The Uses of Human Urine and Faeces in Agriculture: Guidance for Future Experiments

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Abstract

This paper focuses on the use of human waste for crop fertilization, and other agricultural purposes. The overriding objective of this study is to pave the way for increased use of human "waste" in agriculture - to turn a problem (human waste) into a solution (e.g. increased food production, while reducing treatment and environmental costs).

The inspiration for this project was a 2010 visit to La Democracia Government School in Belize, during which I proposed the use of urine to fertilize moringa trees. The original intent of this project was to carry out that experiment; however, a hurricane sidetracked the project. Hopefully the results of this paper will help to guide that experiment later this year.

I begin with a description of the current use of waste for agricultural purposes: the benefits, costs, and downsides of waste treatment and reuse for farming. In addition, I discuss the results of a survey of U.S. elementary students to discover their willingness to consider the direct use of urine for fertilizer, and to help us explore the means by which we might promote its use.

1 Introduction

In August, 2010, a group of about twenty educators (all enrolled in Miami University's Global Field Program) made a trip to Belize, to learn more about the rainforest and marine ecology of that country formerly known as British Honduras. I was a member of that group.

1.1 Background of This Study

This study arose because of a comment School Director Aretha Wilshire made to me during our visit to her school (La Democracia Government School), concerning the poverty of the soil there. She hoped that we might "adopt" students to feed (on a subscription basis), and I asked whether the school had any community gardens. She replied that the soil on the campus was too poor. That comment set me to thinking of the tropical tree *moringa oleifera*, that we used in Haiti for multiple purposes, such as erosion control, replenishment

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of nutrients in the soil, and the nourishment of the school children as well[18]. Moringa is sometimes referred to as “the miracle tree” for its nutritious leaves and for its many other almost magical uses. For example, in addition to providing vitamins via its leaves, we can produce a fine oil from its seeds. Furthermore, its seeds can be crushed and used to filter and treat water so as to render it potable[6].

The idea of using urine as a fertilizer is another idea which I encountered in Haiti, during a sabbatical there in 2006-2007. Because of the need for public sanitation, I began working with very simple toilet systems. Several of those systems make use of excrement for fertilization, and I facilitated putting two of those systems into place: arborloos and dry toilets[21]. Many authors and organizations suggest using urine to nourish plants[23, 36, 24, 29, 27, 1]. The two systems I implemented make use of excrement in different ways. Arborloos preserve the excrement in place, and a tree is planted in the excrement-laden soil; dry toilets are called “dry” because the urine is separated from the faeces: the faeces is stored at an elevated temperature until it’s “baked safe” (after approximately one year[14]), and the urine is collected directly to drums outside the toilets and used only days later for fertilization.

During the sabbatical we created a nursery on the campus, and I introduced human urine as a fertilizer for the plants in that nursery. The urine was obtained from plastic drums attached to the campus’s dry toilets. Others in Haiti have done the same thing: the organization Youthaiti (led by Gigi Pomerantz) attests that garden productivity has tripled through the use of “Pipi Pou Jardin” – “Pee for the Garden”[22].

I had originally hoped to accomplish two things in this project: we wanted to introduce the community of La Democracia to the use of *moringa oleifera* as a food crop, and we hoped to demonstrate the value of using urine as a fertilizer. Could we demonstrate to the children of La Democracia school (and hence to their parents) that urine is a commodity to be used, rather than a waste to be disposed of?

I’d hoped to try an experiment with the students of La Democracia Government School, in which we would grow moringa trees under two scenarios: those fertilized with water, and those fertilized with urine. I approached two employees of the Belize Zoo – Education Director Celso Poot and Environmental Educator Jamal Andrewin – who were willing partners in this venture, and agreed to take a large part of the responsibility for the project. I sent them seeds of several varieties of moringa from Florida, and once the seeds arrived (in early September) they were bagged and subsequently germinated, with Andrewin providing direct care and follow-up. Unfortunately, Hurricane Richard scuttled our project temporarily: the zoo suffered major damage, and was forced to close for several months (but reopened in December, 2010). The school was also severely damaged, and closed for awhile. Our experiment would have to be postponed.

Because we have not yet been able to run the experiment, this IAP project was refocused: I want to consider the current use of human waste for fertilization, and also look at young children’s perceptions of the use of urine for agriculture in the U.S. We hope to use their responses to proceed with the original experiment, only better informed about attitudes of children towards the use of waste in fertilization.

1.2 The Survey

One challenge that we foresaw as we prepared to run the moringa experiment was to get people – in particular, Belize school children – to overcome their reluctance to work with urine, even when used for a practical purpose, such as fertilization. Colleagues from the Global Field Program suspected that girls, in particular, might have trouble with this experimental design. We subsequently urged that the students be informed that the urine could come from any member of the family (presumably a male would be more inclined to help produce the necessary urine).

Because of this, I undertook a survey with American third-grade school children, to gain insight into their willingness to use urine to fertilize plants. The results of this will be discussed below. First, however, let's see how waste has been used historically.

2 On the Use of Human Waste for Agriculture

James Lovelock asks an important question in his book "The Revenge of Gaia": is it "possible that in the evolution of Gaia, the great Earth system, animals have evolved to excrete nitrogen as urea or uric acid instead of gaseous nitrogen... for altruistic reasons?" ([19], p. 18) He conjectures that animals have evolved to excrete urine as we do so as to nourish plants, which require the nitrogen. It would be energetically smarter for us to excrete our waste as gases, but no known mutant has ever arisen to do so. Presumably we (in the animal kingdom) understand the value of plants, and want to encourage them: hence we engage in this bartering relationship with them, exchanging our urine for their productive growth; we then devour them to encourage our own growth.

