HUMAN EXCRETA FOR FERTILIZATION OF NON-EDIBLE TROPICAL PLANTS

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Abstract

Open defecation, untreated sanitary and washing wastewaters are a serious problem in many poor areas. If the nutrients of human excreta would be seen as economical resource there would be reasons to build separating dry toilets and use valuable urine and washing waters for plant fertilizer and irrigation. This paper describes plants that could be cultivated in tropical areas utilizing wastewaters. The plants presented are mainly non-edible, since many people are not willing to use consciously human excreta for fertilization in food production. The survival abilities of these plants under water-logging or salt stress are considered. Plant species which could be used as fibers, light construction, fuel, fodder or timber, are presented. The regulations related to CITES-lists are presented. Since human urine can contain schistosomiasis spreading eggs, some plants known to have toxic effect on host snails of schistosomiasis spreading eggs are included. The better, safe latrine coverage would benefit especially women, but it would improve food and water hygiene.

Key words: millennium goals; schistosomiasis; timber; urine; wastewater; women

1. Introduction

Open defecation of urination is often practiced in developing countries, because still 2.6 billion people do not have any access to latrines according to United Nations http://www.un.org/waterforlifedecade/factsheet.html . The ability to use toilet has been counted as a human right in Bangladesh (National Sanitation Strategy, 2005). Many more people (children, people working outdoors or travelling etc.) urinate or defecate outside occasionally when latrines are too distant. Soil microorganisms degrade human excreta to chemical components, which vegetation can totally utilize. If the amounts of human and animal excreta are moderate per area and there are no generally known serious phototoxic symptoms caused by this excreta. The vegetation area needed for degradation of all excreta produced by one person is theoretically equal to the land area needed for food production of the same person. This area is highly dependent on climate but it can roughly be calculated to be 100-500 m^2, though this area can be as small as under 50 m^2 in tropics where different plants in different growth stages can grow all the year in different layers i. g. from high trees or climbing plants to small grasses and the photosynthesis area of roads, roofs or ponds can be efficiently utilized.

Human feces lead directly to waters pose a hazard to water and food hygiene and therefore good hygienisation of feces would be most essential. Plain pure urine on the contrary is usually microbiologically acceptable. Because it contains an abundance of nutrients its spreading into the soil without vegetation leads to nitrate contamination of groundwater and eutrophication of surface waters. Anyhow, urine can spread schistosomiasis eggs and this disease is known to spread via snails living in fresh waters as in dams (Ofoezie, 2002). Some plants which can inhibit the host snails of this pathogen are included. Urine contaminated with feces of course contains enteric microorganisms. It should be emphasized that the normal urine is a powerful fertilizer but it cannot replace irrigation water. Toilet waters are, anyhow, often used after appropriate dilution (and possible hygienisation) as irrigation water and fertilizer with only modest treatments (Quazi, 2005).

The volume of water used during each toilet visit depends on the availability of water. If there is tap water, more than 10 liters of water/per visit can be used only for transporting toilet wastewater away. In addition, anal cleaning requires more water, thus the water consumption and electricity needed for pumps is remarkable. On the other hand, if women or other people must carry water into the latrine, the water consumption is less (maybe typically 1-3 liters) per a flush and possibly during the dry season there may be no flushing water.

In the ideal world it would be possible to build for all people water pipes with safe drinking water and a wastewater pipe with effective wastewater treatment. However, this would be expensive and will only come to fruition in the distant future. If a latrine could be seen as an investment and not only as a cost, more families could build an own family latrine. This aim of this paper is to show that a latrine can also give income so that more latrines would be built and used so that millennium goals could be reached. The paper is aimed to serve social workers, engineers and other non-agronomist officers who help households, schools and other organs for sustainable development.

2. Improvements to environment are now possible with low costs

The risks of contaminating water and food chains could be already now reduced if we could reduce radically the volumes of enteric wastewater gaining access to drinking and irrigation water. Dry toilets are one possibility but they are not easily accepted in cultures where anal cleaning is traditionally done by washing. A separating toilet with urine utilization could represent another possibility, if urine would be accepted for fertilization, since pure urine is recognized as being a useful fertilizer also for edible plants (Richert Stintzing *et al.,* 2005; Heinonen-Tanski *et al.,* 2007; Pradhan *et al.,* 2007).

