Human urine harvesting and utilization as organic fertilizer

Introduction:

In order to grow plants that supply our food, fertilizers such as nitrogen, phosphorus, potassium and about 25 other additional elements are needed. Today, artificial fertilizers account for the largest share of these nutrients but, at the present rate of use, the available resources will be rapidly depleted. Use of excreta as fertilizer has been implemented only to a limited extent. Rather, they have been flushed out into the rivers, resulting in a lack of oxygen in the aquatic resources. These resources have also been polluted with pathogenic microorganisms to the extent that many large rivers have become virus infected more or less permanently. It is thus better to create a closed system, with no pollution from bacteria or viruses, where *human* fertilizers are harvested and used to feed the following year's crops (Wolgast 1993). Nutrients are removed from fields with the harvested crops; in sustainable agriculture, therefore, the amounts of nutrients removed from a field should be returned to it (Jonsson 1997).Today, there is mainly an outflow of nutrients from farms to society. For a sustainable society, it is necessary to recycle these excreta back to the farms (Vinneras 2002).

Ecological sanitation regards human excreta as a resource to be recycled, rather than as a waste to be disposed of. The notion of excreta being merely waste with no useful purpose is a modern misconception, which is at the root of pollution problems resulting from conventional approaches to sanitation. There is no waste in nature, and all the products of living things are used as raw materials by others. Recycling sanitized human urine and faeces by returning them to the soil serves to restore the natural cycle of life-building materials that has been disrupted by current sanitation practices. Where crops are produced from soil, it is imperative that the organic residues resulting from these crops are returned to the soil from which the crops originated. This recycling of all residues should be axiomatic to sustainable agriculture (Gumbo, nd).

There are many reasons for recycling the nutrients in excreta:

1. Recycling prevents direct pollution caused by sewage being discharged or seeping into water resources and ecosystems.
2. Recycling returns nutrients to soils and plants, and reduces the need for chemical fertilizers.
3. It restores good soil organisms to protect plants, and it is always available locally, wherever people live (Esrey1998).

Human excreta as fertilizer:

For adult persons who maintain approximately the same mass during their lifetimes, the excreted amounts of plant nutrients are about the same as the amount eaten. The excreted amounts of plant nutrients depend on the diet and thus differ between persons as well as between societies (Jonsson 1997; Jonsson and Vinneras 2003). The volume of faeces produced per person depends on the composition of the food consumed, with meat and other foods low in fiber producing smaller volumes than food high in fiber. (Guyton, 1992).

Half the nitrogen fertilizer ever produced on Earth was used during the last fifteen years. This increase in the use of nitrogen fertilizer has led to massive increase in agricultural yield and has, in fact, allowed humans to largely avoid the food shortages historically predicted to accompany our recent population boom. In this sense, nitrogen fertilizer has been an enormous boon to humans. However the recent increase in nitrogen use may have serious potential drawbacks as well, such as aquatic pollution and the increased production of greenhouse gases, leading to global climate change (Harrison J). Human urine is rich in nitrogen and the growing requirement of nitrogen for our food security can be easily met with urine harvesting. This will substitute the requirement of artificial fertilizer and helps in reducing the green house gases (GHG) as well. On an average if a person's urine is harvested and utilized as fertilizer then it will reduce 16 kg GHG per year. Every person is a moving fertilizer unit capable of reducing carbon emission if his/her urine is return to soil. The value of NPK in urine is approximately 150 INR per person per year.