2.1 The Treatment and Reuse of Human Waste

At some point in human evolution (dating back to at least 3200 BCE, in Scotland[31, 16]) we began to understand the importance of public sewage treatment. Taken to the extreme, we in the U.S. now spend enormous amounts of money every day to process our waste through treatment plants, then dump the treated waste into our surface waters. The treated waste continues along until it reaches the next town downstream, which must then diligently treat the water they intend to drink so that it may be consumed safely by humans in their town. Then <u>their</u> waste is treated, and dumped back into the waterways, and on and on. We in the Cincinnati region participate in this process, but there are some dangerous violations: anyone who has kayaked in the Licking River cannot fail to notice the large pipes whose open mouths yawn along the river banks. The signs posted next to them tell the story: in the event of heavy rains, this pipe may dump raw, untreated sewage into the Licking as the treatment plants become overwhelmed. Swimming, then, would be ill-advised....

"Thirty years ago, thousands of American cities dumped their raw sewage directly into our nation's rivers, lakes, and bays. Today, because of improved wastewater treatment, our waterways have been cleaned up and made safer for recreation and seafood harvest. And, because of the strict Federal and state standards, the treated residuals from wastewater treatment (biosolids) can be safely recycled. Local governments make the decision whether to recycle the biosolids as a fertilizer, incinerate it or bury it in a landfill."[11] In this paper we're focused on the first of those three choices: using biosolids (and bioliquids) as fertilizers.

Bjorn Vinneras provides us with an overview of modern waste in his Ph.D. Thesis[38]:

- There are three components of modern wastewater: faeces, urine, and greywater.

- Faecal matter must be sanitised to be used (e.g. using "thermal composting" – that is, heating it up in a compost pile; or chemical sanitation – which can even be carried out using urea, separated from the urine: "Addition of 30 g urea-nitrogen per kg of wet weight faecal matter resulted in total inactivation of the monitored organisms, E. coli, Salmonella spp, Enterococcus spp, Salmonella typhimurium 28B phage and Ascaris suum eggs, within 50 days of treatment at 20°.”).

- Unfortunately, the situation for the use of faeces is not as positive as for that of urine: “Today no simple, reliable, cost-effective and scale independent sanitation method is available for treatment of faecal matter.”

- Urine may be disinfected by simple storage[12].

More information on the safe use of human fertilizer can be found in other sources (e.g. [30], which I found especially helpful).

Estimates of human production of waste vary, but it seems that several agree that we produce on the order of 500 litres of urine per year[5, 7], which could result in approximately 13.3 kgs of urea per year[19]. Humans produce about 50 liters of faeces per year[5]. “These contain about 4 kg of nitrogen, 0.5 kg of phosphorous and 1 kg of potassium, the three basic elements for plant growth. The exact amount varies from region to region depending on food intake. Seventy per cent of the nutrients excreted by humans are in the urine fraction.”[5]

Another way to think about what we excrete is in terms of nutrients: “The annual amount of toilet waste is about 520 kg/person. This amount includes altogether 7.5 kg of nitrogen, phosphorus, and potassium, and some micro-nutrients in a form useful for plants. If the nutrients in the faeces of one person were used for grain cultivation, it would enable the production of the annual amount of grain consumed by one person (250 kg).”[20] More precisely, another estimate is “about 4 kg of nitrogen, 0.5 kg of phosphorous and 1 kg of potassium, the three basic elements for plant growth. The exact amount varies from region to region depending on food intake. Seventy per cent of the nutrients excreted by humans are in the urine fraction.”[5] Ultimately, we're interested in what one's excrement would produce in terms of food: “The urine from one person during one year is sufficient to fertilize 300-400 m^2 of crop to a level of about 50-100 kg N/ha.”[28] The authors of this text propose the standards in Table 1: If Lovelock's estimate of 13.3 kgs of urea is correct, then using

Table 1: Proposed default values for excreted mass and nutrients. Vinners et al., 2006 (based on Table 2 of [28])

Parameter	Unit	Urine	Faeces	Toilet paper	blackwater (urine+faeces)
Wet mass	kg/person,year	550	51	8.9	610
Dry mass	kg/ person,year	21	11	8.5	40.5
Nitrogen	g/ person,year	4000	550		4550
Phosphorus	g/ person,year	365	183		548

Vinneras's thesis work (30 g of urea to treat 1 kg of wet faeces) and an estimate of 51 kg of wet faeces per year (Table 1), we see that one person's urea could disinfect 8.7 person's faeces. This would leave 7.7 person's urine to carry out other important work (e.g. fertilization of crops).

While urine does vary across cultures, the relative composition of urine has been known for some time, thanks in part to NASA, the space program of the United States. NASA paid contractors to investigate the composition of urine back in the early days of the space

Estimated excretion of nutrients per capita in different countries (from Jönsson & Vinnerås, 2004)

Country		Nitrogen kg/cap, yr	Phosphorus kg/cap, yr
China	total	4.0	0.6
	urine	3.5	0.4
	faeces	0.5	0.2
Haiti	total	2.1	0.3
	urine	1.9	0.2
	faeces	0.3	0.1
India	total	2.7	0.4
	urine	2.3	0.3
	faeces	0.3	0.1
South Africa	total	3.4	0.5
	urine	3.0	0.3
	faeces	0.4	0.2
Uganda	total	2.5	0.4
	urine	2.2	0.3
	faeces	0.3	0.1

Figure 1: The quality of a country's excrement varies[7]. It appears that the nutrients in the excrement are directly related to standard of living (as measured by the United Nations' Human Development Index): Uganda (143) and Haiti (145) are the least developed of these countries, followed by India (119), South Africa (110), and China (89)[37]. This suggests that we can use the quality of a nation's excrement to determine how well off they are....

program, because long space journeys would only be possible if space flights would include the reprocessing of urine for drinking water for its astronauts.

