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| <b>Author(s)</b>   | Hammer, Martina<br>Avendano, Viviana<br>Christiane Jung   |
| <b>Address</b>   | Institut of Wastewater Management, AB 1-02, TUHH,<br>21071 Hamburg, Germany<br>International Biogas and Bioenergy Center<br>Heimstr. 1, 74592 Kirchberg/Jagst, Germany  |
| <b>Telephone</b>   | +49-40/428782982<br>+49-7954/926203<br>+34-966697598  |
| <b>Fax</b>   | +49-40/428782684<br>+49-7954/980330   |
| <b>Mobile</b>  | +34-656726410   |
| <b>E-mail</b>  | <a href="mailto:m.hammer@tuhh.de">m.hammer@tuhh.de</a> , <a href="mailto:mvivia@yahoo.com">mvivia@yahoo.com</a> , <a href="mailto:c.jung@tu-bs.de">c.jung@tu-bs.de</a>  |
| <b>Short CV for Introduction Purposes ( 100 words max)</b> | Presenter will be Martina Hammer.<br>Martina Hammer graduated with a M.Sc. in Agroecology from the Norwegian University of Life Sciences. She specialised in the field of wastewater recycling. Now, she is enrolled in PhD studies at Hamburg University of Technology as a DBU scholarship holder working in the field of pharmaceutical residues in urine. |
| <b>Photograph attached ( jpg)</b>                          |    |

# **Implementation of ecosan in Havana's urban agriculture and the potential of urine as organic fertilizer**

## **Introduction**

Cuba, especially Havana, is facing problems of wastewater treatment and supply of fresh food products in particular through its political insulation combined with an ongoing urbanization and extension of its cities (ONE, 2002). Experience and successes in the implementation of organic agriculture, well-working agroecosystems in the countryside, and people's own initiative in setting up small gardens inside the cities, started to encourage urban agriculture. Raul Castro, the successor as political leader of Cuba created its future vision: to guarantee and even extend the success of urban agriculture he plans to use all free areas in Havana for the establishment of agriculture until the year 2006. The hope is to minimize and even close Havana's lack in food supply. This goal is difficult to realize because water needs for gardens often compete with the needs of citizens. Also, gardens experience a one-way flow in their nutrient management. Nutrients are leaving gardens in form of food products; they are not recycled to guarantee nutrient supply for gardens. On the other side, wastewater management and sanitation systems lack capacity and are in urgent need of rehabilitation (Alonso & Mon, 1998). Drinking water and sanitation systems of Havana are summarized as having an old, insufficient infrastructure and a large deficiency of treatment equipment; hence, most of the water is released untreated into the sea (Alonso & Mon, 1998).

Recently, the idea was born to use the one for the benefit of the other. Wastewater provides water, nutrients, and organic matter to urban agriculture while urban agriculture provides its treatment. Through this linkage, it becomes possible to optimize nutrient cycling and organic matter accumulation, to close the energy flow, to reuse resources, and to sustain urban agriculture as well as wastewater treatment in combination with secure food production and higher supplies for the urban population. On this principle of closing the loop between sanitation and agriculture the new sustainable sanitation concepts known as ecosan (ecological sanitation) are based.

Some cases of wastewater use in urban agriculture in Havana already exist. Reasons are unavailability of other water sources in the outskirts of Havana, scientific interests, knowledge of the positive sides of wastewater, and interests in an improvement of Havana's wastewater treatment problem. But until now, only untreated wastewater is used in fruit and flower production.

The aims of this study were:

- (i) To describe Havana's urban vegetable production and to analyze production constraints
- (ii) To explore the potential of ecological sanitation approaches for providing water, organic matter and nutrients.

The first aim was conducted in the first part of the study to gain a wide overview of the situation of urban vegetable production in Cuba, specifically Havana. The second part goes more into details and was part of a GTZ-ecosan supported research project. Hence, this study focuses on the possible approaches addressing challenges to reuse wastewater under ecological sanitation principles.

## **Material and methods**

### **Selection of investigated gardens**

For the first period ten gardens were selected to represent the variety of size, purpose (i.e., crop production versus research and demonstration gardens), ownership (private versus public), and management practices. The gardens ranged from 144 m<sup>2</sup> to more than 8000 m<sup>2</sup>. The smallest were private while the larger ones were owned by national research

organizations active in the area of urban agriculture or by EHM, the urban horticulture company that owns most of the gardens in Havana.

