plants grow (Figure 2.2). A nutrient loop is thus created where nutrients are recycled back into food growth.

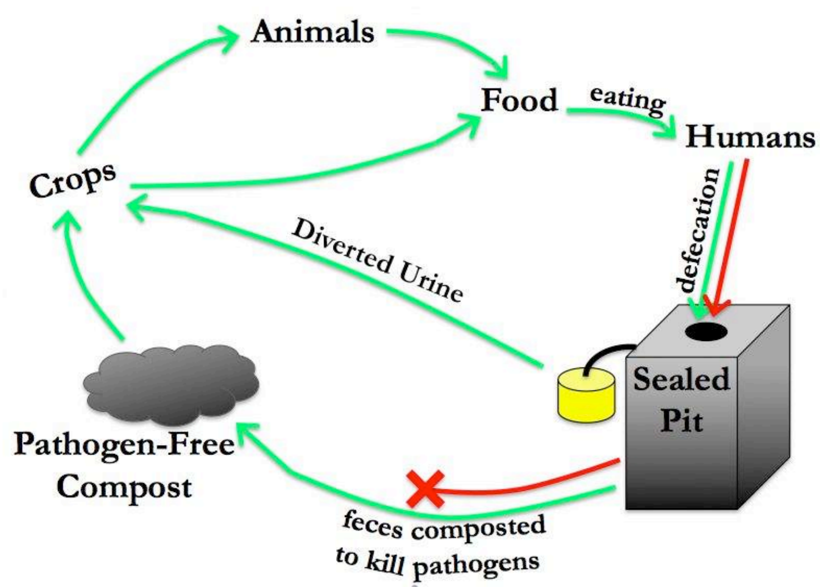

Figure 2.2: Closed-loop sanitation, in which human excreta are ideally turned back into plant nutrients efficiently and safely. Green indicates nutrient travel; red indicates pathogen travel.

In the developed world, closing the sanitation loop saves energy and materials that would be required for treatment (Tuhus-Dubrow, 2008: C3). It also has the potential to limit discharge of high volumes and low concentrations of nutrients that occur during point discharge to surface waters. In the developing world, closing the loop saves resources, increases crop yields, and offsets the need to buy fertilizer.

People have been using human and animal feces to fertilize crops for centuries[3] because they have understood that feces helped plants grow, but the re-use of human feces has not often been implemented in a sanitary manner. The focus of development organizations has therefore generally been the proper inactivation of the fecal pathogens. Sealed pit latrines, composting latrines, and arborloos[4] have all been used to help keep feces properly disposed until pathogens are killed. Then the feces can be used safely to fertilize crops.

While it is important to encourage the proper disposal of feces, this has often overshadowed the importance of urine in closing the sanitation loop. Urine has often been separated with the sole purpose of keeping the feces dry for faster pathogen destruction. Now, researchers are noticing that urine itself has much inherent value and is an important product of closed-loop sanitation.

Benefits of Feces: Further Reading

The focus of this report is on urine and its use, but this is not to minimize the importance of moving towards the safe re-use of feces. Urine will be discussed in contrast to feces to point out that it may be the easier of the two to start focusing on. The reader will find a lot of useful information on feces re-use in *Closing the Loop: Ecological Sanitation for Food Security* (Esrey et al, 2001) and in *Guidelines on the Use of Urine and Feces in Crop Production* (Jonsson et al, 2004).

[3] "Until recently, the reuse of human excreta as a fertilizer was the norm in most cultures and societies, and it was an established practice in Europe and the United States earlier this century" (Esrey et al, 2001: 12).

[4] The Arborloo is a moveable slab latrine with a dry, shallow pit. When the pit is full, it is topped with soil and a tree is planted. The slab is then relocated to a new pit, and the cycle begins again. See *The Arborloo Book* (Morgan, 2000).

2.2 The Benefits of Urine as a Fertilizer

There are many reasons that urine works so well as a fertilizer. Human urine contains very few, if any, pathogens but contains the majority of plant fertilizing nutrients (Esrey et al, 2001: 12). This high nutrient, low pathogen combination means that urine can be used very easily and safely to increase the yields of food crops. Add to this the ease and low cost of separating urine in most developing world sanitation systems, and it is easy to see why the use of urine fertilizer could mean very real benefits for farmers and families with small gardens.[5]

2.2.1 Basic Plant Nutrition

All plants need certain proportions of air, water, and several nutrients in order to grow. Each of these must be present in sufficient amounts if the plant is to continue to live and grow. When any of these is in short supply, it will limit the growth of the plant. If a plant is deficient in water, for example, adding more nutrients will not help the plant grow. If a plant is deficient in a certain nutrient, such as nitrogen, this deficiency will limit the growth of the plant even if all other nutrients are available in excess. A deficiency in any single nutrient will be the limiting factor for growth.

Ninety-six percent of the nutritional needs of a plant are met by hydrogen, carbon, and oxygen, all of which are found in air and water (Esrey et al, 2001: 44). The remaining nutrients are divided into two categories: macronutrients and micronutrients. The macronutrients nitrogen, phosphorus, potassium, magnesium, calcium, and sulfur are needed in larger proportions than micronutrients and are therefore usually the limiting factor in plant growth (Jonsson et al, 2004: 2).

Farmed land often becomes especially deficient in nitrogen, phosphorus, and potassium (Jonsson et al, 2004: 2). These can be replaced by adding compost, manure, organic matter, or fertilizer. Indeed, most commercial fertilizers are labeled with an NPK number that delineates the proportion of nitrogen (N), phosphorus (P), and potassium (K) it contains. Though each are important for all plants, a rule of thumb is that nitrogen is important for stem and leaf production (the green stuff), phosphorus for root production, and potassium for fruit production and ripening (Morgan, 2003: 1).

2.2.2 Importance of Nitrogen

For most plants, "The use of N is usually higher than the total use of the other macronutrients and micronutrients together" (Jonsson et al, 2004: 2). Even if plants are growing, insufficient nitrogen in soils will lower the protein content of many plants and feeder crops (Esrey et al, 2001: 45). Note the importance of nitrogen in amino acids and protein chains. Nitrogen, therefore, is essential for both the

[5] Note that urine diversion can be used in other beneficial ways, such as improving septic system operation (Esrey, 2001: 29) and improving the nutrient content and breakdown of non-human-feces compost (Kvarnstrom et al, 2006: 39).

growth of plants that will provide valuable vitamins and nutrients for the people consuming the plants, and nitrogen is also essential in the amount of protein that will be consumed.

The large amount of nitrogen losses from many farming practices also increases the need for nitrogen in food production systems. Plants consume a large amount of nitrogen from the soil, and when plant material is removed during harvest, the nitrogen goes with it. Large nitrogen losses also occur when people burn their fields after harvest, as is the case in Mali, for example (Abdulai and Binder, 2006: 211). An optimum amount of nitrogen is therefore rarely present in farming systems, with soils in Africa being particularly deficient in nitrogen and other nutrients (Sanchez and Palm, 1996: 4).

2.2.3 High Nutrient Content of Urine

Figure 2.3 shows the proportions of excreted nitrogen and excreted phosphorus found in urine (the remaining portion being found in feces) from research done on Swedish excreta and Chinese excreta. It can be seen that a much higher portion of excreted nitrogen leaves the body in urine, with nitrogen often being the limiting factor in plant growth as discussed. The data for phosphorus vary, but it can be seen that a substantial portion of excreted phosphorus leaves the body in urine as well. Concerning potassium, Drangert states that the proportion excreted in the urine can be as high as 75% (1998: 161).

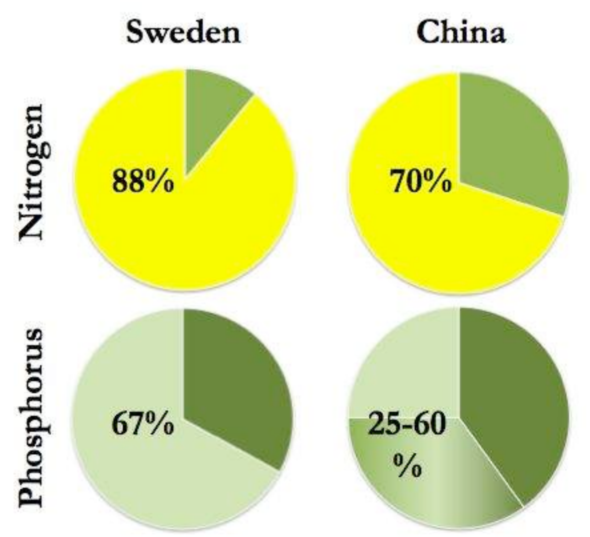

Figure 2.3: Percent of excreta nutrients found in the urine (as opposed to feces) of Sweden and China. Data from Jonsson et al (2004: 7)

When these nutrients are mixed with feces as in normal sanitation systems, they are mixed with harmful pathogens and difficult to recover in a useable form[6] (Tuhus-Dubrow, 2008: C3). Yet even when the urine is kept separate and discarded, these valuable nutrients are being lost. Open urination and even urine runoff into soak-pits mean urine is added to the soil in excessive concentrations, and often not

[6] A note concerning developed countries: "Urine makes up less than 1 percent of all waste water in developed countries, but contains a huge portion of the nitrogen and phosphorus. Those nutrients are essential to agriculture, but harmful to water bodies, and removing them is the most energy-intensive part of treating waste water" (Tuhus-Dubrow, 2008: C3).
A note concerning treatment in developed countries: "Lower starting levels of nitrogen and phosphate mean that the microbes in the aeration tanks can do their job much more efficiently, taking just one day compared with about 30, thus reducing the energy demand of the aeration tanks. What's more, the resulting sludge is richer in organic matter and generates more than three times as much methane. In fact, says Wilsenach, separating out 50 to 60 per cent of the urine could turn sewage works from net consumers to net producers of energy to the tune of about 2.5 watts per person" (Lawton, 2006: 2).

near plants that would benefit. When the urine is separated and stored, these nutrients are easily harnessed and can be applied to plants for increased production.

2.2.4 Low Pathogen Content of Urine

The urine of a healthy person is sterile, and although bacteria are picked up in the urinary tract, they do not pose a significant health risk from a healthy person (WHO, 2006: 34). Furthermore, few diseases are transferred through urine, and the risk of transfer for these through the use of urine fertilizer is insignificant, with the exceptions being: (1) schistosomiasis or (2) the possible contamination of urine with feces, both of which can be minimzed (WHO, 2006: 36). Schistosomiasis can be prevented with urine collection techniques, and urine can be treated if fecal contamination is suspected. Even with these two concerns, risks of transfer are low enough that urine collected within a family and used on that family's crops is assumed to pose no health risk, with the assumption being that the family would know if someone had accidently contaminated the urine being used (Jonsson et al, 2004: 10).

While any design must consider the risk of pathogen transfer, there may actually be health benefits to using urine as a fertilizer, especialy if used in a safe manner. It is suspected, in fact, that urine which is currently added to both drop-and-store systems and of flush-away systems poses a greater health risk than diverting that same urine for use as fertilizer (Esrey et al, 2001: 40; Jonsson et al, 2004: 8). "In practice, inactivation of pathogens in the soil may contribute importantly to overall risk reduction[7]" (WHO, 2006: 42).

2.2.5 Ease of Separating Urine

It is often assumed that new latrines must be built in order to achieve urine separation. Many development workers encourage closed-loop sanitation, but push for building expensive composting latrines. They point out that retrofitting existing systems can be expensive and ineffective in sanitizing feces (Esrey et al, 2001: 15). But this is not the case for urine separation. Using a little creativity and behavior modification, urine separation can be an easy, cost effective addition to most

Figure 2.4: Urine separation devices. (Right photo from WHO with permission (2006: 86); left from GTZ with permission) (Kvarnstrom et al, 2006: 17).

[7] "Inactivation is often more rapid in the soil and on crop surfaces than in stored excreta and greywater and more rapid on crops than in soils" (WHO, 2006: 42).

on-site systems. In West Africa, where squat-hole latrines are used, people can collect urine in containers and easily use systems such as the one described later in this report. Modified squat holes have also been developed, as shown in Figure 2.4.

Even in places where seat toilets are used, the seat can be modified to collect urine even from seated females. At worst, urinals can still be set up to collect a portion of the urine, preventing at least some of these valuable nutrients from being wasted and providing some fertilizer. Again, once the value of this collected urine is seen, people will be more willing to upgrade to a modified urine-separating seat.

The collection of urine takes some getting used to, but once people see the effect it can have on their food crops, they are much more willing to change their behavior. In places like Benin in West Africa, urine separation was not easily accepted, but once locals started seeing an increase in crop production, it became valuable to them, to the extent that robbers are known to steal jugs of urine in the night and return them empty (Kvarnstrom et al, 2006: 7). Rather than taking an all or nothing approach to closed-loop sanitation, urine separation can be looked at as the low hanging fruit on the closed-loop sanitation tree: once urine separation is understood and valued, people will be more likely to embrace the value of more complicated components of larger closed-loop systems.

2.2.6 Benefits in Terms of Feces Breakdown

While some of the benefits of urine diversion were mentioned in the preceding section on nutrient cycles, it is important to reiterate that urine diversion offers additional benefits in terms of fecal decomposition and pathogen destruction. Encouraging people to divert urine from their current sanitation systems allows those systems to work better. A dryer pit means faster destruction of pathogens from desiccation (WHO, 2006: 85). Less urine in the pit also means less unpleasant odor, since most of the smell from conventional mixed toilets comes from transformation of urea to ammonia (Drangert, 1998: 158).

Furthermore, a dryer pit means less horizontal travel of pathogens and surrounding water resources, such as rivers or wells. In countries where water is used for anal cleansing, it is a small step for people who already avoid adding urine in the pit to move slightly to avoid anal cleansing water in the pit as well. And if contents are to be removed from the pit, this dryer, less odorous feces is much easier to work with, and its handling will be much more sanitary due to a lack of splashing. Easier removal of feces increases the lifetime of the toilet (Kvarnstrom et al, 2006: 2). All of these effects lead to a more sanitary environment.

3. HOW URINE WORKS AS A FERTILIZER

NOTE: The document "Guidelines on the Use of Urine and Feces in Crop Production" by Jonsson, et al, was invaluable in developing this section of this report. Anyone seeking more information on the nutrients in urine and their relation to plant growth, or on the proper and hygienic use of urine fertilizer of food crops, is highly encouraged to consult this thorough and interesting document. An updated version of the document will be available the summer of 2010, while the current document (and many others concerning closed-loop sanitation) can be found on the ECOSAN web page at: <http://www.ecosanres.org/pdf_files/ESR_Publications_2004/ESR2web.pdf>

3.1 Studies on the Nutrient Content of Urine

Very few studies have been performed to determine the exact nutrient breakdown in urine, and the problem is compounded by the fact that proportions will depend on the current diet of the person excreting the urine. Table 3.1 gives the mass of nitrogen, phosphorus, and potassium excreted by humans each year for several sources. The data that has been found shows that a substantial proportion of these important plant nutrients are found in urine.

Table 3.1: Mass of Certain Nutrients Excreted per Capita per Year.

Nutrient	Urine [kg/cap/yr]	Feces [kg/cap/yr]	Total [kg/cap/yr]	% of Nutrient Found in Urine
Nitrogen	4.0	0.5	4.5	89%
Phosphorus	0.4	0.2	0.6	67%
Potassium	0.9	0.3	1.2	75%
Source: Swedish Data (Drangert, 1998: 161)				
Nitrogen	2-4	0.3-0.55	2.3-4.6	87%
Phosphorus	0.2-0.37	0.1-0.2	0.3-0.57	67%
Source: (Kvarnstrom et al, 2006: 3)				
Nitrogen	--	--	--	70%
Phosphorus	--	--	--	25-60%
Source: Chinese Data (Gao et al via Jonsson et al, 2004: 7)				

A method has been developed to estimate nutrient outputs in human excrement as a function of consumed protein. The FAO provides per capita protein consumption data on a country-to-country basis. This data can be used to predict the nitrogen and phosphorus outputs with the following equations (Jonsson et al, 2004: 5):

$$\text{Nitrogen} = 0.13 \times \text{Total Food Protein} \qquad \text{(Equation 3.1)}$$

$$\text{Phosphorus} = 0.011 \times (\text{Total Food Protein} + \text{Plant Food Protein}) \qquad \text{(Equation 3.2)}$$

This is valuable information, especially since nitrogen is often the limiting nutrient in agricultural systems.

Nutrient concentrations in the urine can then be calculated if urine production rates are known. The average human produces from 0.8 to 1.6 liters of urine per day, with Swedish data showing 550 liters per person per year (Vinneras via Jonsson et al, 2004: 7) and Chinese data showing 580 liters per person per year (Gao et al via Jonsson et al, 2004:7). When estimating the urine volume produced, it is important to consider factors that will affect the liquid consumption and the amount of perspiration of a given person or population. These factors include eating and drinking habits, working conditions, climate, and the season in which urine is collected.

3.2 Estimating the Nutrient Contents of Urine in Mali

According to FAO data, Malians consume 63.7 grams of protein per capita per day, and 74.1% of the protein (or 47.2 grams/cap/day) comes from plant sources (FAO, 1999: 4). Using Equation 3.1 and Equation 3.2, the nitrogen and phosphorus excreted by a Malian would be 8.3 grams/day and 1.3 grams/day, respectively.

To calculate the nutrients that are excreted in urine (as opposed to the numbers above, which are the combined urine and feces output), this study assumes that the percentages from Gao et al (via Jonsson et al 2004: 7) provide a better representation of Malian excreta, both because of the relatively small amounts of meat in the typical Chinese and Malian diets, and because the Chinese case represents a more similar situation than the other numbers available (presumed to come from samples in the developed world). It should be noted that nitrogen is the more important nutrient for calculations in this report, and the nitrogen percentages in Table 3.1 are similar. This report will therefore assume that urine contains 70 % of the nitrogen and 25-60 % of the phosphorus excreted from a typical Malian, as reported by Gao et al (via Jonsson et al 2004: 7). The nitrogen and phosphorus excreted in one Malian's urine would therefore equal **5.8 grams/day** and **0.33-0.78 grams/day**, respectively.

To calculate the concentration, existing data for urine production should be used. Mali is a hot West Africa country where over 93% of the people work in agriculture (PRB, 1998: 1). Although Mali is dry for most of the year, the projects discussed in this report were all done during the rainy and humid farming season, meaning water availability is higher. During farming season, people were working long hours in 35-40 degree Celsius heat and perspiring heavily. And although almost two-thirds of Mali is in the Sahara desert, all of these projects were done in the semi-arid southern third of the country. These high perspiration conditions should be canceled out by the high availability of water, so this report will assume the widely accepted value of 1.5 liters of urine output per capita per day (Jonsson et al, 2004: 7). Using these combined assumptions, the concentration of nitrogen and phosphorus in the urine of a Malian would be **3.9 grams/liter of urine** and **0.22-0.52 grams/liter of urine**, respectively.

