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VUNA – Scaling Up Nutrient Recovery from Urine

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ABSTRACT

By recovering nutrients from urine, the VUNA project (www.vuna.ch) aims to contribute to a sanitation system, which is affordable, produces a valuable fertiliser, and reduces pollution of water resources. In the eThekwini Municipality in South Africa, a system was set up to collect urine from urine diversion dry toilets (UDDT). The collected urine was processed into fertiliser.

In a first set of trials, urine was collected from 700 households, in order to evaluate potential collection systems: An institutionalised system operated by the municipality workers was compared with an incentivised system, where the drop-off of urine at semi-centralised collection points was compensated with monetary incentives. Furthermore, potential collection schemes were analysed with computer simulations and business models.

To recover the nutrients contained in urine, different process technologies were developed and tested:

1) Via *struvite precipitation*, phosphate can be recovered from urine. The process is simple to install and operate, though recovers only part of the nutrients, which can potentially be recovered from urine, i.e. nitrogen and potassium remain in an effluent, which has to be treated.

2) *Biological nitrification combined with distillation* produces a concentrated solution containing all nutrients in urine. The biological process is more complex to operate and needs constant supervision, but ensures a hygienic and complete end product.

3) *Electrolysis* of urine is a novel process to treat urine. In future applications, it is expected to treat urine in compact reactors. However, research is still at an early stage and needs further efforts towards a roll-out.

Social acceptance studies ascertained that UDDTs are not necessarily readily accepted by the final users. However, target-specific education and sensitisation of toilet users can lay a foundation for a broader acceptance, which can be further strengthened, if excreta is given a value by processing it into reusable end products.

The VUNA project has evolved from a strong collaboration between all partners, which has been characterised by an interest in functioning technologies both in South Africa and in Switzerland.

KEYWORDS

Sanitation, Nutrient Recovery, Urine Treatment, Fertiliser Production, Public Health

1. INTRODUCTION AND PURPOSE

By recovering nutrients from urine, the VUNA project (www.vuna.ch) aims to contribute to a sanitation system, which is affordable, produces a valuable fertiliser, and reduces pollution of water resources. The project originated to respond to sanitation challenges in eThekwini, the Municipality encompassing the greater metropolitan area of Durban, in the province of KwaZulu-Natal (KZN), South Africa. In addition to being an undisputed need for human beings, the access to basic sanitation has also become a constitutional right in South Africa. As a consequence of racial discrimination during the Apartheid regime, large parts of the South African population had been deprived of appropriate sanitation. In KZN, the sanitation backlog was a major cause for a cholera outbreak in 2000/2001 (Mudzanani et al., 2003).

During the post-Apartheid transition, the necessity to address the needs of previously discriminated parts of the population became evident (Roma et al., 2013) and triggered the new government to legislate upon sanitation in a National Sanitation White Paper (DWAF, 1996) and a National Sanitation Strategy (DWAF, 2003). As a response, municipalities across the country have put into effect sanitation programmes to address the needs of the poorest parts of the population, which previously did not have access to sanitation.

As part of the overall water and sanitation drive, the eThekwini Municipality pioneered a programme providing 300 L water free of charge and a urine diversion dehydration toilet (UDDT) to all households in un-served rural and peri-urban areas (Gounden et al., 2006). UDDTs were chosen, because they comply with the following criteria:

- no water is needed for the disposal of excreta;
- drying of the faeces simplifies the collection and disposal of the faeces and inactivates pathogens;
- urine can be collected for later use as fertiliser. If there is no need for fertiliser and no risk of environmental pollution, urine can be infiltrated into the ground;
- the toilets can be maintained by the toilet users.

Up to date, more than 80 000 households have been provided with the eThekwini model of UDDT featuring two dehydration vaults, which are used alternatingly to allow for sufficient time for the faeces to dehydrate. In the initial version of the eThekwini UDDT, the diverted urine is conveyed to a perforated soak-away pipe, which is buried in the permeable subsoil.

