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Integrated Water-Less Management of Night Soil for Depollution of Water Resources and Water Conservation

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ABSTRACT
Use of water for flushing night soil and enormous sewage disposal are responsible for pollution and depletion of fresh water resources in India and other countries. The review of traditional methods in the world provides idea of zero-waste discharge residential units. Experiences and research in India, China, Japan, America and Sweden has indicated feasibility of waterless management of night soil, composting and use of biofertilizer product in agriculture. A novel idea of ecological management of night soil and urine is presented in which night soil may be conditioned for transportation and treatment by adding suitable waste product(s) from industry and other sources. Different night soil treatment methods are reviewed and emphasized the need for further research on whole cycle of *ecological* management or *sustainable sanitation* depending on local conditions. The benefits of this system are zero sewage discharge, reuse of waste as resource, recovery of nutrients in waste as fertilizer, production of fuel gas and reduction of pathogens in biofertilizer. This will help in water conservation and regenerating the quality and quantity of river flow for use as water ways and irrigation and to improve the public health. Potential technical intervention and research needs are discussed in this article.
***Keywords* -** Pollution, Night Soil, Sustainable Sanitation, Biofertilizer

I. INTRODUCTION

The unscientific method of night soil disposal using water medium is the main culprit resulting in pollution of water bodies in India. The conventional approach to depollute the rivers in India, through development of costly sewers and sewage treatment plants, has been proved to be irrational and impractical from the experience of Ganga Action Plan (GAP) without any success. GAP has consumed enormous amount of public money that could he been used for development. The zero waste-discharge concept may be adopted for residential areas generating night soil and domestic waste for which technological intervention of mixed composting [1] is necessary.

Various options are available for water less processing of night soil, based on the principles of traditional methods as well as initial work done in 1980s and experience in certain other countries and incorporating new ideas of recycle and reuse using waste from different anthropogenic activities as resource for this purpose. These options are discussed, which need research intervention through government support and efforts of scientists to formulate and commercialize the technology and designing of treatment plants for a family or for a community, and infrastructure to use of the biofertilizer to improve the farm soils. This will reduce the use of chemicals fertilizers, motivate the people to produce the green agricultural products and the soil fertility will be maintained for a longer period, making India rich in agricultural production.

II. HUMAN WASTE RICH IN PLANT NUTRIENTS

The Table 1 presents the average composition of human excreta and urine. Both contain considerable amount of organic matter, carbon, nitrogen, phosphorus, potassium and calcium. They are, thus regarded not as waste, but as resource to recover nutrients for crops through suitable technology.

Table 1: Composition of Human Excreta

Item	Feces	Urine
Quantity (wet) per person per day (g)	100-140	1000-1310
Quantity (dry solids) per person per day (g)	30-60	50-70
Moisture content (%)	70-85	93-96
Approximate composition (per cent dry weight)		
Organic matter	88-89	65-85
Carbon	44-55	11-47
Nitrogen	5.0-7.0	15-19
Phosphorus (as P2O5)	3.0-5.4	2.5-5.0
Potassium (as K2O)	1.0-2.5	3.0-4.5
Calcium (as CaO)	4.5	4.5-6.0

III. HISTORY OF TRADITIONAL WATERLESS NIGHT SOIL MANAGEMENT

The research and development on waterless management of night soil might get great benefits from the review of traditional water less disposal of night soil which has been practiced in almost all cultures. The use of human waste to increase and sustain soil fertility dates back to over 4000 years in the countries of Asia (China, Japan, Vietnam, Cambodia, Korea, India etc.) and western pacific. A working assumption for a developing country is that adults produce about 350 g of feces per day in the urban areas and 1.2 kg per day in rural areas.

3.1 India

In India, there was routine method of mixing night soil with soil, agricultural waste and domestic waste and allow for composting in a ditch. The compost was then used in agricultural fields. Animal waste was also to be used for composting after mixing with plant waste. Every village used to have certain areas outside the village for men and women separately for open defecation, where night soil was used to be covered by soil and left for natural process of composting. Agricultural fields were also used for open defecation by the people to improve the soil fertility. The cattle or sheep were used to rear in the fields so that their dung is added to the soil and undergo natural composting ultimately improving soil fertility.

3.2 China

Most organized collection and use of human excreta from cities and its transportation to fields were seen in China [2] more than 2500 years ago and enabled them to sustain more people at a higher density than any other system of agriculture [3].