Nutrients in human urine:

Urine contains 88 % of excreted nitrogen (N), 67 % of excreted phosphorous (P) and 73% of excreted potassium (K), the remainder is in the faeces. An adult excretes on average 500 litres (0.8-1.5 L per day in 4-5 times) of urine and 50 litres of faeces per year. Children urinates about half of the adults amount. The excretion of nutrients differs from country to country and is basically based on diet. The average estimated nutrients found in human excreta in India are as below:

	Nitrogen (N) per person/year	Phosphorous (P) per person/year	Potassium (K) per person/year
Urine	2.4	0.3	1.1
Faeces	0.3	0.1	0.4
Total	2.7	0.4	1.5

Source: Jonsson et al. (2004)

Urine is a high quality very clean fertilizer, easy to collect and use. It can be applied pure or diluted. The fertilizing effect of urine is comparable to the application of the same amount of plant nutrients in the form of chemical fertilizers (Jonsson 1997). A field trials and pot experiments in Sweden have shown diverted human urine to be comparable to mineral fertilizers. It was found that for nitrogen, the fertilizing effect is equal to, or just a little bit poorer than, mineral fertilizers, while for phosphorus, the fertilizing effect is equal to, or just a little bit better than, mineral fertilizers.

According to Wolgast (1993) the fertilizers excreted by one person are sufficient to grow 230 kg of cereal each year based on an average human production of 500 litres of urine and 50 litres of faeces per year.
The total quantities of nutrients in human urine are significant when compared with the quantities of nutrients in the mineral fertilizers used in agriculture. Thus, by separating human urine at source, the amounts of nutrients recycled to arable land can be significantly increased while at the same time the nutrient load of wastewater can be significantly decreased (Jonsson 1997).
The application rate of urine should always be based on the desired N application rate and the urine or urine mixture should be quickly incorporated into the soil, to minimize ammonia loss. The best method of doing this is by applying urine to farrows or holes, which have to be covered over immediately after application.

The fertilizing effect of urine is similar to that of a nitrogen-rich chemical fertilizer, and should be used similarly. It is therefore best used on nitrogen-demanding crops and vegetables. As a rule of thumb, a concentration of 3-7 grams of nitrogen per liter of undiluted urine can be expected (Vinnerasa et al 2003).
The fertilizing effect of source-separated urine has been tested in some experiments in Sweden and appears to be almost as good as that of the corresponding amount of chemical fertilizer, provided that ammonia emission from the urine is restricted. Using the recycled toilet products as fertilizers will therefore save chemical fertilizers containing almost the same amount of nutrients and thus also the resources needed to produce and distribute them (Jonsson 1997). According to Vinneras (2002), the largest single energy requirement in the conventional production of rapeseed in Sweden is the manufacture of the mineral nitrogen fertilizer used. Jonsson (2002b) also notes that reduction of the amount of urine, and therefore the nitrogen load, in sewage, reduces the electrical energy requirements of a wastewater treatment plant by up to 36% due to the fact that less aeration is needed. He estimated further that the energy break-even transport distance for urine was approximately 95 km with a truck or 221 km with a truck and trailer. There will also be correspondingly less nutrient emissions from the plant. He states that, if all urine is diverted, the nitrogen emissions will probably decrease by 80-85% and the phosphorus emissions by 50%.

A further advantage of using human urine instead of chemical fertilizers or sewage sludge is the very low concentrations of heavy metals found in urine (Jonsson 1997). Vinneras (2002) states that urine and faeces contribute only very small amounts of heavy metals to sewage, as most of these contaminants originate from grey water and other sources.
Although desiccated faeces contain fewer nutrients than urine, they are a valuable soil conditioner. They may be applied to the soil to increase the organic matter content, improve water-holding capacity and

increase the availability of nutrients. Humus from the decomposition process also helps to maintain a healthy population of beneficial soil organisms that actually protect plants from soil-borne diseases (Esrey et al 1998).Vinnerasa et al (2003) argue that the main contribution from the faecal matter is the phosphorus and potassium content and the increase in buffering capacity in areas where soil pH is low.

Some practical examples of agricultural utilization of human excreta:

Use of human urine and faeces for food production is an age old practice in China. In some countries in Africa the use of human urine and faeces is also accepted. However, in India the handling of human excreta is culturally taboo and its use for food production is very rare. Human excreta are seen as waste products, unhealthy, unhygienic and detrimental to humans.