In 2010, the Swiss Federal Institute of Aquatic Science and Technology (Eawag), eThekwini Water and Sanitation (EWS), the University of KwaZulu-Natal (UKZN), and the Swiss Federal Institute of Technology Zurich (ETHZ), jointly launched the

VUNA project to develop technologies and methods for managing urine collected from UDDTs. The project was conceived to integrate the fields of expertise of all project partners: Eawag has a long-standing record of research on urine diversion. Eawag's research in this field has been driven by the finding that urine contains most nutrients excreted by humans (Larsen & Gujer, 1996). Several urine treatment technologies were studied such as electrodialysis (Pronk et al. 2006), struvite precipitation (Etter et al. 2011) or nitrification/distillation (Udert and Wächter, 2012). While some projects targeted sanitation issues in developing countries, e.g. in Nepal (project STUN, Etter et al. 2011), a large transdisciplinary study was conducted to evaluate separate management of urine in an industrialised country such as Switzerland (project Novaquatis, Larsen et al. 2009). eThekwini's sanitation programme has been characterised by a participatory and learning-based approach to raising awareness on water and sanitation (Gounden, 2011). The roll-out of innovative sanitation systems in eThekwini has been scientifically backed by the Pollution Research Group (PRG) at UKZN, both on technological aspects and user acceptance studies (Gounden et al., 2006). The VUNA project also comprises the Centre for Development and Cooperation (NADEL) at ETHZ, which has a long standing research program on economy in developing countries. Furthermore, the Environmental Chemistry Laboratory (LCE) at EPFL joined the VUNA project for research on pathogen inactivation during urine treatment. The VUNA project was funded by a consecutive four-year grant by the Bill & Melinda Gates Foundation. All project partners complemented the grant with own funds.

With its broad base uniting science and practice, the project embarked on scaling up nutrient recovery technologies and implementing urine treatment beyond laboratory scale. In summary, VUNA's motivation to develop the appropriate sanitation technologies founds on multiple drivers:

- improve hygiene and sanitation by giving excreta an added value both economically and socially,
- protect the environment, in particular water resources, from excessive nutrient input and harmful substances,
- recover nutrients and make them available as agricultural input.

While UDDTs have been used in many regions worldwide for several years, there is a lack of full-scale technologies for nutrient recovery from urine and business models for urine management. VUNA aims at providing solutions for these challenges.

2 DESIGN AND METHODS

The VUNA research activities evolved simultaneously in South Africa and Switzerland. The following paragraphs first present an overview on the urine collection network used in eThekwini (at the scale of neighbourhoods). The second sub-section presents an overview on the studied urine treatment technologies both at Eawag and in eThekwini (for a summary, see Table 1 resp. Figures 2 and 3). The third section describes the social acceptance studies, which accompany the technology roll-out.

Urine collection networks

Institutionalised and incentive-based collection from household UD toilets in eThekwini: In 2010, in a first step, 100 household UDDTs in the rural and peri-urban parts of eThekwini were retrofitted with urine collection tanks, to 1) provide sufficient urine for treatment experiments, and to 2) assess the urine pick-up system, which was established by the Municipality. The first set of 4 litre collection tanks was emptied twice a week by EWS service vehicles and volumes were recorded on a daily basis. This assessment provided practical knowledge for the second step in scale, when the scheme was expanded to approximately 700 households in 2012, and the 4 litre tanks were all changed to 20 litre tanks. At this stage, a comparative study was launched to determine, whether the pick-up mechanism established by the Municipality (institutional collection scheme) could be partly replaced by a drop-off scheme (incentive-based collection scheme), where toilet users would drop off their full urine tanks at a central location, if they were provided with monetary incentives (Tilley and Günther, 2012). Currently, the next expansion of the collection scheme is being designed by eThekwini and further scenarios are evaluated (Joseph et al., 2014). The urine collected by the Municipality is ultimately transported to the so-called Newlands-Mashu field test site, where the VUNA reactors process it into fertiliser. The field test site also hosts an agricultural hub, where agricultural training classes take place. Through this link, a high number of participants is exposed to the new technologies, and fertilisers can be tested directly on the premises.

In order to determine the efficiency of the collection schemes and compare potential optimisations, the researchers made use of survey-based field studies: Roma et al. (2103) conducted a baseline study to assess how users perceived UDDTs and the subsequent collection and treatment of urine. In Tilley and Günther's (2012) first survey, people's stated willingness to drop off urine was determined, and then tested over the course of a field experiment, during which real cash incentives were offered in exchange for urine. On the other hand, Rossboth et al. (2013) developed computer models to optimise the urine collection and simulate selected scenarios. In a further step, extensive business models were developed and will be tested in the field (Joseph et al., 2014).