Human urine is rich in nutrients but dependent on diet. For example the human excreta formed by Thai rural people contains approximately half the nitrogen content of excreta from Western countries, since the Thai diet contains less protein than the Western diet (Schouw *et al.,* 2002) and people living in tropical climate excrete a relatively higher percentage of nitrogen in sweat and less in urine than people in temperate climate (Huang *et al.,* 1975; Huang *et al.,* 2002). Therefore Western calculations about urine volume and nitrogen content can be assumed to represent overestimations. Furthermore in climates, where there are seasonal heavy rains, the soil will regularly be cleaned of water soluble nitrogen and thus the risks of over fertilization with nitrogen are smaller than is the case in Western countries. If people eat mainly vegetarian food their excreta may contain similar ratios of nitrogen and phosphorus as taken up by plants and this ratio is 10:1 for most plants (Knecht and Göransson, 2004). Thus there are no specific risks for unbalancing plant nutrients if human excreta are used as plant fertilizers (Pfister and Baccini, 2005).

Tropical vegetation usually has high water requirements. Mean evapotranspirations have been estimated to be some 3-5 mm/day in Philippine (Stöckle *et al.,* 2004) or in India (Amin *et al.,* 1997) and thus annually 1400-1500 mm of water can be released by vegetation. Thus a single medium size tree with crown area of 25 m^2 could evaporate approximately 100 l water each day corresponding to the wastewater volume from one family latrine. Thus the trees growing with the latrine wastewater can play an important role when controlling floods and bounding nutrients, and thus also the risk of flooding and consequent pollution of water can be reduced. If the latrine wastewater is dried efficiently by vegetation, then bad odors are reduced and mosquito larva would have fewer niches to spread malaria, dengue or other diseases and also schistosomiasis could be partly controlled.

Vegetation could be planted near to discharge pipes of latrine so that the pipes could not be seen and the landscape could be more scenic. The plants selected in this report can be grown in tropical home plots, schools or common areas. Some of the plant species presented are resistant to permanent water logging and salt stress, which are problems in coastal areas. If the male trees of nutmeg, rambutan etc. were included, there would be many more species that could be cultivated with human excreta.

The plant residual leaves and branches can be used as bedding materials in composts or as fuel, so that women could get more easily firewood which in addition, would mean that more natural forests could be protected. The firewood is economically important for poor people who often must use even half of their income for firewood (Quazi, 2005).

Since the scientific literature released to the fertilization of tropical plants is limited, the fertilizer needs of different plants have been estimated from the knowledge of the energy or protein content in their leaves, fruits or other parts as well as from the growth rate.

2. 1. Many potential plant species

2. 1.1. Plants having potential to destroy host snails of schistosomiasis

Foxtail agave (*Agave attenuate*) originates from Mexico but it is widely cultivated as an ornamental and it can be propagated vegetatively. Its dry leaves contain compounds known to destroy efficiently *Bulinus africanus* (causing schistosomiasis) and *Anopheles arabiensis* (spreading malaria) but less *Daphnia pulex* (Brackenbury and Appleton, 1997). The same research workers reported that the toxicity of leaves against fish, rabbit skin or cornea was very low and the germination of cereals was inhibited only at much higher concentration than that needed for *B. africanus* and *A. arabiensis*.

Clark and Appleton (1997) found that also *Gardenia thunbergia* leaf power in water had a high toxicity against *B. africanus* and in addition they recommended that the leaves of *Apodytes dimidiata* and possible *Warburgia saluris* had so much mollucicidal activity that they could be used against snails. **Gardenia** is a small South-African tree used as ornamental due its white big flowers. **Apodytes** (in Swahili **mlambuzi)** with its edible red or black fruits can reach 25 m height and grow in dry areas of Sub-Saharan Africa (Lovett *et al.,* 2006).

If wastewater tends to form ponds these plants and especially gardenia and apodytes could be useful so that their leaves could be used against snails cultivated both of them so far of ponds that their roots are not water-logged.

2. 1.2. Fiber plants

Cotton (*Gossypium spp)* is an annual plant and one of the most important plants in tropical and semitropical areas. Cotton seed boll pods can be harvested some six months after seeding and seeding can be done in the tropics at any time. Due to its rapid growth and harvesting of nutrient-rich seed bolls, cotton needs an abundant supply of fertilizers (Sawan *et al.,* 1998, Blaise *et al.,* 2005) and thus the cultivation of cotton would fit well near latrine outlet areas rich in nutrients. Cotton seeds can first be grown in small pots and the young seedlings can then be planted near latrine outlets meaning that the small scale cultivation is not expensive. Since the yield must be collected during many different days, it is convenient to cultivate this plant in home plots and use seed boll fiber could in women handicrafts and, health care. Animals can feed on cotton seed residues. Cotton with its red beautiful flowers and seed boll pods has also decorative value. Cotton is, however, known to be sensitive to insects and phytopathogenic micro-organisms (Rothrock *et al.,* 2004) so it may be difficult to cultivate it in the same plot permanently without the use of pesticides.

