Source Separation: New Toilets for Indian Slums

Dr. Johannes Heeb, Dr. Ken Gnanakan and S.S. Wilson
Abstract

- A new toilet center has been constructed in the Rajendra Nagar Slum (Bangalore/India), which allows separated collection of urine and feces.
  - Urine is used directly as a fertilizer on an agricultural education campus.
  - The feces are professionally composted. The compost is up to now used to grow medical plants on the campus as well as for banana production.

- A new sustainable development concept is being tested here, which tackles the problems of sewage water and feces and creates an opportunity for slum development: The income generated by the project (users fee, compost, bananas) can cover 50 % and more of the running cost of the toilet centers.
Project Context I

Photos:
- 1: Rajendra Nagar Slum (Bangalore/India)
- 2: Open wastewater drains and drinking water well (water-tub not visible)
- 3: Where no toilets exist ...

In the city of Bangalore, which has a population of 6.5 million and is amongst the fastest growing cities of the world, slums are part of the daily scene and are present in all areas of the city.

Rajendra Nagar is a large slum with inhabitants belonging to different caste, religion and race. Since the majority of households in the Rajendra Nagar Slum do not have their own toilet, and only one functioning communal toilet exist, the establishment of numerous compost toilet centres is considered to be of very great significance. Associated with this is the hope that living conditions for many thousands of slum residents will improve, and that in particular considerable improvement will result for women and children. They have so far been forced to carry out toilet activities in the open field before dawn or after dusk. Sexual harassment and rape has been a recurring problem.
Project Context II

- Photo:
  - 4: Meeting with slum women to define project objectives

- In the cultural and religious context of India the handling of feces is a topic that attracts great prejudice. People that come into contact with feces, in particular those who earn their low income through its disposal are positioned at the lowest level of social ranking. This project aims to initiate a process of changing attitude. Through tailored design of the toilets, a cleverly devised logistical system for the transport of the feces, as well as through professional composting it is to be demonstrated that the handling of feces does not represent "dirty work", but rather an interesting income potential for the slum residents.
Project Objectives

- **Improving living conditions**: establish toilet centers to improve living conditions in the slum and to minimize the risk of disease spreading during monsoon flood periods.

- **Compost and fertilizer production**: collecting urine and feces (by using urine separation toilets) for the production of compost and fertilizer.

- **Generating income for slum development**: the compost and urine can be used in agriculture (mainly for non-food production). The income will be used for paying the running costs of the systems.

- **Integrating slum dwellers and self-responsibility**: the slum dwellers will be instructed to operate the toilet systems. Representatives of the slum shall be involved in the project. The project will maintain an emphasis on women and children, but total participation from the whole community will be sought to ensure the success of the program.

- **Changing values in a long term perspective**: in the cultural context of India handling feces is very problematic and difficult. Since the sanitary problem is considered to be key problems of low-income settlement, solutions to solve these problems are very much required. Resolving a cultural stigma is the key to solve this problem and therefore a long-term goal of this project.
# Finding an appropriate Solution

## Need/Demand
Prioritization of problem situation by the slum dwellers (specifically by the women):

1. Access to save and clean toilets
2. Closing open drains

## Economical Frame Conditions
1. Lack of finances to cover drains
2. Lack of jobs in the slum

### Decision to build toilet centers

<table>
<thead>
<tr>
<th>Ecological Aspect</th>
<th>Flush toilet system connected to sewage system</th>
<th>Source separation toilet system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecosystem based design</td>
<td>--</td>
<td>+</td>
</tr>
<tr>
<td>Considering waste as a resource</td>
<td>--</td>
<td>++</td>
</tr>
<tr>
<td>Multi-functionality</td>
<td>--</td>
<td>+</td>
</tr>
<tr>
<td>System integration</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Renewable energy based</td>
<td>--</td>
<td>0</td>
</tr>
</tbody>
</table>

### Decision to build source separation toilet centers
What urine and feces contribute to the wastewater load

Urine and feces together contribute...

- 60 % of organic load
- 99 % of nitrogen
- 100 % of phosphorus

... to the amounts we find in domestic wastewater

The separation of urine and feces from the wastewater flow solves already a big share of the wastewater problem (including hygienical problems.)
Design - Material Flow Concept

- Toilet-center in slum
- Source separation
  - Urine
  - Feces
- Washing water
- Onsite treatment and infiltration
- Composting site on countryside campus
- Green garbage
- Low quality waste paper
- Compost
- Banana production
- Medical plant production, further agricultural production
- Composting
  - Feces
  - Water
  - Urine
- Village/town
- Local computer industry
- Slum dwellers

5.2.2003
Design - Toilet Center

Photos

- 5: Cross section of toilet showing the concept of the source separation
- 6: Toilet after completion. On the right hand side: the small filter system for the washwater. On top of the toilets: two water storage tanks with a volumina of 1000 l each. White pipes on the top of the toilets: Ventilation pipes (not visible on the cross section on photo 5)