From the onset of the collection scheme throughout the expansion, the eThekwini Municipality accompanied the urine collection with an educational campaign. Municipal liaison officers kept in close contact with the ward councillors, the political representatives of the respective wards. To connect with eThekwini's participatory approach, local facilitators were designated to create a link between the toilet users and the Municipality in each research area. Although the municipal outreach was supported with print material, e.g. brochures (see Figure 1), a significant impact was only achieved with direct contact to the population, as previously experienced (Gounden, 2011).

Fig. 1: Schematic drawing of urine collection and processing into fertiliser in the brochure used to explain the VUNA project to toilet users.

Urine treatment technologies

Table 1 presents a summary of the urine treatment processes examined within the VUNA project and their respective scale both in Switzerland and South Africa. The subsequent paragraphs provide an overview on the process characteristics. For a detailed description refer to the referenced literature and to Udert et al. (2014).

Within the VUNA project, the following reactor developments were carried out (for an overview see Table 1 and Figures 2 and 3):

Struvite precipitation in South Africa: Struvite precipitation is a simple chemical process. By adding magnesium salt (e.g. MgCl2, MgO) to urine, more than 90 % of the phosphorus and approximately 5 % of the nitrogen are precipitated as struvite (MgNH4PO4•6H2O) (Etter et al., 2011). The struvite particles are then separated from the liquid via filtration. Based on the reactor design developed by Etter et al. (2011) in Nepal, a first manually operated struvite precipitation reactor was set up at the Pollution Research Group‘s (PRG) laboratories at UKZN. The reactor processed part of the urine collected from the household UDDTs in rural and peri-urban eThekwini (Grau et al, 2012a). The operation of the reactor at UKZN led to two further developments: 1) An improved version of the first manually operated reactor was relocated to the Municipality‘s field test site and operated in conjunction with training programmes for municipal employees (Rhoton et al., 2014); 2) a fully automated reactor was developed and constructed at the PRG premises. The latter served to fine-tune process parameters, such as optimum magnesium dosage or filter replacement (Grau et al., 2012b). Fertiliser efficiency of the produced struvite was tested in greenhouse trials at the UKZN School of Agriculture, Earth and Environmental Sciences and at the ETHZ Crop Nutrition Group.

Nitrification and evaporation in Switzerland: In a two-stage process, urine is first biologically stabilised (i.e. part of the ammonium contained in urine is transformed into nitrate). In a second step, the liquid contained in the nitrified urine is evaporated to obtain a concentrated nutrient solution. Based on preliminary laboratory experiments (Udert et al., 2003; Udert & Wächter, 2012), a pilot scale moving bed biofilm reactor (MBBR) was constructed to treat the urine collected in the storage tank. With a membrane dosing pump, urine is continuously added to the reactor at a set rate. Two reactor columns of 120 L liquid volume each are operated in parallel treating the female and male urine, respectively. The column contains Kaldnes® K1 biofilm carriers with a bulk volume of 60 % of the total reactor volume. The aeration assures both complete mixing of the reactor content and sufficient oxygen input for the biological processes to take place (Etter et al., 2013). In addition, several laboratory reactors were run at Eawag and EPFL to investigate specific questions on reactor kinetics, removal of pharmaceuticals, or inactivation of pathogens respectively (Hug et al., 2013; Oezel et al., 2013; Schertenleib, 2014). Nitrification experiments were backed with computer modelling, in order to achieve maximum process robustness (Etter et al., 2013). To evaporate the liquid contained in nitrified urine, an industrial steam compression vacuum distiller (ProwaDest E20, KMU Umweltschutz GmbH, Hausen, Germany) is used. The distiller is energetically optimised, i.e. a maximum of heat is recovered from the effluent to pre-heat the influent. The resulting product was tested as a fertiliser in greenhouse trials (Bonvin, 2013). Laboratory-scale experiments and computer calculations were used to determine the chemical stability of the final concentrated product, the possible loss of free ammonia and the separation of specific salts such as NaCl with sequential evaporation (Huber, 2011). Scientific publications on these subjects are currently in preparation.

Nitrification and Evaporation in South Africa: The nitrification and evaporation plants in eThekwini are identical to the ones operated at Eawag. To process a maximum volume of collected urine, the plants are located directly on the premises of the Newlands-Mashu field test site, where the collected urine is stored in large tanks.

