Sustainable Sanitation

Practice

EcoSan Club

Issue 17, 10/2013

- Sustainable Sanitation Alliance members take a closer look at the Bill & Melinda Gates Foundation's sanitation grants
- Assessment of non-household toilet facilities in the Kathmandu Valley, Nepal
- Response of Okra (Abelmoschus esculentus L. Moench) to different Levels of Human Urine
- Removal of Selected Pharmaceuticals from Urine via Fenton Reaction for Agriculture Reuse

Miscellaneous

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Sustainable Sanitation Practice (SSP) aims to make available high quality information on practical experiences with sustainable sanitation systems. For SSP a sanitation system is sustainable when it is not only economically viable, socially acceptable and technically and institutionally appropriate, but it should also protect the environment and the natural resources. SSP is therefore fully in line with SuSanA, the Sustainable Sanitation Alliance (www.susana.org). • SSP targets people that are interested in sustainable sanitation systems and the practical approach to it. • Articles are published after blind review only. • Sustainable Sanitation Practice is published quarterly. It is available for free on www.ecosan.at/ssp.

Sustainable Sanitation Practice (SSP) hat zum Ziel praxisrelevante Information in hoher Qualität im Zusammenhang mit „sustainable sanitation“ bereit zu stellen. „sustainable“ also nachhaltig ist ein Sanitärsystem für SSP wenn es wirtschaftlich machbar, soziokulturell akzeptiert, technisch als auch institutionell angemessen ist und die Umwelt und deren Ressourcen schützt. Diese Ansicht harmoniert mit SuSanA, the Sustainable Sanitation Alliance (www.susana.org). • SSP richtet sich an Personen, die sich für die praktische Umsetzung von „sustainable sanitation“ interessieren. • Artikel werden nur nach einer Begutachtung veröffentlicht. • Sustainable Sanitation Practice erscheint vierteljährlich, kostenlos unter: www.ecosan.at/ssp.

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Publisher: EcoSan Club, Schopenhauerstr. 15/8, A-1180 Vienna, Austria • chairperson: Günter Langergraber • website: http://www.ecosan.at/ • scope: EcoSan Club was funded as a non profit association in 2002 by a group of people active in research and development as well as planning and consultancy in the field of sanitation. The underlying aim is the realisation of ecological concepts to close material cycles in settlements.

Medieninhaber: EcoSan Club, Schopenhauerstr. 15/8, A-1180 Vienna, Austria • Obmann: Günter Langergraber • Gegenstand des Vereins: Der EcoSan Club wurde 2002 als gemeinnütziger Verein von einer Gruppe von Personen gegründet, die in Forschung, Entwicklung, Planung und Beratung in der Siedlungshygiene - Sammlung, Behandlung oder Beseitigung flüssiger und fester Abfälle aus Siedlungen - tätig waren und sind. Das Ziel des EcoSan Clubs ist die Umsetzung kreislauforientierter Siedlungshygienekonzepte (EcoSan Konzepte) zu fördern, um einen Beitrag zum Schutz der Umwelt zu leisten.

Cover Photo / ***Titelbild***

Editorial

During the last year we received several papers that have not been in line with the specific issues produced. But still they are worth publishing and therefore we decided to publish 4 of these papers in this issue of SSP:

- von Muench et al. describe how the Bill & Melinda Gates Foundation uses the SuSanA discussion forum for linking their projects,
- Chhavi Raj Bhatt et al. present a study from Nepal in which he assessed non-household toilet facilities in the Kathmandu Valley
- Arago Jr. and Sarabia describe results from experiments in the Philippines of using human urine for fertilizing okra, and
- Abdel-Shafy and Mansour discuss removing pharmaceutical compounds from urine using Fenton Reaction.

The next issues are already planned:

- Issue 18 (January 2014) will present the outcomes from the constructed wetlands workshop held at UFZ in Leipzig, Germany, from 12-14 June 2013, and
- Issue 19 (April 2014) will summarize main results and achievements from the EU FP7 funded project CLARA (http://clara.boku.ac.at/).

As always we would like to encourage readers and potential contributors for further issues to suggest possible contributions and topics of high interest to the SSP editorial office (ssp@ecosan.at). Also, we would like to invite you to contact the editorial office if you volunteer to act as a reviewer for the journal.

SSP is available online from the journal homepage at the EcoSan Club website (www.ecosan.at/SSP) for free. We also invite you to visit SSP and EcoSan Club on facebook (www.facebook.com/SustainableSanitationPractice and www.facebook.com/EcoSanClubAustria, respectively).