3.3 The Fertilizing Ability of Urine

One reason that urine is an appropriate fertilizer is because the majority of the highly available nutrients in urine exist in a form that plants can use easily.[8] Seventy-five to 90 % of the nitrogen in urine is in the form of urea,[9] which becomes primarily ammonium ions in an aqueous solution of near neutral pH. This ammonium can be biochemically transferred to nitrate (NO_3^-) in the presence of oxygen (Jonsson et al, 2004: 9). Phosphorus is excreted as phosphate ions (Jonsson et al, 2004: 9). The majority of potassium, sulfur, and most minerals are also present as free ions (Jonsson et al, 2004: 9). These nutrients are directly available to plants in these forms without processing. As with chemical fertilizers, urine is therefore a dilution of fast-acting plant nutrients that can work quickly to nourish plants (Kvarnstrom et al, 2006: 4). Comparable crop yields have been found when using equivalent amounts of chemical and urine fertilizers on many different crops.

Table 3.2 shows the results of trials done in various crops in various countries in West Africa. In these trials, unfertilized crop production is consistently lower than fertilized, and urine fertilizer is comparable to commercial fertilizer and, in some cases, outperforms it. Urine has also been shown to make certain fruits and vegetable plants produce faster. For example, banana trees in India fertilized with urine bore fruit 15-20 days before trees fertilized with synthetic chemical fertilizer, and the bunches from

Table 3.2: Crop Yields in Metric Tons per Hectare for West African Experiments. Trials used similar plots and varied the use of fertilizer: no fertilizer, urine fertilizer, and chemical fertilizer with nutrient equivalents of urine fertilizer (CREPA, 2006: 3).

Type of Crop	Non-Fertilized	Urine Fertilized	Chemically Fertilized	Country of Trial
Cabbage	19.1	32.0	31.0	Togo
Cassava	45.0	60.0	60.0	Iv. Coast
Cotton	0.18	0.35	0.38	Mali
Corn	2.4	3.6	3.5	Benin
Eggplant	2.8	16.0	17.1	Burkina
Lettuce	6.8	15.7	13.3	Togo
Okra	1.7	2.3	2.6	Burkina
Sorghum	2.3	3.8	4.1	Burkina
Tomato	2.1	5.2	5.8	Burkina
Yams	4.0	8.0	6.0	Iv. Coast

[8] This is partly because "[u]rine has been filtered by the kidneys… and contains only low molecular weight substances" (Jonsson et al, 2004: 9).
[9] "The plant availability of urine N is the same as that of chemical urea or ammonium fertilizers" (Jonsson et al, 2004: 9).

urine-fertilized trees weighed 3 kg more each (Daiji World, 2008:1). Many other examples of successes with urine fertilizer have been documented (see Appendix B).

A fast-acting fertilizer like urine fertilizer has several benefits. Assuming the nutrient content can be estimated or measured with reasonable accuracy, the fertilizer can be applied in specific doses to meet known nutrient needs. Fast-acting fertilizers can also be used to rectify some diagnosed nutrient deficiencies, even on specific plants. Nutrients can also be applied at specific times in a plant's lifespan to optimize nutrient uptake.

The downside of using a fast-acting fertilizer is that plants cannot use all the nutrients provided at once, and unless soil surrounding the plant can hold those nutrients, the nutrients will travel below the root line of plants quickly and be lost to the plant. This is why fast-acting fertilizers are best used during the life of the plant and must be applied at regular intervals to work efficiently. If soil conditions are right, however, some nutrients can be held by the soil until the plant has a need. Urine fertilizer can usually be applied to farming or garden plots throughout the year, but unless soil nutrient retention is high, it is best applied during the life of the plant like a chemical fertilizer (Jonsson et al, 2004: 18).

3.4 Monetary Value of Urine Fertilizer

This section will briefly explore the monetary value of urine, but it should be noted that economics is not currently a driving force behind use of urine in most developing world communities. Urine has great value as a readily available source of fast-acting crop nutrients, but the storage and transport of large volumes of urine makes large-scale use difficult. As the prices of fertilizers go up, and as storage techniques become more affordable, urine will gain monetary value.

In the majority of farming systems, nitrogen is the most sought after nutrient addition to crops. In Mali, as in most regions, urea fertilizer (*urée* in French, which is used in Mali) is the most widely purchased nitrogen fertilizer[10] (Glibert et al, 2006: 443) and, therefore, provides the best cost-equivalency comparison with urine. It should be noted, however, that urine provides additional benefits as well, with relatively large amounts of phosphorus, potassium, and other nutrients. When these nutrients are desired, they can add economic value to the urine being collected.

The calculations for this section will use the assumptions and calculations concerning Malian urine from Section 3.2. Urea fertilizer in Mali is 46 % nitrogen by mass, so 1 kilogram of fertilizer contains

[10] "Worldwide use of urea as a nitrogen fertilizer and feed additive has increased more than 100-fold in the past 4 decades, with a doubling in just the past decade alone" (Glibert et al, 2006: 441).

0.46 kg of nitrogen. The author found the price of urea fertilizer to be 400 CFA[11] (US$0.80) per kilogram in the capital and in three different market towns in Mali in April and May of 2009. This means that one kilogram of nitrogen is worth 870 CFA (US$1.74).

As referred to in Section 3.2, a Malian is estimated to urinate 5.8 grams or nitrogen per day, or 2.1 kilograms of nitrogen per year. This would mean that all the urine collected from one Malian would be worth 1800 CFA (US$3.60) per year, a very low number. Put another way, a 20-liter jug of pure urine, which would be filled by 13 Malians in one day or one Malian in 13 days assuming the 1.5 liters of urine per person per day from Section 3.2, would contain 0.075 grams of nitrogen and be worth approximately 65 CFA (US$0.13). This 20-liter jug of urine weighs approximately 20 kilograms (44 pounds).

3.5 Challenges Presented by Urine Use

The use of urine as a fertilizer presents three main challenges that are universal concerns, regardless of the cultural and social condition of a given community: possible toxicity to plants, volatility of nitrogen, and the possible presence of diseases.

3.5.1 Possible Toxicity to Plants

As with any fertilizer, urine fertilizer can be applied in excess. Over-fertilization can introduce toxic levels of nutrients into the soil and kill plants. As is often the case with urine fertilizer, the large amount of nitrogen is the main concern. Fortunately, the toxic level of nitrogen is very high. A rule of thumb is that the toxic level of nitrogen is approximately four times the normal fertilization rate (Jonsson et al, 2004:4). This provides a large factor of safety for the use of urine fertilizer. If nitrogen is kept at an acceptable level, it is generally accepted that, except in rare cases, the other nutrients present in urine will stay at an acceptable level as well.

Hormones have been the subject of some debate, as most hormones, including those increased or decreased through the ingestion of pharmaceuticals, exit the human body through the urinary tract. The current thinking is that most of these products have existed in nature for some time and can decompose naturally[12] (Jonsson et al, 2004: 8). It is, in fact, probably better to spread these hormones over a larger area in small doses as a fertilizer than to follow the current practice of greatly

[11] One CFA, the currency of most French-speaking West African countries, is equal to approximately 0.002 US Dollars.
[12] "[I]n many countries the human consumption of pharmaceuticals is small compared to that by domestic animals, as in most countries most commercial feeds contain antibiotic substances... Furthermore, the human use of pharmaceutical substances is small compared to the amount of pesticides (insecticides, fungicides, bactericides and herbicides) used in agriculture, which are just as biologically active as pharmaceutical substances" (Kvarnstrom et al, 2006: 53).

concentrating the urine in small areas, making for slower breakdown and increasing the likelihood of contaminating soil and water sources (Jonsson et al, 2004: 8).

3.5.2 Volatility of Nitrogen

Another concern is the volatility of nitrogen in urine. "The high pH of the urine in the collection vessel, normally 9-9.3, coupled with its high ammonium concentration, means that there is a risk of losing N in the form of ammonia with the ventilated air" (Jonsson et al, 2004: 11). This volatilization of ammonia occurs rapidly, with increased volatility as temperatures rise, and substantial amounts of valuable nitrogen can be lost to the atmosphere (Glibert et al, 2006: 448). Further, the contact of urine with the atmosphere creates unpleasant odors, as anyone who has smelled urine evaporating on a latrine floor can attest. Odor does not affect the usefulness of urine fertilizer, but it can dissuade people from use. Urine fertilizer must therefore be collected and applied with as little atmospheric contact as possible, both to conserve nitrogen and to reduce unpleasant odor.

3.5.3 Possible Presence of Disease

Finally, although the presence of disease and risk of transmission is low, design of any urine fertilizer collection system must minimize the risk of exchange. The WHO states the following concerning these pathogens in *Guidelines for the Safe use of Wastewater, Excreta, and Greywater: Volume 4*:

> "It can be concluded that pathogens that may be transmitted through urine (Table 3.3) are rarely sufficiently common to constitute a significant public health problem and are not considered to constitute a health risk in the reuse of human urine in temperate climates. [Schistosomiasis] is an exception in tropical areas, however, with a low risk of transmission due to its life cycle. The main risks in the use of excreta are related to the fecal and not the urinary fraction. Reducing fecal cross-contamination of the urine fraction is therefore an important control measure" (WHO, 2006: 36).

In a person with a communicable disease, the disease plausibly present in his urine poses a minimal health risk, except under the following two conditions (WHO, 2006: 34-36):

1. There is a risk of schistosomiasis transfer.
2. There is a risk of fecal contamination of the urine (i.e., there is a risk that feces has been mixed in with the urine after it has exited the body).

If these two risks can be minimized, then urine can be considered safe for re-use as fertilizer. People in places where schistosomiasis is a concern, such as Mali, can take certain precautions in order to prevent the transfer of the disease, although the WHO states that the risk is "low" (WHO, 2006: 36). Urine left in a sealed container for 48 hours, for example, will inactivate the schisto parasite (CDC, 2008: 2).

Systems can also be designed to minimize the chance of fecal contamination, or urine can be treated to inactivate the fecal pathogens. Yet, even when these conditions are met and risks are considered minimal, all designs must consider the possible presence of disease and must work to minimize risk to the lowest level that is practically possible.

4. THE URINE COLLECTOR

4.1 Urine Collector Design Process

Any urine separation, collection, and application system must overcome the challenges presented by the use of urine fertilizer: toxicity to plants, volatility, and the possible presence of diseases. The system must also be designed to overcome behavioral obstacles for a given person or community if the technology is to be sustainable. In terms of the urine collector, additional design concerns for Malian communities (and many other developing world communities) include the following:

- Made from locally available parts.
- Low cost.
- Easy to use.
- Can be used with existing latrine.

Figure 4.1: Urine Collectors Used in Mali. (Left photo by Gemma Kite with permission; right by the author).

As mentioned previously, while there are many excellent urine separation systems, development organizations often seem to push large and expensive systems with the goal of replacing old latrines completely and composting feces. While this may work well in some communities, there is a danger that the high cost and/or complexity of such systems might be too large a hurdle for communities who have very little experience with the nutrient value of human excrement. This research report will focus on these smaller urine systems that can easily and inexpensively complement existing latrines, and the author of this report would like to encourage more consideration of these types of systems when considering a sanitation plan for developing communities.

It should be mentioned that most literature on urine collection cautions against the use of metal system parts due to the corrosive nature of urine (Jonsson et al, 2004: 35). However, in Mali, and perhaps in other places, le Centre Régional pour l'Eau Potable et l'Assainissement (CREPA), a West African NGO that pushes closed-loop sanitation, has been using empty oil drums (often two welded together on end) for long-term urine storage. Furthermore, experience from this study shows that funnels made from locally available non-corrosive metal[13] lasted through two years of urine use without signs of wear.

4.2 How to Build the Urine Collector Used in Mali

4.2.1 Making the Container: Jugs and Funnels

If urine is to be used as fertilizer, it needs to be collected in order to allow measured dilution and application rates, rather than applied randomly at possibly toxic doses. In Mali, the most readily available container is the 20-liter plastic jug, which can be purchased year round in most market towns (Figure 4.2A). These jugs are used everywhere in Mali, even in the smallest villages, to transport water, gasoline, kerosene, and cooking oil. Translucent jugs (the yellow or cream-colored jugs) should be used so that the urine level within the jug can be observed at any time.

The mouth of these 20-liter jugs is only about 5 centimeters wide, which makes urine collection difficult without a funnel. Tole metal funnels designed to fit snuggly into these 20-liter jugs are available in most major towns, and local blacksmith's can be employed to manufacture these funnels out of stainless steel metal (Figure 4.2B). Ideally, the blacksmith also adds a screen at the bottom of the funnel to prevent debris from falling in (Figure 4.2C), but this is not crucial.

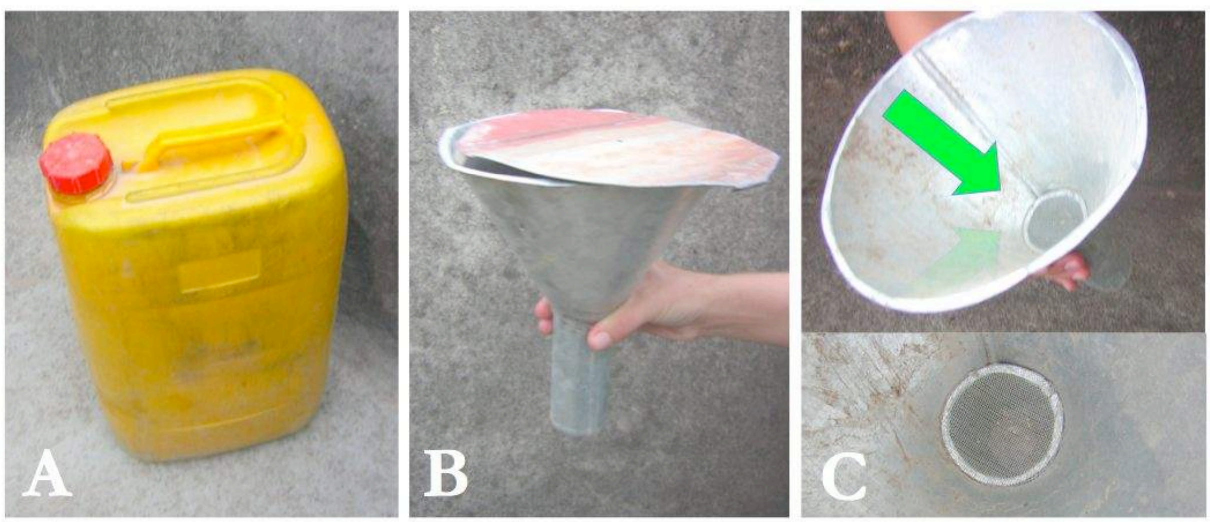

Figure 4.2: The urine is collected in a 20-liter jug (A) using locally-made non-corrosive metal funnels (B), ideally fabricated with a screen in the funnel mouth (C) to prevent debris in the jug. (Photos by Gemma Kite).

[13] The author observed this non-corrosive metal in the field. Called "tole" locally, it is used for awnings and used by blacksmiths in the fabrication of water buckets and watering cans.

When the collector is being presented to Malians, at this point they start to wonder, as the reader may, how women and short children are supposed to collect urine. The following explanation is given during training sessions to put the participants at ease:

> This funnel is not for sitting. It helps put urine into the jug easily. It is no problem if, for now, only men put urine in the container while they are standing. But in places where people understand how valuable urine is for crops, people leave an old can or cup in the latrine. Then, if a women or children use the latrine, or if a man cannot be standing, they can use the can to collect their urine [presenter slightly squats and holds can in front of groin] and let everything else fall into the pit. Then they can come to the funnel and dump in their urine.

Explaining in this way shows the women how it is possible for them to collect urine, but it avoids making them feel pressure to adopt a new behavior.

4.2.2 Making the System Airtight: Rubber Strips and Plastic Bags

The collector needs to have an airtight seal to prevent nitrogen loss and foul odor. Even when the funnel fits well into the jug mouth, there is often an undesirable gap that needs to be sealed. Long rubber strips (cut from old tires) are used locally, mostly to tie down baggage on motorcycles and bicycles, but they are also used to temporarily seal leaky pipes and faucets. These are available in every market town. Once the funnel is pushed snuggly into the container, a half-meter rubber strip is wrapped around the mouth and tied to seal any air gaps (Figure 4.3D).

The funnel mouth also needs to be sealed off. For this, there are small, clear plastic bags available in every shop in the country. Shop-owners and vendors in even the tiniest villages use these sturdy little bags to sell every solid and liquid good imaginable. As long as no holes are present, old bags can be used as easily as new ones. Three or four bags are placed one inside of the other for extra durability (Figure 4.3E). The center bag is then filled with about 5 centimeters of water. The air is pushed out, and the bag is tied near the top and tied to a 1.5 to 2-meter string (Figure 4.3F). Tying the bag in this way allows the water to flow in the center bag. When this is placed in the funnel, the water flows to seal the funnel mouth, preventing nitrogen from escaping (Figure 4.3G).

The unused end of the string is tied to the latrine wall or a tree. When a person wants to add urine to the collector, she can simply pull the string up, add urine to the funnel, and then lower the plastic bag back into the funnel. This prevents any contact with the urine and also maintains the airtight seal. The collector is now complete unless it is stored in a rain-prone location.

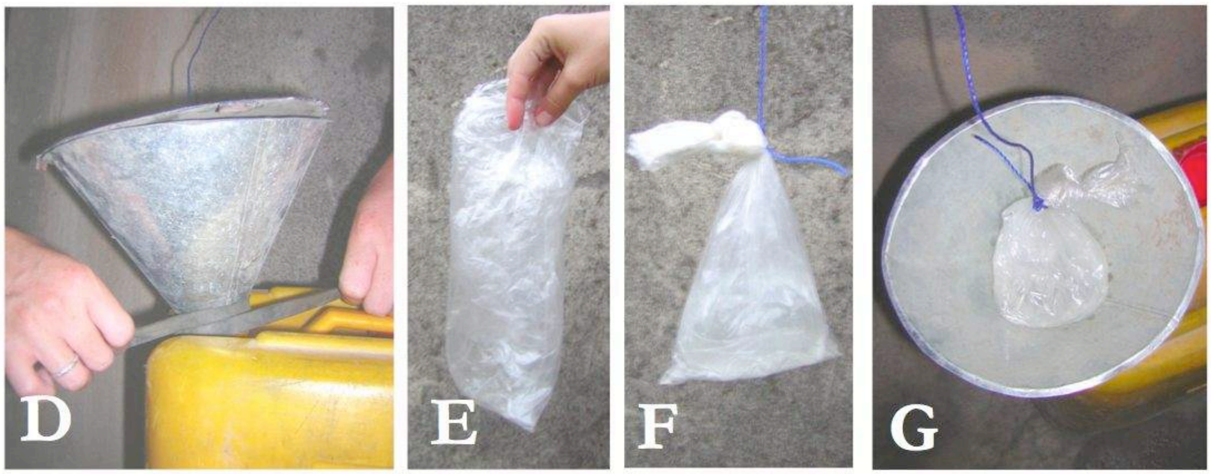

Figure 4.3: The collector is made airtight using a rubber strap (D) and plastic bags (E) filled partially with water and tied (F) which sit on and seal the funnel (G). (Photos by Gemma Kite).

