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Use of Urine

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Sustainable Sanitation Practice (SSP) aims to make available high quality information on practical experiences with sustainable sanitation systems. For SSP a sanitation system is sustainable when it is not only economically viable, socially acceptable and technically and institutionally appropriate, but it should also protect the environment and the natural resources. SSP is therefore fully in line with SuSanA, the Sustainable Sanitation Alliance (www.susana.org). • SSP targets people that are interested in sustainable sanitation systems and the practical approach to it. • Articles are published after blind review only. • Sustainable Sanitation Practice is published quarterly. It is available for free on www.ecosan.at/ssp.

Sustainable Sanitation Practice (SSP) hat zum Ziel praxisrelevante Information in hoher Qualität im Zusammenhang mit „sustainable sanitation" bereit zu stellen. „sustainable" also nachhaltig ist ein Sanitärsystem für SSP wenn es wirtschaftlich machbar, soziokulturell akzeptiert, technisch als auch institutionell angemessen ist und die Umwelt und deren Ressourcen schützt. Diese Ansicht harmoniert mit SuSanA, the Sustainable Sanitation Alliance (www.susana.org). • SSP richtet sich an Personen, die sich für die praktische Umsetzung von „sustainable sanitation" interessieren. • Artikel werden nur nach einer Begutachtung veröffentlicht. • Sustainable Sanitation Practice erschient vierteljährlich, kostenlos unter: www.ecosan.at/ssp.

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publisher: EcoSan Club, Schopenhauerstr. 15/8, A-1180 Vienna, Austria • chairperson: Günter Langergraber • website: http://www.ecosan.at/ • scope: EcoSan Club was funded as a non profit association in 2002 by a group of people active in research and development as well as planning and consultancy in the field of sanitation. The underlying aim is the realisation of ecological concepts to close material cycles in settlements.

Medieninhaber: EcoSan Club, Schopenhauerstr. 15/8, A-1180 Vienna, Austria • Obmann: Günter Langergraber • Gegenstand des Vereins: Der EcoSan Club wurde 2002 als gemeinnütziger Verein von einer Gruppe von Personen gegründet, die in Forschung, Entwicklung, Planung und Beratung in der Siedlungshygiene - Sammlung, Behandlung oder Beseitigung flüssiger und fester Abfälle aus Siedlungen - tätig waren und sind. Das Ziel des EcoSan Clubs ist die Umsetzung kreislauforientierter Siedlungshygienekonzepte (EcoSan Konzepte) zu fördern, um einen Beitrag zum Schutz der Umwelt zu leisten.

Cover Photo ***/ Titelbild***

Editorial

The SuSanA factsheet on "food security and productive sanitation systems" states that

> "*The nutrient content of human excreta depends on the diet and varies between countries as well as between individuals. Excreta contain all essential micronutrients and an average amount of plant available macronutrients of 4.5 kg/person/year (kg/p/a) for nitrogen, 0.6 kg/p/a for phosphorus and 1.2 kg/p/a for potassium. Most plant nutrients are found in the urine with a formulation similar to ammonium and urea and comparable results on plant growth. A combined application of faeces and urine is advantageous, since faeces are a very good soil conditioner due to its high share of organic matter. The use of excreta in agriculture improves the pH, the nutrient content and water retention capacity of the soil as well as the ability of plants to withstand insects, parasite attacks and pests*". (see www.susana.org)

"***Use of urine***" is the thematic topic of the third issue of ***Sustainable Sanitation Practice (SSP)***. If urine is collected separately, treated and converted to agricultural usage, the biggest step towards nutrient reuse and highly efficient water protection is taken.

The papers present various aspects on the use of urine: Practical experiences from the use of urine in Ethiopia, West Africa and from the United States of America are presented. Findings on the fate of pharmaceutical residues in urine are summarized in another article. The final contribution gives an outline on updated guidelines on the use of urine that will be published during 2010.

The next issue (issue 4, July 2010) will present the main results from the ROSA project (*Resource-Oriented Sanitation concepts for peri-urban areas in Africa*) which lasted from October 2006 until March 2010 and proposed resources-oriented sanitation concepts as a route to sustainable sanitation. ROSA was implemented in four pilot cities: Arba Minch in Ethiopia, Nakuru in Kenya, Arusha in Tanzania, and Kitgum in Uganda.

Information on future issues is available from the journal homepage (www.ecosan.at/SSP) and will be regularly updated. Please feel free to suggest further topics for issues of the journal to the SSP editorial office, Ms. Isabelle Pavese (ssp@ecosan.at). Also, we would like to invite you to contact the editorial office if you volunteer to act as a reviewer for the journal.

SSP is available online from the journal homepage at the EcoSan Club website (www.ecosan.at/SSP) for free. We do hope that SSP will be frequently downloaded and further distributed to interested people.

With best regards,
Günter Langergraber, Markus Lechner, Elke Müllegger
EcoSan Club Austria (www.ecosan.at/ssp)

Content:

implementing organisation:

Opening minds and closing loops – productive sanitation initiatives in Burkina Faso and Niger

This paper shows how two agriculture funded sanitation projects in rural Niger and Burkina Faso have introduced sanitized urine and faeces as new fertilizers for improved local nutrient management, food security and health.

Authors: L. Dagerskog, M. Bonzi

Abstract

The link between food production and sanitation is at the centre of two agriculture funded sanitation projects in Burkina Faso and Niger. Productive sanitation is used to increase food security, based on the fact that urine and faeces from a family of ten contain nutrients equivalent to approximately 100 kg of chemical fertilizer, locally worth ~80 US$. Urine contains the main part of these nutrients and is relatively easy to collect and reuse. The agriculture extension officers have a key role in supervising participative tests with urine as a fertilizer that help create demand for sanitation. Farmers are trained on how to produce liquid and solid fertilizers from urine and faeces, by eliminating the dangers and capturing the resources via the good use of simple urinals and "productive toilets". The article describes the arguments and methodology used in the projects and perspectives for up scaling in Burkina Faso and Niger.

Introduction

By emphasising the strong link between sanitation and agriculture, the Regional Centre for low cost Water and Sanitation (Centre Régional pour l'Eau Potable et l'Assainissement à faible coût, CREPA) has obtained funds from the agriculture sector with the main objective to improve food production in rural areas via the promotion of sanitized urine and faeces as fertilizers. The two main productive sanitation projects at the moment are the ECOSAN_UE$_2$ project in province of Kourittenga, Burkina Faso, and the PS-Aguié project in the province of Aguié, Niger (see boxes at the end of the article). Urine is central in both projects, since it is relatively easy and cheap to collect and represents a substantial and often neglected source of nutrients. This article develops the arguments used to involve the agriculture stakeholders and the methodology and current results of the two projects.

Nutrient management and the link to sanitation

The big picture

On a global level, the price hike of chemical fertilizers in 2008 and the emerging "peak phosphorous" and "peak oil" indicate that the era of cheap chemical fertilizers is coming to an end (see Cordell, 2010 for details). Since there is no substitute for phosphorous in food production, our societies will need to improve nutrient management on all steps along the productive cycle.

The agriculture sector is trying to reduce nutrient losses from soils as well as recycling animal manure and plant residues, but relatively little effort has been made to recycle the nutrients present in the food taken away from the field for human consumption, and subsequently excreted

Key actions for introducing sanitized urine and faeces as fertilizers:

- Illustrative examples of the quantity of fertilizer in human excreta and results of reuse
- Simple urinals for "liquid fertilizer" production and composting/dry latrines for "solid fertilizer" production
- Involve the agriculture extension officers
- Participative evaluation of urine as a fertilizer to create demand for productive sanitation
- Sensitization on dangers and resources in excreta – and how to eliminate dangers and maintain the **resources**
- Follow up on the whole productive sanitation chain i.e. collection, sanitization and reuse.

as urine and faeces. The global phosphorous flow analysis by Cordell et al. (2009) estimates that only 10% of phosphorous in human excreta is recycled to arable soil, while 50% ends up in water and 40% under-ground or on non-arable soil. These losses are equivalent to around 20% of the annual phosphorous mined (Cordell et al. 2009).

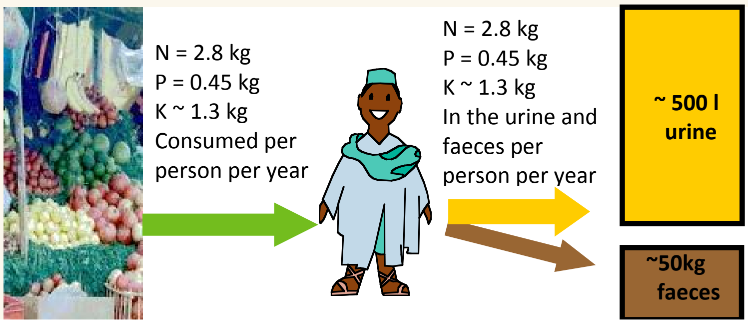

Figure 1. The average annual fertilizer production per person

In Burkina Faso and Niger chemical fertilizers are out of reach for most farmers, while a growing population increases the pressure on arable land. Table 1 shows the difficult soil fertility and sanitary situation in these two countries with low chemical fertilizer use, high nutrient losses from agricultural land, a high percentage of open defecation in rural areas and a high number of child deaths per year due to diarrhoea.

Safe recycling of urine and faeces can help improve both food production and health, but the farmers are rarely aware of the possibilities of how to "eliminate the danger" and "use the resources" in human excreta.

Table 1. Challenges with soil fertility and sanitation in Burkina Faso and Niger

	Burkina Faso	Niger
Chemical fertilizer use 1996-2002[1] (kg NPK*/ha/yr)	5.9	0.9
Estimated nutrient balance 2002-2004[2] (kg NPK*/ha/yr)	- 43	- 56
Open defecation in rural areas in 2006[3] (%)	83	92
Annual child deaths due to diarrhoea[4]	24 300	26 400

* NPK = $N+P_2O_5+K_2O$
[1] Morris et al (2007)
[2] Henau and Baanante (2006)
[3] UNICEF/WHO (2008)
[4] UNICEF/WHO (2009)

The fertilizer value of human excreta

To capture the attention of agriculture stakeholders it is important show that human excreta contain a substantial amount of plant nutrients. According to Jönsson et al. (2004) the amount of nitrogen and phosphorous in human excreta can be calculated from protein consumption. There is an equilibrium over the human body - what comes in sooner or later also comes out, except during growth when a minor part of consumed plant nutrients is incorporated in growing body tissue. Dagerskog (2007) used the method proposed by Jönsson et al. (2004) and statistics on protein consumption (FAOSTAT, 2005) to estimate the human fertilizer production for the ten countries in West Africa concerned by CREPA's ECOSAN program: Benin, Burkina Faso, Congo, Côte d'Ivoire, Guinea, Guinea Bissau, Mali, Niger, Senegal and Togo. An average person in these countries excretes annually 2.8 kg of nitrogen (N), 0.45 kg of phosphorous (P) and approximately 1.3 kg of potassium (K) with the urine and faeces (Figure 1).

This regional average was used to illustrate the value of human excreta in Burkina Faso. The annual quantity of N and P in urine and faeces from a family of ten persons corresponds roughly to the quanitity of N and P in 50 kg of urea and 50 kg of NPK(14-23-14) which are the two most common chemical fertilizers in Burkina Faso (Table 2).

The local market price of 50 kg of Urea and 50 kg of NPK in Burkina Faso is about 80 US$ (SOGEDIF, Feb. 2010). The total Burkinabè population of ~15,6 million inhabitants then excrete the equivalent of 125 million US$ worth of fertilizers per year. In addition, urine and faeces are complete fertilizers, containing the main plant nutrients (N, P, K) as well as the important trace elements and organic matter.

Table 2. The annual quantity of nutrients in the excreta from 10 persons compared with chemical fertilizer

Fertilizer	N (kg)	P (kg)	K (kg)
Urine et faeces from 10 persons in one year	**28**	**4.5**	**13**
50 kg of urea and 50 kg of NPK(14-23-14)	**30**	**4.9**	**7**

Comparing urine and faeces as fertilizers

The distribution of plant nutrients between urine and faeces depends mainly on the digestibility of the food. In general the absolute majority of N and K are excreted with the urine while P is more evenly distributed between urine and faeces (see Jönsson et al. 2004 for details). Faeces, rich in phosphorous and organic material, are a suitable base fertilizer while the nitrogen rich urine is a suitable cover fertilizer.

