

Experiences from the EcoSan full scale pilot project solarCity Linz

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ABSTRACT

In the city of Linz, Austria, a project designed for 460 population equivalents using urine separation toilets was started in 2004. The closure of the material flow cycle as one main target is being carried out in this project by means of urine separation toilets, compost filters and constructed wetlands. Only about 10% of the people who moved there did so on account of this ecological sanitation project. After six months of operation the first survey, including the urine separation toilet performance, was conducted. Most of the practical problems in operation result from the wrong type of maintenance or the incorrect use of the separation toilets (people have to be sitting down while urinating). The key issue, which has become apparent, was the improvement of public relations to increase the amount of information for the inhabitants. Additionally, results of a mass balance show the practical loss from urine separation toilets of nitrogen. This paper demonstrates the advantages and drawbacks of ecological sanitation concepts made in practice.

KEYWORDS

Compost filter; constructed wetland; ecological sanitation; sustainability; urine separation

INTRODUCTION

In recent years centralized urban drainage systems have mainly been built to fulfil the requirements of sanitation facilities in densely populated areas. Conventional sanitation collects and transports wastewater in the sewer using (drinking) water as a transport medium. In Western countries this flush-and-discharge option is the norm. Ecological Sanitation (EcoSan) is a method that can be applied to deal with the problems of end-of-pipe sanitation and is, therefore, an alternative approach to avoid the disadvantages of conventional wastewater systems (Langergraber and Muellegger, 2005). Human urine and faeces are recognized as resources which should be reused, and not only seen as waste products. The main aspects of source orientated systems are (Werner *et al.*, 2003):

- reducing the health risk related to the sewer system, contaminated water and waste
- preventing the pollution of surface water and groundwater
- preventing the degradation of soil fertility and
- optimizing the management of nutrients and water resources.

Wastewater can be seen as a resource; the nutrients nitrogen (N), phosphorus (P) and potassium (K) in particular are alternatives to commercial fertilizers (Lienert *et al.*, 2003). Phosphorus is an essential nutrient for all life forms and is a key element in many physiological and biochemical processes. Therefore, phosphorus is usually the critical limiting element for animal and plant production. Current estimations of figures vary from 60–130 years when irreplaceable phosphorus resources will be exhausted (Steen, 1998).

According to Jönsson *et al.* (2004) approx. 75-90 % of nitrogen in the urine is excreted as urea and urea is quickly hydrolysed to ammonium, usually within hours. Ammonium is directly plant-available and an excellent nitrogen fertilizer. Urea and ammonium are two of the most used nitrogen fertilizers in the world.

The possibility of nitrogen, phosphorus and potassium recycling in agriculture as substitute of commercial fertilisers, where small losses of nitrogen in the form of ammonia appear in reality, was already demonstrated by Jönsson (2002).

Wastewater can be divided into

- yellow-water (urine including flushing water),
- brown-water (faeces),
- black-water (mixture of urine and faeces) and
- grey-water (wastewater from the laundry, kitchen, bathroom, etc.).

According to Otterpohl *et al.* (2003) approx. 87% of the nitrogen and about 50% of phosphorus present in household wastewater is to be found in urine. Of course, these figures vary in reality; other research works have confirmed the range of these figures – nitrogen from 70 to 90 % (see e.g. Jönsson, 2002; Larsen and Gujer, 1996; Larsen *et al.*, 2001)

Many source orientated projects have already been carried out worldwide on a small scale (e.g. Wendland and Oldenburg, 2003; Oldenburg *et al.*, 2003; Lienert and Larsen, 2006). But there is still a lack of practical on-site experience with medium to large scale pilot projects.

MATERIAL AND METHODS

Project solarCity Linz

In 1992 a master plan for Linz-Pichling, located in the southern part of the city Linz, Austria (approx. 200,000 inhabitants), was elaborated for this new city district named *solarCity*. The development area *solarCity* was built with a view to being an “Ecological Residential Area”. From 1995 to 1998 several architectural and landscape design competitions took place which led to the design of 1,300 new apartments, in a low energy building standard, on an area of about 60 hectares. In addition to new technologies such as solar technology or energy-saving technology, an ecological sanitation concept for a part of this area is also one of the innovative ideas behind *solarCity*.