Ramie (*Boehmeria nivea*), **jute** (*Corchorus* sp.) and **fiber hemp** (*Cannabis sativa*) are widely cultivated industrial plants. Their fertilizer needs are not well documented, but generally the yield has improved by fertilization (Scheer-Triebel and Leon, 2000; Banik *et al.,* 2003; Patel and Thakur, 2003) and especially by split fertilization (Bhattacharjee *et al.,* 2000). Considering the annual yields and fertilizers used for these plants it seems that too low fertilizer level might often limit the yields. If there is a need to cultivate these plants and shortage of space and fertilizers, it could be beneficial to cultivate ramie near to latrine pipes.

Textile hemp (*Musa textilis*) grows, as do other bananas, in less than one year and it has smaller size than edible banana. All bananas tend to benefit from good fertilizer status in soil and thus their cultivation could be an interesting possibility, if their leaf stalks can be used making for ropes, nets, hammocks, hats, mats or other purposes (Jensen, 2001).

Kapok, white silk-cotton tree (*Ceiba pentandra*) can reach up to 30 m in height (Jensen, 2001) and it grows rapidly. It can grow also in poor soils but growth is better if urea and phosphate fertilizations are used (Gupta and Mohan, 1991). Kapok is used as stuffing material in building materials, toys, cloths, textile bags, furniture pillows and other handicrafts. Its seeds are rich in nutrients so they fit for poultry feed (Narahari and Asha Rajini, 2003). As a rapidly growing tree and with an ability to benefit from high amounts of nutrients and water kapok tree would be expected to grow well adjacent to latrine outlet sites.

Silk cotton tree, red cotton tree (*Bombax ceiba* or B. *malabaricum*) is even larger (up to 40 m) than the kapok tree (Jensen, 2001) and its red flowers are decorative. The bark has been used for rope making. In addition, its timber wood is valuable, i. e. this tree is multipurpose.

Mulberry tree (*Morus alba*) leaves are used for silk fiber production by silk worms. These trees are usually pruned as small trees or shrubs so they fit to small sites. If the leaves are regularly eaten by silk-worms, which make from leaf protein silk fiber protein, the plant must have a high protein synthesis capacity and a high need of nitrogen. Abbasov and Ataev (1970) have shown that mulberry trees grow better than the non-fertilized controls if 90 or 180kg/ha/a nitrogen was used. Therefore the mulberry tree would be expected to thrive in the vicinity of latrine discharge pipes. Mulberry tree can't survive if the soil is too alkaline (Gill *et al.,* 1987) thus latrine should not be washed with sodium hydroxide or lime. Not only silk worms eat the leaves, they can be fed to cattle or rabbits so this tree could be converted into animal protein. The wood can also be utilized for fuel or sport goods (Jensen, 2001). Humans could also eat mulberry berries.

2.1.3. Light construction material plants

Rattans (canes) are the names given to many different climbing palms - lianoids (Jensen, 2001). These plants usually need a trunk on which they can climb. Rattans grow rapidly and thus they would benefit from the rich nutritional status of latrine pipe discharge sites. Rattan products are popular for making light furniture, baskets, toys or sport items (Chan, 2000) sold also in Western countries.

Bamboos (*Bambusa vulgaris* and many more species from different genera) are rapidly growing grasses (Chan, 2000) and some of them can grow to over 30 m (Jensen, 2001). Different bamboos are used for the construction of houses, fences, supporting poles for climbing plants, furniture, baskets, musical instruments, and sport goods. They can even be used for plywood or paper making. Transportation of bamboos on bikes or rickshaws is a very common sight in South Asia. The very rapid growth of bamboos means a high nutrient need. Bamboos are often seen in tomb sites and close to water bodies, where they might benefit from soil or sediment nutrients, as near public latrine in Peradeniya Botanical Garden. Private farmers have cultivated bamboo using human excreta and earned well money from this production (Quasi, 2005).