With best regards,
Günter Langergraber, Markus Lechner, Elke Müllegger
EcoSan Club Austria (www.ecosan.at/ssp)

Content

Sustainable Sanitation Alliance members take a closer look at the Bill & Melinda Gates Foundation's sanitation grants

This paper explains how 85 sanitation research grants awarded by the Bill & Melinda Gates Foundation are being discussed on the open Sustainable Sanitation Alliance discussion forum in order to link these innovative sanitation science and technology research projects to the wider international sanitation community.

Authors: Elisabeth von Muench, Dorothee Spuhler, Trevor Surridge, Nelson Ekane, Kim Andersson, Emine Goekce Fidan, Arno Rosemarin

Abstract

In late 2012, the Bill & Melinda Gates Foundation awarded a grant to the Stockholm Environment Institute to showcase the Foundation's significant investments in sanitation science and technology. The aim of the project is to engage a broad range of experts, practitioners in developing countries and sanitation enthusiasts in an open discussion on the outcomes of the Gates Foundation's sanitation science and technology grants. The platform for this discussion is the open discussion forum hosted by the Sustainable Sanitation Alliance (SuSanA) since July 2011. The discussion forum enables convenient and efficient exchanges of information, experiences and practical problem solving ideas. So far, 61 of the 85 sanitation research grants awarded by the Foundation have been introduced and discussed on the SuSanA discussion forum in five thematic categories. The category with the highest number of grants is "Resource recovery from human excreta or faecal sludge" followed by "Processing technologies for excreta or faecal sludge".

Introduction

Background and aims

The Bill & Melinda Gates Foundation (BMGF) committed more than USD 265 million to the water, sanitation, and hygiene sector during the period 2006 to 2011 (BMGF, 2011). Since 2010, 85 research organisations worldwide have received grants under the sanitation science and technology grant schemes "Global Challenges Explorations" (GCE), "Reinvent the Toilet Challenge" (RTTC) as well as other grant schemes which are part of the BMGF Water, Sanitation & Hygiene (WSH) strategy.

In late 2012, the WSH Team of the Foundation awarded a grant to Stockholm Environment Institute (SEI) to showcase the significant investments of the BMGF in sanitation science and technology. The idea was that an open online discussion can spark more ideas and collaboration, and can help everyone achieve their goals more efficiently. The partnership of the BMGF, SEI and SuSanA as well as the sharing on the discussion forum is in line with the "Global Access Policy" that the Foundation embraces and which is described in all grant agreements and contracts that the Foundation makes.

The SEI project team is composed of SEI staff and other SuSanA community members (see author list), and

Key facts:

- The Bill & Melinda Gates Foundation (BMGF) recognised the importance of the Sustainable Sanitation Alliance (SuSanA) and its discussion forum and library. They have therefore decided to utilise this platform to increase the level of awareness, knowledge dissemination and sharing of research results (fundamental and applied) on advances in sanitation science and technology which have come about as a result of grants awarded by the BMGF.
- The Stockholm Environment Institute (SEI) team which consists of SEI staff as well as SuSanA community members has so far introduced and facilitated discussions on the SuSanA discussion forum of 61 of the 85 sanitation research grants awarded by the BMGF under the grant schemes "Grand Challenges Explorations" (GCE), "Reinvent the Toilet Challenge" (RTTC) and "Others".

works in close cooperation with the SuSanA secretariat at the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in Eschborn, Germany.

The main aim of the SuSanA discussion forum in general is to accelerate learning within the sanitation sector. With this platform, forum users can in a convenient way discuss their experiences, problems as well as successes and can find answers to their questions. The information can also be found by any internet user. The community moderators are recreating on the forum the 'SuSanA spirit' of openness, respect and passion for the cause.

The aim of this SEI-led project is to engage a broad range of experts, as well as practitioners in developing countries and even the general public to source and discuss innovative and sustainable sanitation solutions in order to accelerate learning within the sanitation sector. The vehicle for this process is the SuSanA discussion forum which was launched in July 2011 and is managed by the SuSanA secretariat at the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in Eschborn, Germany.

Overview of the sanitation grants by theme and location

The BMGF has awarded sanitation research grants under the grant schemes „Grand Challenges Exploration" (GCE Rounds 6 and 7), „Reinvent the Toilet Challenge" (RTTC Round 1 to 3) and "Others". The "rounds" refer to different calls for proposals, e.g. the RTTC calls for proposals in the Round 1 applications closed March 2011, for Round 2 in May 2012 and for Round 3 in November 2012. All these grants have been grouped by the SEI project team into five thematic categories (see Figure 1 and Figure 2):

1. Resource recovery from excreta or faecal sludge (28 grants)
2. Processing technologies for excreta or faecal sludge (25 grants)
3. User interface (13 grants)
4. Faecal sludge transport (3 grants)
5. Enabling environment and others (16 grants)

Most of these grants made by the Foundation are in the thematic category "Resource recovery from excreta or faecal sludge". This theme is in line with the vision document of SuSanA which underlines the importance of regarding excreta as a resource (SuSanA, 2008). It underlines the fact that the BMGF sees this as a very important field of research. At the same time, due to the scientific and engineering focus of these particular grant schemes, the category "Processing technologies for excreta or faecal sludge" also has a large number of grants.