Human excreta, particularly urine, are excellent fertilizers and soil enhancers, and their efficacy has been proved in many countries under a variety of climatic conditions. Using urine is considered harmless and inoffensive. Urine contains more nutrients than faeces. On average a person produces about 500 litres of urine per year. Urine contains the major part of the daily excretion of nitrogen (N), Phosphorous (P) and potassium (K). The plant availability of N urine is the same as that of chemical urea or ammonium fertilizer. The nitrogen efficiency of urine is approximately 90% of that of mineral fertilizer and it is low in heavy metals. However, experience has shown that urine diversion sanitation is acceptable, and the handling of urine poses far fewer taboos than that of faeces.

1 Japan introduced the practice of reusing human excreta for agriculture in the 12th century, which lasted until the middle of the 19^{th} century. Farmers purchased urine and faeces from people in the urban areas and, due to the country's closed policy, typhoid, cholera and other communicable diseases were virtually unknown. Farmers also used to place buckets at street corners in the towns and villages, collecting free urine from pedestrians and providing a simple public toilet at the same time (Matsui 1997).

2 Chinese farmers have commonly used human excreta, often untreated, to grow food. In Rooftop gardening only urine is used to grow vegetables, such as cabbages, beans, pumpkins and tomatoes. In the fields, both urine and faeces are used to grow corn, rice, vegetables and bamboo. However in last 5-6 years modern double-vault urine-diversion toilets have gained popularity and over 100,000 toilets have been built in densely populated rural and urban areas for safe use of human excreta as fertilizer. Apart from this government is promoting large scale public private partnership for implementing ecosan projects in urban areas and there are some initial successes as well. In Dongsheng city of China 843 apartments in 4-5 storied building have been installed with entire aspect of ecosan (urine diverting latrines, solid waste disposal and grey water management). Urine is collected at a centralized location in an underground tank and being transported by urine tankers to nearby villages where framers used urine for their crop fertilization.

3 India, In a pilot project in Kerala, urine from toilets was diverted into a growing area attached to the back of the toilet. Bitter gourds were grown, which were sliced, fried and eaten. In Manipur state, harvests of potatoes and chilies, where urine was used as fertilizer, were very good compared to harvests fertilized with chemical fertilizer, such as DPA, urea and potash (Singh, 2003).Urine diverting latrines have been recently piloted /demonstrated in Tamilnadu and Karnataka and the community has started using the urine and faeces as fertilizer in their household garden. In Tiruchi, Tamilnadu community ecosan block has been constructed in periurban area and the initial reports are encouraging. This community ecosan toilet block is generating a demand for urine by local farmers for using it for their banana and maize crops. In Bangalore comprehensive research is underway by Bangalore Krishi Vigyan Kendra on the urine utilization for banana and maize plants under Indian conditions. The initial results are very encouraging and the detail protocol for use of urine in Banana and Maize plants will be available soon. Some more research are underway for urine utilization on variety of crops in Indian condition and the results will be disseminated through out the country for promotion of urine based fertilizer as a substitute to chemical fertilizer.

4 Guatemala, deforestation and erosion are serious problems throughout the highland areas. This is the result of the high population density in these zones, together with inequitable land distribution and the use of the more gently sloping and flatter lands for the cultivation of cash crops, thereby forcing the subsistence crops to be cultivated on steep slopes. To counteract this situation of increased soil loss, the use of human faecal matter as soil conditioner by subsistence farmers is of particular value. While it is recognized that this practice may not solve the area-wide problems of deforestation and soil erosion, it is regarded as an appropriate and low-cost method for improving the fertility and productivity of the soil of the individual farming family and for the country as a whole. The farmers are aware that the application of chemical fertilizers to the fields without replenishing the organic fraction leads to an impoverishment of the soil (Strauss and Blumenthal 1990).