4.2.3 Making a Rain Lid: Whatever Works

Only pure urine should be added to the collector. If the urine is diluted by rain or wash water, the nutrient concentrations will be altered and render application rate calculations invalid. If the urine collector is being used during periods of rain, as it is during the Peace Corps Mali projects, and if the collector is under an open sky, as many latrines in Mali are, then a roof or lid must be constructed to prevent rain from entering the container. Old bucket bottoms can be used, or a blacksmith (even the one who manufactured the funnel) can make a lid for the funnel (Figure 4.4H). Lids are best made with a small lip or folded corners. A small hole should be placed in the center where the string will be threaded through (Figure 4.4 I). Now, when the string is lifted, the lid will come up with the bag, urine can be added, and the bag and lid can be re-lowered (Figure 4.4 J). The collector is now complete.

Figure 4.4:. A rain lid (H) may be necessary. Poke a small hole and bring the string through (I). Lift the string (which lifts the lid) to add urine (yellow arrow) (J). (Photos by Gemma Kite).

4.2.4 The Cost of a Malian System

Table 4.1 shows the cost range for each component, both in US dollars and in CFA, the local currency in many French-speaking West African countries, 1 CFA equals approximately 0.002 US dollars. The cost for the entire system ranges from $2.80 to $5.70, tending towards the lower cost because many of the items required for assembly can be found around the house, and Malians will do most anything to cut costs. Even though the price is low for Americans, a $3-4 purchase can be prohibitive for some Malians. Chapter 7 will discuss ways to make this manageable for communities.

Table 4.1: Cost Ranges for Collector Components

Item	Cost in CFA	Cost in $US
20 Liter Jug	400-750	0.80-1.50
Funnel	1000-1500	2.00-3.00
Rubber Strip	0-100	0.00-0.20
4 Plastic Bags	0-50	0.00-0.10
String	0-100	0.00-0.20
Rain Lid	0-350	0.00-0.70
Total	**1400-2850**	**$2.80-$5.70**

4.3 Adapting Collector Design to Other Communities

The collector design used for Peace Corps Mali projects is only one of the possible ways to efficiently and effectively collect urine using a small and inexpensive system. The design above is the fifth or sixth version of designs that have and will continue to improve. As problems arose, the design was updated, sometimes with the help of volunteers, and often exclusively by the Malians. Smaller jugs, plastic funnels, and min-thatch rain covers have all been used in Mali. One Sanitation NGO suggests using a burnt-out incandescent bulb to seal the funnel mouth (CREPA, 2006: 4). Some people prefer urinals with hoses that lead to jugs outside the latrine. Other systems pass urine through perforated underground pipes or rock beds (although these must not be buried too deep since urine travels down beyond the roots of most plants quickly) (Clough et al, 1998: 202). It is even possible to simply urinate into a jug and reseal the jug with a cap without ever using a funnel. As far as nutrient collection, the system is working if:

1. There is no ambient strong urine odor.
2. There is urine in the jug.

A strong urine odor means the jug is not sealed properly, and that means valuable nitrogen is being lost to the atmosphere. Some nitrogen and odor will be released when the seal is lifted and urine is added to the collector, but this should only be temporary. Experience during this study has shown that the system described in the previous section will not cause a foul odor. During this study, many Malians who had complained about the smell with the first few designs were very happy with the current design. Moreover, the author had several systems cause bad odor in his own latrine before the one above was installed and caused no further odor problems.

Surprisingly, getting urine in the jug is the harder of the two conditions to satisfy, but if a community has worked together on a collector, there can be success. The most important thing is to meet the community's expressed needs. As will be discussed in Chapter 7, the design must be cheap enough, readily available, and easy enough to use, or people will not change their behavior. A developer or community leader may think a change is easy or obvious, but community members might not agree. Adapt the above design based on the goods that can be bought near the community and the level of comfort of community members with urine contact.

Also be aware that obstacles can change over time. Once people start seeing success with urine fertilizer, they will change their behavior more readily. Ideas about urine will begin to shift, and priorities will change. For example, if urine is seen as highly valuable, people will worry more about cost of collection and less about ease of use. Even in communities where urine fertilizer had only been working for one growing season, some Malians who had seen the urine fertilizer work had already begun skipping the funnel and bag system. With each visit to the latrine, they were collecting urine in cans, unscrewing the lid of their 20-liter jug, carefully pouring the urine in despite the bad odor, and screwing the lid back on. This is a much more complicated and undesirable behavior, but it removes the majority of costs for collection.

5. URINE COLLECTION AND DILUTION TO MAKE FERTILIZER

5.1 Urine Collection and Dilution Process Design

5.1.1 Existing Collection and Dilution Practices

The spreading of disease has to be taken into consideration whenever urine fertilizer is used. Even though the risk is low, it is best to minimize contact with urine to prevent possible spread. Creating as many barriers to transmission as possible allows for some error in the application of urine. The collector in the previous section was designed to create barriers to contact with the urine of different individuals, but once the urine is collected, diluting and applying the urine may cause some unwanted contact with urine. The goal is to minimize the already low health risks.

When fecal contamination of urine is not a problem (i.e. when there is no chance of feces entering the urine storage container), the next biggest health concern regarding urine in many developing world countries is schistosomiasis (often call schisto). The schisto parasite is transferred from host to host through urine. Again, the WHO states that the risk is low but must be considered (WHO, 2006: 36). To avoid the spread of schisto, urine can be held in a container for 48 hours. During this time, if schisto cercariae cannot find a human host, they will die and the life cycle of the parasite will be broken (CDC, 2008: 2).

Some have suggested longer storage in an effort to kill the majority of all possible pathogens in the urine, but this is usually only recommended for larger systems (Jonsson et al, 2004: 10). For these larger systems, urine stored in a sealed container for one month will raise the pH of the urine to 9 or above, killing any harmful pathogens[14] (CREPA, 2006: 2). "Concentrated urine provides a harsher environment for microorganisms, increases the die-off rate of pathogens and prevents breeding of mosquitoes" (WHO, 2006: 70). This amount of storage can be impractical for many communities, especially before the value of urine fertilizer is understood. By encouraging minimal contact with the urine, and by encouraging hand washing after weekly use, designers can minimize the risk of spreading diseases. As stated earlier, many feel that urine reuse for fertilizer may pose less risk than having done no urine separation at all (Esrey et al, 2001: 40; Jonsson et al, 2004: 8).

Many different dilutions have been suggested by different organizations. Urine can be applied to plants undiluted, so long as the toxicity level is avoided (Jonsson et al, 2004: 17; Kvarnstrom et al, 2006: 39). The Regional Center for Potable Water and Sanitation (CREPA), a prominent ecological sanitation NGO in West Africa, suggests a 1:1 dilution (CREPA, 2006: 4), and the author saw first hand the positive effects this dilution had on lettuces and corn at a CREPA Mali facility. Morgan suggests dilutions ranging from 1:3 to 1:5, depending on the age and type of plant (2003: 20). Projects in Mexico typically use a 1:5 to 1:10 dilution (Esrey et al, 2001: 19).

While there may be no need to dilute urine at all, there is value in spreading the concentrated nutrients of urine over a greater volume. Think of planters who add sand to small grass, flower, or carrot seeds in order to make spreading easier and more even. Concentrated urine nutrients are like small seeds, and water molecules are like the sand, allowing nutrients to be scattered more evenly. The undiluted application is likely better used in larger, more centralized systems, where additional dilution will greatly add to the weight and volume of collected urine.

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[14] "Storage of urine has been shown to give sufficient treatment with respect to pathogen reduction" (WHO, 2006: 87).

5.1.2 Mali Project Collection and Dilution Process Design

Like the collector design, the process of urine collection and dilution has improved through trial-and-error along the way. From the beginning, cultural and community-specific concerns for Malians included the following:

- Easy to mix
- Easy to remember
- Easily carried to fields
- Easily applied to crops

At first, the CREPA Mali application of a 1:1 water to urine fertilizer every two weeks was suggested to Malians, but regular visits showed that people were forgetting to stop adding urine to the jug after the half way mark. Also, many could not keep track of the two-week time span, forgetting when they had last added urine to their plots. At the same time, visits to field application showed that people were having trouble spreading the urine evenly among trial plots, often accidently dumping most of the fertilizer on a corner of the 1-meter plots and leaving the rest dry.

It was decided that a weekly application of fertilizer with a greater dilution of urine would help solve these problems. Weekly application meant that people count the covering of urine collectors (after 5 days) and application of urine (after 2 days) as part of their weekly routine. Groups were encouraged to decide on these days together so that they could remind each other (cover the collector on the morning of the mosque day each Friday and apply the fertilizer on Sunday, for example).

Greater dilution was needed because families were not able to fill half the jug in the days required for a weekly fertilizer application. Families had been filling about half of the 20-liter jug in 12 days and letting it sit for 2 days during the weekly application (a production rate of about .8 liters of urine per household per day). A 1:3 urine to water ratio was chosen, allowing families to collect a quarter of the jug in 5 days (a rate of 1 L/household/day). These urine production rates are much lower than the assumed per *person* daily production rate of 1.5 L/capita/day due to many possible factors, most notably frequent urination in fields and places other than their home latrine. Regardless, most people interviewed thought the dilution was good and said that they typically filled the jug with 5-liters of urine in 4 to 5 days. A 1:3 dilution also made the math for dilution much less complex for locals than a more precise ratio.[15]

[15] A 1:3 urine to water ratio means 1 liter of pure urine for every 4 liters of mix, which divides evenly into the 20 liter jug 5 times. This provides for nice whole numbers when pure urine doses of .25 L, .5 L, 1 L, or 2 L are desired for crops.

The other mistake made early on was telling people to mix the fertilizer at home. Although water is more readily available in the home, it was difficult to transport the full jug, which is more likely to leak when filled to the brim. This was especially a problem for the many people who carried things to the field on their heads. Malians can usually handle the 20 kg weight on their head, but they don't enjoy being dripped on by diluted urine. They were soon encouraged to bring the urine out to the fields and dilute it there. When water was not available in the fields, they typically carried urine out the day of covering and brought a jug filled or basin[16] with water to complete the urine dilution.

As mentioned throughout this report, once people see the value of the technology, obstacles to use and local attitudes may change. Weekly application was used to encourage routine and mutual reminding among community members, but once one participating villager saw his urine-fertilized corn growing greener and taller, he starting filling his jug a quarter full in three days and applying urine every five (keeping the 2 days for killing schisto). The author taught another woman who preferred weekly application how to full her jug higher than the quarter mark each week and then dilute the urine in her fields using an extra bucket[17]. Other Malians participating in projects during the study asked about collecting full jugs during the fallow (non-growing) season for use when farming began again.

5.2 How to Collect and Dilute Urine in Mali

When using the collector described in Section 4.2, the process of collecting urine is as follow:

**Before you begin*: It is best to use a marker or nail scratch (not too deep!) to mark the 5-liter level on the outside of the jug to indicate when 5 liters of urine have been added. Five liters of urine topped off with 15 liters of water will give the 1:3 urine to water dilution needed.

1. Add **only** urine to the collector up the 5-liter mark. This will probably take 4 or 5 days.
2. Let the jug sit closed for 48 hours. During this time, it is best to remove the funnel and close the jug with the original cap of the jug. People can also place a rock, cloth, or large bag, or even relocate the collector outside the latrine altogether, to remind people not to add more urine. This will prevent the spread of schistosomiasis.
3. After 48 hours, take the quarter-filled jug to the chosen application area.
4. Fill the jug the rest of the way with water and shake the jug to mix it a bit.

The fertilizer is now ready. Using the concentrations calculated in Section 3.2, this 20-liter jug of urine fertilizer (being 5 liters of pure urine) has approximately 29 grams of nitrogen and 1.7-2.6 grams of phosphorus at concentrations of 0.98 grams/liter and 0.055-0.13 grams/liter, respectively.

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16 Almost every family in Mali has at least two 20-liter jugs or large wash basins devoted solely to carrying water.

17 This was accomplished by pouring the pure urine into a jug until the required 5 liters remained, adding water, agitating, applying the fertilizer as usual, and then pouring remaining pure urine back into the jug and adding more water.

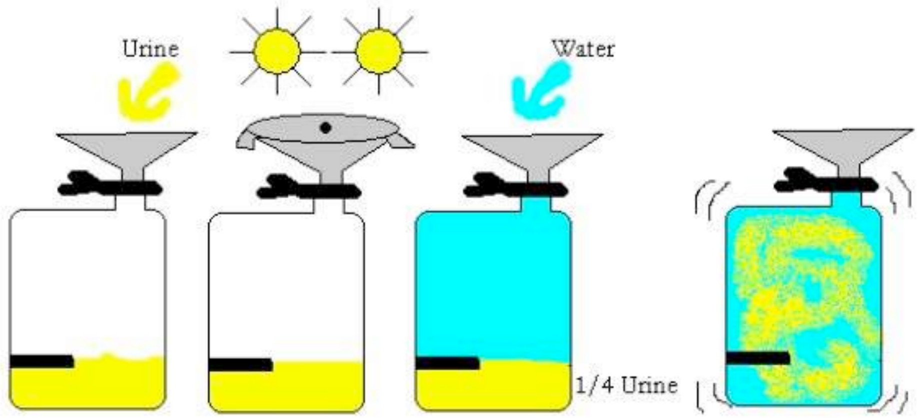

Figure 5.1: The Process of Collecting Urine and Making Fertilizer. Fill to ¼ with pure urine, let stand for 48 hours, take to the application area, fill to the brim with water, and mix.

5.3 Adapting Collection and Dilution Process to Other Communities

The collection and dilution process outlined here is just one possibility, and locals should be encouraged to adapt the process to their local needs. As long as toxic levels of nitrogen application are avoided, communities can do no wrong. They may not be applying fertilizer with maximum efficiency, but that is part of the learning process. As they get more excited about urine fertilizer, they will become more engaged in the learning process, more accepting of community leaders' and aid-workers' suggestions, and more meticulous about using the process efficiently.

6. PROPER URINE FERTILIZER APPLICATION

6.1 Urine Fertilizer Application Process Design

6.1.1 Existing Application Practices

The efficient application of a specific nutrient depends on the type of plant and the stage in the plant's lifespan. Lettuce, for example, requires a lot of nitrogen for leaf growth, but too much nitrogen on a carrot makes large leaves and a small orange root. Corn is often fertilized with phosphorus earlier in life than with nitrogen due to different uptake needs at different points in growth. These specifics can make fertilizer calculations complicated. Luckily, several rules of thumb exist that apply to a wide range of plants, allowing communities to select the level of complexity they are willing to deal with.

In terms of plant nutrient application, most researchers use the nitrogen concentration as their benchmark. They do this because nitrogen is present in much greater concentrations in urine than other nutrients and because nitrogen is the nutrient needed in the greatest quantity by the majority of plants. If the nitrogen requirements of a crop are met and also kept well below the toxicity level, then the other nutrients in urine will also be present in beneficial quantities and will remain well below toxicity levels. As mentioned earlier, the majority of fertilizer purchased in the developing and developed world is nitrogen fertilizer, with urea fertilizer (*urée* in French) being the most prevalent (Glibert et al, 2006: 443).

A commonly used application rate for crops in general is 75-100 lbs. of nitrogen per acre (84-112 kg per hectare) per cropping season (Spradley, 2007). Johnson et al have also suggested the urine from one person for one day (they estimate 1.5 L/day) per crop per cropping season as a general application value (Jonsson et al, 2004: 3). This would be equivalent to applying 0.25 liters of pure urine to one square meter of crop every two weeks for 3 months, the typical amount of time to fertilize most field crops in Mali. CREPA suggests 30-80 kg of nitrogen per hectare as a general number for cereal crops (CREPA, 2006: 3).

Plant-specific application rates can also be obtained from government agencies, from seed shops, and from local NGO's that focus on efficient crop fertilization. Table 6.1 shows several nitrogen application rates recommended for Mali by CREPA. These can be used to find urine application rates for a certain crop, or they can be used to refine more general application rates. A village may grow mostly onions and okra, for example, so 150 kg of nitrogen per hectare can be chosen as the standard application rate for the urine projects done there instead of the general rule of 84-122 kg per hectare per cropping season.

Table 6.1: CREPA Recommended Annual Nitrogen Fertilization for Various Crops (CREPA, 2004: 53)

Crop	N- Need (kg/ha/yr)
Sorghum	60
Millet	60
Corn	80
Okra	150
Onion	150
Salad	150
Cabbage	180
Tomato	180

In terms of a plant's lifespan, plants generally need the most nutrients in the middle third of their life, and especially do not use nutrients efficiently for the last third or fourth of their life span (Jonsson et al, 2004, 18). When soils have good nutrient retention and high organic matter content, these nutrients can be applied throughout the year and will be available in the soil whenever the plant needs them most. Because urine is a fast acting fertilizer, traveling into the soil and beyond the roots quickly, it is best applied when plants need them most (Kvarnstrom et al, 2006: 4; Clough et al, 1998: 202). Urine fertilizer can be applied on fields and plots outside of the growing season, but these nutrients will not be used as efficiently (or at all) by crops once they are planted.[18]

[18] One study of the feasibility of soil storage of urine nutrients found that urine stored in soil for only 28 days lost 37% of its original nitrogen (Jonsson, 2004: 19).

The WHO recommends that urine fertilizer not be applied one month before crops will be ingested to avoid the possible presence of disease (WHO, 2006: 44). Although the possibility of disease is low, this month allows ample time for any possible pathogens present in urine to be inactivated to a safe point, adding another layer of protection from disease transmission (WHO, 2006: 71). Fortunately, this coincides with the inefficient use of plant nutrients during the last third of a plant's lifespan. Avoiding this last month of a plant's life will therefore aid in disease transmission prevention and avoid the inefficient use of nutrients.

When choosing application rates, care must also be taken to avoid overly frequent nutrient application. This can make the plant too dependent and prevent proper growth. If a plant receives daily fertilizer application, the roots will concentrate at the points of application rather than grow down and spread in search of nutrients as they normally would. This would make the plant very weak and susceptible to uprooting by wind or water flow. There is a balance that needs to be achieved between providing useful nutrients and "hardening" the plant to be resistant to fluctuating climate and soil conditions.

Finally, the method of urine fertilizer application must prevent excess nitrogen loss to the air. The goal is to integrate the urine into the soil with minimal atmospheric contact. This has generally been accomplished by scraping out shallow trenches near the crops, applying the urine, and then recovering the trench.