Information about the sizes of the grants is given below (BMGF, 2013):

- The 57 GCE grantees initially received 100,000 USD each for their research in "Phase 1".
- About one third of these GCE grant projects have in the meantime been awarded a second phase of funding. The GCE grants for Phase 2 are generally higher than the grants for Phase 1.
- The eight RTTC grants of the first call (Round 1) as well as the four RTTC grants of the second call (Round 2) were typically around 400,000 USD for Phase 1, and 1-3 million USD for Phase 2 (eight of these RTTC grants are already now in the second phase of funding).
- The 14 grants in the category "Other" were on average 4 million USD in size.

Table 1 provides an overview regarding countries that are represented by the research organisations. The countries of the global South that appear in Table 1 are not coincidental but are countries where research in sanitation is generally receiving a good degree of national government support.

Methods and activities carried out

The starting point for the project consisted of transferring 128 grantees who were already part of the BMGF "Sanitation Network", but not yet SuSanA members, into the SuSanA membership database. At the same time, their 150 posts which they had made in the period of about one year prior to December 2012 were also transferred. This "Sanitation Network" was a closed discussion forum

Table 1: The 85 sanitation research grants grouped by country of lead organisation.

Region	Country where lead organisation is located	Number of grants	% of total number of grants
American continents	Brazil, Canada, Ecuador, Mexico, USA	50	59% (USA alone: 52%)
Europe	Germany, Great Britain, the Netherlands, Norway, Spain, Switzerland	19	22% (UK alone: 13%)
Asia	Cambodia, China, India, the Philippines, Singapore, Thailand	9	11%
Africa	Ghana, Kenya, Senegal, South Africa, Tunisia	7	8%

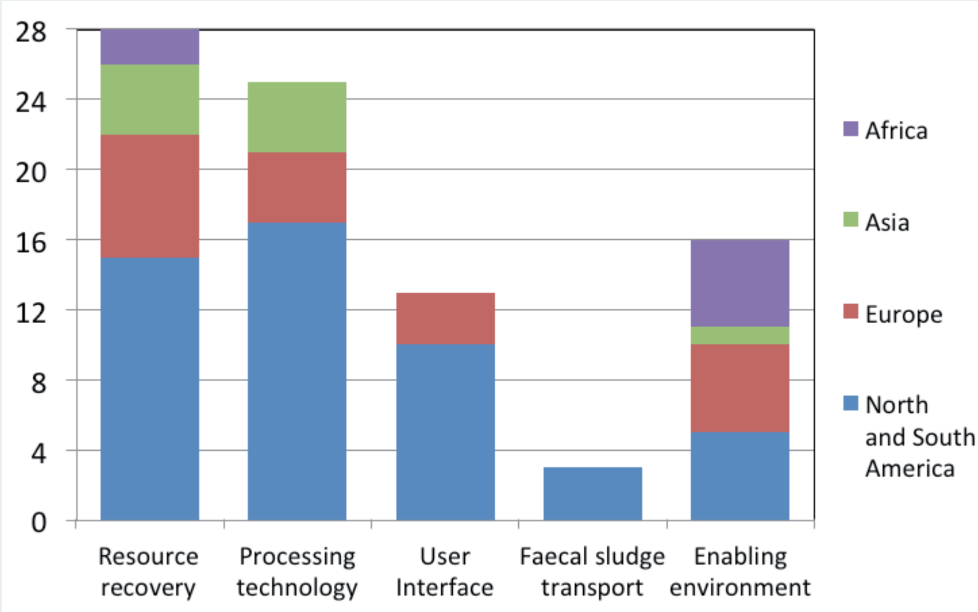

Figure 1. The 85 sanitation research grants grouped by theme and location of lead organisation.