The project *solarCity* was carried out by the local public service company LINZ AG (project management) in cooperation with the project partners OtterWasser GmbH (design), Engineering Consultant Steinmüller (project management, process engineering), and the Hamburg University of Technology, the Institute of Wastewater Management and Water Protection (scientific consultancy). The total costs (investment, operation, maintenance, research sponsorship, etc.) are fully covered by the LINZ AG company. The LINZ AG

company sees this research project as part of the company's responsibility towards society. LINZ AG is the second largest public service company in Austria.

The construction of all parts (separation toilets, urine collecting pipes, etc.) and the on-site information, provided at the latest in the course of signing the rental or sales agreement, were done by the three non-profit residential cooperatives (each cooperative was responsible for two apartment buildings). A public residential cooperative was charged with these tasks for the day nursery and school. A contract between each residential cooperative and the LINZ AG regularizes all tasks of the project partners. One very interesting aspect of this contract is the total cost coverage for adapting the existing project *solarCity* to a conventional sanitation system by the LINZ AG company in the case of a possible failure of this project *solarCity*. Public relation work was not successful and satisfying. Hence, public relations had been changed in the course of this project and is now fully being conducted by the LINZ AG company and the city of Linz. Something which is also interesting is the fact that only about 10% of the people who moved there did so on account of the urine separating project. Therefore, the practical experiences made by the inhabitants living there help to gather important information about the acceptance of source orientated concepts.

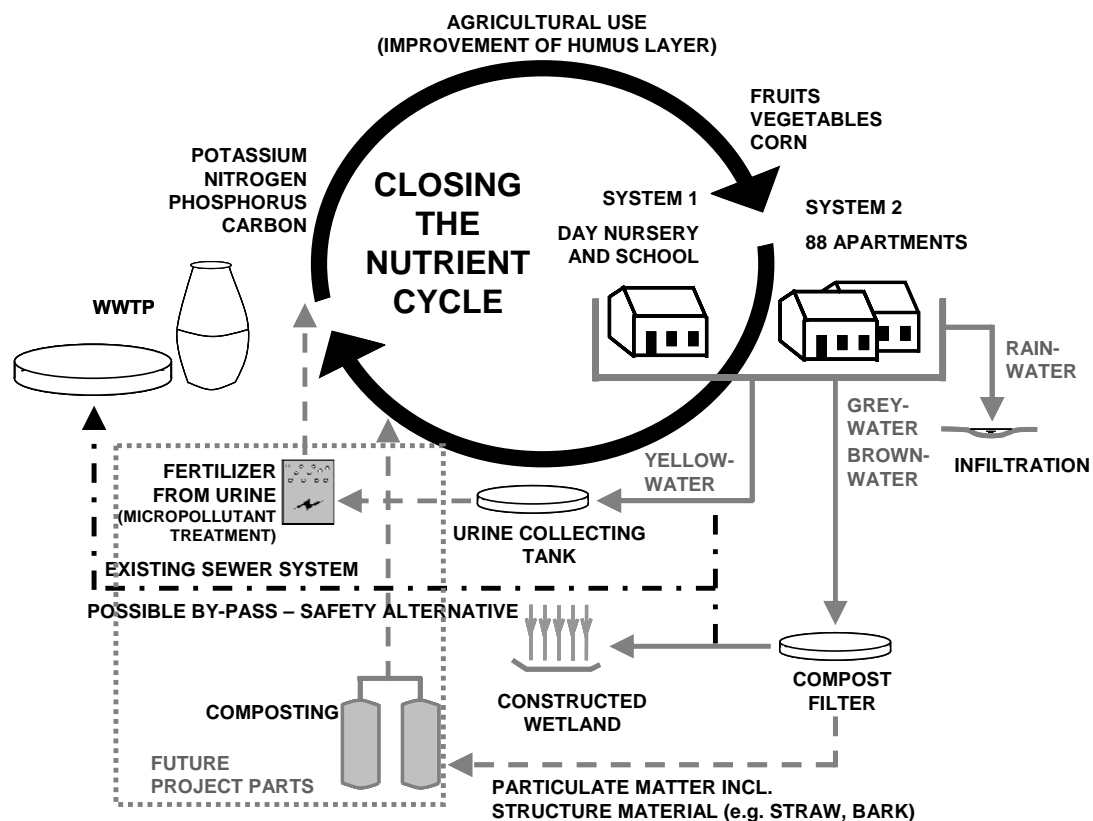


Figure 1. Principle of *solarCity* Linz (Modified acc. to Otterpohl and Oldenburg, 2008).