Oil palm (*Elaeis guineensis*) is a common 20-30 m tall tree in many tropical areas. It is an important industrial plant since its seed oil is used for food processing and making soap (Jensen, 2001). In addition it is cultivated in big farms to make biofuel for car gasoline. Palm leaves are very often used for roofing, walls or fences. The young leaves and press cake fiber can be given to animals and on the other hand urine and feces from grazing cows and goats has found to be a good fertilizer for oil palm and these excreta improved soil structure (Devendra, 2004). Since urine and feces of ruminants are beneficial to the yield of oil palm, also human fecal matter must be a beneficial fertilizer so that oil palm can produce its fruits with high energy content.

2.1.4. Timber trees are beneficial but the restrictions imposed by CITES-lists need to be respected

Several timber trees have also many other uses. They or their leaves can be used as firewood or fodder, and the bark can be used as medicines or for tanning. In some cases there are also fruits or seeds, which are utilized by people or animals. Trees give shadow and act as windbreaks. They are important in creating a more attractive landscape. The cultivation of tall trees can also protect the natural coastal mangrove forests, which are extremely important for controlling against major storms and flooding as well as reducing the effect of high waves or tsunamis as occurred 26 December, 2004 and reported by FAO (2005).

The trees are useful for improving the soil properties. The root activity and the falling leaves increase soil organic matter content as has been reported by Osman *et al.* (2001) and roots can bind soil and make it less erosion-sensitive. Thus the serious water erosion can be controlled by trees.

Before cultivating tropical trees, it is essential to consider the **CITES-list** (Convention on International Trade in Endangered Species of Wild Fauna and Flora), which is an agreement between governments supervised by the United Nations Environmental Programme. This agreement is aimed at preserving the environment so that rare and vulnerable animals or plants are protected. Many valuable tropical timber tree species have been placed on this list in order to save the natural forest from illegal felling. Often industrial countries demand a certificate to show that a plant on the CITES-list has been cultivated in a way which is ecologically and environmentally acceptable. Therefore, if a tree species is placed on the CITES-list, it requires a certificate on its cultivation origin. The governmental authorities must give guidance on how this certificate can be obtained. The CITES-lists are different in different areas so that natural plant species are protected in the areas where they naturally grow. The web site http://www.cites.org/index.html provides more knowledge about species on this list. Some very vulnerable plant species are placed on the red list (see www.wcmc.org.uk/species/plants/red_list.html). One certification system is supervised by FSC (Forest Stewardship Council) and this certification system is accepted by European furniture makers.

Roseapple (*Syzygium jambos*) is an ornamental fruit tree but its fruits are not considered to be tasty and they are used as raw material for rosewater and leaf oils can serve perfume industry. This tree is some 10 m high so that it can be cultivated in small yards. The heartwood serves as good timber (Jensen, 2001). This tree thrives in wet conditions and it tolerates also waterlogged areas and thus it could be cultivated in the lower parts of banks receiving latrine pipe effluents. Its botanical relative, *S. aromaticus,* produces clove and this tree is known to favor from nitrogen fertilization (Martin and Dabek, 1988).

Indian jujube (*Ziziphus mauritiana)* is a small tree (15 m high). It can grow in different soils including the occasionally waterlogged or arid conditions. The reddish timber is used for turnery products. This tree can be cultivated to feed lac insects (*Coccus lacca*) in order to produce shellac (Jensen, 2001).

Sapodilla, lamut or noseberry (*Manilkara zapota*) is a fruit tree and a furniture timber tree usually grown to about 20 m high. This tree is rich in white latex, which has been used for chewing gum and different industrial applications. It tolerates strong winds and salt, which makes it interesting on coastal areas (Jensen, 2001). It can also grow in relatively poor soils but good fertilization increases growth rate (Zech *et al.,* 1991). However, this tree cannot grow in permanently waterlogged sites and thus it should be planted on the upper part of bank areas.

Cempedak *(Artocarpus integer*) is a fruit tree (typically less than 20 m high), but its wood is valuable and durable as timber and its latex can also be used. Thus it is similar to its botanical relative jackfruit tree *(Artocarpus heterophyllus*), which is well-known as a medium sized (20-30 m high) fruit tree. In addition, cempedak leaves can serve as animal feed and its bark as tannin for leather. The timber is known to be termite resistant and a medium hardwood. Both *Artocarpus* species are used in making furniture, boats and for house construction.