Double-vault urine-diverting toilets were introduced here because they were regarded as the most suitable technology for the people of the area. Ash, or a mixture of ash and soil or of lime and soil, is added after defecation. This, together with the separation of urine, renders the faecal material alkaline, with a pH of around 9. This enhances pathogen die-off. The mixture of decomposed, humus-like material of faecal origin and ash, called “abono”, is dried in the sun and then stored in bags upon removal from the vault until the farmer uses it in his fields at the time of tilling. The potassium levels of the “abono” are much higher than ordinary excreta due to the addition of ash, which is very rich in potassium. On average, the application rate of “abono” amounts to the equivalent of about 2 500 to 3 000 kg/ha for each plant cycle. With the average “abono” production rate of about 425 kg per year per family, the family's fertilizing potential for maize crops is approximately 1 900 m2 on the basis of the phosphorus content of the “abono” and 2 580 m2 on the basis of potassium, but only about 123 m2 on the basis of the nitrogen content. The fertilizer from these toilets is therefore complemented by the collected urine, or else nitrogen-fixing crops such as legumes are planted in rotation with other crops (Strauss and Blumenthal 1990).

5 Zimbabwe: A unique tree-panting method that is combined with a composting toilet, called the *arborloo*, is used in Zimbabwe. A small hole suitable for planting a tree is dug; the size is approximately 600 x 600 x 600 mm, thus forming a shallow pit for a toilet. A lightweight, removable slab is placed over the hole and a simple toilet structure, which is also easily movable, is erected above it. The unit is fitted with a conventional pedestal or squat plate. The shallow pit fills up relatively quickly with faeces, which are covered with ash or soil. As soon as the hole is full, the superstructure is moved to another similar hole, while the first hole is topped up with soil and a fruit tree planted in it. In this way, whole orchards of productive fruit trees are grown. The most commonly planted trees are avocados, paw-paws, mulberries, mangoes and guavas (Morgan 1999).

6 Ethiopia: A popular practice here is FAITH gardening (**F**ood **A**lways **in the H**ome). The concept is based on a vegetable garden divided into sections that are planted in rotation, at intervals of a few weeks. Thus, while some patches are producing food, others have seed still germinating. In this way there is a constant supply of available food. The vegetable patches are well composted with “human manure” and any other suitable organic material, such as garden refuse. Urine is also used as a liquid fertilizer. Excellent results are obtained (Edstrom 1999).

7 Sweden is probably the country with the most advanced system of collection and reuse of human urine, where it is practiced by farmers on a large, mechanized scale. In a number of settlements (called ‘eco-villages’) or apartment blocks in the country the residents have ecological sanitation systems with urine diversion toilets. The urine from the houses or apartments is collected in large underground tanks, and what the residents do not use themselves is collected by farmers in road tankers and used for fertilizing their crops. The usual practice is to spray it onto the lands while they are being prepared for planting, and then harrow it into the soil before sowing the seed (Austin & Duncker, 2002). It has been found to be a valid substitute for mineral fertilizers in growing cereals, with no negative impact on the crop or the environment (Esrey & Anderson, 2001). In 19th century Danish countryside urine was stored and used as a detergent for washing clothes and dyeing. A project conducted in Vaxholm, Sweden, in 2004 with the objective of achieving a system for the use of urine in agriculture concluded that it is possible for municipalities to organize stable systems for agriculture. The study also concluded that it is not a problem to find a use for human urine in agriculture, even in a large city in Sweden (Stintzing, 2005). The farmer’s perception of the use of urine in Sweden is that the more concentrated the urine is the better it is from a farmer’s perspective.

8. **Mexico**, fermented urine is recommended as a fertilizer. Before sealing the container to avoid loss of nitrogen, users often add a handful of soil as a catalyst for the fermentation process. For fertilization

purposes, users have reported varied dilution ratios of urine to water (from 1:5 to 1:4) (Clark, 2003). Unfermented urine can be sprayed as a fungicide. Indigenous people in south-eastern Mexico claim that the use of urine as a fungicide was a traditional Mayan practice (Clark, 2003).In Mexico City, experimentation with fermented urine to grow food showed that leafy vegetables do very well (Esrey & Andersson, 2001). These included lettuce, cilantro (coriander), parsley, celery, fennel, scented herbs, prickly pear, and chile piquin (bird peppers). Good results were also obtained with cauliflower, broccoli, cabbage and root produce (turnips, carrots, beets and onions). Sawyer (2003) demonstrated in a pilot project in the municipality of Tepoztlán in Morelos that it is feasible to harvest urine and develop a reuse system in the urban context. Achievement of the pilot project included harvesting urine in public places for use in agriculture. Through the project, various technologies have become available in the local market for the collection and storage of human urine. After several years of study it became clear that plants fertilized with urine grew more rapidly, and were larger and healthier than those grown using conventional agricultural techniques. Less water was used in this instance as well.