The favourable location of the project *solarCity* is given by the possibility to discharge yellow, brown, and grey-water also into the existing conventional sewer system. This sewer by-pass (safety alternative) can be utilized in case of malfunctions or optimization work of project components (Figure 1).

The project *solarCity* of a total of 460 population equivalents using urine separation toilets was started in 2004 with the construction phase. The closure of the material flow cycle as one

main target is being carried out in this project by means of urine separation toilets, compost filters and constructed wetlands (see figure 1). The stormwater is infiltrated on-site by means of infiltration depressions.

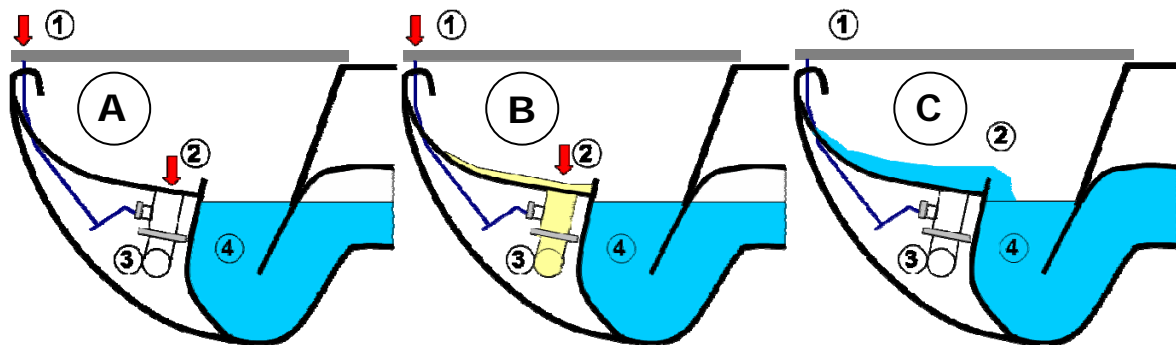


Figure 2. Functionality of the urine separation toilet.

Urine separation toilets of the Roediger company (figure 2) were installed in 88 apartments (system 2), in a public school and in a day nursery (system 1). The system consists in total of six urine collecting tanks. Additionally, in the school as well as in the day nursery, waterless urinals are used. Brown-water and grey-water is treated first in compost filters, the particulate matter is filtered by a filter sack, and afterwards in two constructed wetlands: one for the apartments (system 2) and the other one for the public school and the day nursery (system 1).

The separation toilet (figure 2) has two outlets: a conventional outlet ④ in the back part of the bowl, and an urine outlet ③, which can be opened or closed by a moveable plug ②. During the usage of the toilet (person is sitting) a lever ① will be activated and the plug ② for the urine outlet is opened. The urine can flow in a separate urine pipe to the urine collecting tank. After standing up the lever is deactivated and the plug is closed. The flushing water (also brown-water) is drained in the rear outlet like in a conventional toilet and is transported to the compost filter. Shalabi *et al.* (2008) have already described in detail the part of compost filters in source oriented system and its operation.

Survey

After seven to eight months of operation the first survey with main focus on performance and maintenance of urine separation toilets was conducted. Compared with other surveys in the field of urine separation (Pahl-Wostl *et al.*, 2003; Lienert and Larsen, 2006) no questions of general acceptance were asked. Of the 88 apartments 67 surveys (20 female singles, 8 male singles, 19 matrimonial communities, 20 families) of directly involved inhabitants could finally be analyzed in this research project.