To sum up, "[u]rine is an aqueous solution made up of more than 95 per cent water, with the remaining constituents made up of urea, creatinine, dissolved ions (chloride, sodium, potassium, etc), inorganic and organic compounds or salts. Most of these remain in solution, but there can be a tendency for phosphorus-rich substances to sediment in containers that are stored for hygienization."[28]

Peter Morgan, the creator and chief promoter of extremely low-tech "Arborloo" toilet, has carried out experiments designed to demonstrate the efficacy of the idea of recycling excrement into agricultural production. For example, he did an analysis of the soil of an arborloo, and found high levels of all major nutrients required for growth. The arborloo soil was a combination of just faeces, urine, and the poor topsoil in place (see Table 2). Morgan has also carried out experiments illustrating the advantages of urine as a fertilizer,

Table 2: Analysis of Arborloo pit soil compared to a mean of various topsoils(reproduced from [21]). Nitrogen (N*) and Phosphorus (P*) are expressed as ppm and Potassium (K*), Calcium (Ca*) and Magnesium (Mg*) as ME/100gms.

Soil source	pH	N*	P*	K*	Ca*	Mg*
Local topsoils means (N=9)	5.5	38	44	0.49	8.05	3.58
Arborloo means (one year after tree planting)(N=2)	5.95	111	309.5	0.95	11.07	5.1

with remarkable results. We detail those and other results now.

2.2 Results of Using Urine as a Fertilizer

First of all, let us note that what we are suggesting is actually old news: "In Japan the recycling of urine and faeces was introduced in the 12th Century and in China human and animal excreta have been composted for thousands of years."[12]

Furthermore, it is important to note that we do not recommend urine or excrement for fertilization of any field crop. It's one thing to pour some of your own urine onto the ground to nourish a tree; it's quite another to eat cabbages sprayed with someone else's urine for fertilizer, or as a pest inhibitor.

Because we will not be eating directly from the roots of our moringa trees, we are not overly concerned with the issue of urine consumption. That being said, it might be good to note (as did the authors of [30]) that "...urine is normally sterile"[9]. There is no evidence of any uptake of viruses, etc. into the leaves or other edible parts of moringa, or other plants.

We'll now take a look at some specific examples of the use of urine in agriculture, with positive results:

- In tomato plants, and cabbage: urine-fertilized plants produced equally to minerally fertilized plants, and much better than non-fertilized plants, bearing 4.2 times as much fruit as nonfertilized plants. This was accomplished with no health risks as well (test for enteric indicator microorganisms were negative), as shown in Figure 3[15].

- Experiments with lettuce, spinach, and tomatoes in Zimbabwe are summarized in Table 3.

CONSTITUENTS OF HUMAN URINE EXCEEDING 10 mg/1. FROM REFERENCE 12

Item	Formula	Formula Weight	Range mg/l	mg/l	Solubility Limit In A Binary Solution g/100g H_2O
Total Solutes			36,700	46,700	---
Urea	H_2NCONH_2	60.1	9,300	23,300	119
Chloride	Cl^-	35.5	1,870	8,400	---
Sodium	Na^+	23.0	1,170	4,390	---
Potassium	K^+	39.1	750	2,610	---
Creatinine	$C_4H_7N_3O$	113.1	670	2,150	8.7
Sulfur, Inorganic	S	32.1	163	1,800	---
Hippuric Acid	$C_6H_5CO{\cdot}NHCH_2{\cdot}CO_2H$	179.2	50	1,670	0.367
Phosphorus, Total	P	31.0	470	1,070	---
Citric Acid	$HOC(CH_2CO_2H)_2CO_2H$	192.1	90	930	208
Glucuronic Acid	$C_6H_{10}O_7$	194.1	70	880	S.
Ammonia	NH_3	17.0	200	730	---
Uric Acid	$C_5H_4O_3N_4$	168.1	40	670	0.00645
Uropepsin (as Tyrosine)	$HO{\cdot}C_6H_4{\cdot}C_2H_3(NH_2){\cdot}CO_2H$	181.2	70	560	0.04
Bicarbonate	HCO_3^-	61.0	20	560	---
Creatine	$HN{:}C(NH_2)N(CH_3){\cdot}CH_2{\cdot}CO_2H{\cdot}H_2O$	149.2	0	530	1.4
Sulfur, Organic	S	32.1	77	470	---

SUMMARY OF C, N, O, H AND ORGANIC S IN TYPICAL HUMAN URINE

Item	Amount mg/l	C (12.0) mg/l	N (14.0) mg/l	O (16.0) mg/l	H (1.0) mg/l	S (32.1) (Organic) mg/l
Inorganic Salts	14,157	100	0	1,877	7	0
Urea	13,400	2,680	6,253	3,573	893	0
Organic Compounds	5,369	2,466	1,211	1,231	347	134
Organic Ammonium Salts	4,131	1,630	659	1,576	266	0
TOTAL	37,057	6,876	8,123	8,257	1,513	134

Figure 2: NASA technical reports from the late 60s and early 70s provided a rigorous look at some of the constituents of urine.[25, 26] NASA's figures suggest that Lovelock's urea estimate is a little high: NASA's estimate (combined with 500 liters of urine per person per year) put the average urea production of a person at only 6.7 kgs (about half of Lovelock's figure).