### Interviews

Two different kinds of interviews were conducted to address the groups working with urban vegetable production. The reason was to receive a balanced overview from stakeholders working in the gardens and active in the scientific research and administration. Gardeners/administrators were asked to answer a pre-prepared interview schedule. Onsite observation took place to gain additional information and an improved understanding of the situation of the gardens. Later on, several visits were added to ask for further details, reassurance, and to talk to other people working in the gardens. With this strategy it was possible for the gardeners to gain a better knowledge about the interviewer and her interests and they could add valuable information. Members of non-governmental organizations, governmental institutions, and scientific experts were interviewed with the help of specific case-designed interview schedules. The data collected were of qualitative and quantitative character. Data about production management was used qualitatively to present and explain the management system. Results on water, nutrient, and organic matter supply of the 10 gardens are shown in numbers.

### Water measurements

Water was assumed to be a limiting factor for urban vegetable production. Therefore, this aspect was addressed by measurements of the amounts of water ( $l/m^2 \cdot d$ ) available for the gardens. Four different methods were used dependent on the specific garden's situation. The amounts of water were conducted by measuring the volume used daily out of the storage tank, the administrator knew the specific amounts applied, water supply was calculated with the help of information given by the gardeners and by water meters installed onsite, or the water was determined by volumetric-flow measurements (Yoo & Boyd, 1994).

### Organic matter measurements

Next to water, organic matter was conducted as limiting factor. Therefore, measurement of organic matter supply was done. The method used depended on what type of organic matter was addressed. In the case of compost, compost piles were measured and the amounts calculated by the times applied per year and  $m^2$ . When the organic matter was bought, the gardeners could give information in most cases on how often and how much (per  $m^2$ ) they applied. If this was not possible, the amount had to be estimated: truck loads per year and average bulk density of compost (average moisture of  $1 m^3 = 600 kg/m^3$  (Esser, personal communication)). These results were supported by analysis of the nutrient content of randomly sampled lettuce plants *Black Seeded Simpson* cultivated in the gardens.

### Workshops

In the second period, workshops with 80 local farmers were taken as an initial step to introduce and discuss the ecosan approach for Havana's urban agriculture. The farmers were interrogated regarding their personal opinion before and after the workshop to detect the tendency of the reuse of wastewater in urban agriculture. The workshops were also used to find farmers willing to cooperate in more detailed investigations under local conditions.

### Field trials

One garden of the first period was selected to continue with more detailed research on the impact on lettuce, variety *Black Seeded Simpson*. The cultivation process was only changed in the aspect of fertilization. Everything else like irrigation and plant disease control were kept the same. The measures of the trials were  $6.9 m^2$  and the height  $0.1 m - 0.2 m$  above ground level. The total area was  $75.6 m^2$ . The distance between the plants was  $0.1 m$  and the plant density was 360 plants per trial. A block design was implemented with two different treatments regarding fertilization. The design included one repetition of the original one. Two different soil substrates were used: one was newly prepared with organic matter for

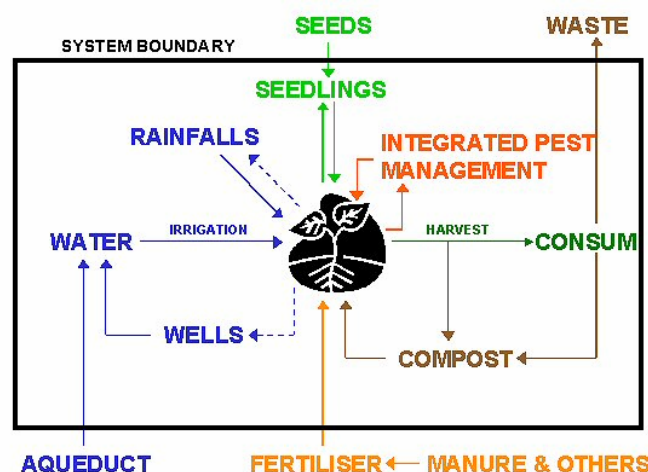
cultivation purposes following the recommendations of the ministry (MINAG, 2003); the other one was left untreated since the last harvest. The two treatments were: a. fertilization of the plants with diluted urine and b. no application of additional fertilizer during cultivation. Treatment b represents the usual practice of the farmers. Both treatments were tested on both soil types. The combination untreated/no application worked also as overall control for the experiment. The urine was kept 9 weeks in plastic tanks. To ensure the hygienic conditions of the product pH was checked once a week. Immediately before application the urine was diluted with water in relation 1:5 and 3 l/m<sup>2</sup> were applied once before cultivation and once during cultivation of the lettuce plants. Nutrient analysis was conducted as shown in Table 1. The statistical analysis was conducted with SATRGRAPH 4.1. When significant differences appeared the Duncan test was applied to determine the sequence of the mean. This experiment was conducted in participation with the Agricultural University of Havana.