3.3 United States of America

Almost 50 percent of biosolids created in the United States are applied to land, with the majority being used in agriculture. However, biosolids used in the United States aren't night soil. The night soil along with sewage is carried to treatment plant from where the effluent is used for irrigation. The pathogens are removed in treatment plant. Biosolids treated once are called Class B biosolids, and can be used with various restrictions, because while the pathogen levels are reduced by a single treatment, they're not completely gone. That requires a second treatment—often using high temperatures—and turns the biosolids into Class A biosolids, which have no detectable pathogens and can be used anywhere.

3.4 Other Countries

In Mexico, in 15th and 16th century, the sweepings and excreta used to be placed in special boats moored at docks around the city and were used to fertilize the agricultural fields. Urine was collected in containers in all houses, then mixed with mud and used as a fabric dye [4]. In Peru, the Incas had a high regard for excreta as a fertilizer, which was stored, dried and pulverized to be utilized when planting maize [3]. In the middle ages, human excreta and greywater was routinely used in agriculture. European cities were the source of agricultural fertilizers by gong farmers in England. The practice of directly using the nutrients in excreta and wastewater for agriculture therefore continued in Europe into the middle of the 19th Century [3]. Traditional forms of sanitation and excreta reuse have continued in various parts of the world for centuries and were still the common practice at the advent of the Industrial Revolution.

IV. ABANDONMENT OF TRADITIONAL SYSTEM

In 20th century, the system of recovery of nutrients and organic matter from excreta and greywater was replaced with sewer-based sanitation systems, at least in cities. This happened due to growth of urban settlements and increasing distance from agricultural fields and production of cheap synthetic fertilizers. This resulted in production of enormous sewage beyond treatment capacity, and pollution of water bodies. The dilution of nutrients in sewage also made it difficult to recover the nutrients for agricultural purposes. Under such conditions, recovery of nutrients from wastewater was continued by using raw, treated or partially treated wastewater from irrigation in agriculture with associated human risks if used in improper way.

V. RESEARCH ON ECOLOGICAL MANAGEMENT OF NIGHT SOIL

5.1 Sustainable Sanitation or Ecological Management of Human Waste

The term Ecosan was first used in about the 1990s (or perhaps even late 1980s) by an NGO in Ethiopia called Sudea. They used it for urine-diverting dry toilets coupled with reuse activities. In the ecosan concept, human excreta and wastewater is regarded as a potential resource - which is why it has also been called "Resource Oriented Sanitation".

The Swedish International Development Cooperation Agency (SIDA) funded the research project “SanRes R&D Programme” during 1993 to 2001, which was further extended by “EcoSanRes Programme” carried out by Stockholm

Environment Institute (2002–2011) [5, 6, 7]. The German Government enterprise GIZ initiated Ecosan Program from 2001 to 2012, which was in later years named as Sustainable Sanitation for which Sustainable Sanitation Alliance was founded in 2007. Research on safe use of urine and feces in agriculture was carried out by Swedish researchers, and Hakan Jonsson and his team published Guidelines on the Use of Urine and Feces in Crop Production [8], which was later incorporated into the WHO Guidelines on Safe Reuse of Wastewater, Excreta and Greywater [9]. The multiple barrier concepts to reuse in this publication have given clear understanding on how excreta can be used safely.

In China, the policy is the establishment of technology to effectively use organic waste (Kitchen garbage) generated at individual sites and to mix it with dehydrated sludge to augment methane fermentation and composting. Night soil treatment facilities use ultra filtration membrane separation type heavy load treatment process. Similarly septic sludge from house hold septic tanks are charged into night soil treatment facilities. One experimental treatment plant [10] to treat night soil and septic sludge consisted of a pretreatment tank, consisting of screen and a trap (for removing silt ad floating materials, 0.03-1.5% respectively), heating to 55 ^{0}C for one hour (to destroy pathogens and to provide heat for anaerobic digester) in which organic waste is partially converted into biogas and parasitic eggs and some pathogenic bacteria gets inactivated over a ten day period. Then a series of three stabilization ponds – anaerobic and facultative processes in first two ponds - and the effluent is delivered into third fish pond to provide supplementary nutrients. There was sufficient DO and food in the third stabilization pond for rearing of fish.