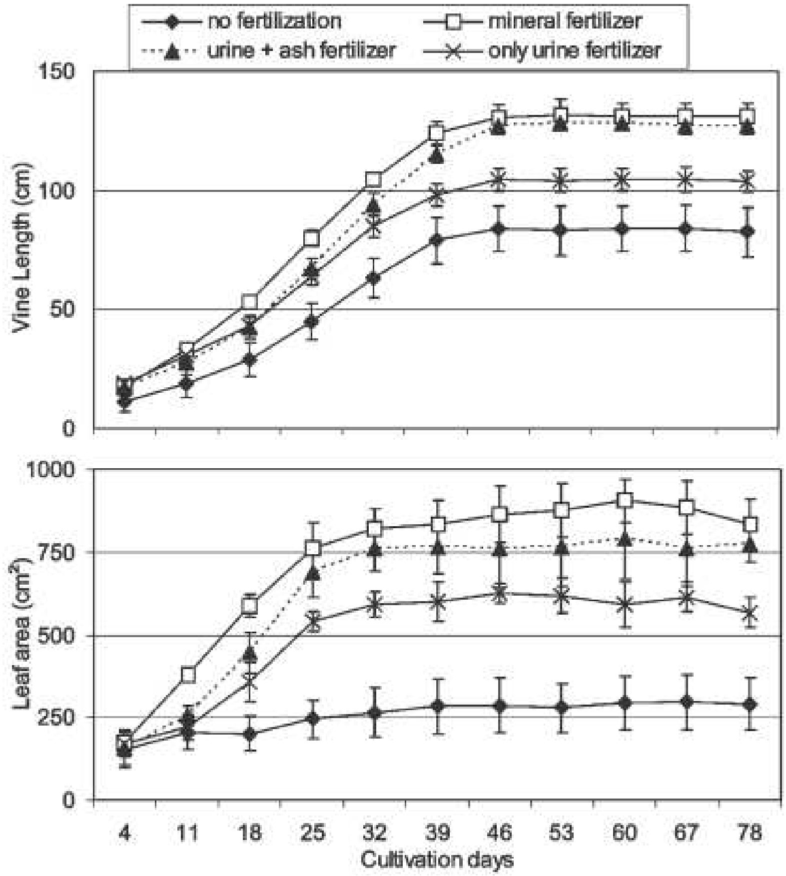

Figure 1. Growth rate of tomato plants from different fertilizer treatments on the basis of leaf area and vine length on different cultivation days (arithmetic mean (AM) and standard deviation (SD) bar) (N = 5). Spearman's analysis showed that the growth rates of vine length and leaf area were positively correlated (r = 0.910, P = 0.0001 and N = 44).

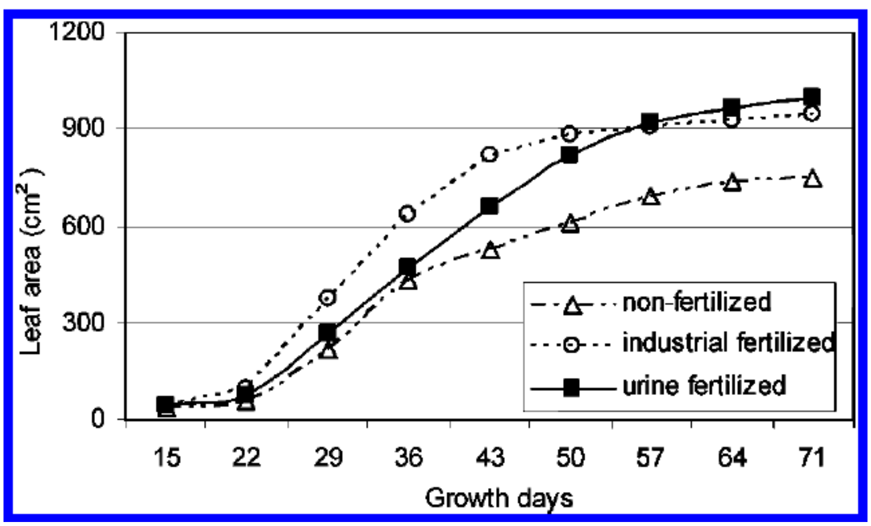

Figure 3: Many different foods have demonstrated the value of urine fertilizer. The second figure shows how urine facilitated the growth of cabbage leaves. Asymptotically the leaf sizes were the same for mineral fertilization and urine treatments.[24]

Table 3: Average yields (grams fresh weight) in plant trials with urine as a fertilizer to vegetables in Zimbabwe. Morgan, 2003 (after Table 13, of [28])

Plant, growth period, and number of repetitions (n)	Unfertilized plants (g)	Fertilized, 3:1 water/urine application 3x per week (g)	Relative yield, fertilized to unfertilized
Lettuce, 30 days (n = 3)	230	500	2.2
Lettuce, 33 days (n = 3)	120	345	2.9
Spinach, 30 days (n = 3)	52	350	6.7
Covo, 8 weeks (n = 3)	135	545	4.0
Tomato, 4 months (n = 9)	1680	6084	3.6

- Experiments with eggplant, okra (gumbo), and tomato in Burkina Faso are summarized in Table 4.

Table 4: Yield of vegetables as an average of three years of field trials in Burkina Faso (Source: CREPA). Urine and mineral fertilizer gave a statistically significant yield increase compared to unfertilized control. However, there is no statistical difference between yields using urine or mineral fertilizer. Table from [28]

	Egg plant (t ha^{-1})	Gombo (t ha^{-1})	Tomato(t ha^{-1})
Unfertilized control	2.8	1.7	2.1
Mineral fertilizer	17.8	2.7	5.7
Stored urine	17.7	2.4	5.2

Clearly, many experiments and programs have demonstrated positive results with urine as a fertilizer. There is every good reason to suspect that our experiments with moringa in Belize will be successful, and that it is certainly worth investigating the value of this waste product as a cheap replacement for otherwise unaffordable fertilizers in poorer areas (such as Belize).