**Table 1:** Analysis conducted in field trials

| Measurements                                | Method           | Analysis |      |        |
|---|------------------|----------|------|--------|
|   |                  | Urine    | Soil | Plants |
| pH  | pH-meter         | X        | X    |        |
| Total Nitrogen                              | Messler          | X        | X    | X      |
| Phosphorus (P <sub>2</sub> O <sub>5</sub> ) |                  | X        | X    | X      |
| Potassium                                   | Flame photometry | X        | X    | X      |
| Organic matter                              | Walkley y Black  |          | X    |        |
| Ca <sup>++</sup> /Mg <sup>++</sup>          | Volumetric       |          | X    |        |
| Yield (kg/m <sup>2</sup> )                  |                  |          |      | X      |

## Results and discussion

To provide a better overview about the meaning of urban vegetable production means, the vegetable gardens are presented in their production system (see Figure 1). The different subsystems as cultivation system, seeds & planting, pest management, water, nutrient, and organic matter supply are pointed out to present the material flows of the system and to show the imports into and exports out of it. The garden system's boundary is defined according to the spatial dimensions of the gardens. For example, everything leaving the garden's area is declared as export.



**Figure 1:** System's scheme

The limiting factors for urban agriculture can be seen in the imports towards the system. They are: seeds, water, fertilizer and organic matter. All imports besides seeds can be supplied by ecosan, therefore they were investigated more in detail.

Water for the gardens originates from wells installed on the site or the urban drinking water network supplies the gardens. The priority use of drinking water is for domestic purposes. Usage in agriculture is accepted nowadays, but official approvals by the state are planned for the near future. The investigation shows that there exists a wide range (from 0.28 to 14.3 l/m<sup>2</sup>) in the actual water supply between the different gardens. Only three gardens (No. 2, 8, and 10) are below the lower value of 4 l/m<sup>2</sup>\*d. In contrary, two gardens (No. 3 and 4) show very high daily amounts, and it has to be doubted if they are really true.

**Table 2:** Water supply in the gardens

| Garden No.                            | 1 | 2       | 3        | 4        | 5       | 6   | 7       | 8       | 9   | 10   |
|---------------------------------------|---|---------|----------|----------|---------|-----|---------|---------|-----|------|
| Amount of water (l/m <sup>2</sup> *d) | 6 | 2.1-3.1 | 6.8-10.2 | 9.7-14.3 | 5.0-5.2 | 4.3 | 3.9-4.3 | 3.5-4.2 | 6.4 | 0.28 |

Overall, water supply is not a problem, although there is a slight difference between larger and smaller gardens. Good water supply depends more on the administration of each garden and the administrators'/gardeners' agility and cleverness than on the size and legal/production type. The gardens below the mark of 4 l/m<sup>2</sup> support this result: one is small, one is medium, and one is large. Another influencing factor is that the survey was conducted from June till September – the rainy season in Cuba. So, people might have more problems, especially if they get their supply from the official drinking water net, in winter when the precipitation is lower. Precipitation is the main source of supply the official net relies on (Vasqu ez & Cordero, personal communication).