Key Figures

- Users per day: ca. 600
- Number of toilet Rooms: 4 for men, 4 for women.
- Number and volume of collecting bins per toilet room: 2 Polyethylene-bins with a volume of 120 l each. One bin for urine storage, one bin for feces storage.
- Dimensions of toilet center: according to local conditions, sizes of bins, etc.
Design - Squatting platform

A: Footrest
B: fecal hole
   20 cm Ø
C: urine hole
   10 cm Ø
D: washwater hole
   10 cm Ø

Photo 7

Figure 1

Photos
- 7: Squatting platform (same type for men and women)
- 8: “How to use the toilet”

Figure
- 1: Cross section of squatting platform
5.2.2003

Design - Source Collection and Maintenance

### Photos
- 9: Urine storage bins (red) and feces storage bins (blue) in service chamber
- 10: Daily change of bins - each bin is replaced by a clean and empty one.
- 11: One third of the volume of the clean fecal storage bins is filled with waste paper before placed in the service chamber. The papers soaks water from anal washing. No waste paper is filled into the urine storage bins!
Design - Transport: “Feces and Urine turn into Resources”

Photos
- 12: Transport of the storage bins with a truck with closed body.
- 13: Closing nutrient cycles between urban and rural areas

Transporting feces and urine with an expensive truck over a distance of ca. 10 km was (and still is to a certain extend) a point of public criticism on the project. It is important to realize that transport of the “resources feces and urine” is needed to close nutrient cycles between urban and rural areas.”
Design - Composting of Feces

Photos

- 16: Compost heaps on agricultural campus. The heaps are covered with tarpaulin in order to avoid water loss caused by evaporation and in order to regulate the temperature in the compost heap in a optimal range of 45 and 55 °C (see also figure 3) A digital rod thermometer is needed to control the temperature. From time to time the tarpaulin shall be removed for watering (e.g. during rainfall). The compost shall be kept humid but not wet.
- 17: Preparing the “compost sandwich” (see figure 2)

Figure 2

- 2: “Sandwich concept” of compost heap. The fresh feces are poured on a pre-prepared bed of compost and waste paper, when covered with green waste and compost. The first turning of the “compost sandwich” is done after 3-4 weeks.
Safety Aspects

- Photos
  - 20: All work staff involved in the project was served with a comprehensive vaccination program.
- While working at the compost facility wear special working clothes (trousers, jacket, gloves, boots). When emptying the drums with the feces wear also safety glasses and a head cover is recommended.
- It is strictly forbidden to smoke, eat or drink in the red zone. After working in the red zone take off the working clothes and wash hands and arms before smoking, eating or drinking. The same procedures are recommended after working outside the red zone.
- Working clothes and tools should be kept separately. When ever possible expose them to direct sun light. Wash the working clothes at least once a week with washing powder at 80-90°C.
- The tools must be cleaned at the end of each working day.
- Injuries of the skin must immediately be disinfected and protected from further infection by dressing the wound. Therefore, the foreman has to carry a small first-aid box.
Controlling the Compost Process

Temperature control
- Among the most important controls is the daily check of the temperature in the compost heaps in the course of time. This allows to be sure to work within the safety zone (see figure 3). The temperature is measured with a digital rod thermometer. The temperature shall be recorded in a process protocol.

Control of the mixture of feces and additions.
- Record weight or volume of the used additions, the amount and the characteristics of the feces (dry, normal or humid) and record it in the process protocol.

Humidity control
- While the composting process on the stacks lasts, humidity has to be controlled at least each time the material is restacked; this is done by hand. If necessary it has to be corrected by adding liquid or by mixing with dry or wet compost.

Control of Compost quality
- The compost quality has to be controlled and monitored.

### Agronomic Parameters of Compost Sample

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Result</th>
<th>Guide Number</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dry matter (dm)</td>
<td>59.3 %</td>
<td>46%</td>
<td></td>
</tr>
<tr>
<td>org. matter</td>
<td>46.3 %</td>
<td>35%</td>
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</tr>
<tr>
<td>total N</td>
<td>31.1 kg/t dm</td>
<td>13 kg/t dm</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>10.7 kg/t dm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P2O5</td>
<td>24.4 kg/t dm</td>
<td>7 kg/t dm</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>7.8 kg/t dm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K2O</td>
<td>9.4 kg/t dm</td>
<td>9 kg/t dm</td>
<td></td>
</tr>
<tr>
<td>Mg</td>
<td>6.8 kg/t dm</td>
<td>8 kg/t dm</td>
<td></td>
</tr>
<tr>
<td>Ca</td>
<td>32.1 kg/t dm</td>
<td>70 kg/t dm</td>
<td></td>
</tr>
<tr>
<td>Pb</td>
<td>43.5 kg/t dm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cd</td>
<td>0.4 kg/t dm</td>
<td>1 kg/t dm</td>
<td></td>
</tr>
<tr>
<td>Cr</td>
<td>41.3 kg/t dm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td>155.0 kg/t dm</td>
<td>The high content of Cupper has to be investigated</td>
<td></td>
</tr>
<tr>
<td>Hg</td>
<td>0.6 kg/t dm</td>
<td>1 kg/t dm</td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>22.7 kg/t dm</td>
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</tr>
<tr>
<td>Zn</td>
<td>297.0 kg/t dm</td>
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</tr>
</tbody>
</table>