2.3 Excrement as a Deer Repellent

It is worth noting that urine is not proposed exclusively as a fertilizer: it also appears that urine might be useful as a pest-repellent. There is anecdotal evididence that human urine can be used for pest control, e.g. against deer. I have personally used my own urine in this way (I am engaged in an experiment using it for deer repellent this spring). I have found others who subscribe to this hypothesis as well[33, 2]. My son Thad calls our product, which we apply with a hand-pumped sprayer, "Yureene". He figures that renaming it will throw off those who would otherwise be disgusted by our methods, and maybe we can even sell the stuff. (Thad's a card.)

Another proposed entry in the Deer Repellent category ("Eco Friendly, and truly works!") extolls the use of Milorganite[32], without actually mentioning that Milorganite is produced at the waste treatment plant in Milwaukee, Wisconsin. It is human excrement, treated, bagged, and sold to consumers: as the author exclaims, “Another good thing about this fertilizer is it is cheap! Nine dollars for a 36lb bag.” Another gardener agrees[3], but this one knows that Milorganite is Milwaukee’s “sludge”. All the details are available at Milorganite’s website[4]. At least one controlled study suggests that Milorganite does, indeed, provide protection from deer[34]. Similar claims come from Kammermeyer[17]: “Milorganite is partially composted sewage that has been dried at an intense heat. It is also a high quality, slow-release fertilizer. Apply about 5 lbs per 100 square feet at two to four week intervals. It is reported to work well in spring and summer, but may be less effective in winter.” Stephens, et al. say that “Milorganite, when broadcast over newly emerging soybeans, is an effective temporary deer repellent, which reduces negative effects of deer browsing and benefits wildlife food plot establishment. The repellent does not eliminate deer damage, however, and efficacy varies by location. Although we did not measure environmental differences among locations, we believe weather, deer density and alternative food source availability likely influence location-specific efficacy.”[35]

3 A Survey of American School Children Concerning the Use of Urine

There has been some research about societal norms concerning our relationship with and the handling of excrement[8]. As one might expect, in most societies

- people feel that handling faeces is worse than handling urine;
- the odor of one’s own faeces is more tolerable than that of others;
- women tend to handle the faeces of children and the sick;
- defecating in public is nowhere acceptible, even as open-defecation is practiced extensively throughout the world. It is a practice accompanied by shame, and usually only carried out at night, in the woods, or under similar cover. In fact, a current trend called “Community-Led Total Sanitation” relies on shame to stop the practice of open-defecation[10]. I feel compelled to give an example of this practice, which is often a plague of the city: in Haiti, in major cities, citizens are familiar with the “sachet noir” – black sac – which is a small black plastic bag filled with faeces. For lack of a toilet, an urban dweller will shit in a sack, then throw it into a convenient alleyway or along a road. This is evidently also called a “flying toilet”[10].
- One important general rule is that it is generally more socially acceptible for men to urinate in public than for women.

One of our reasons for focusing on urine is this: working with urine is more socially acceptible. We are working with the less noxious of the two types of waste. Because we’ll be working with school children of elementary age, I chose to create and administer my survey to students in the U.S. of approximately the same age as those children in Belize who might be carrying out our experiment.

3.1 Methods

The survey and the letter that I sent to the teacher are appended. It was necessary to obtain permission from the Principal before we could give the survey, and the result was that my follow-up question – which was an open-response question, asking the students for ideas on how to encourage other children to undertake the handling of the urine for a good cause – could not be asked. I made due with the first page, which is included in the appendix.

This was a convenience sample: my son Thad is in one of the 3rd grade classes of Johnson Elementary School, Ft. Thomas, KY, and his teacher Mrs. Snider agreed to help out with this survey. I was able to convince a second teacher to participate, as well.

While I offered to have teachers make suggestions regarding the questions, they were not responsive to that (I suppose that they are simply too busy). I emailed them a link to the survey, and asked them to see if they felt that the survey would be appropriate for 9-year-old children. In particular I was interested in the language that I should use in asking these questions of the students.

The questions were formulated to determine several things:

- their sex;
- how they feel about gardening, and about working in the earth;
- their "yuck level" for dealing with worms (a proxy for their "yuck factor" for dealing with urine;
- how they feel about the **concept** of using urine as a fertilizer;
- how they feel about the role of urine as a pollutant;
- how they feel about the **specific use of their own pee** as a fertilizer (whether they are okay with the concept, and whether they'd actually consider doing it, if they didn't have to touch it); and
- whether they feel that this is an example of recycling.

One of the issues that I struggled with was the manner by which I could solicit feedback from the students. I attempted to use words that the students might relate to (e.g. "Yuck", and "Cool!"), and this is one of the places where the assistance of the teachers might have been especially appreciated; but evidently the students were okay with this set of responses.

The teachers in each class were instructed to keep the instructions and questions moving, and to attempt to prevent any vocalizations by the students (e.g. "gross!", or the like), so as to avoid bias. I don't know how successful they were at that....

3.2 Data

I received 44 responses to the survey from the two classes, which are found in their entirety in Table 6 of the appendix.

There were 21 boys, and 23 girls; 23 students in class 1, and 21 in class 2.

It might be interesting to compare the responses by sex, because it was hypothesized by members of the Belize team of students that girls might be more reluctant to use urine than the boys.

3.3 Results

In our survey we did not find any statistically significant differences between the results for the boys and for the girls. The survey size was rather limited, which worked against us. Table 5 shows that there were not dramatic differences between the sexes.

Table 5: These are the results of the survey questions by sex, for a quick visual inspection of differences (by percentage) of the possible responses.