6.1.2 Mali Urine Application Process Design

Cultural and community-specific concerns for Malians regarding the urine fertilizer application included the following:

- Visible improvement on crops
- Easy to remember
- Minimal urine contact
- Avoidance of foul urine odor
- Fear of contact with food

The application rates for Peace Corps Mali projects were calculated and chosen to provide easily measured application rates that would most likely produce visible yield increases. A complete calculation of rates will be outlined in Sections 6.1.3, 6.1.4, and 6.1.5. From the beginning, people who were trying urine fertilizer were encouraged to separate existing plots into urine-fertilized and non-fertilized areas. In an ideal experiment, people would divide up their uniform crops on uniform soil into a grid of random fertilized and non-fertilized quadrants. The lack of experience with formal plot experimentation and the small volumes of urine fertilizer being produced by each family (20 liters per week) made this impractical. Instead, some scientific accuracy was sacrificed for simplicity.

People were encouraged to select an existing planting area and select one portion of it for consistent urine fertilization. Garden plots were often easily split in two, while in fields, a corner section was often chosen for urine application (see Figure 6.1). This meant that fertilized crops were adjacent to non-fertilized crops and could be compared visually without formal measurement. In Mali, field crops are generally grown in the wet season (June to September) and garden crops in the cold season (October to February).

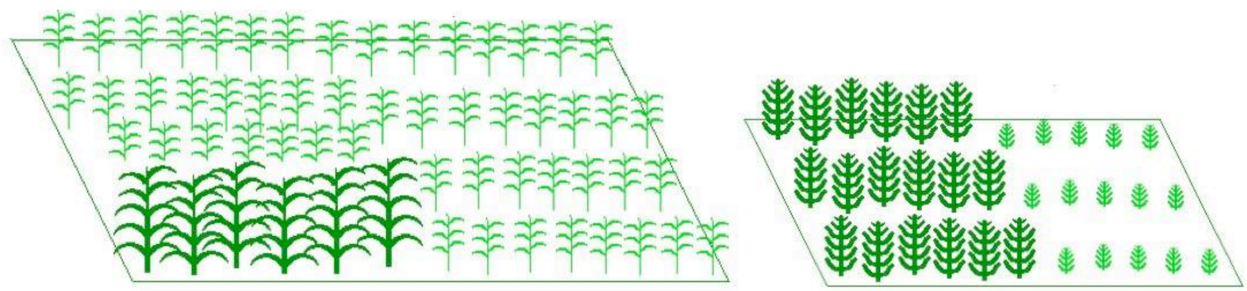

Figure 6.1: In order to allow direct comparison of fertilized and non-fertilized crops, a portion of a field can be chosen for fertilization (left), or small garden plots can be split in two (right).

As mentioned in Section 5.1.2, people were encouraged to choose one day of the week for consistent application to make remembering to fertilize easier. Ideally, this day would be the same for everyone in a village or group so that they could all help remind each other to fertilize. Although fertilizer is most efficiently applied during the middle third of a plant's life, for simplicity, it can and will be applied starting at the time of planting (Jonsson et al, 2004: 18). Urine fertilizer will cease to be applied one month before harvest as recommended by the WHO (2006: 71).

People were also encouraged to use a specific container when applying the urine to avoid unnecessary contact with the urine and provide an extra barrier in possible disease transmission. Plastic cups and small pails are widely available in 1-liter and 4-liter volumes. Even if a person does not own these, they can easily find someone who does, measure out 1 or 4 liters into their chosen container, and mark the level with a nail scratch or dent.

It should be noted that the stored urine fertilizer develops a brownish color and a foul odor. This deterred some people from its use, but surprisingly, the majority of people had no problem using the fertilizer once they understood that disease transmission was very unlikely. It should also be noted that some of the people initially deterred by the brown color and smell of the urine began using the fertilizer after they saw improvements in the crops of others who had used the fertilizer without issue.

The ideal way to prevent valuable nitrogen from escaping into the atmosphere is to dig a small trench near crops, apply the urine fertilizer into the trench, and refill the trench to bury the fertilizer. This was impractical for Malians, however, because they rarely plant seeds in straight rows. Encouraging row planting or digging small holes next to each plant proved too sudden a change in the farmers' routine.

Instead, people were encouraged to apply the urine fertilizer and then, once the fertilizer had seeped into the ground, water the area using regular water, thereby transporting most of the urine fertilizer sitting on the soil surface into the ground. Although this was not a perfect solution, people reported that the urine odor was not very strong, indicating that most of the urine nitrogen had likely been pushed under the soil and retained. Clough et al have shown that 10 mm of water added after fertilizer has soaked in can keep ammonia volatilization to 0.1% of applied nitrogen per day on several soil types (1998: 196). People were told to apply fertilizer low to the ground, under the leaves and as close to the stem as possible without actually getting urine on the stem[19].

Of the people who were willing to use the urine fertilizer, some who saw and trusted its effectiveness were still worried about applying it to edible portions of food directly. Some people did not want to apply urine to their salad because they were uncomfortable with the leaves possibly having urine on them. Others did not want urine fertilizer on their potatoes and carrots, which grow underground. These people were just encouraged to continue applying on crops they were comfortable with. In the future, they will be likely to talk to others who have used urine on potatoes and salads they have eaten without consequence and will be likely to change their mind at that time. Yet, even if some people remain against fertilizing carrots, potatoes, and salads, they will still be using urine fertilizer in beneficial ways on other crops. It is more important to stay positive and encourage than it is to prove the universal benefits of urine fertilizer.

[19] "Urine should be applied close to the ground and preferably mixed with or water into the soil" (WHO, 2006: 71).

<u>6.1.3 Full Calculation of Malian "Garden Crop" Application Rate</u>

This section starts with a complete step-by-step explanation of how to calculate a rate of urine fertilizer application based on local conditions, and each step is shown in practice for the calculation of the application rate for garden crops using urine fertilizer made using a 1:3 Malian urine to water ratio. All the calculations and assumptions required to find the final application rate, including those explained in previous sections, have been included again here for easier reference. The new information that is required to calculate the result of each step in typed in bold so users can easily replace numbers for their own communities.

Please note that this entire calculation assumes that application rates will be based on urine nitrogen, both because the nitrogen content in urine is so high compared to other nutrients and because nitrogen is often the limiting factor in farming systems. If another nutrient is desired or presents a possible toxicity issue, these calculations must be adjusted; however, this will not generally be the case.

Steps A thru D have been discussed in previous sections of this report, but are repeated here:

A. Use known data or Equation 3.1 from Jonsson et al (2004: 5) to determine total excreted nitrogen.

FAO (1994: 4) gives 63.7 g protein per capita per day for Malians

N = 0.13 × Total Food Protein = 0.13 × (**63.7 g/day**) = 8.3 grams N/day in excreta

B. Use known data or estimate % of excreta nitrogen in urine to determine urine excreted nitrogen.

This report uses Chinese data from Gao et al via Jonsson et al (2004: 7) to assume 70%

8.3 grams N/day in excreta × (**70 % N excreted in urine**) = 5.8 g N/day in urine

C. Use daily per capita urine volume to determine urine nitrogen concentration.

This report uses 1.5 L/day from Jonsson et al (2004: 7)

(5.8 g N/day) ÷ (**1.5 L/day**) = 3.9 g N/ L of urine

D. Use chosen dilution rate for fertilizer to calculate concentration of nitrogen in mixed urine fertilizer.

This report uses 1:3 urine to water ratio from Morgan (2003: 20), means 1 L urine per 4 L mix

(3.9 g N / L of urine) × (**1 L of urine /4 L of mixed fertilizer**) = 0.98 g N / L mixed fertilizer

Steps E thru K are calculations that have not up to now been discussed in this report.

E. Find maximum nitrogen fertilization rate for a desired crop or type of crop.

For simplicity, one fertilization rate for all garden crops was desired.

N fertilization rate from Table 6.1 (CREPA, 2004: 53) range from 150-180 kg/ha/yr

Maximum is 180 kg/ha/yr, or **18 g/m^2/ yr**

F. Use maximum rate and fertilizer N concentration to find fertilization required for the crop.

(Maximum rate required) / (N concentration in fertilizer from Step D) =

(**18 g /m^2/yr**) / (**0.98 g N / L mixed fertilizer**) = 18 L of fertilizer mix / m^2 per year

G. Decide on frequency of application during growth period. This report uses weekly application.

H. Use frequency of application and crop lifespan to find number of total applications.

This report assumes garden crops grow for 3 months in Mali **MINUS one month for safety**.

(**3 months** – 1 month before harvest) × (**4 weekly apps/month**) = 8 weekly applications

I. Use fertilizer rate from Step F and number of applications from Step H to find application rate.

(**18 L of fertilizer mix/m^2**) ÷ (**8 weekly apps**) = 2.3 L of mix per week

J. If desired, simplify the rate of application for easier use by community members.

A dose that would ensure a large increase in crops was desired to show Malians that urine would not harm their crops and indeed would enhance them. Also, the fast-acting nature of urine fertilizer means that many nutrients may be lost if not applied properly.

A rate of **4 liters of mix per week** was therefore chosen and can be modified later.

K. If rate is for a group of crops, use application rate to check for toxic dose on most vulnerable crop.

Use known toxicity OR 4 times the suggested safe rate (Jonsson et al, 2004: 4)

4 times the most vulnerable garden crop = 4 × (**150 kg N/ha**) = 600 kg/ha = 60 g/m^2

Application Total = (4 L mix/m^2/week) × (.98 g N/L mix) × (8 weekly apps) = 32 g N/m^2

Total Applied N for all garden crops is less than the toxicity for most vulnerable crop, so okay!

6.1.4 Summarized Calculations of Malian "Field Crop" Application Rate

The process from Section 6.1.3 was also used to calculate the recommended dose for field crops. One number was desired for typical field crops in Mali.

Steps A through D were identical for this calculation.

Step E: Table 6.1 gave the range of 60-80 kg N/ha/yr for field crops (millet, sorghum, and corn).

Step F: Using the maximum value of 80 kg N/ha/yr, **8.3 L of mix/m^2 are required**.

Step G: Weekly application was chosen

Step H: 3.5 months of growth yielded **10 weekly application**s.

Step I: **0.83 liter of mix** is required per square meter per week.

Step J: The author had done trials with Malians using 1 liter of mix per square meter of field crops per week, and some of those Malians claimed they saw little difference. In later trials, 2 liters of mix/m^2/week was recommended and ensured visible differences. **2 L of mix/m^2/week** was therefore chosen.

Step K: The toxic dose is the low number (60 kg N/ha) multiplied by 4, which equals 240 kg N/ha, or 24 g N/m^2. (2 L of mix/m^2) × (0.98 g N/ L of mix) × (10 weekly apps) = 20 g N/m ^2 applied, which is lower than the toxic dose, so the chosen dose is not toxic.

6.1.5 Summarized Calculations of Malian "Tree" Application Rate

The process from Section 6.1.3 was used to calculate the recommended dose for trees, but was somewhat simplified since recommendations for trees in Mali are provided by CREPA in grams of nitrogen per year. These values can be seen in Table 6.2.

Table 6.2: CREPA Recommended Annual Nitrogen Fertilization for Various Trees (CREPA, 2004: 53)

Tree	N-Need (g/yr/tree)	N-Need (g/wk/tr)*
Banana	100	2
Mango	50	1
Papaya	100	2

*Grams per week calculated by author based on 52 weeks per year.

Steps A through D were identical for this calculation.

Steps E through I can be condensed because the recommended doses are given per tree per week. Since weekly applications have been chosen for Malian projects, the calculation is:

The maximum value of 2 grams of N per week per tree multiplied by (1 L of mix/ 0.98 g N) equals a dose of 2 liters of mix per week per tree. This dose gave great results for banana trees during several trials, so it was chosen as the recommended dose.

To check for toxicity, the toxic dose is 4 times 1 gram/week/tree, which equals 4 grams/week/tree. This is more than the 2 grams of N per week per tree used to calculate the amount of mix required, so the dose is not toxic.

6.2 How to Apply Urine Fertilizer in Mali

To apply urine fertilizer in Mali, first, select a crop to fertilize. In Mali, apply the following guidelines:

- **Urine fertilizer is bad for** flooded rice, because the urine will become diluted in the fields and because people wade through when weeding and harvesting.
- **Urine fertilizer has little effect on** beans and peanuts, because these already fix their own nitrogen. There will be some improvement due to other nutrients present in urine, but this will be a waste of valuable nitrogen if the fertilizer could be used elsewhere.
- **Urine is best for** corn, millet, sorghum, salad greens, and spinach, because nitrogen helps the leaves and stalks grow large and strong (Jonsson, 2004: 20).
- **Urine also works great on** everything else, including carrots, beets, and tubers[20].

Second, choose the application area. When using the collector described in Section 4.2 and the collection method described in Section 5.2, one 20-liter jug full of urine fertilizer (1:3 urine to water ratio) should be available each week. The fertilization rates for different crops in Mali, calculated and explained in the previous section, are as follows:

Application Rates

Fields:	**2 Liters** of urine fertilizer* **per Square Meter** of field crops **per Week**.
Gardens:	**4 Liters** of urine fertilizer* **per Square Meter** of garden crops **per Week**.
Trees:	**2 Liters** of urine fertilizer* **per Tree per Week**.

**Note: These doses are given in liters of urine fertilizer, NOT pure urine.*

Choose an area or several areas for weekly application. Section off a portion of a field or split garden plots in two (See Figure 6.2 on page 28). Outline the area with sticks or stalks to remember where the urine has and will be applied each time.

- **For field crops**, choose **10 square meters** of a field (since 20 liters of urine fertilizer applied at 2 liters per square meter means the same 10 square meters can be fertilized each week).
- **For gardens**, choose **5 square meters** of garden plots. Try to choose garden plots that can be split so that fertilized and non-fertilized areas are adjacent. Malian garden plots are often roughly 1 meter by 2 meters. If so, choose five of these and split them each in half.
- **For trees,** choose **10 trees**. Try to find a group of the same species of trees that are next to each other and split them in half.

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[20] "[T]here is no reason not to use urine [on] other crops, as experiences from all over the world show good results" (Jonsson, 2004: 20).

Third, find a container that will be used to apply the urine each week. Plastic cups and pails are widely available in 1-liter and 4-liter increments. If these cannot be purchased, people can use an old can or pail. Borrow a neighbor's 1-liter cup to find the height of the desired volume (1, 2, or 4 liters) and mark the level with a nail scratch.

Fourth, **remember to stop applying urine fertilizer one month before harvest**. This will be a final barrier against the spread of any possible pathogens still present in the urine at the time of application. Malian farmers know how long they have before harvest and just need to help remind each other of the one-month before harvest mark.

Now, weekly urine fertilizer application can begin, starting at or near the time of planting.

1. Bring the container of known volume to the area of application. (The urine fertilizer should already be here, diluted and ready to go from Section 5.2).
2. Spread the urine fertilizer evenly according to the application rate for the chosen type of crop.
3. Wait until the urine fertilizer has seeped into the ground. This can take from 10 seconds to a few minutes, depending on how dry and porous the soil is.
4. Once the urine fertilizer has seeped in, water the area with regular water to push the nutrients into the soil so nitrogen will not escape. This also helps control odor.

If urine-fertilized areas start to suffer compared to non-fertilized areas, stop application. Find out if other people have been using urine on similar crops and consult them. Up to the date of this writing, only a few Malians experienced decreased yields, and all were found to be due to incorrect dosages of fertilizer mixing or application.

The majority of Malians saw greener leaves, taller plants, and larger fruits and vegetables. If this happens, be sure to bring other community members to these plots. The community members will be able to see the difference for themselves, and the Malians who themselves applied the fertilizer will be able to explain what happened, which has much more of an impact than an outsider's explanation.

6.3 Adapting Urine Fertilizer Application to Other Communities

Please refer to Section 6.1.3 for a complete step-by-step explanation of how to calculate application rates based on local crop nitrogen needs and desired complexity. Also, it is important to note that the WHO recommends that urine always be applied close to the ground and should never be applied using a sprayer (WHO, 2006: 71).

As stated previously, fertilizer application complexity needs to be balanced with practicality. The number one priority is avoiding toxic nutrient levels. After that, communities must decide how much detail they are ready to explore. Some communities may only be ready for the general dose of 1.5 liter of urine per square meter per cropping season suggested by Jonsson et al (2004: 3). Others may be ready to try different urine concentrations for specific plants. Others still may explore plant-specific application intervals and specific doses at certain points during the plants' lifespan.

Community leaders and aid workers need to work closely with locals to find how much complexity can be used at first. This will likely be a process of trial-and-error. And as always, once people see urine fertilizer working on their crops and their friends' crops, they will be ready to move to increasing levels of complexity. Even after everything is working, everyone needs to be working together to continually adapt suggestions and calculations to meet each other's needs.

In every community, the comparison of adjacent plots will likely be a very valuable component of urine application. The visible difference in a urine fertilized and non-fertilized area of the same crop on the same soil will make the effects of the fertilizer obvious (See Figure 6.2). And in the same vein, using a urine dose that will provide more of an increase in yields will be more important than maximizing urine nutrient use. Once people see that urine does not kill their crops and in fact makes them larger and greener, they will then be ready to explore more efficient nutrient doses, and people who were unwilling to try at first will start coming on board.

Figure 6.2: Corn plots without (left) and with urine fertilizer (right) in Zimbabwe. The adjacent plots allow direct visual comparison of results. (Photo by Peter Morgan with permission) (CREPA, 2007: 96).

7. STARTING AND SUSTAINING PROJECTS

This chapter will discuss the steps and timeline for implementing urine fertilizer projects. The project design and implementation process used for Peace Corps Mali urine fertilizer projects has been based almost solely on the development philosophy put forth in the book *Two Ears of Corn* (Bunch, 1985). The first section of this chapter provides a brief summary of this philosophy, but readers are encouraged to consult the book further for a more in-depth and excellent discussion of development. After this summary, subsequent sections of this chapter will return to the format of previous design chapters: an explanation of the thinking behind the design of the project implementation process, a step-by-step guide to implementation, and a section on how the implementation process can be adapted to other communities.

7.1 Introduction to *Two Ears of Corn*: A Useful Development Approach

Two Ears of Corn by Roland Bunch was written in 1985, but it is still considered an important development today. At the time, Bunch had compiled information about some 30 years of international projects that had been done by the development organization World Neighbors. In the book, he finds approaches that have failed and mistakes that have been made over and over again in the field, and he offers alternative approaches that have worked in sustaining projects. Unfortunately, most of the mistakes outlined in the book are still happening today in 2010. Indeed, many books and articles that offer innovative new approaches to international development often echo the same ideas that Bunch wrote about 25 years ago.

The problems stem now, as they did then, from two misconceptions. The first misconception is that providing convincing information in sufficient quantity will be enough to change people's behavior. The second is that a lack of means is often the only thing holding a person back from trying a new idea, and that giving a hand-out such as money or free materials will spur people to try. Experience has shown that both of these ideas, especially the latter, can do more harm than good because they do not take into account that people need to be excited about a idea in order to start and keep using it. Behavior change is a slow and difficult process, not just in the developing world but for humanity in general.[21] Behavior change must be nurtured in specific ways if it is to be sustained.