The baseline study for the project in Aguié, Niger, showed that defecation is mostly done in the fields around the villages, while the shower/ablution area is the preferred place for urinating (CREPA, 2009). In this situation, a better urine management would make the greatest difference to the local nutrient recycling. However this does not mean that open defecation should be encouraged for any reason. While defecating in the fields can bring the nutrients in faeces back into the productive cycle, it is a health hazard and a sub-optimal way of recycling as it is not applied at the place, time and dose to optimize plant growth.

Results and project experiences

Introducing the new fertilizers - methodology

Both projects have followed a similar methodology when introducing sanitized urine and faeces as fertilizers. The methodology is based on how other new fertilizers are usually introduced, via practical participative tests:

- All concerned stakeholders are informed on the new fertilizers, showing the experience from CREPA's ECOSAN projects in West Africa and photos from other projects around the world.

Figure 2. Two bags of fertilizer were brought along for sensitization sessions in Niger to illustrate the annual amount of nutrients that are present in the excreta from one family

The population is sensitized on the amount of fertilizer they **produce (Figure 2) and the** local agriculture extension officers are trained.

- Urine collection starts via simple urinals (jerry can and a funnel) to enable tests with the locally produced "liquid fertilizer".
- Participative tests are done to demonstrate the virtue of urine as a nitrogen fertilizer (urine compared to urea) at farmer field schools and on individual fields.
- Participative evaluation of the test plots.
- Training of village facilitators and artisans.
- Sensitization in the villages using SARAR/PHAST tools for understanding the dangers as well as the resources in human excreta and on how good use of latrines and urinals can help

Table 3. The scale at local level of the two projects

	ECOSAN_UE2, Kourittenga, Burkina Faso	**PS-Aguié Aguié, Niger**
Number of villages involved:	30	11
Vegetable farmers :	366 farmers trained on urine application methods	25 farmers involved in participative tests, 22 others applied urine on own initiative
Cereal farmers:	1255 farmers tested urine in 30 farmer field schools, 500 have done tests on own initiative	122 farmers tested urine in eight farmer field schools, 65 have done tests on own initiative
Agriculture extension officers trained:	29	10
Surface fertilized:	A total of 5,7 ha for cereal tests in farmer field schools (half with urine) and 27 ha for individual tests (with and without urine).	A total of 0,7 ha for cereal tests in farmer field schools (half with urine)
Urine collected :	?	> 125 m3 during 2009
Households producing solid fertilizer via toilets:	318 (712 toilets still to construct)	150 (another 60 toilets under construction)
Households producing liquid fertilizer via urinals:	2000	1143

UDDT with adobe superstructure

Urine separation integrated on the slab

Urinal dug down for squatting

Figure 3. UDDT and urinal in Kourittenga, Burkina Faso

eliminate the dangers and capture the resources.

- Construction of fertilizer factories (latrines) that enable the production of "solid fertilizer" as well as "liquid fertilizer".
- Follow up on the whole productive sanitation chain i.e. collection, sanitization and reuse.
- Use inter-village visits to spread the message. In Niger the first pilot farmers were taken on a study trip to exchange and train with farmers in Burkina Faso. These first pilot villages were then visited by other villages in the province.

Scale

The two projects operate on a limited scale, but serves as references for further productive **sanitation initiatives in Burkina Faso and Niger. Table 3 provides a summary of the scale of the two projects.**

Production of liquid and solid fertilizer

In both projects urine collection was soon started using simple urinals. After the urine tests as fertilizer and sensitization sessions on the dangers and resources in excreta, the latrines were introduced. In Kourittenga it was decided to opt for the urine diverting dry toilet (UDDT), and build solid double vaults with cement bricks with a 180 US$ subsidy (Figure 3).

In Aguié, all pilot village households got the simple urinal, and were then offered a choice between a low cost UDDT (called "dry toilet" in Aguié) and a UD Fossa Alterna (called "composting toilet" in Aguié) (Figure 4). The dry toilet is built off the ground and faeces is sanitized by desiccation together with ash, while the composting toilet is a shallow pit toilet were sanitization is enhanced by composting through the addition of organic material and some ash after defecation. All toilets have two vaults/pits used alternately.

Both models were subsidized with around 50 US$ to cover the imported materials and mason fee for the vaults/pits. The composting toilet has been very popular – no roof is needed, no stairs and the anal wash water can enter the pit. A study by Djariri (2009) showed that it would be possible to decrease the subsidy part to 30 US$ with some technical modifications. This is approaching IFAD's aim of a maximum subsidy of 20 US$ per installation.

Storing large volumes of urine is expensive and can be difficult. In Aguié the farmers are advised to enrich their compost or "dirt pile" or apply the urine to the field even during the dry period (covered with soil) if they run out of storage possibilities.

Urine quality

In Niger the urine was sampled during four different occasions and analyzed with the results presented in Table 4 :

Urine can either be transferred from a pot to the jerry can or enter directly. Dug down it is adopted for the squatting position

The composting toilet with urine diversion

The dry toilet in local material except the slab and vent pipe.

Figure 4. Urinals and toilets in Aguié, Niger

Table 4. Results from analysing agronomic parameters in Aguié urine

Parameter (n=number of jerry cans analysed)	N (n=37)	P (n=33)	K (n=28)	Na (n=9)	Mg (n=3)	Ca (n=3)	pH (n=29)
Unit	g/l	g/l	g/l	g/l	mg/l	mg/l	
Average	6,0	0,8	0,9	3,1	20	36	8,8
Standard deviation	1,1	0,2	0,3	0,2	1,6	3,1	0,2

The urine is especially rich in nitrogen, and in the higher range of the 3-7 g N/l given as indicative values in Jönsson et al. (2004). It can also be noted that sodium concentration is much higher than magnesium and calcium. In irrigation water where the concentration of sodium salts is high relative to other types of salt, a sodic soil may develop, which is characterized by a poor soil structure: they have a low infiltration rate, they are poorly aerated and difficult to cultivate (FAO, 1985). Even though the salt concentration is quite high in urine, the total salt quantity applied per year is not high when compared to irrigation water. However salinity is complex and further research on urine use and salinity would be welcome to avoid long term problems.

Laminou (2009) followed the volume of urine generated from 10 men, 10 women and 10 children (ca. 10 years old) in two villages in Aguié. On average the men produced 1.7 l/day, the women 1.9 l/day and the children 0.9 l/day. With 50% of the population under 15 years, the average daily urine production would be about 1.35 litres per person. Using the concentrations in table gives that the average person in Aguié urinates annually ~ 3 kg N, 0.4 kg P and 0.45 kg K with the urine, which is higher than expected, except for potassium. It should be noted though that the study was made just after harvest time when people have plenty to eat.

Laminou (2009) also analyzed the sanitization of urine after 30 days of storage, and found no micro-organisms except for anaerobic sulphite reducers that were present in 3 out of 9 samples. *Clostridium Perfringens* is one bacteria of this type that can cause food poisoning. However, the infective dose is quite high and clostridium is frequently present in the intestines of both humans and animals and also widely distributed in the environment due to its spore forming capability (FDA, 2009).

Application of urine in agriculture

In Kourittenga, urine tests were done on a relatively large scale. To facilitate application, the furrows were opened and closed using animal traction and the urine was poured directly from the jerry cans (Figure 5).

In Aguié, the preferred application method has been with a bucket and cup. The urine in Aguié was dosed to give the same nitrogen quantity as the locally recommended dose for urea. With a urine concentration of about 5 g N/l and with urea containing 46% N, 10 grams of urea corresponds roughly to 1 litre of urine. After the application it is important to water down thoroughly, or wait to apply until after a rain. Some farmers have had problems with wilting plants after urine application, especially young tomato plants. A solution has been to avoid application during the hottest part of the day and to reinforce watering the two following days after application. For cereals, urine application has been made after a good rain when the soil is humid.
In both projects the local agriculture extension officers have been supervising the participative tests.


Figure 5. Urine transport and application in Kourittenga

Figure 6. Individual test in Kourittenga on sorghum where organic matter (OM) has been used as base fertilizer and urine as an additional source of nitrogen (pile to the right)

Agronomic results with urine

During the tests, urine has been compared to urea as a nitrogen fertilizer, or complementing the farmer's traditional way of fertilizing using only organic matter. The test on **sorghum in Figure 6 is an example of an individual in Kourittenga who** tested the nitrogen effect of urine on sorghum.

The tests in the farmer field schools were monitored more closely, **and Table 5** summarizes millet results from four farmer field schools in Aguié in 2009. All test plots (T0-T3) of 200 m^2 had organic matter (OM) as base fertilizer at a dose of 20 ton/ha. T1 and T2 also had 50 kg/ha of Super Simple Phosphate (SSP) as extra base fertilizer. The N-application was either through 5 grams of urea (T1) or 0.5 litres of urine (T2 and T3) per plant, which with 10000 millet plants/ha gives around 25 kg N/ha.

Urine gave roughly 10-20 % more than urea. This is not surprising as urine, a part from nitrogen, also contains some phosphorous and potassium. Compared to the control with only organic matter, urine increased the yields in general by 40-50%. One 25-litre jerry can of urine gave around 2-3 kg extra grains in the Aguié conditions.

It is important that farmers see sanitized human excreta as something that complement rather than replaces existing fertilizers. Recycling human excreta helps reduce losses, but to increase fertility in degraded soils all available resources are needed: animal manure, crop and food residues, chemical fertilizers as well as human excreta.

Overcoming mental barriers

To consider human urine and faeces as potential resources requires a change of mindset. Such change does not come over night, and initial resistance is normal. Here are some experiences of how mental barriers were over come in the two projects:

- The farmers want to see to believe. It was important to quickly start with urine collection and testing.
- In Muslim societies urine is considered impure and something that one should never get in contact with. On the other hand, the importance of cleanliness in Islam provides a good argument for collecting and taking away urine from the compound. Men also squat when urinating, so the alternative to dig down the urinal was appreciated. When applying urine, gloves and mouth protection are used, and the same clothes are not used when praying. If urine touches the clothes or skin, the accepted solution is to wash well with water.
- The fields closest to the village has always given the best yields since animals and people relieve themselves there and no-one has ever hesitated to eat what is produced from these fields. The new way of recycling excreta is an improvement of what is already done.
- It is possible to eliminate the danger and keep the resources by simple storage for urine or drying/composting for faeces. After sanitization urine is called "liquid fertilizer" and faeces is called "solid fertilizer", which makes it easier to talk about.
- The urine odour is said to be the fertilizer - if it

Table 5. Millet harvests (kg/ha) at four farmer field schools in Aguié.

Village	Dan Bidé	Tsamiya Bakoye	Malloumey Saboua	Zabon Moussou
T0 (OM)	781	660	1244	1209
T1 (OM+SSP+Urea)	1160	893	1318	1000
T2 (OM+SSP+Urine)	1257	1072	1637	1111
T3 (OM + Urine)	1161	948	1773	1399
Surplus yield T2 compared to T1 (%)	8	20	24	11
Surplus yield T3 compared to T0 (%)	49	44	42	16

doesn't smell, it is no good! In Kourittenga, it is compared to the traditional spice soumbala, which is considered to be better the stronger odour it has.

- It is people behind desks who can be the real barriers. Farmers are often very pragmatic in their struggle to get a decent harvest. The productive sanitation approach that both improve the living conditions and food production has been received with open arms in the two projects.
- A much appreciated activity in Aguié was the “blind taste-tests” of vegetables and cereals fertilized with urine and urea. The results show a sweeter taste for urine fertilized vegetables, and in general a higher buying preference for the urine fertilized vegetables both based on taste and appearance (Saley, 2009).

Scaling up potential

In Burkina Faso, the use of excreta derived fertilizers could either be scaled up like other agriculture innovations, or it could go through the national sanitation program (PN-AEPA) that is about to roll out. The PN-AEPA includes the UDDT as a technical option, but it does not explicitly allocate resources for accompanying farmers with the recycling. Fortunately, in Burkina Faso it is the Ministry of Agriculture who is in charge of water and sanitation, so there are good opportunities for synergy between sanitation and agriculture programs, if the political will is there.