Question	sex	R1	R2	R3 (if applicable)	R4 (if applicable)
q2	boys	19.0	47.6	33.3	0.0
q2	girls	34.8	52.2	13.0	0.0
q3	boys	4.8	61.9	23.8	9.5
q3	girls	4.3	71.7	19.6	4.3
q4	boys	9.5	23.8	66.7	
q4	girls	26.1	30.4	43.5	
q5	boys	4.8	47.6	19.0	28.6
q5	girls	4.3	39.1	13.0	43.5
q6	boys	9.5	4.8	85.7	
q6	girls	4.3	17.4	73.9	4.3 (no response)
q7	boys	28.6	38.1	33.3	
q7	girls	8.7	30.4	60.9	
q8	boys	66.7	33.3		
q8	girls	43.5	52.2		
q9	boys	76.2	23.8		
q9	girls	73.9	26.1		

Further results of the survey are presented in a few interesting cross-tabulations. There were several comparisons for which there was clearly no sex-effect: for example, sex versus urine as recycling, sex versus urine's use as a fertilizer,

Table 6: Gardening versus willingness to use pee (Question 2 versus Question 8). This table has an interesting point to make: those who were happy to get out and garden were less likely to willingly use their pee than those who were blasé about it. Those who responded "okay" were overwelmingly willing to use pee (16/22). Those who were "bored" of the garden were less likely to use pee than either of the other two groups. There is borderline significance in this pairing, suggesting a possible interaction (those "okay" with gardening more likely to use pee – $p = .066$).

		use-pee	
garden	yes	no	maybe
happy	5	6	1
okay	16	6	0
bored	3	7	0

Table 7: Question 1 versus Question 8. “Maybe” was not an official option, but one girl decided to add it. As one can see, boys appeared more willing to use their pee than girls (although $p = 0.21$ – not significant at a .05 level).

		use-pee	
Sex	yes	no	maybe
Girls	10	12	1
Boys	14	7	0

Table 8: Question 4 versus Question 8: Those who thought worms are cool or yucky (polar opposites) were about equally likely to use pee (about half); again, the blasé students are the ones who appear more willing to help out ($p = 0.23$).

		use-pee	
Worms	yes	no	maybe
Cool!	13	11	0
So what?	8	3	1
Yuck!	3	5	0

3.4 Discussion

The major upshot is that there were not dramatic differences between the sexes in their responses to the survey. Roughly half of third-grade American children are willing to carry out experiments with urine (which is the more beneficial and safer of the two). There is some evidence that boys are more likely to be willing users of urine (66.7% of boys versus 43.5% of girls). Girls were about three times more likely to react with a “yuck” to a big worm (9.5% for boys, 26.1% for girls), while levels of indifference were about the same (23.8% for boys, and 30.4% for girls).

Half of the girls who expressed a “yuck” to a worm were willing to use urine in an experiment, nonetheless. By contrast, the two boys who expressed a “yuck” were both unwilling to use urine. Ironically, of the girls who said “Cool!” to the worm, only 3 of 10 were willing to use their urine; of the boys it was 10 of 14. That’s one significant difference. There may be some bravado in the girls with respect to the worms, that doesn’t show up when it comes to urine.

The major observation that we can make is there appears that those who have a “blasé” attitude toward gardening are more willing to take a “blasé” attitude toward urine (that is, are more willing to use it in the garden). Whereas I had imagined that the garden enthusiasts would be more likely to find urine exciting, it appears that those with strong opinions about gardening may have just as strong an opinion about the use of urine (and it may well be negative!).

A vast majority of the children understood the value of the reuse of pee (as an exampling of recycling, it was 3 to 1 – “good example of recycling” versus “not a good example”). There is a broad concensus that younger folks are more focused on recycling than is the older generation. This is one fact that we can seize on to leverage this technology: the kids “get” that this might be a good trick for the Earth.

Along the same lines, we all hear talk these days of “going green”, and one of the reasons for both of these initiatives (moringa and urine) is that we’re able to turn waste into something with real utility: the nourishment, both physical and educational, of these students.

Why is using excrement green? Here are some reasons[13]:

1. Using two or more gallons of treated potable water to flush down a half a cup of pee is excessive, and nitrogen and phosphorous are excellent for plants, but 'very' harmful to our waterways.

2. We can avoid transporting fertilizer (using fossil fuels) to your garden.

3. Urine keeps fungus and bacteria at bay, avoiding the need for other treatments that may not be so natural.

4. This process is a boon to third world countries, as it is free, plentiful, and local.

5. A lot of natural gas is used in the production of synthetic urea, and the process of natural gas extraction called "fracking" is getting increased attention in the U.S.: it is a very environmentally dangerous and destructive practice.

6. Runoff of our sewage into our waterways creates oxygen-less dead zones and requires further treatment downstream.

It is important (and frightening) to note that these nutrients we're flushing down into the Gulf of Mexico are actually a limited commodity: the day will come when these materials we need will not be so easily available. "Toilet waste contains virtually all the plant nutrient humans ingest through food and drink and could theoretically be recycled to plants. Phosphorous is a finite resource, with present recoverable reserves calculated to last for less than 200 years (Larsson et al. 1997), whereas potassium is assumed to last for 300 years (Crowson 1992, in Lindfors et al.1995)."[12]

These are message that may resonate with kids, and bring them to consider these relatively dramatic uses of their excrement for society's benefit.

4 Action Component: The Belize Moringa/Urine Experiment

The next phase of our study is to carry out the experiment planned for Belize. This is what we have planned:

The overall goal of our experiment is to compare growth rates of moringa oleifera under two regimens: one using urine as a fertilizer added to the liquid diet of the plants, and the other without. Otherwise, the experimental treatments would be identical.