Neem tree (*Azadirachta indica* or *Melia indica*) grows in many places including wastelands and even highly alkaline soils fertilized with urea (Gill *et al.,* 1987). The tree is usually less than 20 m high but the trunk can be as wide as 1 m in diameter (Jensen, 2001) and since the wood is said to be insect repellent it is very valuable for construction. Furthermore, its seeds and leaves can be used as an insecticide (Rao *et al.,* 1992) and the leaves are used as animal fodder. The plant has also medical and cosmetic value. A high lime content of the soil can cause chlorosis in the neem tree (van den Burg and Kopinga, 1983) but latrine waste is unlikely to contain lime if ash possible used for hand washing is not lead to latrine pit. Neem trees are growing well utilizing urinal wastewaters in a Bangladesh girl school (Heinonen-Tanski, 2006).

Indian almond (*Terminalia catappa*) is often cultivated along streets or home plots as an ornamental tree in the subtropics and tropics (Mattila and Virolainen, 1995). It is native to the East Indies (Jensen, 2001) but it is popular also in the Caribbean, where it has been described to be fast-growing and tolerant to marine wind or salt spray and to be a good provider to shade (Morton, 1985). It grows to approximately 25 m in height. The timber is multipurpose for building or firewood. The leaves can be given to cattle or silkworms. It is a pioneer species growing on disturbed soils and in beach forests. Its kernels are rich in fat (>50%) and protein (>25%). The kernel oil can be used as raw material for medicines or soap and also as animal fodder and human food.

Teak *(Tectona theka or T. grandis)* is very well-known timber wood having high market value cultivated in many countries. The trunk grows straight up to 25-30 m high and 1-2.5 m with diameter. This tree with its big leaves is often cultivated along streets and yards. The wood is used for furniture, house frames, boats, bridges, rails and floodgates. Jensen (2001) recommends that this tree should be cultivated together with Borneo teak or bamboos. It grows well and rapidly with sufficient fertilization (Bhumibhamon *et al.,* 1981). Shortages of nutrients reduce the growth rate and this is reflected in chlorosis and other symptoms (Zech *et al.,* 1991). This tree is on the CITES list. In some countries it is forbidden to export raw teak, since wood-processing provides work and income for local people.

Red sandalwood, rosewood *(Pterocarpus indicus)* is usual in Southeast Asia growing adjacent to mangrove swamps or along streams. The tree can grow to a height in excess of 35 m high and its trunk can be 2 m in diameter (Jensen, 2001). This valuable tree is on the CITES-list. It is used for making furniture and cosmetic products. The wood gives off a camphor or cedar smell and the bark has a red color. The timber quality is reduced in dry season (Jensen, 2001), but should it be cultivated near to latrine pipe outlets, the unfavorable impact of the dry season could be reduced and the timber quality thus improved. It could also grow well near latrine pipes which have earlier got abundantly nutrients but recently there is only water, since phosphorus precipitated can be taken by sandalwood and this tree belongs to the *Leguminosae* family having an ability to get nitrogen from air in symbiosis with nitrogen fixing bacteria. The crown with beautiful yellow flowers can be extensive so this tree provides shade for roads, houses, yards and other vegetation.

Yemane *(Gmelina arborea)* prefers a fertile soil and therefore it could be expected to grow near to latrine outlet pipes. The trunk can be wide and the height can be up to 40 m (Jensen, 2001). The wood can be used for many purposes but also as fuel wood. Its flowers are beautiful. The leaves can be used as fodder for ruminants and the tree has also medicinal value. Improving growth was reported in a fertilization test (Otsamo *et al.,* 1995), even though it can also grow in poor natural soils (Zech *et al.,* 1991). This species is on the CITES list in some countries.

Borneo teak or **Malaccan ironwood** (*Intsia bijuga*) is a large tree (up to 45 m) with the diameter of up 2 m. It requires a good water supply so it grows often on river banks, seashores and swamps. This wood is viewed as a "premium" tree for flooring, stairs, windows or door frames etc. (Jensen, 2001). Furniture made from this tree is sold under the name merbau. This plant belongs to *Leguminosae* so it lives in symbiosis with rhizobia bacteria, which have an ability to fix nitrogen. This tree could grow adjacent to latrine pipes utilizing the phosphorus from latrine residues and providing nitrogen to the other plant species growing adjacent to the trees. The leaves and seeds of all leguminous plants are rich in protein. This species is also on the CITES list.