Electrolysis in Switzerland: Urine electrolysis has recently attracted the attention of researchers, since it features certain relevant advantages in comparison with other technologies: e.g. reactors can be scaled down to fit into a compact container, which could be accommodated in a toilet, or reactors can be switched on and off on demand. However, practical knowledge on urine electrolysis is still limited, given that research is at an initial stage. A first series of experiments has been conducted at the Eawag laboratories, though numerous questions still remain open, e.g. the choice of the ideal electrode material (Zöllig et al., 2013).

Table 1: Urine treatment processes and their field of application in the VUNA project.

Technology	*Description*	*Benefits*	*Drawbacks*	*Scale in VUNA*
Struvite precipitation	after magnesium addition, struvite (MgNH4PO4•6H2O) precipitates and is recovered by filtration	• simple process • high phosphorus recovery (> 90 %) • constant & reliable product quality	• low nitrogen (N) recovery (5 %) • effluent to be treated for N load • Mg input essential	*South Africa*: • two pilot scale field reactors (one manual and one automated)
Nitrification & evaporation	1) urine stabilised in biological process (nitrification) 2) liquid evaporated in distillation process	• all nutrients recovered and concentrated • distilled water as side-product	• energy input required • biological process requires reliable control	*Switzerland:* • laboratory reactors • pilot scale reactor South Africa: • pilot scale reactor
Electrolysis	Electrochemical removal of organic substances, nitrogen compounds, and pathogens	• compact reactors • convenient process control	• energy input required • potentially harmful side-products • nitrogen removal instead of recovery	*Switzerland:* • experimental laboratory reactors

Figure 2: Combined nitrification and evaporation set-up at Eawag enabling complete nutrient recovery from urine (the South African nitrification and evaporation reactors are similar).

Figure 3: Left: Manually operated struvite field reactor at the Newlands-Mashu field test site in eThekwini; Centre: Fully automated struvite reactor at the PRG laboratory; Right: Electrolysis cell for urine treatment at the Eawag laboratory.

Social acceptance

The eThekwini Municipality holds a strong tradition of participatory and learning-based approaches (Gounden et al, 2006; Gounden, 2011). The perception of UDDTs has been closely monitored and lessons have been or will be incorporated into the future design. Roma et al. (2013) present a broad overview of results of a large toilet user survey. They report several maintenance issues and claim for further educational activities. Although urine is reported to be used in traditional medicine and spiritualism in the Zulu culture, its use in agriculture is not common, but farmers are open to future applications (Benoit, 2012). Within VUNA, a second survey was conducted in 2013 to follow the evolution of user perception (Mkhize et al. 2014). Currently, the authors of this study are also developing an educational campaign to address maintenance issues and promote the acceptability of urine as a fertiliser.

3 RESULTS

Throughout the project, VUNA followed an incremental approach to establish a functioning nutrient recovery system in eThekwini. Whereas the first version of the urine collection network responded primarily to the challenge of supplying sufficient urine to laboratory reactors, further developments led to a self-contained system, which could easily be replicated and expanded. As a consequence, capacity of the entire nutrient recovery system is no longer limited by the collection scheme, but rather by the treatment capacity of the present reactors. Both municipality officials and researchers at UKZN are enthusiastic about further scaling up the nitrification process, which currently represents the bottleneck in processing large volumes of urine into fertiliser. The following paragraphs summarise the main findings of the VUNA project at the current stage.

Urine collection networks

In the case of VUNA, the volume of collected urine served as a proxy for the acceptance of the technology. As previous studies have reported low toilet use (Roma et al., 2013), the inception of the urine collection scheme has entailed an increased use. In 2013, the capacity of the collection system attained several 1000 litres per week, which were collected from approximately 700 households. While the incentive scheme was in place, the volume of collected urine surpassed by far the treatment capacity of the reactor at the Newlands-Mashu field site. At present, after the trials with the monetary incentives have been concluded, the urine volume stabilised at 1400 L per week, which are currently collected from 300 households.

At present, data collected during the incentive studies are being evaluated. Simultaneously, further studies have commenced to examine structures of the institutional collection system, i.e. municipality workers picking up the urine from the households. With both approaches, incentives for urine drop-off and institutionalised collection by local workers money, money is directly provided to the local community. Currently, this money originates from the project sponsor, but the final goal is to cover this money with the sale of urine-derived fertilisers. Thus, an extra motivation to use toilets is expected to have a positive effect on poverty reduction.