9. **United States of America (USA):** Experiments in the USA found that maize, which was grown using substantial quantities of urine grew 50% taller than corn grown using no urine at all (BBC News, 2003).

10. **Tanzania:** In the Kagera area in Tanzania, urine has been used as an antidote when somebody has inhaled and ingested poison, by giving that person fresh urine to drink. It has also been used as a pesticide to kill banana weevils (Chaggu & John, 2002). Chaggu (2004) also mentioned that in Bukoba, Tanzania, the tradition of visitors was for visitors to urinate in the host's home garden, which was much appreciated and considered a gesture of respect. This practice has disappeared with the adoption of modern hygiene.

11. **Botswana:** Pilot trials for the agricultural use of urine were identified as the most important follow-up step towards encouraging responsibility for one's own toilet products, and for demonstrating their fertilizing potential. Trials were conducted whereby three plots were prepared in each of 16 locations. One was fertilized with urine, the second one with urine and compost, and the third one without any kind of fertilization for comparison purposes. In all the cases the plots were planted with spinach (Swiss chard). After a certain period, the best results were achieved with the use of compost and urine together. This resulted in participants starting to use urine after the demonstration, and even those without toilets started to collect urine for further use (Hanke, 2003).

Nitrogen losses in urine:

Source-separated urine is a highly concentrated and unstable solution. During storage, bacterial urease hydrolyses urea to ammonia and bicarbonate, causing a pH increase (the pH is related to the concentration of ammonia, NH_3). As a result, 90% of the total nitrogen is present as ammonia and the pH is near 9. After storage, urine contains a large amount of non-ionized ammonia, which can volatilize when the urine solution is agitated during transport or application as fertilizer (Udert et al 2002). Therefore the prevention of ammonia losses during storage and after soil application is important for efficient use of human urine. Therefore it is important to construct the collection, storage and handling system for human urine in such a way that losses are minimized. These losses could be reduced by preventing ventilation during storage and by injecting or harrowing the urine into the soil when spreading. Hellstrom et al (1999) conclude that a decrease in pH will inhibit the decomposition of urea, and that it should be possible to use acids to reduce the pH to about 3. Because the overall objective of the source separation system is to use the urine as a fertilizer, it would be suitable to use acids with a fertilizer value, e.g. phosphoric acid or sulphuric acid. This is supported by Hanaeus et al (1996), who state that the conversion of urea to ammoniacal nitrogen during storage of urine is greatly inhibited by addition of 26 mmol of H_2SO_4 per liter of undiluted urine and a cool temperature. However, they also caution that contamination of urine with faecal matter or wastewater will significantly increase the decomposition rate of urea.

In extensive field tests, Johansson et al (2000) found that ammonia losses during the application of urine in the spring (i.e. just before planting) never exceeded 10% of the amount of nitrogen applied and were usually considerably lower. Furthermore, the ammonia losses measured after the application of urine in the growing crop were negligible, because the growing crop protected the soil surface from wind and sun. He maintains that where the system is properly designed, nitrogen losses during transportation and storage are less than 1%, while the losses associated with application may be less than 2%, depending on the technology used.