The ongoing EcoSan projects in Burkina Faso are still preparing the base, and the information and results are slowly reaching the top. To convince the decision makers there is still a lot of advocacy work needed, with precise and reliable data, as well as good economic arguments. Part of this work is being done within the project in Kourittenga.

In Aguié, Niger, the local partner project partner (PPILDA) will continue to support farmers and eventually extend the approach to the entire intervention zone (260 villages). On national scale in Niger the Rural Development Strategy (SDR) could be a suitable framework to take the approach further. The director of the SDR executive committee has shown interest but wishes to have more national research on hygienic and agronomic aspects.

From an agro-economic point of view, the subsidy of 180 US$ in the Burkina project or 50 US$ in the Niger project for a productive toilet can help a family to potentially collect around 80 US$ worth of fertilizer per year. This is a short pay back time, but the construction and good use of productive toilets require skill and knowledge. A large scale program that provides these new skills and follows up on the whole system will need a lot of time and resources. However, simple urine collection captures the majority of plant nutrients in human excreta and can be done to a much lower cost, and with less skills and follow up. An interesting approach would be to scale up urine recycling via the agriculture sector while sanitation programs promote faeces management. The agriculture extension officers already widely present in the rural areas could disseminate knowledge on urine reuse, and prepare the grounds for further sanitation interventions.

As an alternative to large national programs a recent example from Malawi (Bramley and Breslin, 2010) show that basic productive sanitation services also can be spread on grass root level via business opportunities for small scale entrepreneurs. There are signs of this dynamic in the two projects discussed in this article; In Kourittenga people have initiated urine collection on public places, and in Aguié an individual has already bought 140 jerry cans of urine from his neighbours to enrich his compost.

Conclusion

In the pilot villages in Kourittenga and Aguié, urine and faeces are now looked upon as potential liquid and solid fertilizers. An important reason has been the methodology of participative tests with urine. In rural areas food production is the main occupation and an effective entry door to create interest for sanitation, at least among the men. The women tend to be more interested by the comfort, hygiene and pride-side of productive sanitation. Already a simple urinal makes a difference, as the urine odour in the shower disappears with the collection.

On a global scale, with the absence of political awareness and will, the incentive to recycle human excreta will come with increasing fertilizer prices. In Burkina Faso and Niger were commercial fertilizers are beyond the purchase power of most farmers, there is already a strong recycling incentive. The important knowledge of urine collection and reuse can be spread by the local agriculture extension officers. They are in a good position to lead the yellow revolution!

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The ECOSAN_UE$_2$ project in Burkina Faso is financed mainly with EU food security money (~1.5 million Euro, 2008-2011). CREPA together with the National Environment and Agriculture Research Institute (INERA) and the Ministry of Agriculture implement the project covering 30 villages in the Kourittenga province. Ecological sanitation is combined with soil and water conservation techniques to improve food production.

The International Fund for Agriculture Development (IFAD) granted a 200 000 US$ pilot project for CREPA, PPILDA (a 17 million US$ IFAD-funded rural development project run by the Ministry of Agriculture in Niger) and Stockholm Environment Institute (SEI) to test urine as a fertilizer in the Aguié province in Niger. The objective was to show the effectiveness of urine and to develop strategic tools as well as low cost appropriate technologies for an eventual up-scaling within the PPILDA rural development project and other IFAD funded projects. The PS-Aguié project was carried out during 16 months from Nov 2008-Feb 2010. See www.ecosanres.org/aguie for more information, fact sheets and tools.

overall project:

Experiences from the use of urine in Arba Minch, Ethiopia

Urine crop trials in Arba Minch, Ethiopia, showed the possibility for improving soil fertility and increasing crop yield.

Authors: K. Kassa, F. Meinzinger, W. Zewdie

Abstract

In this paper an overview of practical experiences with the collection and the use of urine from urine diversion dry toilets in Arba Minch is discussed. At two crop trial sites maize was fertilized with urine and the maize yield and the effect on soil was studied. At one site, the yield of urine fertilized maize was increased seven times compared to unfertilized soil. Analyses of the soil fertilized with urine showed that Kjeldahl nitrogen and salinity was increased while pH was decreased at higher rates of urine application. Urine contains important nutrients for the plants and increases the quality of soil; however precautions against the development of salinity in the roots of plants are required. The urine crop trial sites have changed the attitude of many people who had a chance to visit.

Introduction

The EU-funded project called ROSA (*Resource-Oriented Sanitation concepts for peri-urban areas in Africa*) proposed resource-oriented sanitation concepts as a route to sustainable sanitation to meet the UN MDGs. These concepts have been applied in four pilot cities in Eastern Africa, namely Arba Minch (Ethiopia), Nakuru (Kenya), Arusha (Tanzania) and Kitgum (Uganda). Arba Minch is located about 550 km south of Addis Ababa, the capital of Etiopia, and has a population of about 80'000. ROSA Arba Minch was working in the whole of Arba Minch town on the management of solid waste, greywater, faeces and urine to improve sanitation of the town and to increase agricultural productivity in the Arba Minch area. Different resource oriented sanitation systems have been implemented in Arba Minch town including 15 urine-diversion dry toilets (UDDTs), 30 Fossa alternas, 9 Arborloos, 7 greywater towers, 1 biogas unit and more than 5 composting sites.

One of the most commonly used technologies for the source separated collection of urine are UDDTs. Urine is diverted from faeces using separating pedestals. Urine is a valuable flow since it contains phosphate, nitrogen and potassium and can be used directly or after storage. It is a low cost alternative to the application of nitrogen rich mineral fertilizer in plant production. The chemical composition of urine and its plant availability is comparable to chemical fertilizer (Johansson et al. 2001; Kirchmann and Pettersson, 1995).

Figure 1: Typical storage tank in UDDT toilet

Figure 2: Urine storage in UDDT toilet

Considering the contents of the major nutrients in urine, research in applying urine in agriculture especially in developing countries is needed. The use of urine as fertilizer in arid and semi arid regions like Arba Minch gives some knowledge input and also may contribute to the change of the attitude of the people and even decision makers.

The use of urine in agriculture may increase agricultural production and eventually reduce vulnerability in developing countries.

The objective of the research conducted in Arba Minch town was to test urine as fertilizer for maize on two types of soil with different fertility. The yield of maize was used to evaluate the effect of urine application. The impact of urine on the quality of the soil was also investigated by measuring parameters such as conductivity, pH and nutrient content. The trial sites were furthermore used to demonstrate the use of urine to farmers and other community members.

Use of urine and analyses

Urine separation, collection and transport in Arba Minch

Urine is stored in plastic jerry cans or plastic water tanks, which are available from local market, in the vaults of the UDDTs. Joints of urine collecting pipes are connected by adhesives and flexible plastic pipes are used to reduce nitrogen losses in the form of ammonia. The sizes of the tanks depend on the size of the family using the UDDT. Initially, the transfer of urine from the UDDTs tank into the transportable jerry cans was done by pump. However, this resulted into breakage of two pumps, therefore, a cheap method of collection was introduced which is a plastic hose connected at the bottom of the urine tank and lowered to pour the urine and raised and bent to seal it (Figures 1-2). In some occasions neighbours were complaining and UDDT owners were also ashamed of the odour produced when the stored urine was transferred into transporting jerry cans. Taking this as lesson urine was poured carefully from container to container to avoid nuisance.

Initially, the urine used to be transported by the ROSA project in a pick-up car (Figure 3). However, this was not sustainable. Therefore, female and youth group has been identified which has been originally organized to collect the town solid waste from households and business centres. These entrepreneurs are now transporting urine from UDDT toilets to the area of use by donkey carts (Figure 4). The donkey cart was given by ROSA under the condition that the entrepreneurs transport excreta and solid waste to earn extra income by transporting things different from waste. The UDDT users have proposed a certain amount of money they are willing to pay for these services.

For a hygienic point of view, human urine is a “safe” fertilizer with less concern regarding risks for disease transmission when handling (Kvarnstrom, *et. al*., 2006) and it is an uncommon transmission route of disease. In rural Ethiopia, it is common to urinate on fresh wounds to stop bleeding. In order to reduce the risk from possible contamination by faeces, urine is stored at the production or reuse sites. Some families were using the fresh urine directly in their gardens. Urine is one of the components of co-compost produced by organized youth groups; recently the compost producers have started selling their products to private farmers.

The use of urine as a fertilizer in agriculture in Ethiopia is generally faced with some cultural objections, although wastewater use in agriculture is a common practice in Addis Ababa. In Arba Minch reuse of urine was not practiced until ROSA started it in trials. There was a widespread perception that urine may burn the plants. A part from the burning effect, many households in Arba Minch, who were interviewed in the beginning of the project, stated that they would be hesitant to eat vegetables fertilized by urine. Nevertheless, urine trial farms were prepared in Arba Minch. The trial sites were successful in showing that urine

Figure 3: Transportation by pickup car

Figure 4: Donkey cart used for transporting urine, solid waste, and dried faeces

Table 1: Urine application on the maize plant at Arba Minch University Plot (planting on 28.06.2007)

Code	N applied (kg N/ha)	Urine added (ml)				
		21.6.07	04.8.07	28.8.07	17.9.07	Sum
T25	25	100	50	50	38.1	238.1
T50	50	200	100	100	76.2	476.2
T75	75	300	150	150	114.3	714.3
T100	100	400	200	200	152.4	952.4

improves yield and they were also successful in initiating an attitude change. Many people in Arba Minch have eventually consumed urine fertilized maize, lettuce and tomato although they knew it was fertilized by urine.

Methods

Urine fertilizer trials

Arba Minch University farm trial plot

The urine, which was collected from UDDTs, was transported in 20 litre jerry cans and stored in a tank located at the farmland. Twenty plots each with a size of 16 m^2 were prepared in Arba Minch University farm (Figures 5). Five application rates of urine based on nitrogen amount were chosen including four replicates. The application rates were 25kg N/ha, 50kg N/ha, 75 kg N/ha, and 100kg N/ha, respectively (Table 1). The yield of each plot was analyzed when the crops were mature.

Figure 5: Urine application method on farm

The application of urine was done by watering cans after mixing with 50% irrigation water. The plants were counted in rows; the urine irrigation water mixture was applied nearby the roots of the plants keeping the watering at the same pace. The application was done back and forth until the mixture in the watering can was finished (Figure 5).

The application of the urine on the farm was done in different portions at different development stages of the plant before the first signs of the maize tassel and cob appearance. Operators applying urine in the farm were complaining of strong smell in the direction of wind but there have been no problems with odour once the urine was poured on the soil even at high temperatures in Arba Minch.

ROSA office farm trial plot, Secha

Two plots each with a size of 4 m^2 and 16 planting spots were prepared at the ROSA office site and two maize grains were planted in each spot. Each spot of the first plot was treated with 1.2 litres of urine in four portions while the second plot was watered only with water. All watering was done at the same day for all plots. The amount of nitrogen added in terms of urine was 175 kg/ha. Finally, each plant stand was analyzed for the yield and biomass when the crops were mature.

Physicochemical analysis

2.5 gram of soil taken from 20 cm depth were analyzed for potassium using flame photometer after extracting with 100 ml of ammonium acetate buffer solution (Dewis, *et al*., 1970, APHA, 1992). 2.5 gram were analysed for Kjeldahl nitrogen (TKN) after extraction (Dewis, *et al*.,1970, APHA, 1992). pH and conductivity were analysed after shaking the dispersed sample (1:5 sample: water) (Dewis, *et al*.,1970). Urine was analysed for phosphate, potassium, nitrogen, pH and conductivity according to standard methods (APHA, 1992).

Results from crop trial plots

Characteristics of urine

The urine samples were collected from ROSA office for use at the ROSA office trial plot and from construction site UDDT toilets for use at the Arba Minch University trial plot as described above. Table 2 shows the charcteristics of the urine from the 2 sites.