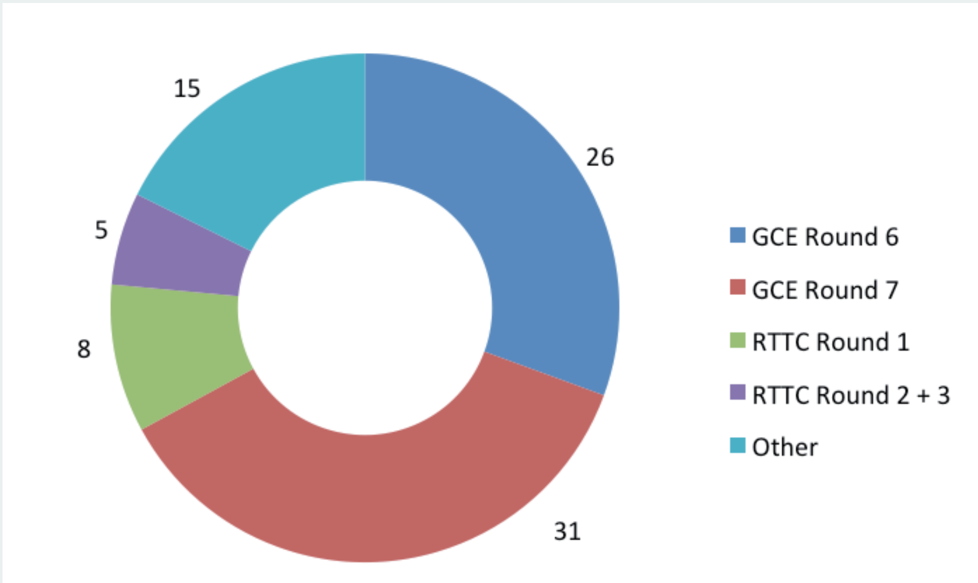

Figure 2. The 85 sanitation research grants grouped by grant type. GCE stands for "Grand Challenges Explorations" and RTTC stands for "Reinvent the Toilet Challenge".

moderated by staff of the BMGF, but had relatively low levels of activity and is now terminated. The idea behind the migration was to open up the formerly closed group of researchers to a much larger audience, where in principle any internet user could find these posts, read them and comment on them. This migration of users (i.e. grantees) and their previous posts took place in December 2012.

When setting up the new space for the grantees in the SuSanA discussion forum our most important consideration was a high level of user friendliness. To this end, some changes were made to the visual appearance and functionalities of the SuSanA discussion forum to make it more user friendly: new navigation and entry page (see Figure 3, top row) and new functionalities to make posts on the forum by e-mail, to send internal e-mails amongst registered users and to use the forum from a mobile device (smart phones and tablet computers).

In the final product, the user – whether it is a grantee or a general SuSanA community member – can now access information in the following ways:

- A new category was set up in the SuSanA discussion forum called "Innovative sanitation science and technology" with six sub-categories (see Figure 3). Here, each grant has one topic thread for its discussion.
- A new category was created in the SuSanA online library where each grant has a place to make documents available online. Other consultancy reports that were commissioned by the BMGF are also available there.

The SuSanA library is therefore available to the Bill & Melinda Gates Foundation's Water, Sanitation & Hygiene Team for dissemination of documents to a wider public audience.

- Videos of presentations by the grantees are made available, for example from their presentations at the Second Faecal Sludge Management Conference in Durban, South Africa in 2012.
- Each grant is first introduced by the grantee, together with links to background reading materials, photos and videos. Then the topic is opened up for discussion amongst the forum members. The grantees are guided by the SEI team through the process of explaining their research results to others on the discussion forum.
- 'Expert chats' or moderated online discussions with Adobe Connect are being carried out for clusters of grants once the grants have been introduced.

For on-going successful operation, the SEI project team has been providing a community management service and a content management and knowledge brokering function on a daily basis which includes for example: seeding the discussion with postings, enriching discussions with relevant background information, prompting members who have additional technical material and knowledge to respond, deleting spam and inappropriate content as soon as possible, moving postings to the right category, splitting or merging discussion threads, etc.