Performance of urine separation toilets and compost filters

The results of toilets and compost filters performance are based on the survey, the maintenance experiences of the company and on a mass balance by means of a three week monitoring program. So far the treatment performance of the compost filters has not been satisfactory due to clogging problems and a resulting decreasing of the filter sack's permeability. Different structure materials as bark and straw have been investigated to guarantee well-performing filter sack permeability.

A three week monitoring program was to give information about urine separation toilets performance; by means of mass balance the loss of nitrogen and urine of urine separating toilets can be evidenced respectively. Figure 3 gives an overview of the monitoring program

of system 1: school and day nursery. The investigated system 1 has two urine collecting tanks each 1,500 l volume. Spot samples were regularly taken at the monitoring points everyday at the same time during the measurement campaign. The samples were brought immediately to the laboratory 2 km away and were analyzed.

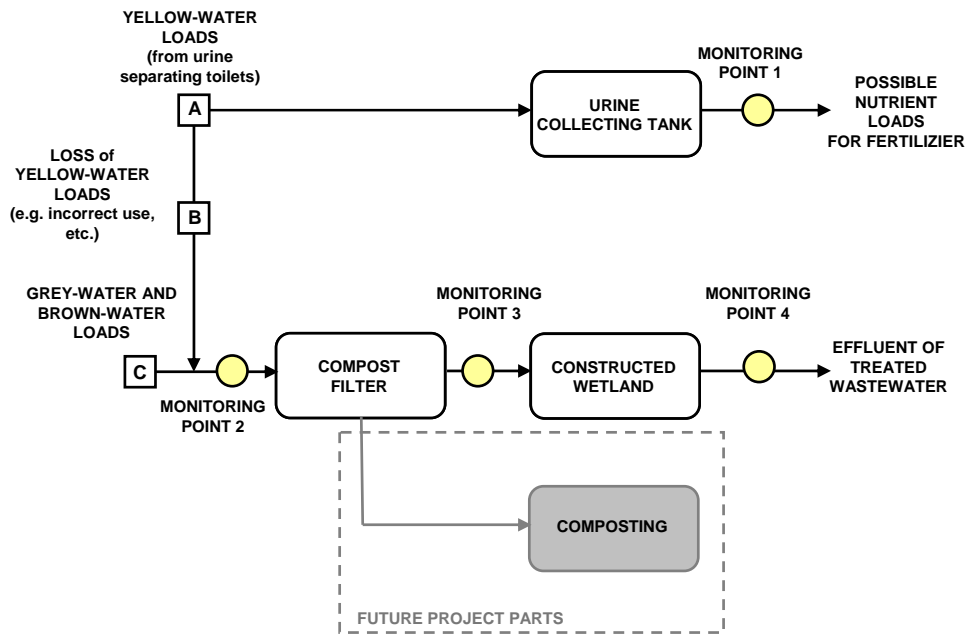


Figure 3. Overview of the monitoring program of system 1: day nursery and school.

RESULTS AND DISCUSSION

Survey results of urine separation toilets

The main focus of the survey was the performance and maintenance indicators of the separating toilets. Therefore, all inhabitants are divided into four different groups:

- single – female
- single – male
- couples
- families

These separate categories are useful for this survey due to any possible influence of the user's experiences like those of small children (couples or families) and the subsequent verification of the answers. One problem which sometimes occurs is that flushing water can be splashed onto the toilet seat due to the design of the bar between yellow-water and brown-water part of the urine separating toilets; 66% of the inhabitants had this problem. Decreasing of the flushing water amount is one possibility, but then the water volume for transporting the faecal matter could be too low and the material might remain in the bowl. 68% of the people had either a problem with not enough flushing water or indicated an increased cleaning work of the separation toilets compared with cleaning of conventional toilets. A special maintenance for the urine separation toilets like cleaning of urine inlet valves was perceived by 71% of those surveyed persons. Everybody used scale remover for the prevention of urine scale on the urine inlet valve. A survey about toilets or urination and defecation behaviour is extremely private; the perception of the cleanness is very subjective. 95% of the toilets were perceived to be clean by the interviewers (cf. figure 4).