So far, maximising the economic yield of the urine collection system has not been of utmost priority. Given the high unemployment rate, the Municipality favours job creation over expense reduction. Nevertheless, the costs for urine collection have to be optimised to make the system viable. When collection costs are broken down, a large proportion is attributed to the walking distance from the toilet to the nearest trafficable road, in the case a municipality worker picks up the urine from the toilet and carries it back to his vehicle (Joseph et al., 2014).

Urine treatment technologies

Struvite precipitation in South Africa: Operation of the struvite reactor at UKZN and the field test site demonstrated that more than 90 % phosphorus can be recovered (Grau et al., 2012a & b). With regard to user-friendliness of the process, substantial improvements were achieved from the first manually operated reactor to the automated version. As described in previous studies (Etter et al., 2011), liquid-solid separation is of prime importance to obtain an efficient process. Concurrently, it is also the main obstacle to complete automation of the process. This means that the struvite particle filter does have to be exchanged and serviced manually even in the fully automated version of the reactor. However, service intervals were reduced in the latter version by running several batches on the same filter fabric.

Grau et al. (2013) developed a novel process for automatic magnesium dosage: either electric conductivity or turbidity measurements in the reactor were used to determine the end point of the precipitation process and automatically switched off the dosage mechanism. The manual struvite reactor (50 L reactor volume) was successfully operated to process more than 1000 L of urine per day without any electrical energy input at the Newlands-Mashu field site (Rhoton et al., 2014). Municipal workers were trained to operate the reactor and their feedback served to further improve design details. The accompanying studies showed that drying of the struvite cake is critical for deactivation of viruses and helminth eggs (Decrey et al., 2011). First results of the agricultural studies showed that the urine-derived fertilisers performed equally or better than synthetic fertilisers (Meyer et al., 2014).

Nitrification and evaporation in Switzerland: Given that the nitrification and evaporation set-up at Eawag has been operated for a longer period of time (2 years at Eawag versus 3 months in South Africa), process parameters are stated based on detailed studies with the Swiss system. However, the system operated in South Africa is identical and is expected to perform equally. In Eawag‘s reactor, the maximum volumetric nitrification rate has reached 420 g N•m-3•d-1, which corresponds to a surface specific rate of 1.4 g N•m-2•d-1 (Kaldnes® K1 biomass carriers). In a 120 L reactor column, up to 50 L urine with an average ammonia concentration of 1790 g N•m-3 have been treated per day. The experience shows that in order to assure a safe and stable operation of the process, sudden influent load surges have to be avoided, given that they may trigger detrimental nitrite accumulation in the reactor (Hug et al., 2013, Etter et al., 2013). The combined process accounts for an approximate electrical energy consumption of 50 Wh•L-1 (nitrification) and 100 Wh•L-1 (evaporation) respectively (Udert and Wächter, 2012).

With respect to the inactivation of microbial indicator organisms, preliminary results indicate that several virus and bacteria indicators are inactivated due to aeration and/or biological activity in the reactor (Schertenleib, 2014). Considering the biological nature of the nitrification process, it has to be operated and monitored continuously. In comparison to the struvite precipitation process, it cannot be interrupted and re-started based on urine availability. However, this drawback is compensated by a complete recovery of all nutrients, which are contained in urine. Besides a concentrated nutrient solution, only distilled water and a small amount of activated sludge are released from the process as outputs.

Nitrification and evaporation in South Africa: The nitrification reactor in South Africa has been operating successfully since November 2013. An evaporator, which is identical to the one operated at Eawag, is to be commissioned in February 2014. Given that the evaporator‘s capacity significantly surpasses the present nitrification reactor‘s capacity (20 L•h-1 (evaporation) versus 2 L•h-1 (nitrification)), eThekwini Water and Sanitation anticipates to increase the nitrification plant‘s treatment capacity by scaling it up, in order to match both the large urine volumes, which are collected, and the evaporator‘s higher treatment capacity. In parallel, a new nitrification plant is planned to be installed in the new EWS Customer Care Centre in Durban‘s city centre. The plant is to further demonstrate the Municipality‘s out-of-the-box-thinking with regard to producing innovative sanitation systems and resolving sanitation issues. By integrating urine diversion into a modern building right in the city centre, the Municipality aspires to prove that dry sanitation is not exclusively a technology for the poor, but rather a technology of the future with a broad field of application.