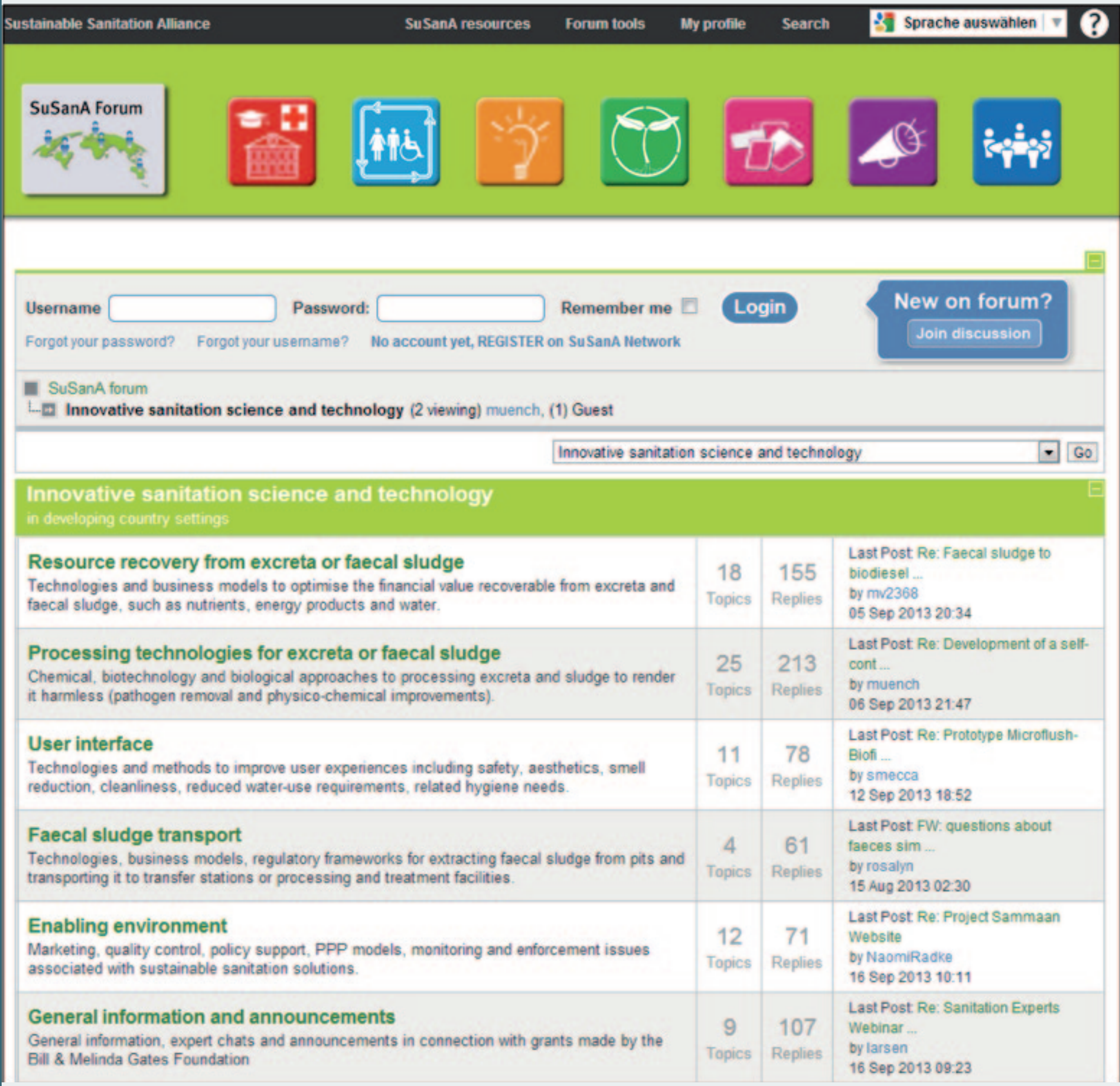

Figure 3: Screenshot of the forum category "Innovative sanitation science and technology", one of eight categories on the forum. The other forum categories can be accessed with the colourful square icons at the top.

Results and outcomes

Use of discussion forum to present results from grants

The grant agreement between the BMGF and SEI foresees that the project team of community moderators has to engage with the grantees to introduce and discuss their research results with the wider sanitation community until April 2014. By September 2013, 61 grantees had already presented their projects and results on the SuSanA discussion forum and engaged in discussions with the SuSanA community.

The premises for discussing the BMGF sanitation grants on the forum are:

- All science and technical ideas can be discussed freely. This forum category is a supportive space for out-of-the-box, unconventional ideas. All discussions are to be conducted in a professional manner with open minds.
- The 'spirit' of the discussion forum is adhered to, i.e. it is collaborative, supportive, personal and friendly.

Together with the SuSanA secretariat and the other dedicated SuSanA members who take the time to make interesting postings or answer questions on the forum, the SEI project team's efforts have contributed to the continued growth in registered users and in forum visits (see Figure 4). Of all the registered SuSanA forum users (numbering 2800 in early September 2013), about 160 are BMGF grantees. Table 2 below shows the most popular topics in the "Innovative sanitation science and technology" category on the discussion forum, as measured by the number of replies received so far.

Findings from our interactions with the grantees

The BMGF set up the GCE and RTTC research grant schemes with the intention of encouraging also those top scientists and engineers who were so far not interested in sanitation in developing countries to turn their attention and innovative minds to this topic. They wanted scientists, researchers and engineers from diverse fields such as material science, chemistry, agronomy, biochemistry, mathematics, automation engineering, logistics, economics, hydrogeology, architecture, urban planning, sociology, marketing, etc. to bring in their expertise and innovative thinking to this topic.