The approach outlined in the book is based on enthusiasm. Bunch says that communities need to be excited about an idea, and this excitement must continue if an idea is to be sustained. Community leaders and development workers can increase enthusiasm for a project that pushes a new idea by

[21] In the developed world, quitting smoking and recycling are good examples of slow behavior change, both being habits that are still ignored by many people despite widely available information concerning the benefits of both.

integrating into communities, staying patient, and getting continual feedback from community members; and in terms of projects, leaders must do the following:

- Start Slow
- Start Simple
- Start Small
- Sustain Enthusiasm for Future Projects

These guidelines apply to any type of development project in any sector: health, sanitation, agriculture, micro-finance, etc. If projects follow these guidelines as much as possible, they offer the greatest chance of success for sustainable behavior change in their communities. Following these guidelines also empowers communities to begin developing on their own without outside help.

7.1.1 Start Slow

Project leaders (leaders from within the community and/or development workers) will have a lot of trouble honing in on community problems and gaining support for a solution unless they start slowly and develop a relationship with community members. Community members will be more likely to listen to new ideas if they are working with someone who has made an effort to understand them. Integrated project leaders will also have a better understanding of problems that future projects may encounter. Leaders can modify project approaches to be more in synch with the everyday lives of community members.

Integrating also allows project leaders to find out what ideas have been previously tried in the community. Trusted project leaders will be able to have more open conversations and receive better answers, and they will understand how the community has dealt with past projects and similar situations. Doing research about nearby communities or similar projects will also give insight into factors that make projects sustainable. Finding out why certain things worked and certain things went wrong will help avoid reinventing the wheel for future projects.

7.1.2 Start Simple (Limit the Technology)

Even after project leaders have identified problems facing a community, there are many cultural and behavioral factors that must be taken into account that the typical engineering design process often ignores. A solution that is cost-effective on paper ends up being very wasteful if time and money are spent pushing an idea that in the end is abandoned by the community. Care must be taken to find solutions that are simple enough to keep people excited about its use. The design process itself can be complicated and involve extensive research, but the final solution that is presented to a community must have small, simple components or a small number of simple steps. Ideally, a new project will focus on one simple idea or technology at a time rather than several.

Most importantly, the idea pushed by the initial project of a new organization must have a very high likelihood of succeeding. Community members must be able to produce visible success on their own without too much outside help. Otherwise, locals will assume that only the project leaders are capable of using the new solution, and they will rely too much on outside help and resources. Once communities are left on their own, the seemingly complicated and confusing idea will be abandoned.

In addition to avoiding dependence and frustration, simple solutions also lend themselves to more adaptation to meet local needs. Community members can easily make adjustments without recalculating a lot of figures or without having to double-check everything with project leaders. Community members will be more likely to make positive adjustments to design and greatly improve on the solution originally presented. Using a solution based on local and affordable materials will also make adaptation by locals much easier.

7.1.3 Start Small

Once extensive research, community input, and engineering design processes have led to one simple solution that meets the community's needs, the temptation is now to teach everyone in the community this seemingly perfect idea as quickly as possible. It is best, however, to try this new idea or technology with a small group of people, ideally 8 to 10 people or families, and it is best to try it on a small scale (on a small section of a crop instead of an entire field, for example).

A small group of people allows the greatest chance of catching problems early, finding a solution, and disseminating the solution to everyone involved. Imagine a scenario in which a new project involves 50 community members trying out a simple new natural pesticide. The pesticide technology has been designed extensively and is now taught to these 50 people who proceed to go out and try it on their fields. Getting feedback from 50 people is difficult, but a few weeks into the project, people start complaining that the pesticide is deterring bugs but attracting rabbits that are now destroying the crops. Project leaders did not have the time and resources to check in on everyone, and now several people's crops have been ruined. These people are angry and bad-mouthing the project. Getting all 50 people to a meeting to discuss the problem is difficult, and most give up on the project completely.

Having a group of 10 people instead allows greater communication. Project leaders can frequently visit and talk with each participant. They can easily call meetings to get feedback and to encourage participants to talk with each other. This allows for rapid identification of problems, and it allows for better discussion to find solutions or adaptations to improve the existing solution. If facilitated correctly, these meetings can be very empowering for participants, as they themselves can often come up with adaptations and solutions with little to no outside help. Encouraging this discussion between participants is an important step toward empowering communities to develop on their own.

The pesticide project scenario above can also illustrate the importance of small scale experimentation. Imagine 10 people using the natural pesticide on their entire field and having a problem arise. It is better to have people try it on 3 by 5 meter plot. In addition to guarding against large risks and losses, smaller scale trials help teach the value of experimentation. A small square on a larger field allows direct comparison of a new technique. Once people see the value of trying any new idea on a small plot, they will be more likely to experiment with new ideas they invent or hear about. They will begin to learn how to try new ideas on their own. This may seem obvious to an engineer, but it is stunning how many development projects embrace an all-or-nothing approach to a new technology.

7.1.4 Sustain Enthusiasm for Future Projects

Once the first group of participants finds success and is excited about the new idea, it is important to show other members of the community this success. This will greatly increase enthusiasm for the projects and encourage new participants. If a natural pesticide worked as intended, it is important to encourage participants to bring friends and neighbors to their fields to see the results. Have participants explain the positive changes (few pests, fatter babies, larger tomatoes, cleaner wash area, etc.) that have resulted from the project. If a community member sees results with her own eyes and hears about successes from her neighbor's mouth, she will likely become very excited about the new technology.

Showing successful projects can have an especially strong effect in terms of urine fertilizer. Many cultures, even in the developed world, have deeply ingrained ideas about excreta that prevent them from readily adopting its use, but experience has shown that in most cultures, "when people see for themselves how a well-managed ECOSAN [closed-loop sanitation] system works, most of their doubts vanish" (Manandhar et al, 2004: 113). A urine fertilizer study in a community in Nigeria found only 8% of the people willing to try urine fertilizer on crops, but once researchers completed an experiment and took locals around the farm to see the successful crops, 80 % of the people now showed "no more inhibitions to eat[ing] urine grown crops," and 95 % "showed willingness to build urine diversion toilets on their premises" (Sridhar et al, 2005: 5). The effect of field trips can be seen in this statement from a Cote D'Ivoirian farmer visiting a CREPA field where cassava was being fertilized with urine:

> We know the quality of this type of soil; we never yield cassava on it. When CREPA started this project we did not believe that they will gain something from this soil, but

> when they harvest the cassava and invited us to come and see, we agreed with them that urine has a great value as fertilizer. The Atieké [local dish] made by this cassava is delicious so there is no change on the taste. We are now convinced and next year we will start our own experience (Kvarnstrom et al, 2006: 7).

Project leaders should also spread the word about successes to other government agencies and organizations to the extent possible. It is important to tell how projects went right *and* how things went wrong so that future projects can learn from successes and mistakes. If more organizations would be honest and clear about what went wrong during past projects, new projects could avoid reinventing the wheel and development could move forward much more quickly.

Once the project has been fine-tuned with a small group of participants, project leaders must now work with participants to sustain enthusiasm and keep momentum going forward as new participants are added and the project spreads. Make sure new participants join slowly enough so they can be supported when problems arise, as with the first small group. It is possible to add more than 10 people at this point if the number of project leaders have increased or if original participants are willing to visit new ones, but do not spread yourself too thin. The project team needs to be able to continue frequent visits with new participants in order to maintain enthusiasm and to combat problems that arise. The slow, simple, small ideas still apply. Development organizations often use their success and momentum to make a project bigger, but it is wise to consider using some of that momentum to first make a small project better.

The approach outlined by *Two Ears of Corn* can thus lead to sustainable projects and permanent behavior change. The guidelines put forth by Bunch do not work perfectly in every situation, but they do give a project the best chance for long-term success. These guidelines are based on experience, not theory, and the patterns in development today seem to lead to the same conclusions.

7.2 Urine Fertilizer Project Design Process

The urine fertilizer projects done in Mali were designed based on the ideas of *Two Ears of Corn* to encourage behavior change and project sustainability. The use of small participant groups to get continual feedback encouraged by this approach meant that collector design, collection and application methods, and project approaches were changing in parallel and were affecting each other. Water engineers are recognizing the strength of this integrated design approach, centered on community feedback, as "a vital component of sustainability that has not been universally applied in the planning and design of water systems" (Guest, 2009: 6128). It is interesting to note that many of the ideas from *Two Ears of Corn* are becoming a part of project design, even when considering developed world communities (See Figure 7.1). Although this integrated approach can seem convoluted at times, constant feedback will lead to a stronger design.

The goal with urine fertilizer projects was to make design components flexible enough to be able to adapt to community needs. Collector design, collection, and application were constantly changing to make for a more durable and sustainable project. Indeed, even at the time of this writing, new urine fertilizer practices have likely been adopted by communities or individuals in Mali that have improved upon those outlined here.

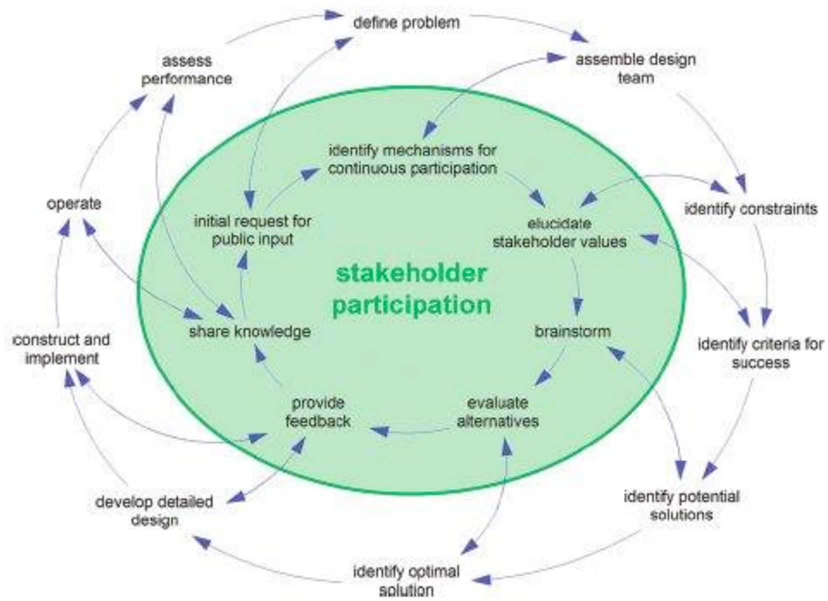

Figure 7.1: A suggested planning and design process used with permission from Guest et al (2009: 6129). The source document discusses the importance of stakeholder participation in nutrient recovery system design. It states that "[p]rojects must account for the local social and cultural setting and include input from the people who will ultimately operate, manage, and benefit from the whole endeavor" (Guest 2009: 6128). This is congruent with the integrated approach of *Two Ears of Corn* discussed in Section 7.1.

Urine fertilizer is well suited to operate under the *Two Ears of Corn* guidelines. Urine fertilizer is a simple technology, inexpensive to collect and easy to apply on crops. Collection devices can usually be made with local materials. Urine fertilizer can be explored with a small group of people on a small portion of their fields or gardens. It is a great way to teach people how to conduct controlled agriculture experiments. Perhaps most importantly, urine fertilizer can visibly improve crops within even a few weeks, keeping people excited about its use.

7.2.1 Small Groups of Committed People

With the guidelines of *Two Ears of Corn* in mind, the project was designed to offer maximum support to a small group of people in order to keep enthusiasm high. In Malian culture, greeting and frequent visits to friends and family are an important way to strengthen relationships. One goal was to keep a participant group small enough that a Peace Corps volunteer and counterpart could visit each participant at least once a week for a long conversation, and multiple times each week to drop in and greet. It was also important to keep the group small in case problems arose, allowing for faster spread of information. It was decided that 10 people would be a manageable size for one volunteer.

A need for enthusiasm also made it crucial to find people who were genuinely interested in the project. Many NGO's in Mali have in the past provided free materials and have paid people for attending information sessions. Indeed, many Malians asked if they would be paid for attending urine fertilizer sessions. Others expected plastic jugs to be available for the taking at the end of the sessions. In any development project, it is best to have project leaders and community members discuss and agree upon obligations that each party will meet. This is best done by outlining a series of step-wise obligations, with each party completing a small obligation in turn with the other. For example, the community agrees to find 30 people to attend a meeting, after which the project will hold a session on latrines, after which interested participants will dig a pit, after which the project will supply cement for a slab, etc.

Discussions with one of the first communities to do Peace Corps urine fertilizer projects, a village called Tantouji, led to two obligations for project participation: prepare field plots (i.e. outline urine fertilization areas with sticks) by a certain deadline deadline, and pay a fee by that same deadline. This deadline was chosen by community members in community-wide meetings to ensure that no one could claim the deadline was unreasonable later. The fee and the work of laying out plots were both enough of a deterrent for uninterested people to stay away.

The fee to be paid must be adjusted for the means of each community. In Tantouji, people were very poor and could not afford the entire collection system. Instead, a portion of the system cost was to be paid to the project under the condition that the system would be used properly. If, after paying the fee and receiving a collection system, a participant did not use the system properly, the author took the system back and kept the fee. Villagers understood that misuse of the system would mean they would lose the system and the money they paid. This deterred people who were just trying to get a free water jug and funnel.[22] The purpose is not to punish people who misuse the collection system. The goal is to prevent people who *would* misuse the system from ever joining the project in the first place. Indeed, participants who make a sincere effort but make mistakes or forget to apply urine now and then should not be punished. Observations of the project in Tantouji confirmed that people who meet the deadline obligations will usually use the system properly during the growing season.

In other communities that are more affluent, the initial fee can cover the entire cost of the system. Even better, participants can agree to purchase all materials on their own by the deadline. These

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[22] In Malian villages, honesty is held high, and community pressure is great when things are agreed upon in public. This pressure is enough to ensure that no one will pay the fee, keep the jug and funnel, and then deny what they had agreed to.

obligations can be changed in any way to meet the conditions of the community so long as mechanisms exist to deter uncommitted people from the project.

7.2.2 Strong Support During the Project to Keep Enthusiasm High

Peace Corps urine fertilizer projects were designed to also provide optimum support to participants, with more frequent assistance early on and more inter-participant assistance as applications progressed. The goal was to provide enough technical support to get participants on the right track, but to gradually become less actively involved in direct technical assistance, instead encouraging participants to remind each other about proper application. Project leaders were still to visit participants frequently, but as the growing season progressed, make fewer visits to the fields and more visits to participants' homes to say, "Hello." The project leaders' roles become less about technical issues and more about encouraging participants.

7.2.3 Small-Scale Experimentation

The collection of only 20 liters of fertilizer each week allowed for 10 square meters of field crops (a small portion of any field) or 5 square meters of garden crop (a modest portion of most people's gardens). This made small-scale experimentation mandatory for participants who were using only one jug. Consistent urine fertilizer application on small plots of crops adjacent to non-fertilized crops produced obvious visible results.

7.3 How to Lay Out a Urine Fertilizer Project in Mali

This section outlines how to do a urine fertilizer project as they have been done in Mali. This is a guide for community leaders or development workers. Though the steps may seem very detailed and complicated, this should be a very smooth, simple process from the viewpoint of participants.

Step A: Feasibility Study

Start by finding out general information to see if urine fertilizer is a viable idea for your community. Ideally, project leaders will be integrated into the community before this process begins in order to have better conversations and obtain useful information. Not everything has to be figured out at once, but more information ahead of time will make for a better project design and will give clues as to how methods can be adapted to local needs. It might be helpful to do a survey asking about things like family size, farming locations, distances from the home, local crops, local fertilizers used and costs, etc. Also, research to see if similar urine fertilizer or closed-loop sanitation projects have been done in the area. This research should be done both within and outside the community, using other organizations, documents, and the Internet.

Decide whether or not describing urine fertilizer up front is a good idea. Some cultures already have experience with urine re-use, but most will think it very strange. Experience with Mali projects showed that telling people that trainings were about fertilizer instead of about urine fertilizer made for greater turnout.

Step B: Make Sure Materials are Available (3 Months Before Planting)

Make sure people can easily obtain materials to build the urine collector that has been designed. Are materials available in the community? Can people find them during weekly markets in other nearby towns? Make sure that people will continue to be able to get the materials once the project leaves. If outside or expensive materials are used, the project will not be sustainable. If local blacksmiths, for example, do not know how to make funnels, either they need to be taught how[23] or another solution must be devised. All collector components must be available and relatively affordable before urine fertilizer trainings can begin.

Step C: Initial Trainings in the Community (2 Months Before Planting)

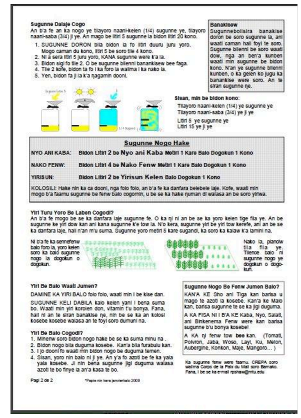
If materials are locally available, it is now time to teach the community about the fertilizer. Have information sessions to explain how the fertilizer works. Be very upfront about how strange urine fertilizer may seem, but tell people about other communities (preferably communities nearby) that have had success with its use. The most important thing is to find a way to convince people that urine use is safe. See Appendix A for resources to create and present information sessions.

Figure 7.2: The author presenting urine fertilizer to a women's group. (Photo by Patty Gaumond with permission).

[23] Making Funnels in Mali: Sometimes a community was interested in urine collection, but no funnels were to be found. Fortunately, almost every village had their own blacksmith or had one nearby. The author would bring example funnels to these local blacksmiths and state the following: "I will pay you extra money this time so that you can try to make this thing you've never made before. Once you have made one and understand how to make it, we will negotiate a fair price for materials and labor that you will charge when other people come." After this lower price was negotiated, the author would then tell community members the price. In Mali, this was sufficient to ensure that funnels would be available at a fixed price.

If possible, have a host-country national give talks about his or her experiences; ideally, this person would even teach the class. Put together simple information sheets in the local language to pass out (see Figure 7.3). Use any other techniques to get people excited about trying urine fertilizer.[24] Even if only a few people are enthusiastic, move to Step D.

Figure 7.3: Even in areas of high illiteracy, such as Mali, information sheets are a valuable reference, as someone in the family or a neighbor can usually read. The sheets will serve as a reference if some details have been forgotten. See Appendix A (page 62) for a sample sheet in English.



Step D: Second Meeting to Explain Weed-Out Plan (1 Month Before Planting)

Call another meeting for anyone interested in trying urine fertilizer. This meeting will outline the requirements for anyone who wishes to join the project. There is no deception here. Be very up front and explain that the project only needs committed people, not people who are hoping to get a free jug or hoping to get paid for attending meetings. Explain that the project will accept the first 8-10 people who pay a fee and who prepare their urine plots (i.e., outline their intended urine plots with sticks) by a chosen deadline. Anyone who fails to pay her fee and outline her plots by the deadline will not be admitted. Again, these requirements are to ensure participants have genuine interest in the project.