Table 2: Typical characteristics of nutrients in urine collected from two UDDT sites in Arba Minch (ROSA office and construction site)

Sample/Parameter	NH4+-N	N-org	TKN	PO43--P	K+	pH	Conductivity
	g/l	g/l	g/l	g/l	g/l	-	mS/cm
Urine ROSA office	3.3	0.3	3.7	0.4	1.6	8.8	25.9
Urine construction site	3.9	0.4	4.2	0.6	2.7	8.9	35.8

It was shown that there is a difference in quality depending on way of storage, storage time and the differences in use of the toilets. The urine from ROSA office was collected from office workers who drink water when they need and the urine from the construction site UDDT was collected from day workers who had a possibility of dehydration. Besides, the conductivity of urine from the construction site was higher maybe because it was stored for a number of days in open sun in a water tank but the urine ROSA office was relatively fresh and was stored under the shade in the vault of UDDT.

Crop yields from trial sites

Figures 6-8 show the maize yield on Arba Minch university trial farm which was fertilized by urine at the rate of 25, 50, 75 and 100 kg N/ha, respectively. Figure 7 shows the maize yield increases with increasing urine application rates. However, finally the increase is stabilized with the increase of urine amount. The difference between the yield of the fertilized and unfertilized maize was not much compared to the results from the ROSA office trial plot shown in Figure 9-12. Figure 8 shows biomass of maize without the cob but the change is not significant. One reason for this might be the damage caused by wildlife before analysis. Figure 9-12 show the results of the ROSA office

Figure 6: Urine experiment on maize at Arba Minch University farm

Figure 9: Left: urine fertilized; right: unfertilized maize collected from ROSA office farm.

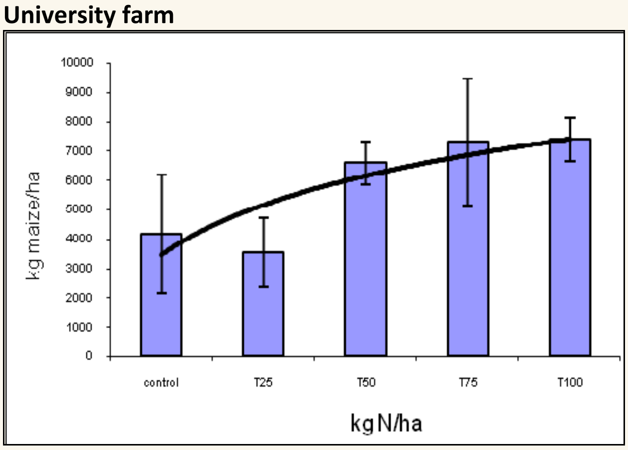

Figure 7: Maize yield (crop trial performed on Arba Minch University farm. The farm land is relatively fertile)

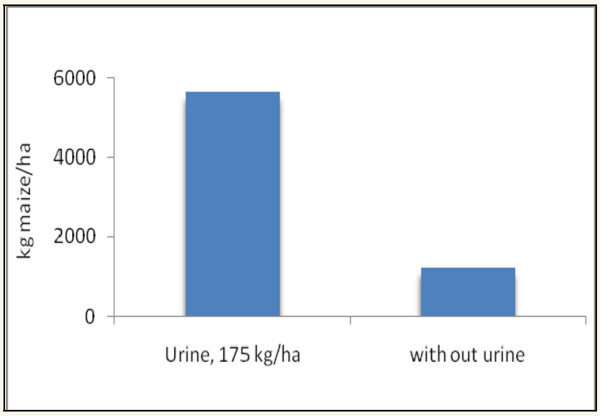

Figure 10: Maize yield (crop trial results of the ROSA Office demonstration farm)

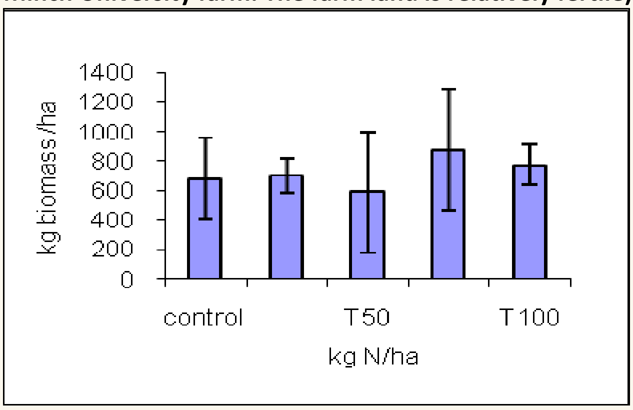

Figure 8: Average of maize biomass measured without cob cover and root (University farm)

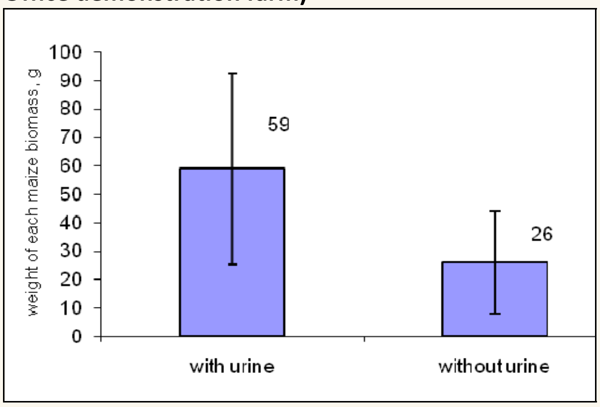

Figure 11: Weight of maize biomass (ROSA office), 175 kg N/ha equivalent of urine was added.

trial farm where there is big difference between the urine fertilized and unfertilized maize most probably because of the initial lower soil fertility. The maize yield fertilized by urine at a rate of 175 kg N/ha is seven times more than the unfertilized maize (Figure 10). The related maize biomass fertilized by urine is twice as much as the unfertilized one (Figure 11).

Figure 12: Control (left) and urine fertilized maize (right) at the ROSA office trial plot

A comparison of the results from the two trial plots shows the dependence of the effect of urine on the initial soil quality. Although the initial soil quality is not indicated here since it was not sampled, the Arba Minch University trial plot is very rich and it was in use as a farm while the farm in ROSA office is lacking nutrients and was not in use for agriculture before. The results of Arba Minch University farm trial plots also showed that the maize yield and biomass increased in response to the increased urine application, but at a slower rate at higher urine applications. Jönsson et al (2004) indicated that the effect of crop yield increases with increasing fertiliser application rates and then remains constant at higher concentrations.

From these two experiments, it is possible to say that less fertile soil has a tendency to give good yield with urine. Hence, the Ethiopian highlands, which are particularly suffering from nutrient depletion, are a promising region for using urine and compost conditioned with urine.

Impact of urine application on soil quality

Figures 13-15 show the soil quality changes after urine addition at the Arba Minch University trial farm plots. The conductivity of the soil increases with increasing urine application which means that there is a possibility of increased salinity as more urine is added to the soil (Figure 13). Farmers who are going to use urine as a fertilizer must irrigate with more irrigation water to leach the salt accumulation in the root zone of the plants. The dilution ratio can start from 3:1 urine to water and above. If 1 litre of urine is added either diluted with 25% or 75% the nutrients that are supplied to the plat are the same. The problem arises when concentrated urine is added salt is being accumulated on the soil surface and not reaching the plant root. Yet, when the urine is mixed with more water the nutrient may be leached or washed away before the roots absorbed it.

Figure 14 Kjeldahl nitrogen and potassium of soil fertilized by urine. The amount of nitrogen slightly increased with addition of urine which is one of the positive values of urine as a fertilizer. Potassium variation with increasing amount of urine was neglegible.

The pH of neat urine applied was about 9 (Table 2). The pH of soil measured after application of urine indicated in Figure 15 decreased with increasing application of urine on the soil. This might be described by as the fact that ammonium is nitrified in soil, releasing two protons and thus decreasing the pH. However, this might be only a temporarily

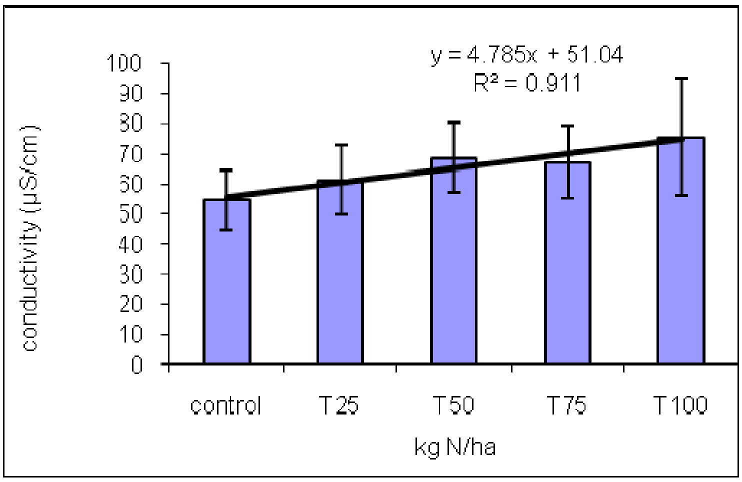

Figure 13: Conductivity of urine fertilized soil after harvesting maize

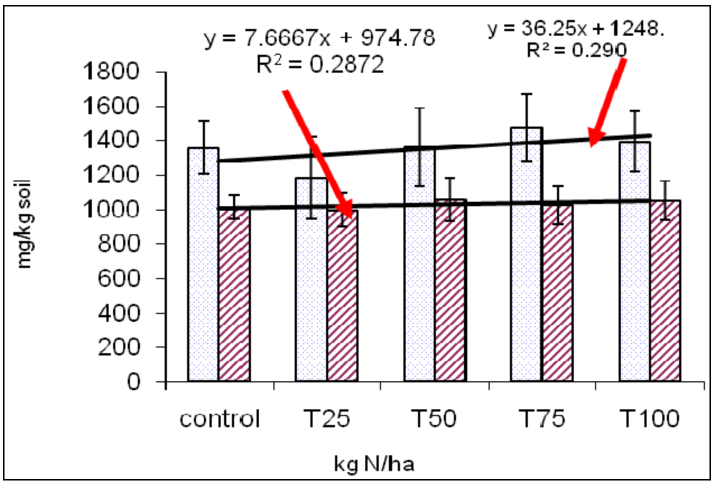

Figure 14: Potassium (filled) and TKN concentration (clean) in the soil fertilized with urine, after harvesting maize

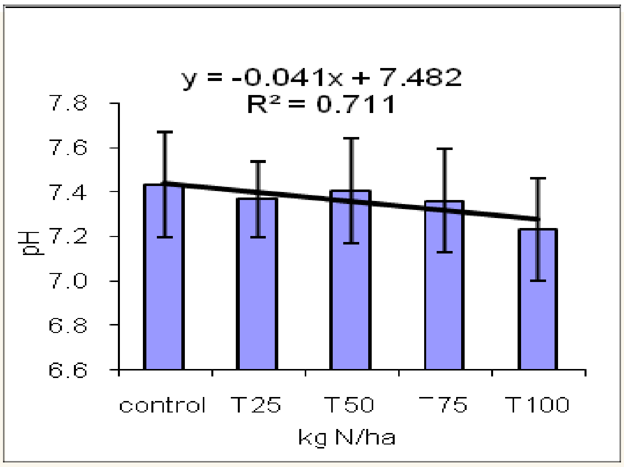

Figure 15: pH of urine fertilized soil after harvesting maize

effect since when nitrate is taken by plant root two hydroxide ions are released which this therefore result in the neutralization of the protons in the soil (Schönning, 2001). Then there might be no pH decline permanently in a soil treated with urine.

Conclusions and Recommendations

Urine collection, transport, treatment and reuse is one of the difficult step in resources-oriented sanitation systems because the society and the decision makers may not be aware of the advantages. In Arba Minch the transport and collection of urine from UDDTs was first done by car but gradually entrepreneurs were involved to independently transport by donkey cart without external support. This is a good progress to sustainability of the implemented sanitation systems.

Youth groups also use urine to enrich the co-compost, which they produce from faeces and organic waste. Costumers are happy to buy the produced compost so that the youth groups can gain an income.

The response of maize plant for urine is very good but it depends on whether the soil is already fertile in terms of nutrients or not. The response is very good in the ROSA office trial farm, while it is smaller at the University trial farm, where the soil had already a relatively high initial fertility.

Urine increases soil fertility but the development of soil salinity might happen especially in areas where irrigation water is scarce. Therefore, appropriate measures such as drainage might need to be taken and salt tolerant crops should be selected.