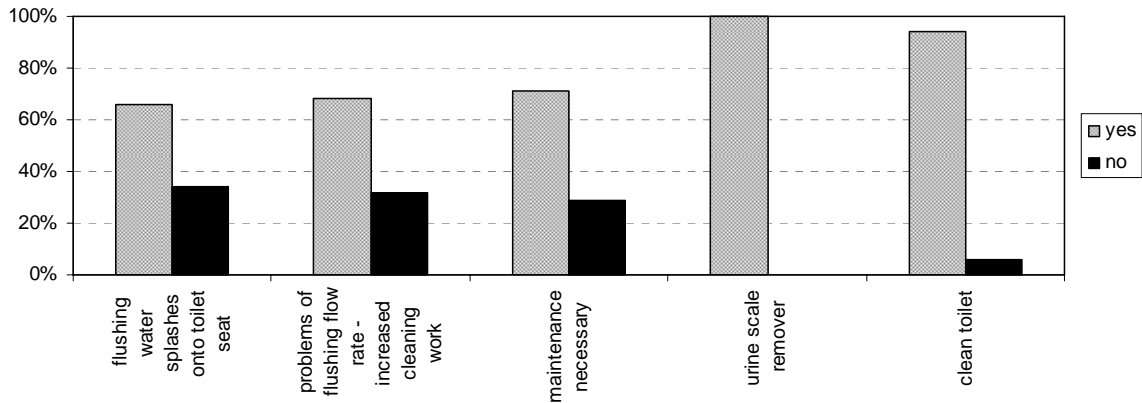


Figure 4. Survey results of different toilet performance and maintenance work of all inhabitants involved.

Most of the questions regarding performance and maintenance were answered similarly by most of the groups (compare figures 4 and 5 - upper left figure). What is also interesting is that only the group ‘single male’ differed. In this group only 13% had problems with not enough flushing water or increased cleaning work.