The intention of putting those scientists into closer contact with the practitioners from SuSanA – many of whom have been working on this topic since decades – was two-fold: (i) to raise awareness of the scientists regarding the challenges and opportunities in the field of sanitation and to give them the opportunity to focus their approaches to be more demand driven and practical; and (ii) to ensure that the sanitation practitioners can take advantage of recent advances in science and technology. The flipside of this approach was that many of these researchers had no prior experience with the realities on the ground in developing countries neither in general nor with sanitation in particular. This is where the exchanges on the discussion forum come in handy. The scientists can use the forum to talk about their ideas and preliminary results in the laboratories or at pilot

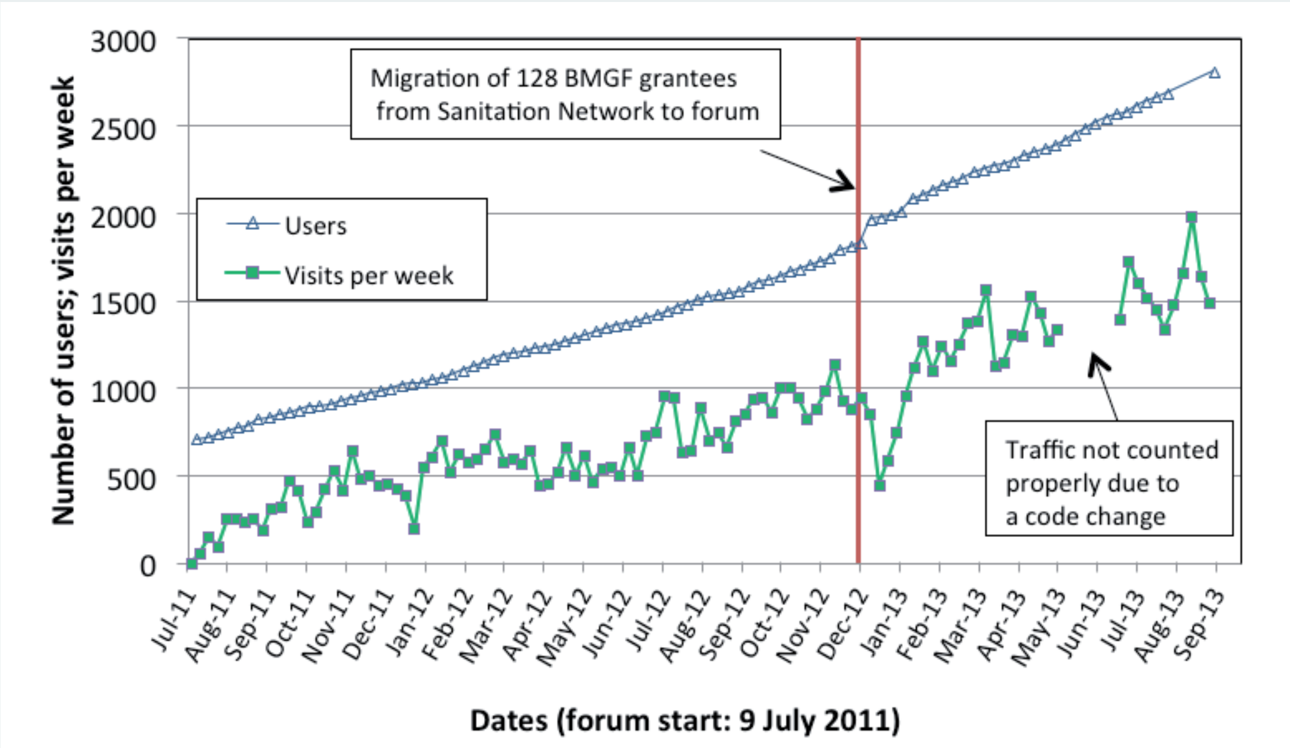

Figure 4. Registered users of the SuSanA discussion forum, and number of forum visits per week versus time since launch of the forum (source: Google Analytics).

Table 2. Top 10 threads in the "Innovative sanitation science and technology" category on the forum (as of 16 September 2013). More statistics about popular forum threads are available on the forum's statistics page.

Topic	Replies
Gates Foundation launches several rounds of reinvent the toilet challenge (RTTC)	47 [a]
Windmill-Driven ATAD (Autothermal, Thermophilic Aerobic Digester for increased pathogen removal)	43
RTTC cost calculation: including capital costs?	40
Using Cocopeat for Treating Septic Tank Effluent (RTI, USA - Philippines, Indonesia, Vietnam and other countries)	35
Does anyone have a good synthetic/artificial recipe of human faeces? - And information on rheological data such as viscosity	30
Scale up urea treatment for safe reuse of excreta (SuSan Design, Norway and Uganda)	23
Diversion for Safe Sanitation - Grant on Advanced Toilet with On-Site Water Recovery (Eawag and EOOS, Switzerland and Austria)	22
re.source: Mobile Sanitation Services for Dense Urban Slums (Stanford University, USA)	22
Enhanced Anaerobic Digestion: A Sanitation and Energy Recovery Technology (San Diego State University, USA)	20
Self Sustained eToilet for households/ Urban-semi urban Public/ Community Sanitation (Eram Scientific, India)	19

[a] This discussion thread on the merits of having such research grants at all was very attractive to the forum readers, having received 20,000 views to date – currently the most viewed of all the threads on the forum.

scale. The practitioners or people living in developing countries can then scrutinise these research projects – in a very supportive and constructive manner – and point out the bottlenecks, pitfalls, past experiences with similar approaches, and general reasons why certain technologies or approaches may not work as intended.