In cases where community members cannot afford the entire system, the initial fee will be a portion of the cost of the entire collection system. The project will take the fee and give the participant a collection system, under the following conditions:

- The participant agrees to use the system properly and make a sincere attempt to fertilize her chosen crops with urine fertilizer. Success is not required, but a genuine attempt must be made.
- If the participant defaults, she will return the system and lose the fee she paid up to that point.
- If she collects and applies urine in good faith, she will keep the system and pay a second fee for use of the system during a second growing season, and then a third, under the same conditions.

The idea is to have three fees that in total will pay for the collection system. Once all three have been paid, the participant will have paid for her own system and now owns it. In Tantouji, a village in Mali, the urine collection system cost 1,350 CFA total, so villagers paid 400 CFA before the first growing season, 450 CFA before the second, and 500 CFA after the third, paying for the system themselves and keeping it upon completion of three growing seasons of proper collector use.

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[24] In Mali, one useful technique was for Peace Corps volunteers to start collecting the fertilizer on their own. Neighbors would come by and ask about the fertilizer, and the volunteer would explain. Some people would be shocked, but others would inquire further, assuming they were one of the first to hear about this new useful Peace Corps idea.

The fee will deter people who are not genuinely interested in the project. The fee is never meant to deter people with genuine interest who lack means. If someone approaches project leaders well within the deadline and gives a good reason that they cannot afford the fee prescribed, leaders can work with her to decide upon another method of ensuring she is committed. This work should still be completed by the deadline. Project leaders should be leery of accepting people who come up with excuses after the deadline has passed, as these excuses can and likely will go on indefinitely.

Project coordinators can use discretion in deciding what constitutes non-payment or default. Experience of the author has shown that it is best to be strict with people who miss the initial plot layout and fee deadline, but to be lenient with participants who make mistakes or forget to apply urine fertilizer now and then. The project should only revoke the systems of people who are blatantly misusing resources (e.g., people using a jug and funnel to transport gasoline to sell, people transporting oil to sell, etc.).

Step E: Weed Out to Find Participants (Two Weeks Before Planting)

Some people will pay the fee and lay out their plots ahead of time. As the deadline gets closer, remind other people who seemed interested that time is running out. Although it may seem harsh, it is important to be strict about the deadline, even if only a few people have fulfilled the requirements. The project will gain more credibility by holding true to the deadline and rewarding people who keep their word. Other people will be able to participate in the next growing season. Initially, the goal is to encourage those who have committed. Even if only a few people instead of the intended 8-10 meet the deadline, work with those people closely instead of worrying about increasing numbers.

Make sure everyone who has paid has outlined the application areas with sticks. Then give each person her collection system. If people have made errors, perhaps about plot size and such, stay positive and help remind them of proper use. It is time to be encouraging. A few errors early on will not greatly affect crop yields, especially since crops tend to take up the most nutrients during the middle third of their life. Help remind participants how urine fertilizer works, and begin connecting them with other participants to build a network of support.

Step F: Get Started- Monitor and Encourage (Planting Time and Beyond)

For the first few weeks, be extra vigilant about visiting participants. Ask to use their latrine and check on the collector, and make very passive and supportive comments if you notice an error. Try to go with people to their fields during the first few applications of fertilizer, offering encouragement and suggestions if errors are being made. In many cultures in the developing world, and this is most certainly true in West Africa, it can be very damaging to someone's self esteem if her mistakes are pointed out in a direct way. Take great care to avoid embarrassing someone, even if this means allowing an error to occur. There is room for mistakes in this process. Let the error happen and remind a participant of a proper technique during the next visit, for example.

Be sure to ask about any troubles that people have been having or things that are bothering them. Discuss with other participants to see if they are having similar problems, and be sure to ask if they've found solutions. Often, participants will have great ideas about how to solve a problem. Get this information to everyone in the group as soon as possible to head off problems before they become unmanageable, and give credit where credit is due to strengthen confidence between participants.

As people begin to gain confidence in themselves, show up less frequently during application. Pop in during the week instead and be supportive. Encourage participants to apply urine fertilizer together and visit each other's fields to help remind each other of proper technique. Provide less technical assistance when it is no longer requested. A project leader should become more of a resource that people can seek out and less of an observer or enforcer. This will empower participants by giving them confidence in their own abilities.

G: Show Off Project Successes (1-3 Months After Planting)

One or two months after planting, crops should start showing visible improvements over their adjacent, non-urine fertilized neighbors. If participants find success, encourage them to show family and friends. Bring skeptical people to the fields to see the difference. If community members can see the difference with their own eyes, they will be much more likely to come to future trainings with an open mind. And if they see the difference and hear how it worked from a fellow community member, they will be much more likely to join the project during the next growing season.

Community leaders and development workers should also start to document success and challenges that have been happening during the project. This information should be shared with other organizations and surrounding communities so that future urine fertilizer users can learn from the current project. Collect stories, take photos of fertilized crops adjacent to unfertilized crops, or even do a survey to share with others.[25]

H: Go to Step C and Repeat

Hopefully, the participants have found success and have been talking with other community members, showing them the improved crops. There will likely be a lot of enthusiasm generated. If possible, carry

[25] The author and his graduate advisor would greatly appreciate being sent any of this information, so that future urine fertilizer projects can be improved. Please e-mail ryanpshaw@gmail.com and jm41@eng.usf.edu. See Appendix A.

that enthusiasm into the next growing season and begin with step C again with new information sessions. The main difference this second time around will be to use first-round participants as teachers and trainers whenever possible. Locals teaching locals will be a much better catalyst for behavior change than outsiders teaching locals.

A Note to Peace Corps Volunteers

Many Peace Corps volunteers, and indeed many development workers, get frantic towards the end of their term of service and start skipping important steps to sustainability in order to get projects done. Try to avoid this temptation. If things are kept simple and small-scale, it should be easy to pass things on to a future volunteer. Even if a site is not getting a new volunteer, someone nearby should be able to assist the counterpart in keeping the project moving forward. If things have moved at the slow pace they should, trying to rush everything at the end will ruin all of those gains. Grassroots development and behavior change is a slow process, and it can take more time than the two years that Peace Corps service allows. It is better to pass on the plan for small project than to squeeze in a mediocre project at the end. The next volunteer will appreciate having something easy and effective to do, and seed will have been planted for truly sustainable change. Too many volunteers do not achieve this sustainability because they are too concerned with completing big projects.

7.4 Adapting to Other Communities and Other Types of Projects

Integrating into the community and doing a feasibility study will give insight as to how the projects can best be adapted to a new community with different needs. It is more important to follow the guidelines of *Two Ears of Corn* than to adhere to the project steps above. The steps outlined here have been tailored to the Malian situation based on lessons the author and other Peace Corps volunteers have learned and may help avoid some common mistakes, but don't be afraid to adapt any part of this. The project layout above is only one possibility. This section highlights some of the biggest concerns that may require adjustments in other communities.

7.4.1 Adapting This Approach to Other Types of Projects

It should be noted that other types of simple, highly successful technologies or ideas can easily be substituted into the outlined project framework. Leaders of projects of all kinds can benefit from this pilot-project approach that helps work out problems with a new technology, offers maximum support to participants, and allows the constant sharing of feedback with and between participants.

7.4.2 When to Tell Community Members about Urine Fertilizer

It is very important to be honest and upfront about the nature and risks of new technologies, but it is the experience of the author that it is difficult to get people to an initial information session if they are told the subject is urine fertilizer. In certain situations, the author did in fact tell people upfront, but this was followed quickly by a synopsis of how urine fertilizer has been used all over West Africa, how it is similar to the use of animal feces on crops, and several minutes about the low-pathogen content of urine. In most cases, it was easier to get people to come to a meeting about a fertilizer they could make on their own. The author feels that this is ethical so long as the first minutes of the information session introduce urine as the fertilizer in question and admits the strangeness of it all (quickly followed by the fact that it is working for a lot of people in Africa[26]). Project leaders should give this issue some thought and decide what is best concerning their target community.

7.4.3 Deciding on Participant Obligations

Plot layout and fee payment by a mutually agreed upon deadline were the two main participant obligations for most Peace Corps Mali urine fertilizer projects, but remember that these only exist to deter uncommitted people from joining the project and taking an opportunity away from someone else. If other obligations can meet this need, they can be substituted; just make sure that community members, not just community leaders, help create these obligations. A meeting with community members should suffice to ascertain if obligations are reasonable. Be a good negotiator, but do not adopt obligations that community members are absolutely against. In the end, there must be a contract, written or otherwise, between the community and the project so that everyone understands her role.

7.4.4 Possible Cultural Barriers

While doing presentations and projects in Mali, there were not many unforeseen barriers to the use of urine. The most important part was convincing Malians of the safety of using urine fertilizers. Most people understood the correlation between using animal excrement and human excrement. One Malian pointed during a presentation to point out that the urine-soaked feces from animal pens is known as the better fertilizer, and many audience members nodded in agreement. Indeed, Kvarnstrom, et al, state "research results show that urine diversion is feasible in West Africa, since the concept was accepted and appreciated by the users in [each of the seven countries where projects took place]" (2006: 7).

Although a few Malian community leaders mentions the possibility of opposition due to certain Muslim and traditional beliefs, no one interviewed raised this issue, nor were these issues mentioned as reasons

[26] It is also working for a lot of people in Sweden, and Latin America, and has been done in China for centuries, in case those with other audiences were wondering. See Appendix B for resources that provide examples in other regions.

others might not try the fertilizer. Still, a more in-depth social and cultural analysis may be required to overcome unforeseen barriers in some communities. Some communities where polygamy is present, as is the case in many West African countries, may have gender issues concerning who is allowed to use the urine collected from the husband or from other wives' children, for example.

7.4.5 Opportunities for Project Documentation

Partly due to the need for simplicity, the early projects outlined in this report do not include scientific measurement of results, instead focusing on obvious visible differences to persuade locals. The thought was that focusing on local enthusiasm early on would later lead to more participants, a stronger desire to learn about urine fertilizer, and more meticulous application with each passing growing season. These phases would all lend themselves to more controlled experimentation. Community members should decide at what point they are ready to take on this extra endeavor.

The narrative of each project, the individual stories, failures, successes, and adaptations, should also be documented whenever possible. This type of project documentation can often seem like a lot of extra work, but it should be seen as a way to add value to all the work that has been done towards a project. Even if everything goes wrong, documenting mistakes and giving reasons will allow another project team to learn from those mistakes. Consequently, even a failed project offers opportunities for future success. And if the project goes well, disseminating this information can help another project work better from the start.

The development community is just now starting to tap into the Internet as a way to collect this valuable information about past projects. Information can be sent to similar organizations doing similar work. Databases can be set up to allow development workers to search for specific types of projects, perhaps done in specific regions, and outline better practices. Wiki-sites allow workers in the field to update the status and progress of projects. Villagers can record videos to explain technologies in local languages. If development organizations begin using these resources to the extent possible, openly sharing information, being honest about mistakes[27], and outlining strategies for achieving new successes, development will move forward at a much more rapid pace.

[27] The need to show progress to donors can often lead to an exaggerated account of success in projects and the glossing over of mistakes that were made. If the development community as a whole can agree to show donors that mistakes can provide valuable lessons, then organizations can start being honest about those mistakes and learning from each other. This will be a difficult shift, but it is an important one development is to improve on a grand scale.

8. RESULTS OF SEVERAL URINE FERTILIZER PROJECTS IN MALI

The following are brief descriptions of some of the urine projects done with the author in Mali. The goal of each was to get community members excited about urine fertilizer technology. Some went wonderfully (Tantouji), some went moderately well (Diallola), and some did not go at all (Pelani). Each experience, and the ideas and feedback of participants from each community, have led to the development of the project methods outlined in Chapter 7.

8.1 Project with the Diallola Women's Group (Kayes Region, Mali)

The first Peace Corps urine fertilizer project in the fall of 2007 was done with a women's gardening group made up of 30 women in Diallola, a peri-urban area on the outskirts of Mahina (a town of 7,000). The women had already been working with the author on a project to fence in their garden and had developed a relationship, so they were very willing to come to an information session. The session went well, but only three women expressed interest in urine fertilizer use. Instead of trying to find other ways to increase enthusiasm (perhaps taking the women on a field trip to urine projects near the capital), the author made the mistake of buying 5 collection systems and simply handing them out to the group. The thinking was that the women would try urine fertilizer, see the difference, and tell everyone they knew about the results. That growing season, only the 3 women who had originally showed interest used their collectors. In hindsight, the women may have only done this because they were afraid of jeopardizing their on-going fencing project, though this would not have affected the fencing project in any way.

Figure 8.1: After finding success with urine fertilizer trials, Mariam Sissoko continued its use during the next gardening season. (Photo by Stephanie Myers, with permission).

The good news is that the 3 women who tried the fertilizer ended up seeing great improvements. They said their tomatoes and peppers were coming out earlier and growing faster with urine. One of the women had also applied urine on a portion of her corn and was amazed at how the corn fertilized only with urine fertilizer was growing even better than the corn she had only fertilized with cow manure (see Figure 8.1). The husband of this woman also saw the improved corn and began collecting his own urine during the next growing season. Unfortunately, the author made infrequent visits to these plots and never got a photo of the improved corn, nor were the women ever properly encouraged to show off their successes.

Also, the urine fertilizer presentations for these women had only focused on information and had not been improved with humor, testimonials, and hands-on demonstrations to increase enthusiasm. The author assumed at the time that simply presenting information would be enough. Even after these 3 women had seen success, they were too shy to make an effort convince other skeptical women about the value of urine. Two year after the first trials, those same 3 women and the one husband were still using urine fertilizer with great success, but the technology did not spread.

8.2 Information Session with Counterparts (Bamako, Mali)

At least twice a year, Peace Corps volunteers from around Mali come to a training center in the capital, each bringing one counterpart from their community. The author had been excited that urine fertilizer worked in Diallola, and a training session in January of 2008 seemed an ideal time to spread the word. The author had also just read *Two Ears of Corn* (Bunch, 1985) two months prior and had many new ideas about how to make urine fertilizer projects sustainable.

At the training center, the author went around each day greeting counterparts and inviting them to sessions about fertilizer. For three nights in a row, the same 40-minute urine fertilizer presentation was given in Bambara, the *linga franca* of Mali. These sessions incorporated as much clean humor and as many stretch breaks as possible to keep people attentive. The first night, 6 people came, and they were all excited, promising to tell other counterparts about the information sessions. The second night, 14 people came, including 2 from the first night. On the third night, about 30 people showed up, again with a few people from the first and second nights. Many counterparts were very excited and told other about urine fertilizer. Further, the author had announced that 10 funnels and lids were available for purchase at full price, and all were purchased by the end of the third session.

Information sessions were given to the volunteers a few days later, many of them being spurred on to attend by their counterparts. These sessions were very effective in getting counterparts and volunteers excited about urine fertilizer, and several went on to present information sessions back in their communities.

8.3 Project with the Village of Tantouji (Kayes Region, Mali)

One of the excited counterparts from the training center sessions was from Tantouji, a village of 600 that was 6 kilometers from the author's site, Mahina. Tantouji had recently lost their volunteer due to a site change, but Moussa (*MOO-suh*), the counterpart, was still eager to work with the Peace Corps. Moussa had proven to be a very committed individual in several instances, including a composting project with the author. Together, they began to work with community leaders and elders to develop a plan for a sustainable project (which has ended-up being the basis for most of the projects done since). Moussa and the community elders spent many meetings deciding what needed to be done. A blacksmith was already making funnels 6 kilometers away (in Mahina) because of the previous Diallola project. The funnels and all other materials could therefore be purchased during weekly visits to the market day in Mahina.

The first community-wide information session for Tantouji was held in March of 2008. The plan was to prepare people to use urine fertilizer on their field crops during the upcoming rainy season, which typically runs from June to August. At the end of the information session, it was announced that a second meeting a few weeks later would explain how villagers could become involved in the project. The second meeting in April explained that the project would only work with a small group of ten people. The fee schedule (explained in full detail in Step D of Section 7.3) was outlined, and the loss of the fee and collection system if it was misused was made very clear. The deadline for fee payment and plot layout were explained, and everyone was given the chance to ask clarifying questions, to ensure that no one could rightfully claim confusion later. Everyone present at the meeting also decided on a May 15th deadline.

In early May, Moussa had collected the fee from 8 villagers, and he began reminding others that the deadline was approaching. Moussa also began checking if people who had paid the fee had also set up their plots. By May 10th, eleven people had paid and set up sticks around their plots. Community members decided it was fair to keep the 11th woman on board since everyone had met the deadline. Participants began planting the last week of May and began fertilizing their crops with urine soon after.

The author moved to a new site on the far side of Mali for a third year extension, but Moussa visited the participants and continued encouraging everyone. He relayed progress over the phone and said results were encouraging. Moussa said participants were seeing increases and showing their friends. Unfortunately, he did not get any photos[28], but he said a lot of new people were asking about trying urine fertilizer during the next growing season. Moussa was then sent enough money to purchase systems so that, using participant fees, the project would be sustainable.[29]

Villagers again found success in the gardening season, and by the time the author returned to visit in January of 2009, 17 people had collected and applied urine on their crops. Moussa had kept track of everyone's names and fee payments in a notebook and was ready to provide training in March.

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[28] The author left a point-and-click camera and two rolls of film with Moussa, who claimed he knew how to work them. Moussa took pictures of the differences that urine made on crops, but unfortunately, both rolls got exposed somehow.

[29] Once the initial systems are purchased for three rounds of participants, the fees being paid will be enough to purchase new systems for each new group. An explanation for this required amount can be found in Appendix A, page 61.

Figure 8.2: Amadou Sissoko (right) stands proudly next to his urine-fertilized onions. Notice the square garden plots behind him. Moussa stands on the left. (Photo by author).

Villagers were very excited about the use of urine. One man showed off his urine fertilized onions (see Figure 8.2). Another woman said she had never expected urine fertilizer to work so well, and that she would always use it from now on. Moussa was very proud. One last visit to Tantouji in November of 2009 found 24 people applying urine fertilizer on their fields, and that number is likely growing still.

This level of sustainability in Tantouji has far exceeded the level of other projects attempted by the author and by other volunteers, but these ideas are all very new. As information about successful projects spreads to other communities, there will likely be more stories similar to the one in Tantouji.

8.4 Projects with Dogon Villages (Mopti Region, Mali)

In the summer of 2008, the author moved to a new site in the Dogon area of the Mopti region in Mali. The Dogon people of this village, named Pelani, lived on very barren land and tired soils. Two married volunteers lived in a Dogon village 20 kilometers away and had a similar situation. The author thought that urine fertilizer would be well accepted in these areas because it would provide much-needed nutrients to the crops on these tired soils. In the end, a combination of problems resulted in no one in the area adopting the use of urine fertilizer.