The organic matter supply was discovered to be very important because the majority of nutrient input is accomplished through it. Gardeners also reported the importance of supply due to high losses by intense and short cultivation times, settling of the soil, and erosion. Also, the topsoil is of poor quality (Companiononi et al., 1997). Topsoil is often mixed with foundation material from ruins, which contain high amounts of sand and do not support the vegetable production. Four main types of organic matter are manure, cachaza, humus, and compost. While compost is mainly produced in the gardens, the others are imported. The situation gets even more complicated because the availability of city-based organic matter is low. Moreover, importing organic matter requires administration, organization, and affordable and dependable transportation. As a result, importing organic matter is the highest expense in urban gardening following salaries.

**Table 3:** Organic matter supply of the gardens

| Garden No.                               | 1    | 3       | 4    | 5       | 6    | 7    | 8   | 9   | 10  |
|--|------|---------|------|---------|------|------|-----|-----|-----|
| Area under cultivation (m <sup>2</sup> ) | 8060 | 4800    | 2040 | 1970    | 1400 | 1120 | 900 | 320 | 140 |
| Amount of OM (m <sup>3</sup> /ha*y)      | 200  | 300-500 | 391  | 563-792 | 167  | 11   | 24  | 7   | 0   |

Official sources mention that an organic matter application rate of 33-167 m<sup>3</sup>/ha\*y is needed (Barcaz Lescaille, 2000). The higher amount is suggested for intense gardening. All persons interviewed claimed their organic matter as insufficient. Gardeners report they needed 2000-3000 m<sup>3</sup>/ha\*y. Only the gardens supported by official bodies like EHM and research institutions have a sufficient organic matter supply according to the official sources stated above. An explanation can be that the recommended amount of 33-167 m<sup>3</sup>/ha\*y might cover the nutrient supply of plants but not the requirements stated by the gardeners. The volumetric amount they need is higher due to material losses. This also explains the variation between the amounts expressed to be necessary.

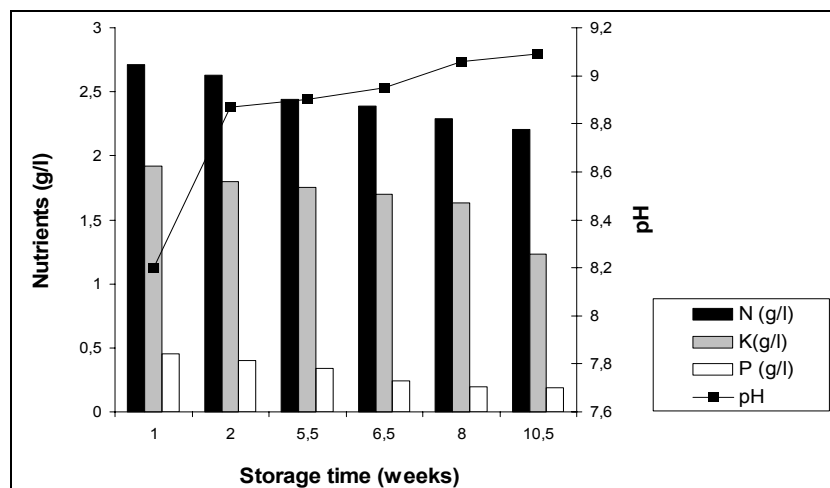
These results were supported by analysis of randomly sampled plants in some of the gardens. The plants show lacks of N (< 4.0-5.5% of total nitrogen referring to Bergmann (1993)), for both state institutions and normal gardens. Also the amounts of P and K are at the lower end of the scale in case of the normal gardens. The plants raised in research beds of state institutions had more nutrients than in the normal gardens. An explanation is a better supply of water and organic matter in national research organizations as well as having technical support (scientists) on site. In general, it became clear that the supply of nutrients for plants is very closely linked to the supply with organic matter, and if this supply is insufficient, the nutrients' contribution will not reach an acceptable level.

With the ending of the first period, the following results were attained: The water supply for the gardens in Havana is not the constraint as it was assumed to be. This finding is shown in the ten cases, where seven of them have a secure water supply, and other stakeholders reported the same. Only in Old Havana large problems were mentioned, and stakeholders were looking for alternative solutions including the ecosan aspect of greywater reuse. In general, if gardeners want to change their system, they prefer to dig a well for an assured and independent water supply, rather than to depend on greywater reuse. Another strong argument against greywater reuse is the low cost for water and water conveyance/irrigation systems. Gardens pay for a fixed volume, so most do not have water meters, or in case they have, they have a fixed cost for a certain volume and extra charges for use over the limit. Additionally, they do not have to worry about health hazards, maintenance, and monitoring. The situation might change in the near future. Experts anticipate changes in water regulations for use in urban agriculture. Then, greywater reuse becomes a promising alternative.