After nine months of working with the grantees we have made the following observations:

- The research projects are full of creative and innovative solutions in order to attempt to meet the criteria of "toilets with no water and sewer pipe connection, no power grid connection and a combined capital and operational cost of less than 5 cents per user per day" (this cost criterion was stipulated for the RTTC grants and was discussed in detail on the forum here). For some of the toilet technologies under development, the practitioners on the forum doubted that the maintenance requirements could realistically be met by the users or service providers, and considered that the investment and operation and maintenance costs would be prohibitive, at least for the poorest of the poor.
- Many of the research projects are achieving promising results and have now been given funding for a second phase while others have not been as successful. A number of publications in peer-reviewed journals, patents, PhD and MSc theses have resulted from the research efforts (the exact number is difficult to determine as the principal investigators often utilise several different funding sources for their research).
- Critical questions as well as encouraging comments from other grantees and SuSanA members have helped the grantees to rethink their approaches and to get new ideas for improvements.
- Learning from both the successes and failures in research and development is extremely important. Nevertheless, talking about project failures is still difficult and almost a taboo, even on this supportive discussion forum, for obvious reasons (such as fear of not getting future grants).
- Some grantees are not yet ready to engage in this sharing process on the discussion forum for the following possible reasons: it is still too early in their research; there are patent considerations; they have a preference for peer-reviewed journal publications; they are not used to sharing in this more informal way; the results have not met the expectations of the researchers; or because the grantees are still new to the topic of sanitation in developing countries and are therefore hesitant to reveal their preliminary results, ask questions or make comments about other people's research projects.

The biggest challenge for the team of moderators is to convince as many of the grantees as possible to put up their ideas, questions as well as research results – including any 'disappointing' results – for discussion and for shared learning as they go along, rather than only work towards peer-reviewed journal papers at the end of the project. On the other hand, some of the people who have been working in the sanitation sector in developing countries for a long time are highly sceptical whether these kinds of research projects – especially the "high-tech" ones – can achieve anything or are just a waste of money. Bringing these two ends of the spectrum together on the discussion forum remains a challenge.

Conclusions

The SEI project team has managed to encourage 61 grantees to introduce their grants and to present their research results on the discussion forum. Many of these grant introductions have already led to vibrant discussions and interesting exchanges, which have enriched the scientists' and engineers' deliberations and have also given the practitioners new ideas on what might be feasible in the future. The SEI project team continues in the background to provide efficient community management and content brokering functions for the forum. Emphasis is put on conducting the discussion in a professional manner with open minds and in a collaborative, supportive, personal and friendly manner. In addition, many project and consultancy reports from the BMGF are now available online for the first time as a result of this project.

The Foundation is using the SuSanA platform as a vehicle for its dissemination work. This emphasises the added value of the SuSanA network as a high quality platform for such exchanges and as a sounding board for sustainable sanitation initiatives. The hard work that the SuSanA partner organisations, individual members and the secretariat at GIZ have put into building up this network since 2007 is clearly paying off.

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BMGF (2013): Awarded Grants. Bill & Melinda Gates Foundation, http://www.gatesfoundation.org/How-We-Work/Quick-Links/Grants-Database# (accessed: 28 June 2013).

SuSanA (2008): Towards more sustainable sanitation solutions - SuSanA Vision Document. Sustainable Sanitation Alliance (SuSanA). http://www.susana.org/lang-en/library/rm-susana-publications?view=ccbktypeitem&type=2&id=267

Links

Information about the sanitation research grants of the BMGF on the SuSanA website:

http://susana.org/lang-en/research/funded-by-bill-a-melinda-gates-foundation

Category in SuSanA discussion forum where the BMGF grants are being discussed:

http://forum.susana.org/forum/categories/96-innovative-sanitation-science-and-technology

Category in SuSanA library where reports funded by the BMGF are available:

http://www.susana.org/lang-en/library?showby=yeardesc&vbls=7&vbl_7=79&vbl_0=0

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Assessment of non-household toilet facilities in the Kathmandu Valley, Nepal

In this study non-household toilet facilities in the Kathmandu Valley have been assessed.