In China, the reuse of night soil is officially stimulated by extension. Sanitation Departments of local governments are responsible to collect and transport night soil from toilets to storage tanks located in the suburbs. All feces, 1.8 yuan per tonne-km, including labour, and costs of vehicle and gasoline are paid by local governments. Farmers pay 12 yuan per tonne and transport from storage tanks to farmland at an average cost of 0.2 yuan per tonne-km (1 US$ = 8.6 yuan). The price of commercial fertilizer is much higher (urea 1,400 yuan/tonne; Ammonia phosphate 2,500 yuan/tonne). Collecting, transporting and processing night soil is not very convenient and it takes much time as compared to handling commercial fertilizer. Statistics show that if 200-500 kg/mu (1 ha = 15 mu) night soil and 80 kg/mu commercial fertilizer (20-20-20) were used instead of 100 kg/mu commercial fertilizer, rice production could increase with 15 kg/mu, wheat with 30 kg/mu, high-quality onions by 20% and grape can reach 2000-2500 kg/mu. This will be profitable as long as transport distances are not too long. A sound system has not yet been developed and treatment processes has not been standardized.

5.2 Field Trials

Agricultural trials around the world have shown measurable benefits of using treated excreta in agriculture as a fertilizer and soil conditioner. The agricultural trials in Zimbabwe of using treated urine showed beneficial effects on green leafy plants such as spinach or maize as well as fruit trees [11, 12]. Another study in Finland indicated that the use of urine and wood ash could produce 27% and 10% more red beet root biomass [13]. Urine has been proven in many studies to be a valuable, relatively easy to handle fertilizer, containing nitrogen, phosphorus, potassium and important micro-nutrients [14].

VI. AVAILABLE TECHNOLOGIES FOR USE / RESEARCH

Options are available for research and planning on night soil treatment processes based on experience in China. Night soil treatment processes include mixed composting, ferment fertilizer manufacturing, storage tanks and biogas digesters.

6.1 Mixed Composting

After pre-treatment, domestic waste is mixed with night soil for co-composting in windrows. Night soil can improve the fertilizing quality of domestic waste by adjusting the compost humidity. When the compost temperature rises, most bacteria and worm eggs in the night soil will be killed. However, with this method, only small amounts of night soil can be treated. This method of treatment is difficult, especially in the rain-ridden areas.

6.2 Ferment Fertilizer Manufacturing

In some cities, after de-watering, night soil is mixed with waste or crop straw. Then, anaerobic fermenting takes place in containers during 20 days. After drying, the product is granulated, packed and sold to farmers. As it is easy to transport, farmers welcome it.

6.3 Storage Tanks

This can be developed from the experience in China. Large storage tanks, 1,000 m^3, have been built in Shanghai, Yantai, Chengde, Hefei, Qingdao, etc. for preliminary treatment of night soil and biogas production. The storage period is usually 2-3 months. Moderate-temperature ferment treatment is used in Qinhdao.

It can achieve satisfying sanitary effects in a relatively short time, but costs a lot of energy. Normal-temperature anaerobic ferment treatment is used in Yantai. This saves energy and has good sanitation effects too.

6.4 Biogas Digester

The application of biogas technology in China dates back to the early 1950s, when electricity was not available in rural areas. But it did not last very long due to lack of experience in constructing and maintaining biogas digesters. Since the 1970s, the development of biogas digesters has entered a new phase. Numerous biogas digesters have been built throughout the country. Today, there are 6.5 million family-size digesters serving 3.8% of China's population. A preliminary target of some 20 million biogas digesters and 10,000 electricity generating stations based on biogas has been set. This would supply about 5% of total household energy in near future. The family digester is always connected with the latrine and the pigsty. Human excreta, pig dung, cow dung and crop residues are the main raw materials used as feed stock. For methane production, in volume as well as speed, human excreta are the best among various feed stock. The biogas digester, as a separate treatment method, is more suitable to be used in small townships and villages.

Direct use of night soil and biogas feedstock or supplementary feedstock is frequently associated with the risk of the spread of intestinal parasites and other pathogens. In this context, the Chinese biogas plants have certain advantages in eliminating the risk because of their settling chambers at the bottom have a long detention time of about six months, which destroys more than 90% of the intestinal parasites and other pathogens. Therefore, safe procedures for handling both influent and effluent must be developed. Corrosive H2S is more prevalent in the human waste than in the animal dung. This may adversely affect engines running on the biogas unless the gas is passed though iron filings for purification [15].