Photo 18: Compost sample (before screening)

The high content of Copper has to be investigated
Impact of Temperature and Compost Turning

Figure 2: Zone of safety of the fecal composting process for Enteroviruses (Ev), Salmonella (Sa), Shigella (Sh), Vibrio cholerae (Vc), Entamoeba hystolytica cyst (Eh), Ascaris eggs (A) and Taenia eggs (T). The red field shows the time-temperature range of the Banglore compost site. (Source !)

Figure 3: Impact of compost turning on the survival rate of Ascaris eggs in compost

Photo 19: Dead („cooked“) Ascary egg (compost sample taken in September 2002).
Urine and Compost Utilization

Photos:
- 14: Jeyraj, in front of the urine storage containers on the agricultural campus. The containers are used to store and dilute the urine.
- 15: Bananas and maize growing on diluted urine and fecal compost.

The urine has to be diluted (dilution rate: 1:20) before used as a liquid fertilizer. The urine can be used for all kind of highly Nitrogen consuming agricultural crop.

The compost can be used for all kind of agricultural crop with the exception of salads or other kind of freshly consumed and not peeled vegetables.
5.2.2003

Material Flows

- toilet-center in slum: 600 users per day
- source separation
  - urine: 200 t/year
  - feces: 100 t/year
- onsite treatment and infiltration
- washwater
- transport to composting site on countryside campus
- compost: 50 t/year
- medical plant production, further agricultural production
- banana production: 50 t/year
- onsite treatment and infiltration
- water
- feces
- green garbage
- low quality waste paper
- compost
- village/town
- local computer industry
- slum dwellers
- transport to composting site on countryside campus
- village/town
- local computer industry
## Estimated Value of Urine and Feces

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Users per day</td>
<td>600</td>
<td></td>
<td></td>
<td>Cost per kg NPK fertilizer</td>
<td>$0.20</td>
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<tr>
<td>Urine per user and day</td>
<td>1.0 kg</td>
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<td></td>
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</tr>
<tr>
<td>feces per user and day</td>
<td>0.5 kg</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Urine per year</td>
<td>219 t</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Feces per year</td>
<td>109.5 t</td>
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</tbody>
</table>

### Nutrient Content

<table>
<thead>
<tr>
<th>Nutrient content of urine per adult and day</th>
<th>Total amount per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>1.0 g</td>
</tr>
<tr>
<td>P</td>
<td>2.0 g</td>
</tr>
<tr>
<td>K</td>
<td>2.0 g</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nutrient content of feces per adult and day</th>
<th>Total amount per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>1.5 g</td>
</tr>
<tr>
<td>P</td>
<td>0.5 g</td>
</tr>
<tr>
<td>K</td>
<td>1.0 g</td>
</tr>
</tbody>
</table>

### Nutrient Value per year

$745
## Costs/Economics

<table>
<thead>
<tr>
<th>Investment</th>
<th>Amount</th>
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<tbody>
<tr>
<td>Construction of Toilets</td>
<td>$7'000</td>
</tr>
<tr>
<td>Construction of Compost site</td>
<td>$4'000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Running costs per year</th>
<th>Income per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salaries (8 Workers)</td>
<td>$8'000</td>
</tr>
<tr>
<td>Users Fee</td>
<td>$3'000</td>
</tr>
<tr>
<td>Transport</td>
<td>$2'220</td>
</tr>
<tr>
<td>Bananas and Medical Plants</td>
<td>$5'000</td>
</tr>
<tr>
<td>Administration</td>
<td>$1'600</td>
</tr>
<tr>
<td>Nutrient Value of compost and feces</td>
<td>($ 750)</td>
</tr>
<tr>
<td>Maintenance and Depreciation</td>
<td>$3'250</td>
</tr>
<tr>
<td>Total Running Costs</td>
<td>$15'070</td>
</tr>
<tr>
<td>Net Costs</td>
<td>$7'070</td>
</tr>
<tr>
<td>Cost per user and Year</td>
<td>$12</td>
</tr>
</tbody>
</table>
Institutional Setup