Big-leafing mahogany (Honduras mahogany or true mahogany) *(Swietenia macrophylla)* is a source of extremely valuable timber used in the fine furniture and musical instruments, boats etc. The bark tannin is used for leather tanning. The tree can grow up to 40-60 m high with a branchless trunk to 18-25 m and 2 m diameter with buttresses to 5 m (Jensen, 2001), and thus it needs plenty of space. This tree originated from Central America and the wild tree has been set on the CITES-list to protect it from illegal felling. There is a special mahogany program in the CITES programme, i. e. in this case a certificate is mandatory. The cultivation of mahogany seedlings has been shown to succeed better if they receive at least some nitrogen (Yao, 1981), potassium, water and light (Dünisch *et al.,* 2002) but its growth is not rapid (Otsamo *et al.,* 1995). It can suffer heavily from nutrient deficiency in calcareous soils (Zech *et al.,* 1991) and too low levels of nitrogen, phosphorus and magnesium could disturb its growth. Wood ash tends to contain too large amount of calcium, and therefore ash must be avoided. Since there are many nutrients which limit its growth, latrine wastewater with its special mix of nutrients may provide exactly the nutrients needed.

Small-leafing mahogany (*Swietenia mahagoni*) is clearly smaller than the big-leafing mahogany (only 30 m high) but it is as valuable as big-leafing mahogany and in practice the timbers from these tree species are not always separated from each other. Since it has more branches the timber of small-leafing mahogany is more interesting than that of big-leafing mahogany but also more difficult to work with. Also this tree can be cultivated legally but there has to be a CITES-certificate if it is to be sold on the Western market. Due to its smaller size, this tree could possibly be cultivated in a smaller space.

3. Discussion

As presented there are many different plants which could grow near to latrine outlets. Thus one can do a question: which plant should be chosen?

The selection can be done first by considering if the main reason is to get a new, economic resource from fertilizers for poor people or if the main reason is to reduce contamination of waters considering eutrophication, enteric diseases, schistosomiasis and malaria. Fiber plants and light construction plants may be a good selection giving yield soon and giving handicraft work for women with low capital. Big trees can be a better selection if the protection of groundwater is seen as the major reason. Big trees needing a long growing period may also fit for public places where they need plenty of place but where they are important for landscape.

The selection of a suitable plant could be based secondly on the size of available site. If there is a sunny open space in the vicinity of roads, ponds or rivers, even the very large trees may be suitable bearing in mind that the cutting of a large tree needs more space and its growth time can take decades. The large trees can of course be cut before they have reached the full size; should the space be needed for some other purposes. It is also possible to prune only one or a few branches to get some money.

Furthermore, the selection of the plant to be cultivated near to latrine outlet pipe should take into consideration the possibility to obtain seeds or seedlings. Some of these plants are available in each area. Some are freely available or at low price. If local seeds or seedlings of good quality and good health are available, they are often adapted to the local climate thus they represent a good choice. There are also seed vendors who can have extensive lists of seeds available and novel plants which can be tried.

In many cases it is better to reduce the final growth time in the final site near to the latrine by sowing seeds first into small pots and later to plant the best seedlings into larger pots and then finally to plant the best seedling near to the latrine site. This can guarantee that there is a living plant competing for resources with weeds.

It is also important to consider whether there will be water-saturated conditions or if there will be dry seasons, which the plant must tolerate. The possible salt tolerance should also be estimated. There may be also a need to re-evaluate the washing detergents so that strong mineral acids or bases (leading also to the smell of ammonia) should not be used.

4. Versatility of plants for future

In many cases it would be useful to cultivate many different plant species together near to the latrine site i. e. two or three herbs and one or maybe two tree species possibly at different growth phases so that harvesting could be done at different times. Small herbal species can often be harvested already after a few months, providing work for women and other family members. On the other hand, the circulation times of many timber species can be 10-20 years, and in extreme cases, even 60 – 150 years.

Over that kind of time scale habits and attitudes may change so that it may be that the use of human excreta for edible plants may no more be a taboo. It is also possible that sanitation may be improved so that it will no more require such amounts of water as used today and then it would not be necessary to drain latrine wastewaters directly into fields or streams. True sustainability in sanitation and plant production may be then accepted in developing and industrial countries.

Acknowledgements: The work has been as an activity of EU project Women, wellbeing, work, waste and sanitation (4Ws); contract ICA 4 CT-2002-10013 presented by EU in their webpages http://ec.europa.eu/research/dossier/do220307/asia_en.html

I therefore thank especially Prof. Mujibur Rahman from Bangladesh University of Engineering and Technology and my other co-workers in Bangladesh, Sri Lanka, India and the Netherlands for fruitful discussions stimulating me to do this work. The Alli Paasikivi Foundation is thanked for the financing of this work. The language of this article has been corrected by Dr. Ewen Macdonald.

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