In contrary, an improvement regarding organic matter supply is strongly needed in the urban vegetable production. The utilization of blackwater fractions could be a potentially effective solution to the observed nutrient and organic matter deficiencies. Although it is technically possible (Palmquist, H. & Jönsson H., 2003; Beckmann, U., personal communication) the socio-cultural aspects have to be taken into considerations. This was the starting point for the second period of the project.

The socio-cultural aspects were determined by workshops with local farmers. The objectives were to inform the farmers regarding the positive and negative effects of an implementation of ecosan in Havana's urban agriculture. The interviews before and after showed an increased acceptance of the ecosan products after the workshop and a generally higher acceptance for urine than for faeces; urine acceptance even increased from 53 to 94%. Reasons for this tendency were the fear regarding the hygienic aspects and the easier application of urine compared to faeces. Therefore, urine was used for the experiments in the second period of the project.

The analysis of the urine used in the experiment corresponded to the values reported in the literature (Johansson, 2000). The pH after 9 weeks storage time increased until 9.1 while the concentration of the nutrients decreased as expected. The final concentration of total nitrogen was 2.21 g/l, of phosphorus 0.19 g/l and of potassium 0.9 g/l (see Figure 2).



**Figure 2:** Nutrient content and ph of urine during storage time

The results of the field trials show significant differences (see Table 4). The highest yield was obtained when urine was applied on soil substrate freshly enriched with organic matter. The yield was 3.39 kg/m<sup>2</sup>. The usual method used, as it was detected in period one, brings a maximum of 2.97 kg/m<sup>2</sup>. While without organic matter the yield is only 2.16 kg/m<sup>2</sup>. This reflects the present situation, when no organic matter is available as observed quite often in smaller gardens.

**Table 4:** Yields of lettuce obtained with different treatments

| Treatment             | Yield    |                   |
|-----------------------|----------|-------------------|
|                       | kg/plot  | kg/m <sup>2</sup> |
| Urine/prepared plot*  | 27.495 a | 3.39 a            |
| Urine/unprepared plot | 26.35 a  | 3.25 a            |
| Prepared plot*        | 24.08 b  | 2.97 b            |
| Unprepared plot       | 17.50 c  | 2.16 b            |
| ESx p<0.05**          | 1,600    | 0,33              |

\*prepared with organic matter

\*\*According to Duncan's Multiple Range test (based on a probability of error of p<0.05) significant differences in the mean are represented by different letters (see Table 4).

The results given in Table 4 were also seen by visual inspection. The lettuce plants fertilized with urine were of a more intense green color and the leaves were larger than of those plants cultivated without additional fertilizer. Similar observations were obtained by farmers who did analogous experiments by themselves with ornamental plants.

## Conclusion

According to the results obtained, it can be concluded that the biggest motivation for the use of ecosan systems in Havana is the demand for a qualitatively good and hygienically safe source of fertilizer and organic material, which must be available and accessible in the urban scope.

The water supply is not the main constraint for the gardens in Havana in the given situation. However, it might change in the near future, when the expected changes in water regulations for use in urban agriculture have been introduced. Then, greywater reuse becomes an approaching alternative.

There exists acceptance for the recycling of nutrients from household wastewater for agricultural purposes mainly using the domestic wastewater fraction yellowwater. Investigations need to be done for implementation of decentralized collection possibilities for urine on local level and for the standardization of guidelines for handling of this wastewater fraction. In addition, experiments using fermented human urine as organic fertilizers are recommended to detect the optimal dosing and agrarian-ecological handling of this product. The guidelines need to be developed in cooperation with the responsible ministries.

To overcome the lack of organic matter, blackwater recycling and implementation should be investigated as well. By demonstration and implementation at research scale, unfounded fears can be cut back and real risks explored.

In general, ecosan is a valuable way which should be discussed further for Cuban conditions. Especially, regarding nowadays' situation where a high demand for fertilizer and maybe in the near future also for water exists. As this research project shows, the farmers are interested in the topic and willing to explore it further.

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