In order to make urine accepted by the Ethiopian farmers widely repeated research and demonstration should be done in different agro-climatic zones and preferably in cooperation with farmer associations.

Acknowledgements

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Are pharmaceutical residues in urine a constraint for using urine as a fertiliser?

This paper provides an overview about pharmaceutical residues in urine and their potential role as constraint for reuse of the urine in agriculture.

Author: M. Winker

Abstract

Urine is an excellent, complete plant fertiliser (containing nitrogen, phosphorus and potassium), but also contains certain amounts of pharmaceutical residues even after prolonged storage as a treatment step. If those substances are polar and hardly biodegradable they can be taken up by plants and thereby possibly enter the human food chain. Research has shown that the low pharmaceutical concentrations provided with urine are unlikely to affect plant development and growth. A full evaluation of the potential toxic effects of pharmaceuticals ingested by humans via urine-fertilised crops is very difficult and has not yet been done. Perceptions of societies towards urine reuse vary widely and can work as a driver or a constraint for reuse.

Introduction

Urine can be used as an alternative fertiliser for agriculture. It contains large amounts of nutrients such as 80% of nitrogen, 50% of phosphorus, and 70% of potassium usually present in domestic wastewater as well as various micronutrients (Ciba Geigy AG, 1977; Larsen and Gujer, 1996; Otterpohl, 2002; von Münch and Winker, 2009). But this usage of urine includes the risk of transfer of pharmaceutical residues to agricultural fields (Lienert et al., 2007a; Winker et al., 2008b). Only recently the fate of pharmaceuticals regarding their accumulation in soils, transfer to groundwater, and incorporation by plants came into the focus of research. However, these effects cannot be excluded as fairly high concentrations of pharmaceuticals are expected in urine (Winker et al., 2008b).

The urine normally ends up in the domestic

Key message:

- Pharmaceutical residues are contained in urine but only in few investigations concentrations have been measured so far. Predicted (German) concentrations were in the range of 0.1 to 103 µg/l of urine and determined for 124 substances.
- Data from literature show that plants are generally able to take up pharmaceuticals. Concentrations in plant parts detected were very low (in the range of ng/kg) even though plants were exposed to high concentrations (mg/kg soil). Nevertheless, pharmaceuticals were also found in edible plant parts.
- Pharmaceuticals can also cause phytotoxic effects in dependence of the applied pharmaceutical concentration. Also here, it has to be mentioned that high concentrations were applied.
- Overall, different plant species have dissimilar sensitivity levels towards the same pharmaceutical as studies have shown. Unfortunately, it is impossible to extend these conclusions to long term effects in general.
- Exposure of rye grass to pharmaceuticals contained in urine at expected "natural" levels as well as at higher concentrations did not affect dry matter production during the growth period of three months either for single pharmaceuticals, or for the combination of carbamazepine, ibuprofen, and 17α-ethinylestradiol.
- Only carbamazepine was shown to be taken up by roots and aerial plant parts of rye grass. The concentrations in aerial rye grass parts were in the mean 4950 µg/kg DM (dry matter), and in roots 225 µg/kg DM. This leads to the assumption that only pharmaceuticals which are persistent in soil and not biodegraded are transferred to plants in measureable concentrations.
- Potential effect of pharmaceutical substances contained in urine towards plants cannot be determined in germination experiments. The urine matrix itself is much more affecting the seedlings due to its specific matrix than the active agents.
- Farmers and consumers are open to urine as fertiliser, although they are aware of the aspect of pharmaceutical appearance. The perception varies not only among the stakeholder groups but also between countries.

wastewater in conventional, sewer-based collection systems. Many of these pollutants are not removed in sewage treatment plants and are thus discharged into surface water bodies and can even reach the groundwater.

The collection, storage and reuse of urine include various challenges. This article provides an overview about recent research (excluding advanced treatment technologies for urine as an excellent overview on that is provided by Maurer et al. (2006)). Additionally, it is also explained why the uptake of pharmaceuticals in plants and the effects on plant physiology and development is of major interest when crops are fertilised with urine. The article is based on the results of the PhD thesis of Winker (2009).

Concentrations of pharmaceutical residues in urine and the effect of storage

Urine contains pharmaceuticals: around 70% of the pharmaceuticals taken in, are excreted via urine accounting for 50% of the overall ecotoxicological risk (Lienert et al., 2007a; Lienert et al., 2007b). Urine analysed in various occasions showed concentrations from 2200 ng/l (fenoprofen; Strompen et al., 2003) to 545000 ng/l (ibuprofen; Tettenborn et al., 2007) (Figure 1). Apart of these substances, substance belonging to various indication groups as well as natural hormones were detected in human urine (Winker et al., 2008b).

As analytics are sometimes difficult, Lienert et al. (2007a) and Winker et al. (2008b) established theoretical calculations to receive a potential overview for Swiss and German urine. Winker (2009) could determine average concentrations in general German urine for 124 active substances (for details see https://www.tu-harburg.de/aww/pharma/). Also pharmaceutical concentrations in the urine of single person under medication were calculated for 173 substances. Additionally, Lienert et al. (2007a) determined the

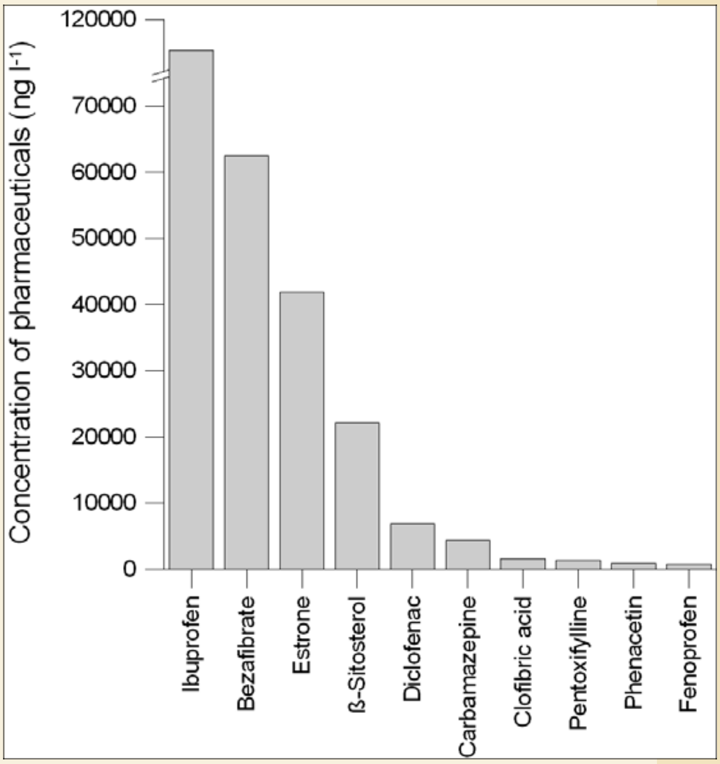

Figure 2. Measured mean concentrations of active agents in German source-separated urine done by Strompen et al. (2003) and Tettenborn et al. (2007) (Vinnerås et al., 2008).

excretion rates per person for 212 active substances along Swiss standards (**Fehler! Verweisquelle konnte nicht gefunden werden.** Table 1 shows roughly the variations of excretion possible among the different active agents as well as it points out the fractions of unchanged and metabolized substances.

Overall, it has to be pointed out that the effect of storage, induced by pH augmentation due to ureolysis (Udert et al., 2003), remains uncertain. Such as Butzen et al. (2005) detected efficient removal for diclofenac after six month; for further pharmaceuticals partial removal at different pH levels. In contradiction to these findings, Gajurel (2007) did not find any decay of clofibric acid, carbamazepine, diclofenac, and ibuprofen in spiked urine during a one year storage period under all investigated storage conditions. Preliminary sampling in the urine storage tanks in

Table 3. Excretion of 212 pharmaceuticals (Lienert et al., 2007a (modified)). Total percentages excreted via urine as well as substances excreted unchanged as parent compound as well as metabolized.

	Total			Unchanged			Metabolized		
	min	av	max	min	av	max	min	av	max
Excretion (%)	0	64	100	0.1	35	100	1	42	124
SD (N)	±27% (212)			±33% (132)			±28% (57)		

“av” determined average of the collected data (for details see Lienert et al., 2007a); “SD” stands for standard deviation; “N” stands for sample size.

the GTZ headquarters in Eschborn, Germany, indicated similar tendency. Several beta-blockers and antibiotics were found in urine stored for more than 1.5 years (Montag and Schürmann, 2010; Institute for Environmental Engineering, RWTH Aachen; personal communication). This finding will be followed up within investigations regarding the storage behaviour of active substances performed by the RWTH Aachen within the project SANIRESCH (2010). Hence, it has to be concluded that pharmaceutical residues are present in urine after storage and have to be kept in mind when it comes to reuse in agriculture.

Uptake and effects of pharmaceutical residues towards plants

Plant experiments

Greenhouse experiments in pots

The fertilising effect of urine is clearly documented (Muskolus, 2008; von Münch and Winker, 2009) but nearly no investigations focused on application of pharmaceuticals by urine except Schneider (2005) and Winker (2009). In the results presented here the focus is laid on uptake of certain pharmaceuticals by rye grass. Schneider (2005) applied diclofenac, sulfamethoxazole or sulfamethazine but in concentrations $5*10^5$ (diclofenac) and $9*10^5$ (sulfamethoxazole) higher than expected for an average German urine (AGU, Winker et al., 2008b) while sulfamethazine is not even present in AGU at all. Winker et al. (2010a) applied carbamazepine (CZ), ibuprofen (IBU), and 17α-ethinylestradiol (EE2) alone and in combinations in the expected natural as well as higher dosed concentrations of those in AGU.

f aerial plant matter (Figure 2) was identified for the entire 3 months experimental period. No visual effects were observed except Control 2 which received only irrigation water without nutrients and thus showed only about 25% of the biomass production compared to the fertilised grass. The lack of fertilisation led to a large weight reduction. The overall dry matter of all plants fertilised with urine did not show any effect irrespective of the kind and concentrations of added pharmaceutical (Figure 2).

IBU and EE2 could not be detected in any soil sample after the 3-month growing period. In contrast to IBU, CZ was detected in all pots irrespective the concentration level. On average, 49% of the applied CZ was recovered 3 months after application. In plants, only CZ could be

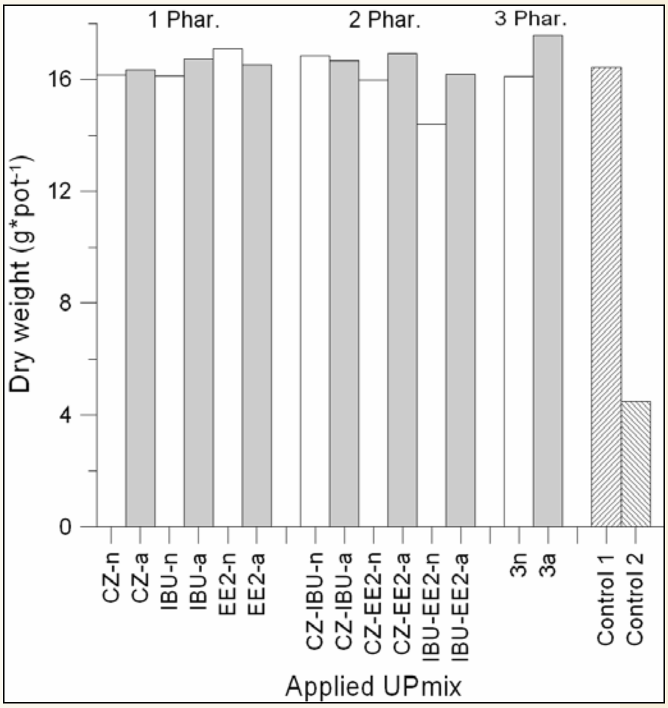

Figure 3. Overall dry weight of plant parts of rye grass determined during the full growth period. n = natural concentration (white bars), a = artificial concentration (grey bars). "Control 1" indicates plants treated with MeOH and urine, "Control 2" did not receive any application beside water; "3" is the designation for the combination of CZ, IBU, and EE2 (Winker, 2009).

detected at artificial concentrations (10 times higher than expected in AGU). CZ concentrations in roots showed a mean concentration of 225 µg/kg DM while a mean of 4950 µg/kg DM was reached in aerial plant parts. This correlates to an average of 0.21% of the total amount of CZ applied to each pot was found in the roots of rye grass, but 30% in the aerial plant parts.