VII. NEED FOR TECHNOLOGICAL INTERVENTION

Ecosan or ecological sanitation offers a wide range of options, high tech and low tech, and thus optimal and economic solutions can be developed for each particular situation [16]. The most common technology in ecosan systems is source separation for urine and night soil, vacuum toilets connected with biogas plants, composting toilets or constructed wetlands etc. The list of ecosan projects in the world are listed by GIZ in 2012 and case studies published by the Sustainable Sanitation Alliance [17, 18].

Based on above experience, it is concluded that the major technological intervention required are:

- Alternate technology to collected night soil directly from toilets, i.e. pneumatic night soil collection system in closed drum;
- Transport of night soil, domestic waste and suitable industrial waste to place of treatment;
- Composting and pathogen removal of mix of night soil, domestic waste and industrial waste;
- Packing and transporting of biofertilizer to the farmers for application on farm lands.

` Apart from these issues, following major issues need attention by the scientists.

7.1 Basic Need to Change the Design of Toilets

Presently the toilet designs are based on use of water to flush out the night soil and urine, and then the use of water medium to carry sewage further to treatment plant or to river or lake. In recently developed urban areas, some improved method such as duel plumbing for using STP effluent for toilet flushing is used to save water. However, the sewage is generated. There is no infrastructure developed at most of these places to use STP effluent for irrigation purpose. The first urgent need is to first use all the treated sewage for irrigation purpose and secondly all the sewage should be brought to STP for treatment. Thirdly, technology and infrastructure should be developed for water less separate collection, transport and treatment of urine and night soil (mixing with conditioner preceding to treatment) using various options and their suitability to local conditions to achieve waterless disposal of night soil to achieve zero-discharge residential areas similar to zero discharge industries.

7.2 Soil Bioreactor as Final Sink of Night Soil

Traditionally in India, night soil used to be disposed in soil by various ways, to improve the fertility of the soil. This is the natural cycle by which the materials taken by biotic component from abiotic component of the earth are returned to earth making it rich to support the biological component further. The most famous example of raw human waste application might be China, where human excrement was used for centuries in an attempt to close the nutrient cycle in their fields, something that agricultural scientist F.H. King cited in the early 20th century as the reason behind China's seemingly perennial fertility.

Although there are still many technical problems to be solved, appropriate technology of night soil treatment can provide a safe perspective for re-using night soil in agriculture and aquaculture. There is need to design a bioreactor to utilize soil or industrial waste product as medium to biodegrade the night soil into compost that is pathogen free and physicochemically suitable as compost for the agricultural fields. The water less system was described in Japan due to water scarcity and unavailability of sewerage system [15].

Night soil contains nitrogen and phosphorus much in excess of that needed for anaerobic digestion. Excessive nitrogen present in the digester causes ammonia toxicity, adversely affecting the fermentative process. Excessive phosphorus normally possesses no problem. Co-digestion of night soil with cow dung has a potential to suppress ammonia toxicity, as the quantity of ammoniacal nitrogen released during mixed digestion is low.

Thermophilic digestion of night soil was found to generate more biogas compared to mesophilic digestion, but both these types of digestion has no differential impact on the gas composition. Besides greater gas output, thermophilic digestion also destroys the harmful parasitic ova and pathogenic bacteria present in the night soil. During the performance of night soil based waste stabilization, it was observed that the generation of methane (0.6 m3 of slurry per day) was higher than the conventional digester (0.15 m3/m3 of slurry/day).

VIII. PROPOSED OUTLINE IMPLEMENTATION OF SUSTAINABLE SANITATION

Following basic guidelines are suggested for further research work to develop technology on small and large scale for the waterless treatment of night soil to produce biofertilizer for use in agriculture.