The protocol we follow will be established in consultation with Director Wilshire (who will choose the most appropriate students, grade, etc.), because we needed to make sure that the students will be capable of handling their end of the experiment. Andrewin of the Belize Zoo will work with school Director Wilshire to identify the students who would benefit most from the experiment. Each student will then be assigned two plants as nearly identical as possible, and one of them will be randomly chosen as a case and one as a control. The children will do this with a coin toss, and the case plants will be marked (e.g. with a flag), so that there will be no confusion about which plants are to receive the urine.

The plants will be kept at school, in a secured environment, so as to protect them from damage by animals and by others, as well as protected from severe weather. They will be placed so as to assure that the plants receive equal amounts of sunshine. The students will only access the plants for a short time each Monday, Wednesday, and Friday, during times when school is in session. The extent of their interaction will be to water and/or fertilize their plants, and then to measure them.

The students will fertilize the case plant with urine mixed with water (diluted 6 to 1 with water); the control plants will receive water only. Each plant will receive exactly the same amount of liquid (8 ounces), which will be delivered via the same small closed plastic bottle each time. The bottles will be "repurposed" from the trash stream, and every child will use the same type and size of bottle.

Other sources vary on these parameters we suggest, such as ratio of water to urine (e.g. another source[1] suggests 8 to 1, but that's partly for pest control on leaves; they also suggest that "...urine must be stored for six days to kill ... harmful organisms" – e.g. bacteria). The ideal parameters probably vary from plant to plant, and from purpose to purpose. This experiment will serve as a benchmark, and we foresee future studies examining the issue of the optimal ratio of urine to water for moringas.

Each plant's growth will be monitored carefully, registered prior to each watering. Measurement will be from the base of the plant, at soil level, to the tip of the highest point on the plant. The children will be educated in the proper measurement of a plant, so that they will be completely consistent and record plant height correctly. The heights will be recorded by the students, and any additional notes will also be recorded (e.g. insect damage, or recent weather of interest). The plants will be allowed to reach 5 feet tall, at which time they will be topped (to encourage more bushing), and then planted (some on the school grounds, to nourish the children; some to be taken home).

At the end of the experiment the school and students are to be given summary information regarding the results of the experiment, as well as information concerning the food value of moringa; the students will then be encouraged to design their own experiments to find the best ways to eat moringa leaves and pods, as well as recipes for its preparation. This is an opportunity for the use of open inquiry, which we will facilitate.

5 Conclusions

Our objective in this paper is two-fold: as we prepare for experiments such as the Belize moringa experiment we need to know

1. what evidence there is that urine and faeces can facilitate plant growth, and
2. by what means we can convince people to make use of excrement, and how they should handle it for optimal effect and to prevent the spread of disease.

In particular, we hope to convince children to carry out experiments with urine, and have sought to discover if American children would be willing to do so. This is in preparation for an experiment that we plan to carry out in Belize. Since the Belizean children are approximately the same age, poorer, and presumably more acquainted with nature (e.g. more rural than the Ft. Thomas, KY elementary students that we surveyed here, our conjecture is that they will be more amenable to the use of urine than our students. Hence it was important to get an idea of how willing our urban American students are to experiment with urine.

There is good news on both fronts:

1. it appears, from numerous sources and experiments, that urine and faeces are an effective and cost-beneficial method of delivering nutrients to the garden, and may have capabilities as a pest-preventer; and

2. it appears from our survey that roughly half of third-grade American children are willing to carry out experiments with urine (which is the more beneficial and safer of the two forms of human excrement). It does appear that boys are slightly more likely to be willing to use urine (14/21 boys versus 10/23 girls, although the difference is not significant at the 0.05 level). On a similar issue, gauged to test the "yuck" factor, girls were about three times more likely to react with a "yuck" to a big worm (2/21 for boys, 6/23 for girls; levels of indifference were about the same: 5/21 for boys, and 7/23 for girls). Interestingly enough, half of the girls who expressed a "yuck" to a worm were willing to use urine in an experiment, however. The two boys who expressed a "yuck" were both unwilling to use urine. Interestingly enough, of the girls who said "Cool!" to the worm, only 3/10 were willing to use their urine; of the boys it was 10/14. That's a significant difference. There may be some bravado in the girls with respect to the worms, that doesn't show up when it comes to urine.

   Interestingly enough, we discovered that those who have a "blasé" attitude toward gardening were more willing to take a "blasé" attitude toward urine (and, hence, were more willing to use it). I was struck by this result: I'd imagined that the garden enthusiasts would be more likely to find urine exciting – but that's not the case.

Hopefully this paper will inspire others who might wish to consider the use of urine (and possibly faeces) for their gardens as well. If nothing else, perhaps it will serve as a weapon, to bolster the defences of those who find themselves in a fight to make use of what society considers a waste product for a productive use. Many of our neighbors don't understand the importance or possibilities, and misconceptions linger about the dangers. We must do what we can to promote this change in our approach to this problem: let's turn excrement from a problem into a solution.

6 Appendices

6.1 Letter to Teachers

Dear Mrs. Snider:

I am studying zoology and botany as a student in a masters program offered through Miami University.

One of the projects I am involved in through this program is a study in association with the Belize Zoo and an elementary school in Belize (La Democracia Elementary). The study is somewhat unusual: it concerns the introduction of a tree (moringa oleifera), sometimes called the "Miracle Tree", but in conjunction with the use of urine as a fertilizer.

As you can imagine, one of the concerns is that students will balk at the use of urine as a fertilizer; therefore one of the areas of interest in the study is attitudes of children with respect to the use of "human manure". With that in mind, we thought that we might compare the attitudes of American children with those of the elementary school in Belize.

I'm wondering if I might take a few minutes (no more than 10) of the children's time on Monday, 11/29, to administer a short survey. I would send you a copy of the survey in advance, of course (so that you could make sure that it is appropriate).

I would also appreciate it if other third grade teachers would be willing to administer it.