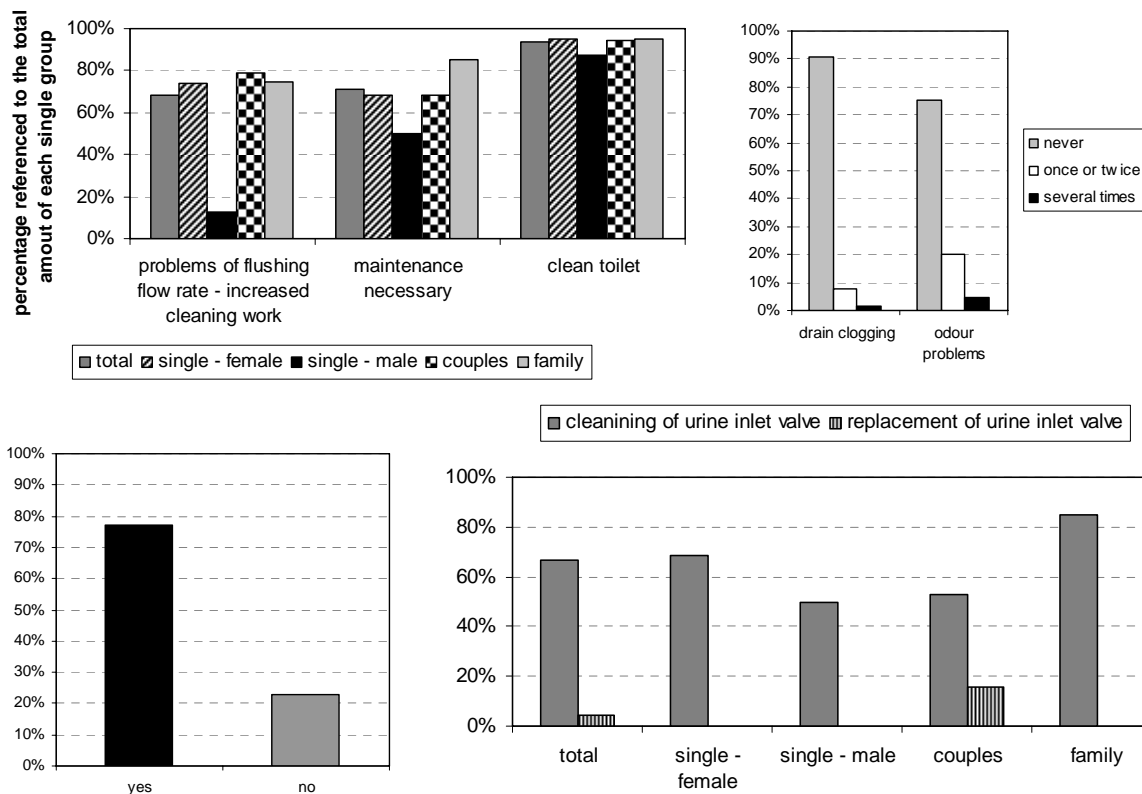


Figure 5. Survey results of performance and maintenance work categorized in four different user groups (upper left figure) and results of possible clogging or odour problems (upper right figure). Results of information work of the project by residential cooperatives bottom left figure) and detail results about urine inlet valves (bottom right figure).

Odour problems of these urine separating toilets usually result from the wrong deposit of the faeces in the front part of the toilet, which is constructed for urine and, therefore, the faeces

cannot be flushed away. This leads to odour problems. Small children cannot reach the right sitting position (cf. figure 6) due to their size. These experiences have also been made in the school and day nursery. In the kindergarten this problem can be prevented because the children are accompanied by a kindergarten teacher who helps the children and, by using the toilet brush pushes the faeces in the back part of the urine separating toilet. A raised platform around the toilet to ensure the contact of the feet with the ground and, therefore, to assure the right sitting position only partly succeeded. The size of the elementary school students is extremely different; very small-sized pupil in the first year to nearly full grown youths in the later years. So, therefore on this large size variation the best-specific solution for each 'size group' was not able to found. A change of the toilet construction by the manufacturer is recommended.



Figure 6. Sitting position of small children on the urine separating toilet – left figure is ordinary sitting position in practice – right figure would be the optimal sitting position to guarantee an optimal operating urine separating toilet.

In figure 5 (bottom left diagram) the result of the information and public relations work is displayed. Although each residential cooperative had the task for this information and public relations work; especially one cooperative did this extremely poorly. Only 77% of all inhabitants had been informed of this source orientated project, of the urine separating toilets, and how to use the toilets. Knowing the fact if this project fails the cost coverage to a conventional sanitation concept adaptation has to be financed by the LINZ AG company one cooperative tried to convince the inhabitants from the beginning that this source orientated project would never be able to succeed. Therefore, the public relations work was rapidly changed and is now being carried out mainly by the LINZ AG company. The first step was a correction of the public relations mistakes by means of a face-to-face on-site information campaign in the summer months of 2007. This information campaign also included immediate on-site repair of possible malfunctions of the toilet and a toilet check particularly the urine inlet valve check. By means of this information campaign the trust retrieval of unconvinced inhabitants mostly succeeded.

Nevertheless, only 11% of the people have a negative opinion of this project; the others are positive to indifferent. The key issue, which has become apparent, was the improvement of public relations to increase the amount of information for the inhabitants.

Results of toilets and compost filters analysis and its performance

The mass balance of system 1 based on a three weeks intensive measurement campaign—the schematic overview is given by figure 3—gives results of e.g. urine loss of the urine separating toilets. An overview of this campaign is displayed in table 1.

Table 1. Average daily mass load balance (g/d) of system 1: school and day nursery; monitoring period from 2007-05-07 to 2007-05-30 (modified acc. to Schroft, 2007).

source or monitoring point	COD	TOC	TKN	NH ₄ -N	P _{tot}	PO ₄ -P
	(g/d)					
A	90.2	61.1	176.0	163.0	18.5	12.6
B*	8.2	5.6	16.0	14.8	1.7	1.1
C	2,015.7	477.2	109.2	65.2	25.2	15.8
MP 1	82.0	55.5	160.0	148.2	16.8	11.5
MP 2	2,023.9	482.8	125.2	80.0	26.9	16.9
MP 3	1,638.1	440.5	126.1	74.0	29.6	16.7
MP 4	42.8	18.8	3.1	0.8	10.5	9.6

* values of losses are based on literature values and estimations

A part of the urine is not collected. Most of the losses result from the wrong type of maintenance (urine inlet valve) or the incorrect use of the separation toilets (people have to be in a sitting position to open the urine inlet valve). The analysis of the mass load balance resulted for this measurement campaign in a possible re-extracted nitrogen rate in the urine separating system of approx. 60% of the total nitrogen load (table 1). All inhabitants use urine scale remover but it was not known that only a treatment of the toilet surface would not remove possible urine scale. So, they urine inlet valve have to be activated (inlet valve is open) before the urine scale remover can be applied. For this purpose diluted citric acid was provided and delivered during the on-site information campaign by the LINZ AG team.