Electrolysis in Switzerland: Zöllig et al. (2013) have tested various electrode materials in order to develop an electrochemical urine treatment process, which is low-cost, reliable, and safe. As a low-cost electrode material, graphite was shown to be suitable to remove ammonia from urine. However, rather low anode potentials (between 1.1 and 1.6 V vs. standard hydrogen electrode) have to be applied to avoid chlorine production, which leads to electrode corrosion and the formation of harmful chlorinated by-products. Alternatively, non-corrodible electrode materials, e.g. boron-doped diamond and iridium dioxide electrodes were tested. In what configuration the electrolysis process is suitable to treat urine – possibly within the toilet housing – will have to be determined in further studies.

Social acceptance

Roma et al. (2013) extensively documented the acceptance of urine-diverting toilets in eThekwini. They reported reluctance to use the toilets, in the case technical problems (such as malfunctioning doors) arise. Furthermore, they stress the need to address customer satisfaction and implement proper educational programmes. At the beginning of the VUNA project, Mkhize et al. (2014) conducted a baseline study, which produced similar results as Roma‘s study. They are currently evaluating data from a second survey, in order to estimate to what extent toilet use and perception of the toilets have been influenced by urine collection among other factors. Based on their findings, the next generation of education programme will be designed.

In order to detect regional differences, responses to the survey are correlated with spatial data. This way, user perception can be better understood in the light of local socio-economic status, organisational structures, or level of hygiene interventions. Also, findings from the survey contribute to improve the toilet design and improve user-friendliness, e.g. the locking mechanism of the door has been modified for better security.

4 CONCLUSIONS

In summary, a first scale-up of nutrient recovery technologies from urine has been successfully concluded in eThekwini. Further up-scaling steps are in the planning process. Although the eThekwini Municipality aspires to be a model in terms of best practice for sanitation programmes around the globe, they are also aware of certain particularities, which assisted them in implementing innovative technology. In this regard, the strong institutional framework provided by the Municipality certainly favoured an efficient and wide implementation. Moreover, along with a strong institutional framework, South Africa is also characterised by a good infrastructural network, which serves mostly the urban centres, and the presence of well-trained craftsmen and modern industries. Thus, the challenge lies in using the available capabilities to develop solutions, which can solve the sanitation challenges of the poor. Within VUNA, eThekwini contributed a large proportion of funds towards the research activities from its own sources. Therefore, it had an inherent interest to lead the project to success. How the eThekwini model can be adopted by other municipalities will have to be investigated in follow-up projects.

In addition to the eThekwini Municipality‘s strong focus on implementation and direct outreach, the well-established collaboration with UKZN‘s research groups (besides the Pollution Research Group, also the School of Development Studies) has paid off too. The local University‘s researchers have been familiar with the situation in eThekwini, given that many of them are originally from the project area. UKZN also provided an infrastructural base for Swiss scientists visiting South Africa to carry out fieldwork on the urine collection scheme and reactor technologies.

Eawag has provided both technological and methodological background to the project. As another particularity of the VUNA project, the technologies implemented in South Africa were not pre-existing technologies, which were adapted to the local needs, but rather new technologies, which were designed to suit the needs of both a South African or a European setting. For the collaborating departments of Eawag, i.e. Process Engineering (Eng), Urban Water Management (SWW), Water and Sanitation in Developing Countries (Sandec), Environmental Chemistry (Uchem) and Environmental Social Sciences (ESS), the VUNA project was an ideal setting to test technologies in different settings and draw conclusions on how to improve these technologies. Lessons learnt from the projects will not only feed back to future reactor generations in South Africa, but also serve to develop novel sanitation systems in Europe.

The work carried out at ETHZ (economic feasibility studies and fertiliser trials) and EPFL (microbial inactivation studies) seconded the findings of the project and, in the case of the latter, contributed to improve the treatment processes in order to ensure the safety of the fertiliser end products.

Conclusively, the close collaboration of all partners was essential for a successful implementation. To embed the technologies in the given setting, communication on various channels was perceived to be of utmost importance. The project team has underlined the need to make results accessible and strives to produce quality material describing details of all aspects from urine collection to the users‘ perception. Furthermore, tri-directional communication between South Africa, Switzerland and the Bill & Melinda Gates Foundation is not limited to project management issues, but relates to findings from the newly developed processes, which are to be used in South Africa, Switzerland and other countries.

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