Germination experiments

Plants show their highest sensitivity as seedlings. Therefore, this development stage is very appropriate for investigations regarding potential pollutants. Germination tests of cress and four different cereals (Winker et al., 2010b) were performed where the seeds were germinated in urine-water mix containing one up to five different pharmaceutical substances in raising concentration.

The seedlings show sensitivity against pharmaceutical agents (Table 2; Winker et al., 2008b). The sensitivity lies far above the concentration levels expected in average German urine. In the most cases the sensitivity lies even above the investigated range of concentrations. Apart, the urine matrix itself is much more

Table 4. Influence on dry weight of the seedlings by addition of one active agent. “>” indicates that the limiting concentration causing an effect was not reached and lies most likely above the tested level (Winker et al., 2010b).

Substance	Cress	Winter wheat	Winter rye*	Winter barley	Oat
EE2	>1.000.000 fold	> 1000 fold	>1000 fold	>1000 fold	> 1000 fold
E2	>10.000 fold	> 1000 fold	>1000 fold	> 1000 fold	> 1000 fold
CZ	>10.000 fold	> 1000 fold	AGU conc.	>1000 fold	> 1000 fold
PI	10 fold - better	> 1000 fold	1000 fold - worse	>1000 fold	> 1000 fold
IBU	>1000 fold	> 1000 fold	1000 fold - better	> 1000 fold	> 1000 fold

* “worse”: the concentration let to a negative effect of the dry weight; “better”: the concentration let to a statistically relevant increase of the dry weight.

affecting the seedlings due to its specific matrix than the active agents. Nevertheless, in certain cases reactions of seedlings towards the pharmaceutical substances could be observed. Overall, it can be concluded that the potential effect of pharmaceutical substances contained in urine towards plants cannot be determined in germination experiments.

Literature review

As already stated, nearly no literature is available on the uptake and effect of pharmaceuticals by plants spread via urine. Nevertheless, research was done regarding the uptake of several active substances and their effects. Data from literature show that plants are generally able to take up pharmaceuticals (Winker et al., 2008a). The concentrations usually detected in plant parts are in the range of ng/kg. Pharmaceuticals have also been found in edible plant parts such as carrot roots and cereal grains (Dolliver et al. (2007) and Boxall et al. (2006)). In addition, Brian et al. (1951) and Stokes (1954) reported excretion of griseofluvin via guttation drops at the leaf apex of wheat seedlings. The rate of movement in plants is influenced directly by rate of transpiration, which in turn is affected by air humidity and temperature. This finding leads to two contradictory assumptions. On the one hand, pharmaceuticals accumulate in leaves (Brian et al., 1951; Stokes, 1954), and higher uptake rates have been found in older leaves (Grote et al., 2004). On the other hand, leaves are able to secrete pharmaceuticals (Brian et al., 1951; Stokes, 1954) and to degrade organic chemicals taken up, in a process comparable to liver metabolism (Komoßa et al., 1995). Moreover, Kumar et al. (2005) reported that the correlation between the concentration applied and uptake is nearly linear, but it is currently impossible to generalise on these findings.

Pharmaceutical concentrations in plants depend on amounts of pharmaceuticals available in the respective growth medium. Mapping of naturally occurring concentrations in plant parts is nearly impossible. The literature screening performed (Winker, 2009) identified studies which could be split into 45 datasets (DS) reporting 9 pharmaceuticals. All studies were performed with concentrations above those expected by urine. In 18 datasets application rates were 2-182 times higher than those expected to be reached by urine fertilisation (see Table 3, ratio DS/AGU) and for 8 of these datasets bioaccumulation or phytotoxicity was reported. The others showed DS/AGU ratios between $2*10^3$ (chlorotetracylcine (Patten et al., 1980) and $2*10^8$ (chlorotetracycline (Jacobsen et al., 2004) and were thus too high to be of help for an evaluation of fertilization with urine.

Pharmaceuticals also cause phytotoxic effects depending on the concentration of the pharmaceutical substance resulting in a change of colour to darker green (Grote et al., 2004); lacking and incomplete colouring (von Euler, 1948; Rosen, 1954); lower chlorophyll content in leaves (von Euler and Stein, 1955); as well as hard and waxy leaves (Rosen, 1954). Moreover, Rosen (1954) reported a lack of lateral root development subsequent to pharmaceutical exposure and von Euler (1948) found thickened coleoptiles.

Studies have shown that different plant species have differing sensitivity levels towards the same pharmaceutical. However, it must be pointed out that many articles were published 20 to 30 years ago and the sensitivity and selectivity of chemical analyses at that time was somewhat lower. Furthermore, it is not possible to extend these conclusions to long-term effects in general, as most tests described in the literature did not last for a whole growing season.

Table 5. The 8 datasets reporting concentration similar to those in the case of urine fertilisation (DS/AGU ratio <200) which showed phytotoxic or bioaccumulative effects (Winker, 2009).

Substance	Plant species	Reported impacts1	Concentration applied	Ratio DS/AGU2	Ref.
Chloroquine	soybean	Phytotoxic: negative impact on w, h, r, s, l (13 d after germination)	8000 ng/kg	182	Jjemba, 2002
Chlorotetracycline	spring wheat	Phytotoxic: positive impact on h, r (27 d after germination)	160 ng/kg	82	Batchelder, 1982
Chlorotetracycline	pinto bean	Phytotoxic: negative impact on w, h, r, s, l (45 d after germination)	160 ng/kg	82	Batchelder, 1982
Chlorotetracycline	green onion	Uptake: 0.013 ng/kg FW in s and l (42 d after transplantation)	100 ng/kg	51	Kumar et al., 2005
Chlorotetracycline	cabbage	Uptake: 0.01 ng/kg FW in s and l (42 d after transplantation)	100 ng/kg	51	Kumar et al., 2005
Metronidazole	soybean	Phytotoxic: negative impact on w, h, r, s, l (13 d after germination)	2000 ng/kg DM	67	Jjemba, 2002
Oxytetracycline	spring wheat	Phytotoxic: positive impact on h, r (27 d after germination)	160 ng/kg	2	Batchelder, 1982
Oxytetracycline	pinto bean	Phytotoxic: negative impact on w, h, r, s, l (45 d after germination)	160 ng/kg	2	Batchelder, 1982

[1] Letters denote weight (w), height (h), roots (r), stalk (s), and leaves (l).
[2] "Ratio DS/AGU" describes the concentration applied in the specific investigation summarised in one dataset (DS) related to the pharmaceutical concentration calculated to be reached in case of urine application. DS/AGU = 1 describes equal conditions, <1/>1 implies that lower/higher concentrations would be applied by a fertilisation with urine under the described conditions. (March 16, 2008).

Importance of the topic in societies

The reaction of societies varies when they are confronted with the issue of urine-fertilised crops. The concerns regarding pharmaceutical residues differ between the different stakeholders. A very important stakeholder group are farmers. In Switzerland, a high percentage of farmers (57%) would accept urine as fertiliser (Lienert et al., 2003). For them, the fate of pharmaceuticals in the environment is one of the concerns mentioned. Approx. 80% of Swedish farmers were interested in using urine as fertiliser (Tidåker et al., 2004). The issue of spreading pathogens and pharmaceutical residues to the fields via any sewage product was the second highest concern after heavy metals and other organic compounds. Nevertheless, as pathogens or pharmaceutical residues were grouped it remained unclear which of the two aspect were in their major focus. Muskolus (2008) interrogated farmers around Berlin. They tend to react conservatively when confronted with the issue. Only one quarter of participating farmers expressed a positive attitude towards urine as fertiliser.

Users of urine-diverting systems or potential consumers of agricultural products fertilised with urine were interrogated in several studies. Amongst the users of urine diversion flush toilets at GTZ headquarters (Blume and Winker, 2010) a remarkable 90% of the participants (218 persons of 900 responded; Blume and Winker, 2010) were positive towards the idea of urine reuse in agriculture. 71% stated explicitly that they would buy crops which have been fertilised with human excreta according to WHO guidelines (WHO, 2006). Other studies showed similar results. Muskolus (2008) interviewed inhabitants in Berlin as well as people with an agricultural background, and 62% of both groups stated that they would buy food produced with urine as fertiliser.

Samwel (WECF, www.wecf.org; personal communication) reported a varying attitude in Easter European and Central Asian countries: Acceptance depends very much upon the awareness of the issue by involved authorities. In the Ukraine and Romania, members of the authorities responsible for hygiene and environment do reject the usage of urine due to the risk of spreading pharmaceutical residues. A major constraint is the lack of legal frameworks for UDDTs and reuse. In Central Asia and the Caucasian region, implementation of urine diversion systems and reuse of urine are well accepted by the authorities. For example in Western Georgia and Northern Kyrgyzstan urine diversion systems are very welcome due to high groundwater levels – normal pits simply fill up with water. Moreover, when a community is well informed, Samwel (2010; WECF, www.wecf.org; personal communication) observed also that groundwater protection can be a strong driver.

Sinar (2008) showed that apart from appearance of pharmaceutical residues in urine, it is important to investigate a societies' attitude on pharmaceutical consumption and that a difference between rural and urban areas might exist. In Ghana, the frequently used pharmaceutical groups (often referred to as indications) are antimalarials, antibiotics, analgesics, antifungals and antihelminthics; in urban areas pharmaceuticals addressing diabetes and cardiovascular diseases are also consumed (Sinar, 2008). While in Ghana, consumption of contraceptives is negligible, they most likely play a major role in Peru. 17α-ethinylestradiol is available for all women for free and very popular (Webb and Fernández Baca, 2006) as a result of the family planning below president Fujimori.

Conclusion

If urine is reused in agriculture, some of the pharmaceutical residues will be taken up by plants and thereby enter the human food chain. This is expected especially for polar and hardly biodegradable substances. A full evaluation of the potential toxic effects of pharmaceuticals ingested by humans via urine-fertilised crops is very difficult and has not yet been done.

Moreover, research carried out so far shows that the expected concentrations of pharmaceutical residues in average urine do not reach concentration levels which affect plant growth and development. This finding can be supported by the fact that the load of hormones and antibiotics in human urine are much lower than in animal manure which is already used in agriculture.

Overall, it can be concluded with the statement of Jörn Germer (cited in von Münch and Winker (2009)) that "*Drug residues in sustainable sanitation products used to supply plant nutrients can hardly be a serious issue in regions where malnutrition, groundwater and surface water pollution due to inappropriate sanitation and irrigation with untreated wastewater is a reality*".

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Backyard Urine Recycling in the United States of America: An Assessment of Methods and Motivations

This paper discusses the newly emerging urine harvesting movement in the United States of America.

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Abstract

In the United States of America awareness and practice of ecological sanitation is in its infancy. In this article we briefly assess the urine harvesting practices of a small group of individuals in the San Francisco Bay Area, California, Portland, Oregon, and coastal Massachusetts. Though there are no coordinated or sponsored urine harvesting projects, a few Americans, learning primarily from the international urine harvesting community, as well as from historic practices, are beginning to implement individual-scale, "backyard" urine harvesting projects. We found that urine reuse is gaining in popularity, is accepted in certain social groups, and that urine harvesters have seen exceptionally beneficial results from using the urine fertilizer. Urine harvesting seems a good first step towards ecological sanitation practices because it is legal in the United States, whereas other practices are not. Some U.S. regulations are now changing around ecological sanitation practices, which bodes well for a trend toward greater acceptance of urine recycling and other ecological sanitation practices.

Introduction

In the United States of America, despite advanced technology, high levels of education, and growing concern about environmental sustainability, awareness and practice of ecological sanitation is in its infancy. In this article we briefly assess residential-scale ecological sanitation practices in the USA by focusing on the urine harvesting practices of a small but active, and representative, group of individuals in the San Francisco Bay Area, California, Oregon, and Massachusetts.