In Pelani, the first problem was that no one had experience working with a Peace Corps volunteer, and the author had only been there a short time and had not yet developed strong relationships with most of the village. To compensate, an information session was only given to a small group of people, but even they were skeptical.

This was partly due to a second obstacle: most people in the village did not discuss bodily function, which were typically carried out very far from the village and in the open. Indeed, only two latrines existed in the entire village. People urinated in their wash areas, but it was generally not mentioned. People did not declare, “I must use the wash area.” Instead, they would just leave without a word. The stigma around discussing these matters made it difficult to convince people that urine fertilizer was safe and worth discussing. The people at the information session listened, but they were not excited and barely interested.

The third obstacle was that the Dogon area of Mali, very poor but also very high in tourist traffic, had typically received large amounts of aid without strings attached. A typical example would be a wealthy tourist visiting the village and then, feeling compelled by generosity, paying for a new pump or a new school in the village. The Dogon people were therefore accustomed to handouts and expected that urine fertilizer projects would be the same. The two people who were interested in urine fertilizer lost interest when they learned they would need to meet certain obligations.

Another information session in Kalibonbon, the village of the two married volunteers, had similar results. Their counterpart has expressed great interest, and people seemed much more excited during the presentation given in the village. When it came time to find participants, however, even the counterpart said it was too strange for him to try. Things were further complicated by the village leaders not advertising the session to women, which is a recurring problem involving community meetings in the Dogon area.

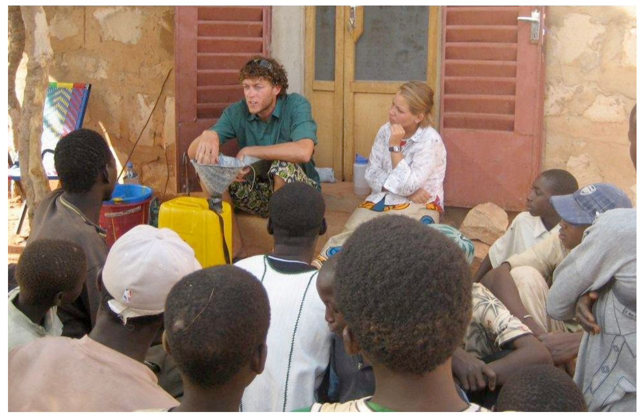

Figure 8.3: The author presenting in Kalibonbon. No villagers tried the fertilizer. (Photo by Joe Wollersheim, with permission).

The projects in the Dogon area show that even technologies that have worked well in certain communities may not work in others. Feasibility studies and integration into the community will help forecast if urine use will be accepted, but even so, there will be cases where enthusiasm will just not be present. If even one person shows sincere interest, work with her if resources allow, but there will be places where interest in urine fertilizer is nowhere to be found.

8.5 Presentation in the Town of Mahina (Kayes Region, Mali)

On a return visit to Tantouji and Mahina in January of 2009, the author presented a urine fertilizer information session to a group of women that had been gathered by a friend of the author. The friend was a middle-aged woman who sold fruit across the street from the funnel-making blacksmith in Mahina. She remembered explanations of what the funnels were for, and upon seeing a CREPA commercial on television about using urine as fertilizer, called to request an information session for her friends. Following the phone call, she also talked to some of her friends from Tantouji who passed by on the way to the weekly market, and heard their success stories.

Figure 8.4: Haidjara Traore now uses urine fertilizer on her onions and papayas, thanks to a training set up by her friend. (Haidjara was reluctant to be photographed, but the children nearby were not). (Photo by the author).

The author arrived at the friend's house and found 10 women ready to listen to the talk. They were all very excited, and at the end of the session, one of the women even bought the funnel and jug used during the presentation. Everyone received handouts about the use of urine fertilizer, some taking the local language versions in Bambara and others taking the versions in French. During the final visit to Mahina in November of 2009, the friend said that 3 of those women were still using urine fertilizer, and a visit to one of them confirmed her excitement.

Although this was an instance of just providing information, which is typically not effective for behavior change, it is important to note that the successes of Tantouji and the advertisement on television were important factors in increasing the enthusiasm of these women. This suggests that the project method outlined in this report can lead to the spread of excitement surrounding urine fertilizer technology into new communities and spur individuals to seek out the technology on their own.

9. LIFE AFTER URINE FERTILIZER PROJECTS/NEXT STEPS

9.1 Projects Building Toward Community Empowerment

If urine fertilizer projects are done in the manner outlined by this report, and if after the second meeting to determine project obligations there is still even one person interested, urine fertilizer is likely to succeed. It may require a lot of time and patience, but working with and encouraging community members to try out the fertilizer, and working through most of the community-specific problems that will arise, will lead to an exciting result: a useful, workable technology applied successfully by locals under local conditions. Urine fertilizer has worked over and over again, and if community members can see the success with their own eyes and hear it from a fellow community member with their own ears, the work of spreading the use of urine fertilizer will already be done. In community-centered cultures like Mali, people will start to tell their friends, neighbors, and others in their market towns about new ideas that work, and these ideas will spread.

Project leaders can facilitate these conversations and make the idea spread faster. They can hold sessions where locals give testimonials or even teach. They can lead field trips to places where urine fertilizer is used.

They can encourage locals to talk about urine use on the radio and get people talking. Once urine fertilizer has been used successfully by local community members, project leaders can be confident that problems will be minimal and that adapted project methods will lead to similar successes. Real sustainable behavior change will start to occur.

Urine fertilizer projects also are a gateway to other technologies and ideas, empowering communities to experiment with new technologies on their own. "ECOSAN technology should not be promoted for its own sake, but for empowering people, making them aware of high resources within their wastes, entrepreneurship development and using indigenous styles rather than replacing them with modern ones" (Manandhar et al, 2004: 112). Community members will become confident in their ability to grasp more complex application rates and times. Practice with calculating urine doses for specific crops can inspire people to learn important math skills. Participants will feel empowered when they teach others about urine fertilizer and become the experts instead of project leaders. The experience from the project of World Neighbors outlined in *Two Ears of Corn* show that this type of slow, simple, and small development can build into sustainable community empowerment in as little is 3 to 5 years, leading to new ideas and increasingly more complex technologies. These practices empower community members to begin developing their communities with little or no outside help.

9.2 Projects Leading Toward Larger-Scale Urine Fertilizer and Closed-Loop Sanitation Use

It is hoped that urine fertilizer used on this initial small scale will also lead to more efficient and larger-scale use. Communities can start using crop-specific doses and application times. They can start looking at more efficient use of phosphorus in the urine (which typically settles towards the bottom of stored urine), as vegetable fertilizers typically have higher ratios of phosphorus to nitrogen (Jonsson et al, 2004: 11, 17). Project leaders and organizations can ensure blacksmiths know how to make funnels in market towns or regional capitals (see Appendix A). They can look into ways to use urine efficiently outside of local growing seasons. Although storage of pure urine is not currently economically feasible in Mali, it may be a possibility in other communities and in the future. Local soil conditions may also permit better nutrient retention and may make storage by incorporating urine into the soil feasible. Further benefits may be found if soil storage of urine is combined with nutrient retention improvements, such as the parallel addition of organic matter or *terra preta* soil.

Further still, local rises in commercial fertilizer prices can lead to urine being valuable enough to sell, and microenterprises can develop (Kvarnstrom et al, 2006: 4). The value of urine is already rising as people begin to understand its effectiveness. As mentioned earlier, CREPA projects in Benin have had occurrences of jugs full of urine being stolen and returned empty, and CREPA has also had difficulty obtaining enough urine for one research site in Burkina Faso ever since people were shown the increased yield of urine-fertilized crops (Kvarnstrom et al, 2006: 7). People want to keep the urine for themselves.

Understanding the fertilizing value of their urine, coupled with knowledge of the fertilizing power of animal excrement, can lead people closer to accepting closed-loop sanitation. If people can see their own excrement being turned into safe, beneficial nutrients for crops, they will be more open to closed-loop sanitation options. This new view of urine and feces can lead to quicker, more sanitary pathogen destruction, healthier crops, and a healthier community.

9.3 Possibilities for Future Research

The amount of research on human urine and the effects it has on crops is limited but growing. As urine and its use in different regions of the world becomes better understood, researchers, development workers, and community leaders will be able to make better recommendations for the use of urine. More data is needed on the nutrient content of urine and the volume of urine that people produce, both in terms of different regions of the globe and different diets of the people. More research is also needed concerning the effect of urine on specific crops and on different types of soil. The effect of soil storage will also be useful information for regions similar to Mali, where soil nutrients are low and urine storage is not yet economically feasible. Soil can be tested before and after urine application, or urine can be incorporated into the soil in the off-season to see the effects on different crops. There is also evidence that urine can improve different types of compost. All of this information will aid in the more efficient use of urine.

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APPENDIX A: Additional Resources for Doing Urine Fertilizer Projects

This section will provide addition information for anyone trying to do urine fertilizer information sessions or urine fertilizer projects. Please feel free to contact the author at ryanpshaw@gmail.com with any questions or to obtain electronic copies of any documents in their original formats so that they can be altered to be of use to other projects. The author can also provide presentation outlines and slides. If possible, also please relay any information regarding projects that are in progress or have finished. Describe what worked, what did not work, how ideas in this report did or did not work well, and anything else that may help others in the future. The following are a few resources that may make new projects easier:

A.1 Urine Fact Sheets

The author has developed a two-page fact sheet (ideally printed on the front and back of a single sheet of paper) that includes all the "how to" sections on building a urine collector, collecting urine, and applying urine (Sections 4.2 on page 17, 5.2 on page 24, and 6.2 on page 33). The in-depth explanations have been removed to offer a concise resource for participants. These sheets provide all the information that participants need in order to use urine fertilizer. Although the participants in many communities may be unable to read, they often know someone who they can ask if a question arises. The pictures on the sheet also serve as reminders.

Sheets should be translated commonly used and/or commonly read languages whenever possible. Readers can e-mail the author to obtain pdf versions of the urine fact sheets in English, Bambara, and French. The author can also send the English version in the original Microsoft Publisher format so that others can translate the text into a local language and alter the format as they see fit. The English version of the fact sheet can be found on the next two pages of this appendix (page 62 and 62).

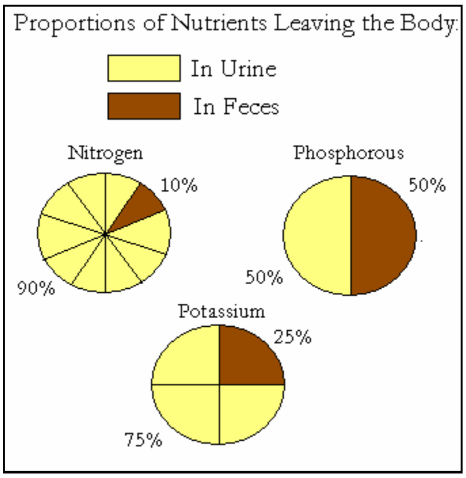
A.2 Presentation Information

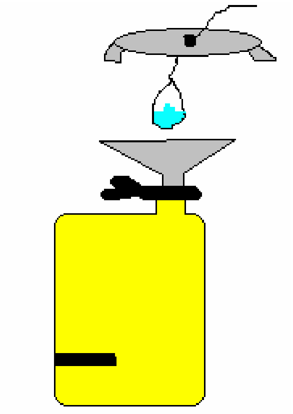
Urine fertilizer information sessions for communities can be based on the content of the urine fact sheets (next two pages) and can be given in the same order. The introduction should be tailored to each community, but the rest of the fact sheet contains all pertinent information. The author usually presented the sessions in this way, the only addition being materials on hand to build a collector and to simulate collection, plot layout, and application. This worked better than pictures in avoiding confusion.

For audiences that are more interested in more detailed explanations behind each step, the information from this report can be used. The author will also e-mail rough transcripts and visual aids from past information sessions upon request.

STARTING TO USE URINE AS FERTILIZER

People have used animal and human feces to fertilize crops for centuries because manure contains many vitamins that plants need. What most people don't know is that the majority of beneficial nutrients leave human and animal bodies through urine rather than through feces, and the majority of urine is pathogen-free. People in the developed and developing world are beginning to use this untapped nutrient potential to fertilize crops with great success. It's currently being tried all over West Africa. This paper will teach you how to collect urine in modified jug and turn it into fertilizer in a safe and cheap manner.

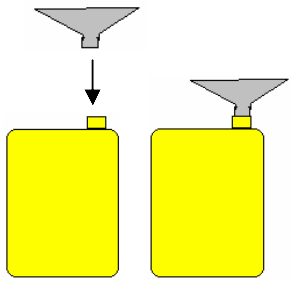




The Urine Collector

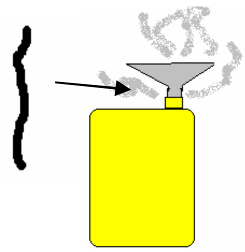
We can't apply urine directly on plants because it's too acidic and will burn the roots of our plants. We need to collect the urine and dilute it.

Start by getting a 20 L yellow jug (not green because we need to see the liquid level inside). Cost: 400-750 CFA

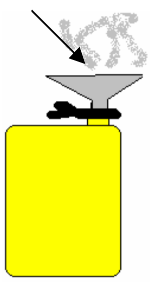


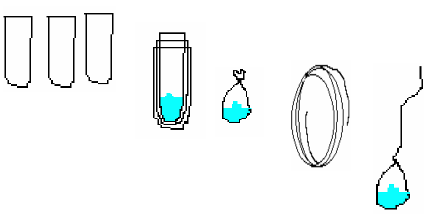
Buy a large mouth funnel that can fit tightly into the jug opening. The stainless steel funnels made locally are best. If possible, have the funnel maker add a screen to block debris from falling in.
Cost: 500-1000 CFA

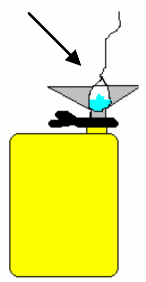
We need to make the jug air-tight. Otherwise it's going to stink, and that stink will mean a lot of precious nitrogen is leaving as ammonia. First, we tie a piece of rubber cord where the jug and the funnel meet to seal any air gaps.
Cost: 0-100 CFA

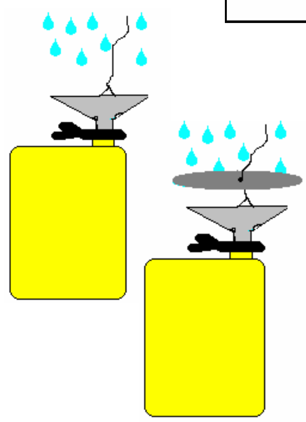


Next, we're going to make a seal for the mouth of the funnel. Put 3 old plastic bags one inside the other and fill the inner most bag part way with water. Push the air out and tie the bags up top so it swims. Now tie it to a string. Cost: 0-50 CFA



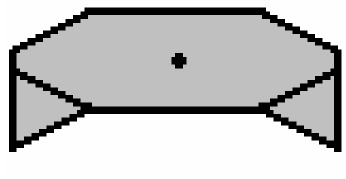


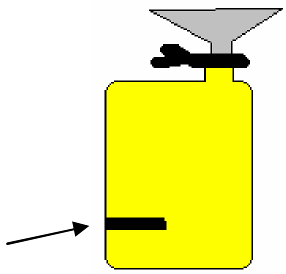




If your latrine doesn't have a roof, you need a cover to keep rain out during the wet season to avoid over-diluting the nutrients in the urine. You can use anything that can sit over the funnel. Put a small hole in the middle and loop your string through.
Cost: 0-350 CFA

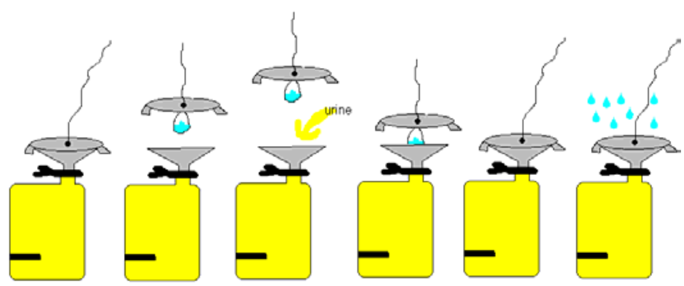
Ask the funnel makers if they can make a nice cover like this out of sheet metal. Ours did for 350 CFA.





Now draw a line at the 5 liter level (1/4 up from the bottom). This is for our dilution of 1 part urine, 3 parts water.

Tada! A beautiful jug ready to collect urine. The rope is attached to the latrine wall. When you want to add urine to the jug, pull the rope up. The bag and cover will rise. Add urine and place the cover once more. The jug is now airtight and rain proof.

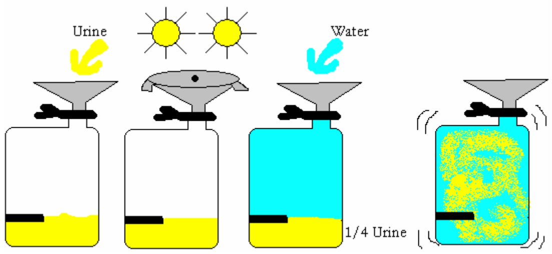


NOTE: Women and small children can add urine to the funnel using a cup. Sit a cup or old can in the latrine. People can urinate into the cup and dump it into the collector afterwards.

Collecting and Diluting Urine

We want our fertilizer to be 1 part urine, 3 parts water: That means we need 5 liters of our 20 liter jug to be urine. Here's what we do:

1. Add **ONLY URINE** to the 5 liter line. This usually takes 4 or 5 days.
2. **STOP** adding urine at the 5 liter line. Now 1/4 of the jug is urine.
3. Let the jug sit for 2 days. This will kill any schistosomiasis in the jug.
4. Take the jug to your chosen garden or field.
5. Now top off the jug with water and mix it a little.



The jug is now 1/4 urine (5 L) and 3/4 water (15 L). Tada! You just made urine fertilizer, and **it's ready to fertilize!**

A Note on Diseases

Only diseases of the urinary tract are transferred through urine. The most common is schistosomiasis, which we kill during collection. Other urinary tract infections are rarely spread through contact with urine, so even though we will take precaution, there is no need to be afraid of the urine.

Application Rate

Fields: **2 Liters of Mix per 1 Square Meter of Field Crops each Week**

Gardens: **4 Liters of Mix per 1 Square Meter of Garden Crops each Week**

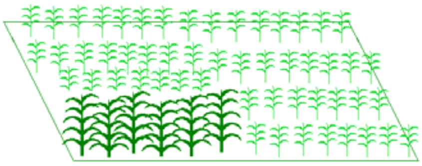
Trees: **2 Liters of Mix per Tree each Week**

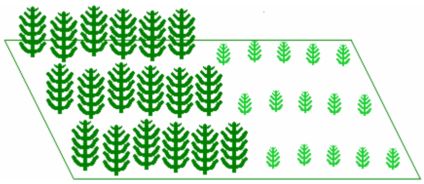
NOTE: These are strong doses that will produce a visible increase in most crops. Once people are convinced the urine fertilizer works, we can use more efficient nutrient application rates for specific crops.