Thank you for your consideration of this matter,

Yours sincerely,

Andrew Long

6.2 Question Excised from the Survey

I was disheartened that the Principal of the school wouldn't permit this question. I'd hoped that there might be a class discussion of this one, but, because he couldn't figure out where this fit in the "standards", he said that the students couldn't be asked this question.

For Discussion

True Story: school children just your age in the Caribbean country of Belize are going to be asked to care for some small trees, and they're going to use their own pee as fertilizer for the young trees.

What advice can you give the scientists to convince these students to participate?

[**If you'd like to write down your ideas, please do!**]

6.3 The Survey Form

How Do You Feel About Gardening?

Respond to each question by circling one of the responses.

Question 1: I am a

Girl   Boy

Question 2: When I think of gardening, I feel

Happy   Okay   Bored   Sad

Question 3: If my parents asked me to work with them in the garden I'd be

Sad   Willing   Happy   Angry

Question 4: If I'm outside and find a big worm in the soil, I would most likely say

"Yuck!"   "So what?"   "Cool!"

The next questions have to do with fertilizer, which enriches the soil to make better crops:

Question 5: Human urine ("pee") is a good fertilizer, and could be used to grow your vegetables: how do you feel about that?

"Fine!"   "Interesting"   "Okay."   "Ugh!"

Question 6: The pee flushed into our toilets is a pollutant, and is causing damage to our ocean life: how do you feel about that?

Fine!   Okay   Bad

Question 7: How would you feel if you were asked to use your own pee to fertilize some beautiful flowers in your parents' garden?

Fine!   Okay   Bad

Question 8: Would you be willing to use your own pee as a fertilizer, if you could do it safely without touching it?

Yes   No

Question 9: Do you think that using pee in this way is a good example of recycling?

Yes   No

6.4 The Data

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Class	Sex	garden	work	worms	fertilizer	pollutant	ask pee	use pee	recycle
1	G	Happy	Willing	Cool	Ugh	Bad	Bad	Yes	Yes
1	G	Happy	Hap/Will	Cool	Interesting	Bad	Bad	Yes	Yes
1	B	Bored	Willing	Cool	Okay	Bad	Fine	Yes	No
1	B	Happy	Happy	Cool	Okay	Bad	Okay	Yes	Yes
1	G	Okay	Willing	Cool	Ugh	Bad	Okay	No	Yes
1	B	Bored	sad	Cool	Ugh	Fine	Okay	No	Yes
1	G	Okay	Willing	Cool	Interesting	Bad	Bad	No	No
1	B	Happy	Happy	Yuck	Ugh	Bad	Bad	No	Yes
1	G	Okay	Willing	so what	Okay	Bad	Okay	Yes	Yes
1	G	Okay	Willing	Yuck	Ugh	Bad	Fine	Yes	Yes
1	G	Okay	Willing	Yuck	Interesting	Bad	Okay	Yes	Yes
1	B	Happy	Willing	Cool	Fine	Bad	Bad	Yes	Yes
1	B	Bored	Willing	Cool	Interesting	Bad	Bad	Yes	No
1	B	Okay	Willing	so what	Interesting	Bad	Fine	Yes	Yes
1	G	Okay	Willing	Yuck	Okay	Bad	Okay	Yes	Yes
1	B	Bored	angry	Yuck	Interesting	Bad	Bad	No	Yes
1	G	Okay	Willing	so what	Interesting	Bad	Okay	Yes	Yes
1	B	Okay	Willing	Cool	Okay	Bad	Fine	Yes	Yes
1	G	Okay	Willing	so what	Okay	Bad	Okay	Yes	Yes
1	G	Bored	angry	so what	Ugh	Fine	Bad	No	No
1	B	Okay	Willing	Cool	Interesting	Bad	Okay	Yes	Yes
1	B	Okay	Willing	Cool	Interesting	Bad	Okay	Yes	Yes
1	G	Happy	Willing	so what	Ugh	Okay	Bad	maybe	No
2	G	Bored	Willing	Yuck	Ugh	Okay	Bad	No	Yes
2	G	Okay	Willing	Yuck	Interesting	Bad	Bad	No	Yes
2	G	Happy	Happy	Cool	Interesting	Bad	Bad	No	Yes
2	B	Okay	Willing	so what	Ugh	Bad	Fine	No	Yes
2	G	Happy	Willing	Cool	Fine	Bad	Bad	No	Yes
2	B	Bored	Happy	Cool	Ugh	Bad	Bad	No	No
2	B	Bored	Willing	so what	Okay	Bad	Fine	Yes	No
2	G	Happy	Happy	Cool	Interesting	Bad	Bad	No	Yes
2	B	Okay	Happy	so what	Interesting	Okay	Okay	Yes	Yes
2	G	Okay	Happy	so what	Interesting	Bad	Okay	Yes	No
2	B	Okay	Willing	Cool	Interesting	Bad	Okay	Yes	Yes
2	G	Okay	Willing	so what	Ugh	Okay	Bad	No	Yes
2	B	Okay	Willing	Cool	Interesting	Bad	Okay	Yes	Yes
2	G	Okay	Willing	Cool	Ugh	nil	Bad	No	No
2	G	Bored	sad	Yuck	Ugh	Okay	Bad	No	No
2	B	Happy	Happy	Cool	Ugh	Bad	Bad	No	Yes
2	B	Bored	angry	Cool	Ugh	Fine	Bad	No	No
2	B	Okay	Willing	so what	Interesting	Bad	Okay	Yes	Yes
2	G	Happy	Happy	Cool	Ugh	Bad	Bad	No	Yes
2	B	Okay	Willing	Cool	Interesting	Bad	Fine	Yes	Yes
2	G	Happy	Willing	Cool	Interesting	Bad	Fine	Yes	Yes