Urine harvesting practices in the USA are growing from the grassroots level. Though there are no coordinated or sponsored urine harvesting projects, a few Americans, learning primarily from the international urine harvesting community, as well as from historic practices, are beginning to implement individual-scale, "backyard" urine harvesting projects. We believe there is similar interest and practice of urine harvesting in other parts of the USA as well.

The USA have a long history of composting toilet use, mainly in rural areas that do not have sewer or septic systems. Traditionally, American composting toilets have not separated urine. All manufactured American composting toilets today combine urine, except one, "Nature's Head", which is designed for use on boats and has only been available since 2007 (Nature's Head, 2010). The most popular book on the subject, The Humanure Handbook, by Joseph Jenkins (Jenkins, 2005; first edition 1994, now in its 3rd edition), advocates combined sources, though most rural compost toilet users encourage people to "pee outside" and not in the toilet. There is only one book about urine harvesting from the USA (Steinfeld, 2004) which includes information on the global urine harvesting

Key messages:

- Urine reuse is practiced in the United States of America even though there are no coordinated projects
- Urine is socially accepted in certain social groups
- Urine recycling is gaining popularity
- Regulations are changing around sustainable sanitation practices
- Urine recycling is legal, contrary to popular belief
- International information on urine recycling could spur growth **of USA's urine adoption**

movement, as well as a few examples from the USA s. A few public examples of urine diverting toilets are found across the country, including one at the office of 2020 Engineering in Bellingham, Washington. Currently, there are plans to build the largest urine diverting project in the U.S. in a future six story building in Seattle, Washington, at the headquarters of the Bullitt Foundation (Pryne, 2010).

During January 2010, we conducted interviews with seven individuals in the San Fransisco Bay Area, California, and two individuals in other states who practice some form of urine recycling (capturing and using urine to fertilize plants). Systems ranged in sophistication from a simple 5 gallon (18.9 liter) bucket (Figure 1) to collection from urine-diverting compost toilets. Interviews with urine recyclers covered basic quantitative aspects (quantities of urine collected and specific collection methods), as well as qualitative aspects (individuals' motivation, sources of information, observed benefits, and social acceptance of the practice).

The results of the interviews show that people have learned from a variety of sources, with the international ecological sanitation movement being a major one. Urine recyclers expressed the belief that American society in general holds an unfavorable view of the practice, but reported that among their friends and colleagues there is much interest and acceptance. Though the scope of this study is extremely limited by the small number of interviews conducted, the information about successes and challenges leads to a few preliminary suggestions for best management practices, and highlights an undocumented segment of the ecological sanitation movement: Americans.

Urine reuse is gaining attention at the global level as scientists, agronomists, backyard gardeners, and development professionals look to this universally available substance for solutions to a variety of water and sanitation problems. Urine collection reduces toilet water use by as much as 80% by decreasing flushes (Larsen, et. al., 2001), and reduces energy needed by sewer treatment plants to remove nitrogen (Wilsenach and van Loosdrecht, 2006). Plant nutrients, mainly nitrogen and phosphorus, can be captured from urine and used as agricultural fertilizer, reducing demand for chemical fertilizers. Composting toilets that separate urine from feces can be easier to manage and have fewer odor problems than non-separating composting toilets, as they contain less liquid.

Figure 1: Fertilizing roses with urine.

As a matter of public policy, urine reuse can reduce infrastructure costs and conserve energy. Recent research also shows that urine may be an efficient source of hydrogen for energy (Boggs et al. 2009).

Urine harvesting projects funded by international or national agencies are found all over the world, from urine diverting flush toilets in apartments in Sweden (Esrey, S. et al. 1998), and the GTZ headquarters in Germany (GTZ, 2005), to community-scale urine collection in Tepoztlan, Mexico (Esrey, S. et al. 2001) and city-scale urine diverting dry toilets in Dongshen, China (SEI, 2004).

For backyard gardeners, urine diverting toilets provide a free source of fertilizer while reducing household water consumption due to fewer toilet flushes. Each adult produces an estimated 1.5 liters per day, (WHO, 2006) which contains about 4 kg of nitrogen, 0.36 kg phosphorus, and 1 kg potassium per year. This amount is enough to fertilize about 300-400 square meters of crop for each person (Jonsson et. al. 2004). The range of low-cost options for collection makes backyard urine reuse accessible for all income levels and for both renters and homeowners.

Legal aspects

In Alameda County, California, where we conducted most of our interviews, there is no legal code that specifically prohibits use of urine or regulates backyard urine use, although public perception generally views it as unacceptable or perhaps illegal. The two legal regulatory bodies that could potentially regulate backyard urine use are the state plumbing code, which, in California, mandates one toilet per dwelling unit connected to either a private septic system or to municipal sewerage (IAPMO, 2007), or the Environmental Health Department, which regulates a large range of concerns related to health and the environment. Staff in California's Environmental Health Departments reported that they had no regulations on urine, and had never been asked about it's use before (Allen, 2010).

Regulations in the United States that historically prohibited legal ecological sanitation practices are changing. In 2009 the California state plumbing code, which regulates greywater reuse, was revised to allow for simple and legal grey water reuse, allowing irrigation of edible crops, reducing discharge depth, and waiving permit requirements for very simple systems from washing machines. Since 2001, beginning with the state of Arizona, drought-affected states like Arizona, Texas, and New Mexico have revised grey water standards, and wetter states such as Oregon are revising standards to allow for legal rainwater reuse. In addition, composting toilet use has been on the rise for many years (While there is a lack of quantified growth trends, reports in the media affirm the growth in use and interest in compost toilets: see http://www.treehugger.com/files/2009/07/composting-toilets-us-cities.php, and http://www.carol-steinfeld.com/compostingtoilets.html though the regulations around it in most states remain prohibitive at worst, and unclear at best.

Given California's history as a region of "early adopters" and cultural visionaries, it is not surprising that a fledgling ecological sanitation movement should emerge here. It is also timely at the current moment, as California has been in drought for three consecutive years. According to the California Drought Center the last two water years have resulted in 63 and 72 percent of average annual precipitation (CA Department of Water Resources, 2009).

The change in state regulations on greywater reflects a growing awareness of the need for increasing water efficiency practices, while the practices of individual urine-recyclers reflect a growing desire for more progressive environmental policies. Urine harvesting is an easy first step for individuals concerned about reducing water use and restoring natural cycles.

The law presents a major barrier in the USA to adoption of many ecological practices. Many sustainable practices, like greywater, rainwater, and composting toilets, are illegal under local and state building regulations. Because of this, early adopters of ecological practices in the United States are often breaking local or state laws. Though most do so without consequence, there is a history of a few "pioneers" being fined, losing property, and being forced to remove the unpermitted projects (Kettmanm, 2009). Organizations are hesitant to attempt projects that break local laws, thus further slowing the progress of ecological sanitation implementation in the U.S. Residential urine harvesting falls outside of existing laws; with increasing knowledge about its benefits, and legality, more users will be able to implement the practice without fear of legal consequence.

Motivation

Nine urine recyclers were interviewed during January and March, 2010. Since there are no sanctioned urine recycling projects in the USA, the authors found the participants through networks of environmental organizations. The participants had a diverse range of occupations: a director of a small ecological justice non-profit organization, an "eco-artist" and dog border, an architect specializing in green design, a gardener and public park employee, a supervisor in a construction company, an ecological designer, a medical program manager, a small businessman, and a statistician.

The nine individuals surveyed range between 27 and 60 years of age; live in cities of the metropolitan Bay Area: Oakland, Berkeley, and San Francisco, or in Portland, Oregon, and coastal Massachusetts. Five of the nine own their homes, while four are renters. The average period they have practiced urine recycling is around two years, though one individual has maintained the practice over a period of twelve years. All nine survey participants voluntarily practice other forms of residential-scale ecological resource stewardship, including recycling and composting, both locally common practices. Most are innovators in other ways: seven of the nine practice some form of unregulated grey water reuse, while two of the nine collect and channel some portion of the rainwater on their property (also an unsanctioned and unregulated practice).

Given the propensity of this group to engage in ecological practices, it is not surprising that their

Figure 2: This "Pee-pee-ponics" system uses urine to water Figure and fertilize plants. Credit: Nik Bertulis

motivations are fairly similar; all cited "saving water" or "problems with sewers" as a prime motivating factor; seven cited "fertilizer" as a primary factor, while four spoke of the importance of having a "free and available," fertilizer, and that the practice itself is "simple and accessible," "makes sense," and is "a good way to turn a problem into a solution." One cited feeling good that "my nutrients are being cycled without compromising further our stressed watershed" and "saving energy at pumps and processing at the waste treatment facility."

Due to the lack of public U.S.-based urine reuse projects, the majority of individuals learned about and were inspired to practice urine harvesting from ecological sanitation projects in other countries. Five attended a workshop or lecture where they learned about urine recycling projects in Mexico, Zimbabwe, Sweden, and China. The rest came to the practice through the experience of "living rurally" (where regulations are more lax and outdoor latrines are common), growing up on "a family farm," or simply "not wanting to flush the toilet" due to ecological concerns. These people learned about the fertilizing benefits later on, through informal conversations with friends. One person began collecting urine while living without a flush toilet during a home remodel, but didn't reuse it (he poured it down a shower drain) until he attended a lecture and learned about other people around the world fertilizing with urine.

Materials and methods

A variety of low-tech methods were used to separate the urine. Three of the respondents use pre-fabricated Separrette urine-diverting inserts in custom made compost toilets as shown in Figure 4 and 5 (most of the prefabricated composting toilets made in the U.S. do not separate urine), while the other five use homemade systems ranging from "a plastic bucket" (Figure 1) and "a yogurt container" to "an antique urinal that was used on trains." One uses a self-made urine diverting toilet and one respondent uses a "pee-pee ponics" system (shown in Figure 2*)*: an outdoor urinal that directly fertilizes a planted container (with a soil medium of 2/3 fine wood chips and 1/3 potting soil). Four respondents are the sole users of their systems; two (who both live alone) use their systems with one or two guests, while the remaining three maintain systems that are used by three or more people (a family of two and three and a collective house of five, respectively).

All of the respondents use the urine to fertilize garden plants and fruit trees. Respondents' answers showed a general lack of concern with precise dilution ratios; dilution ratios range from undiluted use to a ratio of 8:1. No one stored the urine for longer than a week, and did not report any issues with odors.

Figure 3: Urine cured this formerly sick lemon tree in San Francisco.

Seven of the nine reported seeing significant results from using urine as fertilizer. They were delighted in "roses blooming all winter long," "luxuriant plant growth," "super happy bamboo," and that their "bougainvillea really took off and started blooming much more [after receiving urine]." Their reports on edible plants reported a "citrus tree perked up," "I grew very large broccoli, and had happy trees," "my kale and tomatoes were really happy," "I cured a sick lemon tree" (Figure 3), and "after fertilization my peppers took off." Only one respondent observed no results, but reported that he started "only recently" and the trees he fertilizes are currently dormant, and another respondent said he "hadn't done any formal trials and the results were merely psychological benefits at this point." One person noted a dramatic reduction in family water use. His family of three, who also maintain many other ecological practices including reuse of grey water from the laundry and a composting toilet in one of the two bathrooms, has measured its water savings "from 130-140 gallons (492- 530 liters) per day down to 60-70 gallons (227-265 liters) per day."

Social acceptance

Cultural acceptability is an important indicator of the adoption potential of any sanitation practice or technological change; because urine collection is largely unfamiliar in the United States, peoples' reactions to it show a particular sensitivity. One person "only talks about it to people [she] thinks will be interested, like other gardeners," and "sometimes worries what people will think"; Another, who works in the building trade, "doesn't

Figure 5: Composting toilet with Separrette diverting insert.

Figure 4: Urine and faeces collection from toilet in Figure 4.

talk about it with her co-workers," and cites "respecting the other people who live on [her property]" as a concern. A third also cites "personal challenges: a roommate didn't like it," and another says that his friends "seem to feel like its something they'd feel uncomfortable doing." The final person, who uses an antique urine pot, cited perhaps the most extreme concerns over acceptability, saying, "I have to decide what to do when company comes over, usually I hide [the system] when guests come over for a party," and "at first I didn't tell my girlfriend."