Prepare an Application Area

We want to see that there is a difference when urine is used, so it is best to chose an area we can split in two. We put urine fertilizer on one portion and none on the other. We'll be able to see the difference with urine and non-urine crops next to each other. Use sticks to mark off the area where urine will be used.

With field crops, choose a small section of a larger field and consistently apply the fertilizer to that area.





For garden plots, split each in half and fertilize the same half with urine each week.

When to Apply

START APPLYING URINE at the time of planting.

STOP APPLYING URINE one month before harvest. Old plants cannot use extra vitamins efficiently, so the urine is best used elsewhere or saved for later use. This also adds a level of precaution against any microbes that may have been in the urine. The vast majority of microbes in urine die off in one month.

How to Apply Urine

1. Find something to measure out the desired dose.
2. Pour the fertilizer near the ground to prevent urine from getting on the leaves.
3. Wait until the fertilizer seeps into the ground.
4. Now, water the area with pure water. Recall that the nitrogen in urine turns into a gas and escapes (and stinks!). This water pushes the urine into the ground to keep the nitrogen (and smell) there.

For more information, please contact Peace Corps Mali or e-mail rpshaw@mtu.edu

What to Fertilize with Urine

BAD FOR: Flooded Rice, because we don't want that urine sitting in pooled water.

LITTLE EFFECT ON: Legumes, Beans, and Peanuts, because they already fix nitrogen.

BEST ON: Corn, Millet; Sorghum, Salads, Spinach, and other Greens because the nitrogen in urine is especially great for growing bigger leaves and lots of seeds.

BUT GREAT ON: Everything Else (Onions, Tomatoes, Potatoes, Eggplant, Bananas, Peppers, Garlic, Cucumber, Melons, Squash, Okra, Cabbage, Sweet Potatoes, Cassava...)

A.3 A Sustainable Payment Plan

In some places, the urine collection system will be inexpensive enough that it will not prevent participation in a urine fertilizer project. If cost is a problem, as it is in many poor communities in Mali, the project leaders can seek outside funding to purchase entire collection systems. Participants will then make two or three incremental payments towards the purchase of the entire system. These payments can then be collected by project leaders and used to buy additional systems for new participants. In this way, the project can go on indefinitely after the initial capital investment, provided a certain amount of money always remains in the project savings to insure against problems (price increases of materials, damaged systems, etc.).

Project leaders can calculate the initial capital required to purchase collection systems indefinitely and seek this funding. Peace Corps Mali projects typically use 3 equal payments, each paid at the end of each season. When calculating, assume 10 new participants per season, subtract the fees collected each of those first three seasons, and provide for an initial buffer for material increases and damaged systems. If this calculation seems confusing, please e-mail the author for an Excel spreadsheet that will make the calculation easier.

A.4 Getting Funding for Urine Projects: General

The urine fertilizer projects outlined in this report require very little initial capital to continue indefinitely, provided the fees are enforced, are low in complexity, and produce positive results for the majority of participants. Because project participants are paying off the entire collection system with their participation fees, the project is sustainable. The entire project in Tantouji, cost about 27,000 cfa (UD$54), including extra money to blacksmiths to initially practice building the funnel and extra money in case parts break or the price of system components goes up. This $54 purchased enough new systems in the first 3 growing seasons that participant fees will now allow the purchase of 10 new systems for every growing season indefinitely. Peace Corps volunteers do not have administration costs, so the costs are lower, but even other organizations will find the costs of urine fertilizer projects low compared to many development interventions.

It is very easy to find donors for such a small amount of money, especially when project success can be measured (how many people participated in pilot projects, how many kept using urine fertilizer after each season, etc.). Organizations that provide small project grants will likely be eager to fund this type of low-cost, high impact project.

A.5 Getting Funding for Urine Projects in Mali: African Sky

African Sky (www.africansky.org) is a non-profit organization that provides small grants for projects in Mali. The author has explained the projects outlined in this report to the organization, and they are eager to work with Peace Corps volunteers or other groups in Mali who want to do this type of small project. Because the author has explained these projects in detail to African Sky, those applying for funding can explain they are using the method outlined by the author, give a brief summary of the methods, and explain any changes to the method. This will make the application simpler than writing as if it was a totally new type of project. Peace Corps volunteers can find the application for funding on the African Sky website (under "Programs: Peace Corps Mali") or at the following link: www.africansky.org/pdf/African_Sky_Peace_Corps.pdf.

A.6 Setting Up a Funnel and Blacksmith Database

Section 7.3 (Step B) explains the importance of ensuring materials are available locally. In Mali, all collection system components except the funnel were easy to find and were inexpensive. As explained in Section 7.3, the author needed to go to blacksmiths in several towns, show them an example of the funnel, and give them extra money as an incentive to try and build this unfamiliar object. Sometimes the author needed to visit several blacksmiths in a market town before he found one willing to experiment. Once a blacksmith made a quality funnel, the author would negotiate a price, leave an example with the blacksmith, and make sure people knew how to find the blacksmith again. Sometimes community leaders were brought to the blacksmith. Other times, a map and an explanation were left in a central location (see Figure A.1).

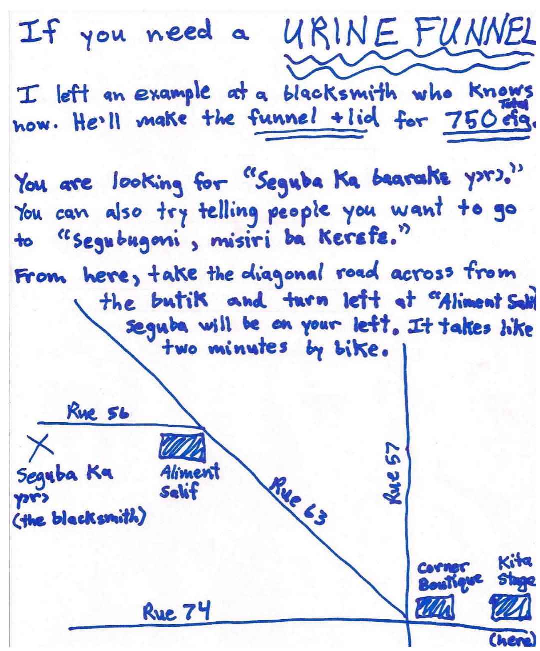


Figure A.1: Blacksmith location map for volunteers in Kita (Kayes Region, Mali).

It would be ideal for project leaders to share this information with other communities. For people doing projects in Mali, funnel makers have been found near the author's two Peace Corps sites, in the Kayes region and the Mopti region. Please e-mail for more information. Also, if the reader has found a funnel maker in other areas of Mali, or if she has found someone who makes a useful urine collector component in another part of the world, please forward that information to the author, who will start a database of these materials and make it available for others in the future.

APPENDIX B: Successes with Urine Fertilizer- Additional Resources

This appendix mentions just some of the exciting successes that have been achieved with urine fertilizer. A short description is given for each, and an abbreviated citation is provided again here for quick reference (Full citations are in Chapter 10). *Note*: Some of the hyperlinks below come up on the browser as lines of random letters and numbers, especially those ending in "pdf". If so, once the browser has loaded, place the cursor at the end of the address bar and hit enter to reload the address.

B.1 Developing World Success

Closing the Loop : Ecological sanitation for food security (Esrey et al, 2001). http://www.ecosanres.org/pdf_files/closing-the-loop.pdf. This document discusses the potential of closed-loop sanitation and urine diversion from many angles, and it has a special section concerning successes in Mexico and Zimbabwe starting on page 19.

Experiments using urine and humus derived from ecological toilets as a source of nutrients for growing crops (Morgan, 2003). http://aquamor.tripod.com/KYOTO.htm. Peter Morgan has extensive information available online regarding ecological (closed-loop) sanitation. He has had great success particularly growing crops in small concrete basins and fertilizing with urine (see Figure B.1).

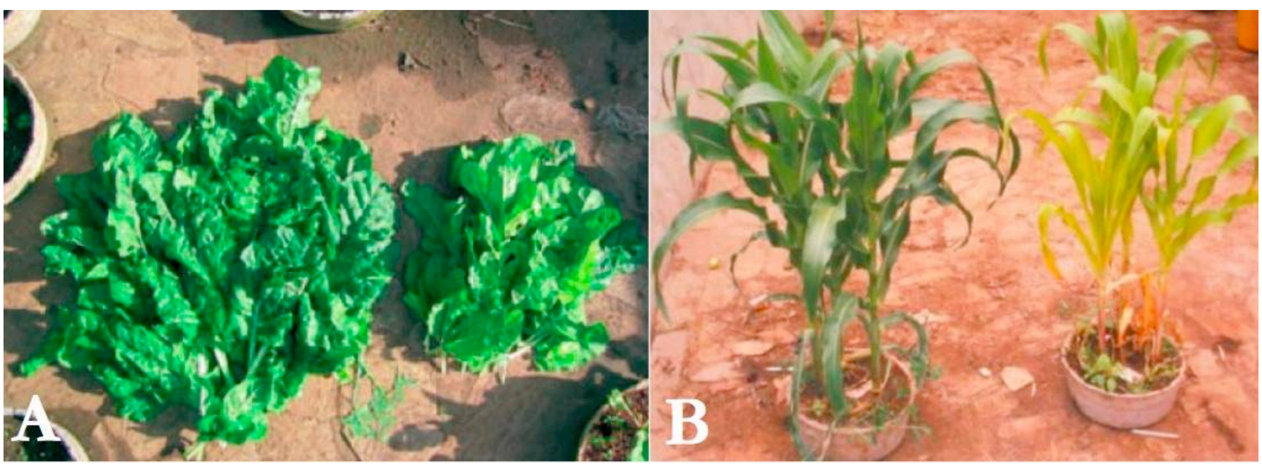


Figure B.1: Spinach (A) and corn (B) fertilized with (left pot) and without urine fertilizer (right pot) from trials by Peter Morgan. (Photos by Peter Morgan, with permission; A: CREPA,2007:91; B: Morgan,2003)

Piloting Ecological Sanitation Toilets in Peri-Urban Community of Nepal (Manandhar et al, 2004). http://www.wedc-knowledge.org/wedcopac/opacreq.dll/fullnf?Search_link=AAAA:3328:42734951#download. This document discusses successes with closed-loop sanitation and urine diversion in Nepal.

Urine Diversion: One Step Towards Sustainable Sanitation (Kvarnstrom et al, 2006). http://www.ecosanres.org/pdf_files/Urine_Diversion_2006-1.pdf. Roughly the first half, and especially the boxes on pages 7-14, gives examples of successful urine projects in the developing world.

Urine Harvesting and Utilization for Cultivation of Selected Crops: Trials from Ibadan, South West Nigeria (Sridhar et al, 2005). http://conference2005.ecosan.org/papers/sridhar_et_al.pdf. This document explains how urine fertilizer was used on experimental plots in Nigeria. Once locals saw the improved crops, many became very willing to try urine fertilizer themselves.

Urine-Treated Plants Yield Bigger Bananas: Study (Daiji World, 2008). http://www.daijiworld.com/news/news_disp.asp?n_id=47074&n_tit=Bangalore:+Urine-treated+Plants+Yield+Bigger+Bananas:+Study. This article talks about success with urine fertilizer on banana trees in India.

B.2 Developed World Success and Possibilities

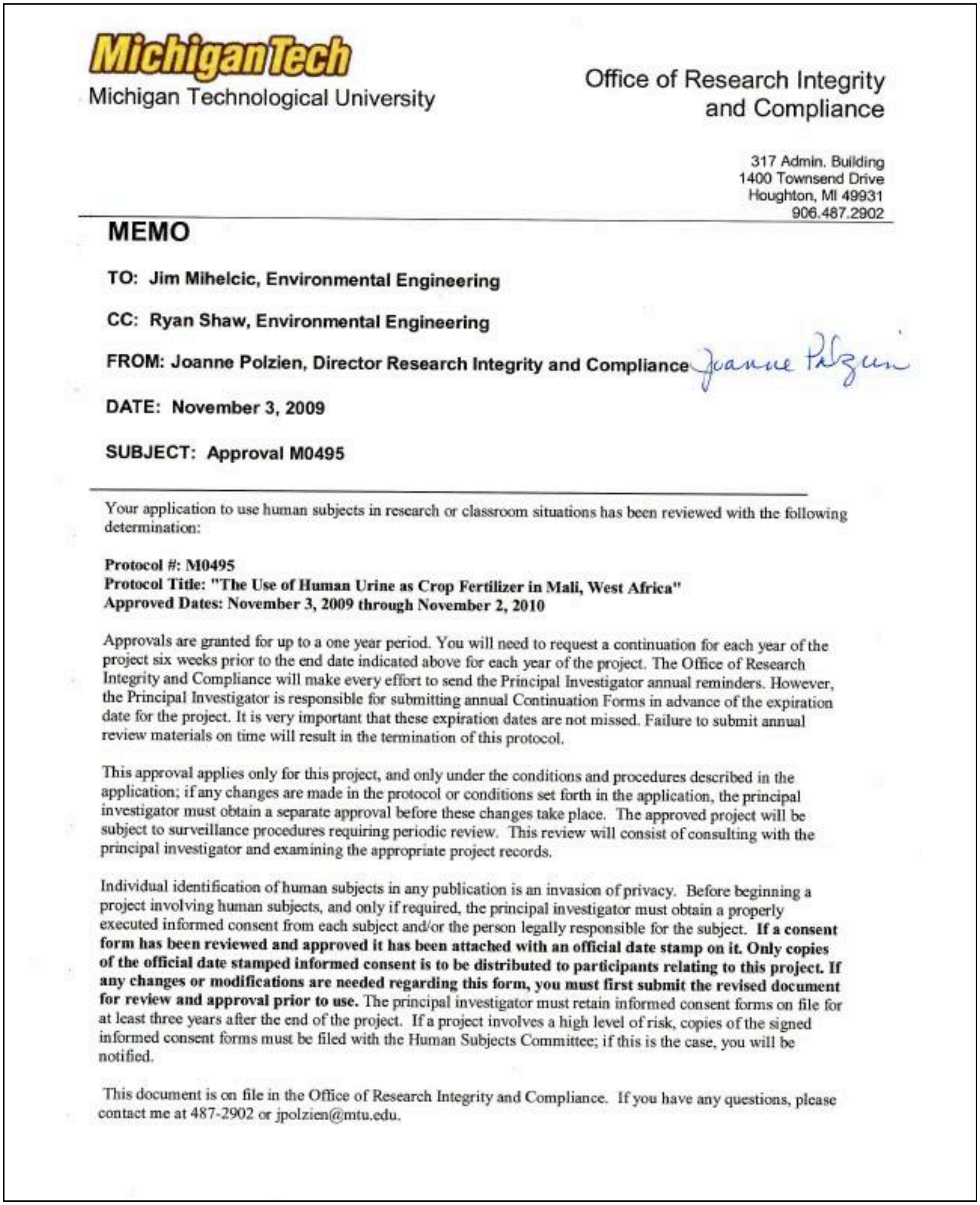
"Pee-cycling." from the *New Scientist* (Lawton, 2006). http://www.newscientist.com/article/mg19225831.600. This article talks about the advantages of urine diversion in modern wastewater systems and discusses pilot projects being done around Europe. The article also explains the science behind one study that claims that, "separating out 50 to 60 per cent of the urine could turn sewage works from net consumers to net producers of energy to the tune of about 2.5 watts per person" (Lawton, 2006: 1).

Urine Diversion: One Step Towards Sustainable Sanitation (Kvarnstrom et al, 2006). http://www.ecosanres.org/pdf_files/Urine_Diversion_2006-1.pdf. Starting on page 19, this document begins an extensive discussion of experiences with urine diversion in Sweden. This section gives an excellent overview of issues that will be encountered in developed world systems, such as E.U. regulations restricting the use of urine fertilizer on crops labeled "organic." The document also talks about exciting new ideas in the closed-loop sanitation field, such as the development of a waterless urinal with an oil seal to prevent nitrogen loss.

"Waste? Not." from the *Boston Sunday Globe (Tuhus-Dubrow, 2008).* This article discusses the necessity of moving towards closed- loop sanitation and gives some examples from Europe and the United States.

"Phosphorus: A Looming Crisis." from *Scientific American* (Vaccari, 2009). http://comste.gov.ph/images/files/Phosphorus-Looming%20Crisis.pdf. Though this article does not discuss urine fertilizer, it explains how urine nutrients like phosphorus will become more important to the fertilizer-intensive farming systems of the developed world in the future.

APPENDIX C: IRB Human Subject Research Approval



MichiganTech
Michigan Technological University

Office of Research Integrity and Compliance

317 Admin. Building
1400 Townsend Drive
Houghton, MI 49931
906.487.2902

MEMO

TO: Jim Mihelcic, Environmental Engineering

CC: Ryan Shaw, Environmental Engineering

FROM: Joanne Polzien, Director Research Integrity and Compliance Joanne Polzien

DATE: November 3, 2009

SUBJECT: Approval M0495

Your application to use human subjects in research or classroom situations has been reviewed with the following determination:

Protocol #: M0495
Protocol Title: "The Use of Human Urine as Crop Fertilizer in Mali, West Africa"
Approved Dates: November 3, 2009 through November 2, 2010

Approvals are granted for up to a one year period. You will need to request a continuation for each year of the project six weeks prior to the end date indicated above for each year of the project. The Office of Research Integrity and Compliance will make every effort to send the Principal Investigator annual reminders. However, the Principal Investigator is responsible for submitting annual Continuation Forms in advance of the expiration date for the project. It is very important that these expiration dates are not missed. Failure to submit annual review materials on time will result in the termination of this protocol.

This approval applies only for this project, and only under the conditions and procedures described in the application; if any changes are made in the protocol or conditions set forth in the application, the principal investigator must obtain a separate approval before these changes take place. The approved project will be subject to surveillance procedures requiring periodic review. This review will consist of consulting with the principal investigator and examining the appropriate project records.

Individual identification of human subjects in any publication is an invasion of privacy. Before beginning a project involving human subjects, and only if required, the principal investigator must obtain a properly executed informed consent from each subject and/or the person legally responsible for the subject. **If a consent form has been reviewed and approved it has been attached with an official date stamp on it. Only copies of the official date stamped informed consent is to be distributed to participants relating to this project. If any changes or modifications are needed regarding this form, you must first submit the revised document for review and approval prior to use.** The principal investigator must retain informed consent forms on file for at least three years after the end of the project. If a project involves a high level of risk, copies of the signed informed consent forms must be filed with the Human Subjects Committee; if this is the case, you will be notified.

This document is on file in the Office of Research Integrity and Compliance. If you have any questions, please contact me at 487-2902 or jpolzien@mtu.edu.