- Project Initiation: ACTS (Banglore) in co-operation with seecon international gmbh
- Project Design: ACTS (Banglore) in co-operation with seecon international gmbh and slum representatives
- Project Management and Administration: ACTS (Banglore)
- Maintenance of Toilets in Slum: scavenger people of the slum
- Composting on Agricultural Campus: ACTS stuff with the help of scavenger people
Further Development

- The project is still under development. The experiences of the first project phases prove the feasibility of the concept. Nevertheless the following aspect will be in the foreground of the next year:
  - Process optimization:
    - Optimization of urine utilization (e.g. for Banana production), feces composting and fecal compost utilization.
    - Optimization of process, operation and maintenance (in progress)
    - Using new additives like dry leaves, etc.
    - Monitoring (Nutrient and Hygiene Aspects)
  - Knowledge Transfer and Assessment
    - Education and Information (Workshops Seminar with NGOs, Governmental Officials, etc.)
    - Knowledge transfer to rural villagers and farmer, schools, etc.
    - Comparative assessment of the system (nutrients, energy, environmental impact, economic viability)
  - Product utilization
  - Production of medical plants (on ACTS-Campus as well as in co-operation with local farmers)
  - Training programs for poor farmers as well as in mulberry, tee and coffee plantations
    - Preparing long-term monitoring project (see appendix).
Required Frame Conditions / Decision Support Aspects

- **Needed skills and capacity aspects**
  - Maintenance of toilets: No specific skills but proper supervising is needed.
  - Logistics - replacing bins and transport: Driver with lorry drivers license. Workers: No specific skills but proper supervising is needed.
  - Composting: No specific skills but proper supervising is needed. The supervisor has to be trained in fecal composting.

- **Application field**
  - The toilet system developed in the project can be considered as an appropriate concept for all kinds of low-income settlements as well as in countryside villages in developing countries. Warm climate conditions support the hygienization process.

- **Arguments to promote technology**
  - Low investment and running costs (income generated by selling compost and bananas can cover up to 50% of running costs).
  - New jobs are generated.
  - Cost of sewer system and wastewater treatment system can be reduced.
  - The valuable nutrient potential of urine and feces can be used.

- **Restrictions for application of technology**
  - Cold climate conditions hindering the compost process
  - Lack of land for composting
Results / Impact / Assessment

By S.S. Wilsson, local project manager

- The toilet-center in the Rajendra Nagar slum was built with the objective of separating urine and feces and converting feces into compost rich in nitrogen content, a practice ignored or shunned over decades. Initially it was feared that reintroducing the practice of converting feces would be opposed due to prevailing culture observed and respected by the people. Considerable time and effort was made to convince the people that human feces were not a waste product, but a rich resource for production of compost.

- To this date the toilet-system is working satisfactorily and to our expectations. For improvement, further methods are being trialled to bring about greater efficiency and to curtail expenditure. Labour is the main constraint and must be dealt with carefully as otherwise workers will put down their tools and quit without notice. Scavengers are not freely available for employment hence replacements are difficult. Thus every part of the project is of paramount importance and must be handled with personal and constant supervision.

- Undoubtedly there is immense appreciation from the people using these toilet-facilities since they were suffering without toilet facilities for a long period. More specifically, the women are very grateful for providing toilet facilities. The women in particular are very happy and content because this toilet provides them all facilities such as water, electricity and reliable wardens who keep the toilet in a very hygienic state all the time. Above all women using the toilet have the assurance of safety and security because the project is run by a responsible organization that pays personal attention to all aspects of this project.

- Conclusion: After the completion of one year we have achieved the desired objectives and it is noteworthy to mention that the public has co-operated well and has accepted that human feces and urine are a valuable resource. Although initially there were some constraints with regard to cultural practices we have comfortably overcome all negative thinking. It is hoped that this eco-friendly toilet will be replicated and the public will realize the value and benefits that could be derived from human waste and urine.
Lessons learned

- **Cultural and social aspects**: Even working in a cultural context where handling feces is considered to be very problematic, the project proved to be feasible. But referring communication is a key prerequisite to success.

- **Technical aspects**: The entire design of the project proves to be feasible. More work has to be done in up-scaling aspects: The existing projects serve toilet access to ca. 600 users. The entire project design has to be adjusted for bigger scale applications.

- **Economical aspects**: The target of the project was to cover all costs investment and running costs by the generated income. The experiences of the existing project show what this cannot entirely be achieved. But the average annual net cost of the project of ca. USD 20 per person proved the project to be economically feasible.

- **Safety aspects**: The experiences prove that a safe handling of the feces as well as the production of a high quality compost is feasible.
References, Literature


Links
  - ecosan: http://www.gtz.de/ecosan/
  - sanitation connection: http://www.sanicon.net
  - Link list to relevant organizations: www.ecosanres.org/EcoSan%20Organisations.htm