At the same time, each of the respondents reported clearly positive reception from those to whom they've revealed their practice, ranging from "bemusement" and "generally positive" to "intrigue" and "inspiration." One person says that after seeing his system, "Some [friends] have even built their own [urine diverting composting] toilets."

Four of the nine cited small technical challenges, such as difficulty emptying the urine container and minor odor issues, but none found these challenges insurmountable.

Reporting other insights into their practices, one said the ability to make the change to urine collection "speaks to how adaptable we are as humans. Our cultural norms are socially constructed, we have such a phobia around pee and poo," but it's "easy to adapt." The architect who specializes in green design and tries to incorporate other ecological practices into his buildings, expressed concern that public health norms in the United States have "made living sustainably illegal" and are so rigid as to have "made the perfect the enemy of the good."

All of the nine respondents demonstrated a sense that urine collection as they practice it is neither legal nor illegal, with comments ranging from "I'm sure it's illegal" to "There's no law against it to my knowledge," to "I try not to know the law." These responses demonstrate at once the lack of regulation of the practice, the lack of information about it, and the spontaneous, "grassroots" approach of these individuals in addressing the perceived problem. One respondent said she felt secretive about it and did not want her neighbours to know, though she wasn't sure if it was actually illegal.

Conclusion

As a major world power and an exporter of both culture and technology, the United States of America has a unique ability to affect the perception and acceptance of sanitation technologies globally. Given the widespread acceptance of the flush toilet as the "gold standard" of sanitation technology and the increasing scarcity of both fresh water and fertile agricultural soils, we believe that wide acceptance of ecological sanitation in the United States can both conserve resources locally and play a crucial role in shifting perceptions of these practices worldwide.

From this small sample of ecological sanitation practitioners in one region of the United States we can draw several conclusions: acceptance of these practices is minimal, with practitioners made up largely of people who share both a high level of ecological awareness and a willingness to engage in practices that diverge from the perceived norm. At the same time, the material benefits (water savings and fertilization) are so considerable as to be observable almost immediately, and acceptance, while slow, is growing, as demonstrated by the fact that the average period of practice among the nine people surveyed is a mere two years.

The recent change in California's state plumbing regulations to better accommodate residential grey water reuse bodes well for a trend toward greater acceptance of urine recycling and other ecological sanitation practices. Given that concerns among our respondents to issues of social acceptance appear to weigh more heavily than technological or infrastructure challenges and those empirical benefits are readily apparent, it appears almost certain that more progressive regulatory frameworks will lead inevitably to wider cultural acceptance of ecological sanitation in the United States.

The increased exposure and awareness of global ecological sanitation practices, including urine harvesting, will help promote increasing ecological sanitation practices in the United States.

Recommendations

There is a lack of studies and projects on urine recycling in the United States. We believe there should be U.S.-focused studies and organized urine recycling projects.

- Americans can be socially accepting of urine use.
- Urine harvesting is a good first step toward ecological sanitation practices.
- Increased knowledge that urine harvesting is legal in the USA can increase numbers of adopters of the practice.
- Increased exposure of the international ecological sanitation practices can positively affect practices in the USA.

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Food Security and Productive Sanitation; Practical guideline on the use of urine in crop production

This paper describes an upcoming publication containing a practical guideline on the use of urine in crop production.

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Abstract

The publication "Practical Guideline on the Use of Urine in Crop Production", is a collaborative effort of several international organisations and institutions active in the field of sustainable sanitation and agriculture under the aegis of the Sustainable Sanitation Alliance (SuSanA) working group on Food Security and Productive Sanitation with Stockholm Environment Institute (SEI) as the lead. It will be launched during 2010.

The Guideline is directed towards decision makers, professionals and extension workers in the sectors of agriculture, water & sanitation, planning and environment as well as the donor community. The main target group is professionals in the sector of agriculture. The text gives practical guidance on the use of urine in crop production as a vital component of sustainable crop production and sanitation systems. It covers key aspects of how to use urine as a fertiliser in productive sanitation systems and also includes guidance on how to initiate activities that will facilitate the introduction of new fertilisers to the agricultural community. The handbook should help in establishing links between research and professionals interested in implementation of sustainable sanitation systems. It is easy to read and informative, with examples from case studies and tips on further reading for those interested.

Use of urine in crop production

Consumed plant nutrients leave the human body with excreta, and once the body is fully grown there is a mass balance between consumption and excretion. This has three important implications:

1. The amount of excreted plant nutrients can be calculated from the food intake, for which data is better and more easily available than for excreta.
2. If all excreta and biowaste, as well as animal manure and crop residues, is recycled, then the fertility of the arable land can be maintained, as the recycled products contain the same amounts of plant nutrients as were taken up by the crops.
3. Differences in composition of excreta between different regions reflect differences in the uptake of the consumed crops and thus in the plant nutrient supply needed for maintained crop fertility in the region. Irrespective of the amounts and concentrations of plant nutrients in the excreta, one important fertilising recommendation is thus to strive to distribute the excreta fertilisers on an area equal to that used for producing the food.

Source separation and safe handling of nutrients from the toilet systems is one way to facilitate the recirculation and use of excreta in crop production. Urine contains most of the macronutrients as well as smaller fractions of the micronutrients excreted by human beings. Nitrogen, phosphorus, potassium and sulphur as well as micronutrients are all found in urine in plant available forms. Urine

Key massages:

- Urine used as a fertiliser can help in the mitigation of poverty and malnutrition, and improve the trade balance of countries importing chemical fertilisers.
- Food security can be increased with a fertiliser that is available free for all.
- Safe handling of urine including treatment and sanitisation before use is a key component of sustainable sanitation as well as sustainable crop production.
- The "Practical Guideline on Use of Urine in Crop Production" will be published during 2010 and will be available from the EcoSanRes and SuSanA webpages, i.e. www.ecosanres.org and www.susana.org, respectively.

is a well balanced nitrogen rich fertiliser which can replace and normally gives the same yields as chemical fertiliser in crop production (Figure 1).

Figure 1. The yield and size of vegetables improves with urine use (Picture from Moussa Bonzi, CREPA, Burkina Faso).

The urine from one person during one year is sufficient to fertilise 300-400 m2 of crop to a level of about 50-100 kg N/ha. Urine should be handled in closed tanks and containers and should be spread directly onto the soil, not on the plant, in N doses equivalent to what is recommended for urea and ammonium fertilisers. In the small scale, plastic watering cans are suitable for spreading the urine, while in larger scale, spreaders for animal slurry are suitable. Air contact should be minimised in order to avoid ammonia losses and the urine should be incorporated into the soil as quickly as possible.

Economics

The economical value of the urine can be calculated by comparing with the price of mineral fertiliser on the local market or by calculating the value of the increased yield of the fertilised crop. An example from Burkina Faso gives at hand that the annual amount of plant nutrients in the excreta from one family is roughly equal to the quantity in one 50 kg bag of urea and one 50 kg bag of NPK. According to Dagerskog and Bonzi (2010) the value of this per person is approximately 10 US$, while the value of the increased yield of maize is approximately 50 US$ per person. The value of a 20 litre jerrycan of urine was estimated to be 25 US cents.

Barriers protect producers, workers and consumers

Health risks associated with the use of human urine in plant production are generally low. Source separation of urine is a strong barrier against pathogen transmission since most pathogens are excreted with faecal matter. The amount of faecal cross-contamination is directly related to the health risk in the system for urine use in crop production. Collection systems for urine should be designed to minimise the risk of faecal cross-contamination. Groups that are potentially at risk are collection personnel and field workers, households, local communities and product consumers. As regards other contaminating substances excreted with human urine (heavy metals, hormones and pharmaceuticals) possible health risks are far smaller than those associated with the common sanitation system and the risk for negative effect on the quantity and quality of the crops is negligible.

The WHO guidelines for safe use of excreta in agriculture (WHO, 2006) promote a flexible multi-barrier approach for managing the health risks associated with the use of excreta in agriculture. This concept is comprised of a series of measures/barriers from 'toilet to table'. Each of the barriers has a potential to reduce health risks associated with the excreta use and it is recommended by WHO to put in place several of these barriers if needed in order to reduce the health risk to an acceptable minimum (Figure 2).

Barriers include for example storage, crop restrictions, withholding periods and reduced contact, correct handling and cooking of the food crop. The practical guideline gives examples of how urine can be handled in a safe way in order to minimise risk of pathogen transmission based on the WHO Guidelines for safe use of excreta in crop production.

Institutional aspects for up-scaling

Economic and institutional aspects are important as productive sanitation systems become mainstream. A challenge is to integrate use of excreta in existing regulatory frameworks. Initially, the following activities are suggested when productive sanitation systems are implemented:

- Identify all stakeholders and clarify drivers and restrictions for each of these groups in relation to the implementation of urine separation, storage, transport and use;
- Include and target the end users (the farmers) in the planning process;
- Organise an arena for joint analysis, planning and monitoring of the stakeholders;
- Organise local communities so that there is a structure for implementation and a structure for monitoring

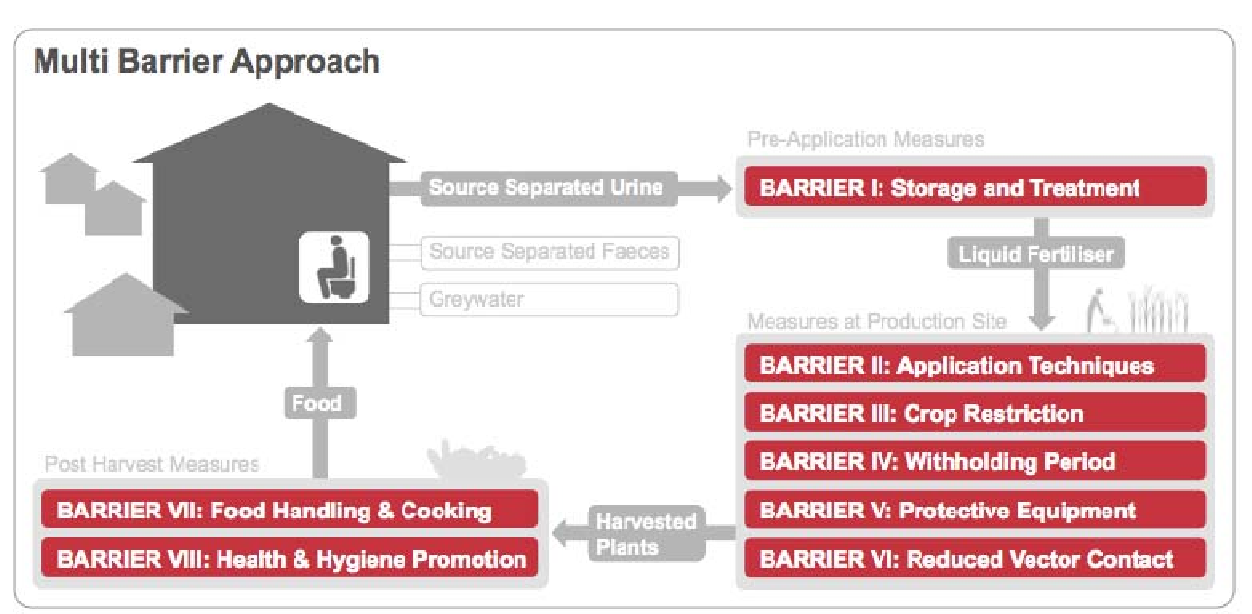

Figure 2. Barrier concept for safe use of urine as a fertiliser.

Very important in dissemination and up-scaling of the use of urine as a fertiliser are participatory local demonstrations involving all parties. Urine as a fertiliser needs to be introduced in the same way as any new fertiliser to the agricultural community. Logistics for handling of urine are discussed in the guidelines and examples are given for large and small scale handling of urine. The logistics are a challenge and there are environmental as well as practical and economical implications of transporting urine if there is no reuse possible on site. However, as is pointed out in the text, local reuse is often possible and urban agriculture provides possibilities for recycling of human excreta.

Although there is a wealth of location specific information in this guideline, every location is unique and further translation and adaptation of the guidelines is required. The last chapter of the guideline gives recommendations on how local guidelines can be developed and reasonably structured. Existing local guidelines from Burkina Faso and the Philippines are provided as an annex.

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