- Avoid use of water or preferably minimum amount of water for disposal of night soil by using appropriate methods like suction method, which is currently used in aeroplanes.
- Separate collection of urine and nigh soil from toilets without using water and greywater from kitchen and bathrooms.
- Treatment of bath/kitchen waste water in Effluent Treatment Plant and diversion of treated water for toilet flushing, or irrigation of garden or farms or to rainwater storage developed in each locality.
- Diversion of rejects of ETP/STP having mineral content to night soil transportation circuit.
- Use of stabilized sediment of STP as biofertilizer in agricultural farms
- Hygienic collection and transport of urine for treatment and final used of treated urine in agriculture as fertilizer
- Hygienic collection and transport of night soil to the place of treatment, which may be a common place for certain residential area or inside housing society or township.
- Use of night soil conditioners (free flowing particulate matter with large reactive area, may be inorganic or organic), such as soil, domestic waste or suitable industrial waste (ex. fly ash/red mud from aluminium plant/ SMS metal slag/lime stone dust in slurry form), to condition night soil to make it suitable for transport, for controlling odor and further processing/treatment at site or at a common place for converting it into biofertilizer, which can be sold to farmers or any person for his garden.
- Research on different options to design night soil treatment unit by augmentation of anaerobic/aerobic processes for conversion within a minimum possible time
- Design of family size and community size treatment units
- Developing infrastructure technology for packing, transport and distribution of composted biofertilizer to the farmers.
- Drawl of river/lake water for domestic use as make up water only by water supply authority.
- Demonstration farms on use of night soil based biofertilizer with emphasis on safety and quality of green agricultural products
- Public awareness programme on safety and benefits of night soil based biofertlizer to the soil and crops
- Smaller drain for rain water harvesting system up to rain water cum raw water pond in the vicinity may be planned; this pond will also receive excess treated greywater. Pipeline interconnection of all raw water/ rain water pond with necessary overflow system to river may be required.

IX. BENEFITS OF SUSTAINABLE SANITATION

9.1 Source of Nutrients for Plants

The agricultural soils are becoming increasingly short of phosphorus [19], which is important limiting nutrient for plants [20]. Similar case is with potassium. It is reported that if collected, phosphorus in urine could supply 22% of total demand [21]. Night soil is also a rich source of organic matter and nutrients to the soil.

9.2 Improvement in soil fertility and Crop productivity

By using biofertilizer, there is improvement of soil fertility, agricultural productivity (green products) and food security.

9.3 Recovery of Nutrients from Waste

Safe hygienic recovery and use of nutrients, organics, trace elements, water and energy from waste is feasible.

9.4 Water resource Conservation

Sustainable sanitation helps in conservation of water resources in good quality, leading to substantial increase in river flow even during lean period. There is reduced water requirement from river for municipal supply system. Intake from river would be reduced from 160 l/day to 20 l/day as makeup water only.

9.5 Conservation of Non-renewable Resources

There is saving of non-renewable resources and energy required for manufacture of chemical fertilizers and availability of biofertilizer would lead to less use of chemical fertilizers. Urea & phosphorous requirement of import will be negligible.

9.6 Saving of Cost of Sewer Line and Sewage Treatment Plant

No sewer line would be required in town/city or villages (as no sewage will be produced), only return water line would be required up to effluent Treatment plant in the vicinity.

9.7 Integrated Waste Management

All so called waste from industries / municipal / domestic areas will be utilized as stabilizing conditioner for making fertilizer with night soil. Thus, there would be no fly ash pond or waste dump yard, saving the precious soil resource.

9.8 Rainwater Harvesting and Groundwater Recharge

Sustainable sanitation would have one rainwater storage pond in each locality to receive run-off water and excess treated greywater which will help groundwater recharge, water conservation and flood control in residential areas.

9.9 Improvement in Aquatic Ecology

Dead zone formation in the river due to high sewage/ phosphorous load being generated will vanish & thus increase aquatic life activities envisaged.

X. CONCLUSION

Our traditional methods as well as the experience in China, Japan, Sweden and America indicated importance of waterless technology for converting night soil in fertilizer, which can be used to develop sustainable sanitation for night soil, urine and domestic waste. This system would help to develop zero waste-discharge residential areas. It is necessary to segregate collection and treatment lines of the kitchen and bathroom wastewater, urine and night soil. Effluent treatment plants may be utilized to treat grey wastewater and the effluent can be used for flushing and for irrigation or industrial use. Treated urine will be used as urea biofertilizer. Night soil may be composted with or without the suitable industrial/domestic waste products, acting as night soil conditioner, with the byproducts of fuel gas and biofertilizer. This will reduce the enormous intake of water; only make up water will be required. As a result rivers would have substantial increased flow and river water that might be utilized for irrigation and water ways. Suitable research intervention is required for pneumatic collection of night soil from the family or community area, its transportation to treatment sites, supply of fuel gas for electricity production or for household cooking, and supply chain of biofertilizers to farmers and consumers to make sustainable sanitation successful and depollution of water resources.