Conclusion:

Artificial fertilizers currently account for most of the nutrients needed by food crops. While human excreta contain virtually all the nutrients that plants require, they have been utilized for their fertilizer value only to a limited extent. Instead, much of the nutrient value in excreta finds its way into aquatic resources, where it is responsible for, among other things, problems of oxygen depletion. Many agriculturalists maintain that it is better to create a closed system by recycling nutrients back to the farmlands from where they originated. Ecological sanitation regards excreta as a valuable resource, not simply as a waste to be disposed of. Extensive studies have been carried out to determine the fertilizing value of human excreta, for various types of crops. Humans excrete some 4.6 kg of plant nutrients in the form of nitrogen, phosphorus and potassium annually. Urine has been found to contain approximately 70 to 90% of these nutrients, and many field trials have confirmed it to be a fertilizer of virtually equivalent value to commercial chemical products. In addition, as opposed to wastewater sludge, urine contains very small amounts of heavy metals. While faeces contain much fewer nutrients, they improve the organic content and improve the water-holding capacity of soils. Human excreta have been productively used as fertilizer and soil amendment in many countries. Although this practice is still limited if examined on a worldwide basis, it has become a popular method of increasing food production, especially among lower income communities that are dependent on subsistence farming for survival, often on poor soils. A number of scientific studies have confirmed the substantial agronomic value of excreta in recent years. Although urine has been used as fertilizer since ancient times in many countries but its use is rare in India. However, it has gained attention after promotion of ecological sanitation in India. People have to think about recycling of urine and how effectively it can be used in agriculture for food production and to lessen our dependency on commercial fertilizer. Human urine can be used as fertilizers as well as pesticide to fight crop diseases.

Thus overall experience suggests that human urine is a good source of nutrients, especially nitrogen. Urine is thus considered to be as effective agronomically as urea. It is an inexpensive, abundantly available, effective organic crop fertilizer

Urine harvesting for use in Tea/coffee gardens

Urine can be utilized as organic fertilizer for almost all plants and trees. The advantage of utilizing urine in labor intensive crops/fruits is even more since the urine can be harvested at site and can be collected from other nearby sources. The most promising areas of urine utilization for large scale farming are in grape orchards, tea/coffee garden since both are labor intensive and done in a cluster. In tea/coffee gardens labors stays near the garden and in full time employment of the tea/coffee gardens. The collection of urine and its utilization will pose no problem.

Urine can be harvested by constructing community urine diverting latrines blocks in the labor residential premises and also by construction of simple and economical waterless urinals near tea garden for collecting the urine for use in field. For larger requirements urine may be collected from nearby villages/ periurban areas by constructing waterless urinals. The advantages of urine utilization as fertilizer will be immense and it will help in substitution of commercial fertilizer.

Benefits of urine harvesting and its utilization in tea/coffee garden:

1. Improved hygienic condition for the laborers at tea garden and its residential facilities.
2. Use of urine as fertilizer in the tea garden for substitution of equivalent amount of commercial fertilizer.
3. Closing the loop returning nutrients to the plants
4. Water saving in flushing the urinal and latrines
5. Cost saving in discharging the human excreta (faeces and urine)
6. Promoting ecological sanitation
7. Promoting organic farming
8. Helping in reducing the carbon emission equivalent to the substitution of commercial fertilizer by urine fertilizer

Calculation of N: P: K from urine harvesting from 300 HHs in a cluster of tea gardens. Assuming average 6 persons per family, no. of persons 1800.

Quantity of urine – 900,000 litres per annum
N per year- 4320 kg
P per year- 540 kg
K per year-1980 kg

6840 kg of N: P: K is available permanently and more will be collected from nearby settlements from rural/periurban/urban areas.

Approximately 6840 kg of commercial fertilizer can be replaced and will save INR 270,000 if urine is harvested and used as fertilizer from 300 HH. It is possible to completely substitute the commercial fertilizer by collecting it from other nearby sources such as in schools, other public places bus stand, railway station, from public toilets, markets etc. Apart from this substantial cost saving would be realized by saving water and its disposal with urine. The use of urine in tea gardens will also reduce the green house gases (GHG) and the tea gardens using the urine as fertilizer will earn substantial carbon credit by doing so.

In the IYS when the entire world is reviewing the MDG on sanitation and working with renewed efforts to meet the MDG by 2012 ecological sanitation and its linkage with agriculture will provide a much needed way forward for attaining the MDG by sustainable sanitation. The urine harvesting and its utilization as organic fertilizer will provide exciting opportunities to link sanitation and agriculture/forestry.