Figure 7. Operation of compost filters with different structure material – left figure bark, right figure straw.

What is also interesting is the fact that the elementary school students used the urine separating toilets in the school for urinating but avoided defecating. It could not be verified if this depends on the urine separating system or is a general behaviour of the students. Therefore, typical literature values differ slightly compared with these measurement campaign values.

First the operation of the compost filter in combination with the filter sack and the structure material bark did not work. The problem was clogging of the filter sack by the cellulose of the toilet paper which lead to an extreme decrease of the hydraulic permeability of the filter sack. Additional research by means of primary sludge by the WWTP Linz-Asten located 2 km away and of the brown and grey-water of the 88 apartments was conducted. This research also included the investigation of the compost filter performance with different structure materials

like straw and different kinds of barks (figure 7). This research resulted in partial success. In combination of an additional settling tank and an intermediate charging of the compost filters (with structure material straw) the hydraulic permeability of the filter sack is sufficient; but this is almost without any security reserve. Further research and optimizing work is currently being conducted. Previous small scale EcoSan project experiences could not deliver this kind of knowledge for medium to large scale projects of this compost filter problem and emphasizes the necessity of medium EcoSan project experiences.

CONCLUSION AND FUTURE WORK

This paper highlights experiences of the source orientated project *solarCity* Linz with 460 PE. Most of the problems result from the wrong type of maintenance or the incorrect use of the separation toilets. But there is still an optimization demand of the urine separating toilet design. An odour problem occurs when these toilets are used by small children due to their size and the wrong 'deposit' of the faeces (sitting position). These experiences were made in the school and day nursery as well as in the apartments of families with small children. A slight amount of additional work cleaning the toilet was perceived by the users; this demand is still acceptable.

Conducting public relations and informing those concerned are extremely important to guarantee the cooperation of the inhabitants. Bad public relations definitely lead to a destructive view of the inhabitants concerned. In this project a re-structuring and improvement of public relations took place as a consequence of public relations mistakes made by one residential cooperative. A positive change of the inhabitants' position to this project *solarCity* Linz by means of restructured public relations work could be recognized. About 10% of the people who moved there did so on account of the source orientated project. Nevertheless, only 11% of the people have still a negative opinion of this project; the others are positive to indifferent.

Most of the nitrogen losses result in this project from a malfunction urine inlet valve or the incorrect use of the separation toilet. The mass load balance analysis of a three weeks measurement campaign resulted in a possible recycling rate of about 60% of the total nitrogen load.

The permeability of the compost filters in combination with the filter sack and the different structure material have been undervalued. This comes from the lack of experience with medium scale source orientated projects. First solutions have been analyzed and are currently being realized to optimize the performance of the compost filters in combination with filter sack and structure material.

This project emphasizes the realization of source orientated projects on a medium to large scale in practice. What is most important is convincing the people concerned in order to achieve acceptance. The inhabitants concerned realize the positive environmental aspect and individual contribution; this point is more important for those involved than the sustainable sanitation concept. The experiences of this project *solarCity* also illustrate the demand to optimize the toilets by the manufacturers; this point was first recognized by the users.

Currently, the LINZ AG is carrying out the last optimization steps. In the future, the main focus of work will be on operation, customer services, project management and public

relations; the ‘hardware’ will be delivered for possible future research partners. These partners will be determined by an official hearing to guarantee a high research standard and access to all possible research partners with good ideas in this EcoSan field. The final steps of these ideas in *solarCity* like the use of compost and urine as fertilizers in agriculture should be realized together with these research partners.

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