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REFERENCES

[1] Sun Xiaojie, Siming Wang, Jiajie Wang, Wenjing Lu & Hongtao Wang, Co-composting of Night Soil and Green Wastes, Compost Science & Utilization, 20(4), 2012, 254-259.

[2] A.D. Brown, Feed or feedback: agriculture, population dynamics and the state the planet (International Books. Utrecht, The Netherlands, 2003).

[3] C. Lüthi, A. Panesar, T. Schütze, A. Norström, J. McConville, J. Parkinson, D. Saywell, R. Ingle, Sustainable sanitation in cities; a framework for action (Sustainable Sanitation Alliance (SuSanA), International Forum on Urbanism (IFoU), Papiroz Publishing House, 2011).

[4] J. E. Becerril, B. Jiménez, Portable water and sanitation in Tenochtitlan: Aztec culture, Water Science and Technology: Water Supply, 7(1), 2007, 147–154.

[5] Simpson-Hébert, Uno Winblad, Mayling (eds.), Ecological sanitation (2., rev. and enlarged ed.). (Stockholm: Stockholm Environment Institute, 2004a, p. iii).

[6] Simpson-Hébert, Uno Winblad, Mayling (eds.), Ecological sanitation (2., rev. and enlarged ed.). Stockholm: Stockholm Environment Institute, 2004b, p. 67).

[7] A. Rosemarin, EcoSanRes Programme - Phase Two 2006-2010. Joint seminar of DWA and GTZ, Deutsche (Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Germany, 2006).

[8] H. Joensson, A. Richert Stintzing, B. Vinneras, E. Salomon, Guidelines on the Use of Urine and Faeces in Crop Production (Stockholm Environment Institute, Sweden, 2004).

[9] WHO, WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater - Volume IV: Excreta and greywater use in agriculture (World Health Organization (WHO), Geneva, Switzerland, 2006).

[10] Bo Ling, Den Ting-ping, min Lou-wei, Wang Zhu-xuen and Yuan An-xiu, Use of night soil in agriculture and fish farming, World Health Forum, 14, 1993, 67-70.

[11] P. Morgan, Ecological toilets – Start simple and upgrade from arborloo to VIP, (Harare, Zimbabwe, 2010).

[12] P. Morgan, Trees as recyclers of nutrients present in human excreta - Main tree report (Aquamor, Zimbabwe and Stockholm Environment Institute, Sweden, 2011).

[13] Surendra K. Pradhan, Human Urine and Wood Ash as Plant nutrients for Red Beet (Beta vulgaris) Cultivation: Impacts on Yield Quality, Journal of Agricultural and Food Chemistry, (Retrieved 10 February 2014).

[14] A. Richert, R. Gensch, H. Jönsson, T. Stenström, L. Dagerskog, Practical guidance on the use of urine in crop production (Stockholm Environment Institute (SEI), Sweden, 2010).

[15] Magara, Yasumoto, Daisaku Sugito and Kentaro Yagome, Design and performance of night soil treatment plants. Journal Water Pollution Control Federation, 52(5), May 1980, 914-922.

[16] P. Jenssen, J. Heeb, E. Huba-Mang, K. Gnanakan, W. Warner, K. Refsgaard, T. Stenström, B. Guterstam, K. Alsen, Ecological Sanitation and Reuse of Wastewater - A thinkpiece on ecological sanitation (The Agricultural University of Norway, 2004).

[17] GIZ, Worldwide list of 324 documented ecosan projects by various organisations (Gesellschaft für internationale Zusammenarbeit (GIZ) GmbH, Eschborn, Germany, 2012).

[18] SSA, Case studies of sustainable sanitation projects (Sustainable Sanitation Alliance, 2013), Retrieved 18 October 2014.

[19] B.L. Shroeder, A.W. Wood, P.W. Moody and J.H. Panitz, Sustainable nutrient management – Delivering the message to the Australian Sugar Industry, Proc. S. Afr Sug Technol Ass, 79, 2005, 206.

[20] Soil Association, A rock and hard place - Peak phosphorus and the threat to our food security (Soil Association, Bristol, UK, 2010).

[21] R. James, Lauren M. Mihelcic, Ryan Shaw Fry, Global potential of phosphorus recovery from human urine and feces, Chemosphere, 84 (6), 2011, 832–839.