Authors: Chhavi Raj Bhatt , Tanja Pircher Adhikary, Dinesh Adhikary

Abstract

This study attempted to understand and describe the state of the non-household toilet facilities located in the Kathmandu valley of Nepal. The premises of 100 toilet areas were visited, of which 98 were assessed for pre-defined basic toilet parameters using pre-designed forms. Nearly two thirds of the toilets had no soap or detergent for hand washing. Nearly 82% of the toilet facilities (n=80) had hand wash basins. 81% of the toilet areas had tapped running water for the purposes of for hand washing, hand rinsing and flushing. 87 toilet areas (89%) had no facilities for drying hands. Cleaning duty rosters were absent in all toilet facilities. Only 37 toilet sites had waste bins. Most of the toilet facilities in the Kathmandu Valley are poor in sanitation and hygiene. There is an urgent need for maintaining and improving toilet conditions and associated hygiene.

Introduction

Health and hygiene are closely related; hygiene and sanitation are the determinants of socio-economic development (Mara et al., 2010). The United Nations General Assembly in 2010 recognized sanitation as a human right (UN, 2010). In the face of rapid and unplanned urban growth worldwide, ensuring sanitation in urban areas is a major challenge to the concept of healthy cities floated by the World Health Organization. Urban areas in developing countries have to cope with large population increases while lacking in essential physical and social infrastructure, therefore putting public sanitation facilities including non-household toilets under strain. More than two and half billion people worldwide are reported to face lack of adequate sanitation which contributes to nearly 10% of the global disease burden, particularly of diarrheal diseases (Mara et al., 2010). The UN's millennium development goal 7, target 7.C is to halve the proportion of the population without sustainable access to safe drinking water and basic sanitation by 2015 (UNDP, 2012a). The coverage of water supply and sanitation in the South-East Asia region (including Nepal) was reported to be 81% (urban 85% and rural 80%) and 27% (urban 75% and rural 20%) respectively (Thompson and Khan, 2003). But when the functionality of water comes into account, the coverage falls to as low as 53% (Water Aid Project, 2012).

Safe and sufficient water and improved sanitation is one of the most effective ways to improve public health (Poverty-Environment Partnership, 2005). Furthermore, the state of public toilets can serve as an indicator of the hygiene and sanitation practice of any population. Toilet practices among people seem to depend on and are influenced by the access to water. Therefore, water availability becomes one of the important assessment parameters to consider. Adequate sanitation not only can prevent endemic diarrhoea, but also can help prevent intestinal helminthiases, giardiasis, schistosomiasis, trachoma, and numerous other globally important infections (Bartram and Cairncross, 2010). Human-associated bacteria can dominate most public toilet facility surfaces (Flores et al., 2011). Hand washing practice with soap after the toilet use reduces the risk of endemic diarrhoea up to 47 % (Curtis and Cairncross, 2003). Therefore, the consequences of hand washing practices to prevent faecal material contracting the susceptible children are utterly important (Curtis et al., 2000). A well-planned toilet provision would include free access to hand washing, efficient hand drying and nappy changing to minimize the likelihood of spread of infection. It is known that the transmission of microorganisms is more effective in wet environments than in dry environments (Patrick et al., 1997). Moreover, damp hands due to ineffective hand

Key messages:

- Most of non-household toilet facilities in the Kathmandu Valley are poor in sanitation and hygiene making themselves high-potential zones for the origin and propagation of toilet-associated diseases.
- The Nepalese government therefore should urgently bring policies and programs to improve non-household toilet facilities and sanitation practices of people.

drying can lead to higher numbers of bacterial colonization in the skin and helps in spreading harmful microorganisms (Larson et al., 1998). Therefore, hand-washing and hand-drying procedures are thought to be essential for good sanitation and hygiene practices.

Nepal is one of the least developed countries with a population of 26.6 million (Government of Nepal, 2012). Human Development Index puts the country at the 157th position revealing a meager situation of development (UNDP, 2012b). The percentage of the population lacking improved sanitation was reported to be 65% in 2004 (UNDP, 2012c). In another report, 19.8 million people of the country were reported to have no access to sanitation (Water Aid Project, 2012). It is noted that water and sanitation expenditure of Nepal was 0.79 % of GDP in 2010 (Water Aid Project, 2012). Infectious diseases, including diarrhoea, are major morbidities (Rai et al., 2002). In the Mid- and Far-Western regions of Nepal, 25 % of households had neither water nor soap available for hand washing (Government of Nepal, 2011). Therefore, it is important to raise awareness about sanitation issues and create a culture of improved sanitation practices in Nepal. Urban population in Nepal characterizes with its mobility and thus is bound to use non-household toilets frequently. Given the burden of diseases partly or wholly attributable to poor sanitation in Nepal, an understanding of the state of non-household toilets can provide insights into potential avenues for improvements. There is limited information available about the toilets' conditions and sanitation practices in the context of Nepal (Water Aid Project, 2012, Government of Nepal, 2011). Kathmandu Valley, the geographical region in Nepal that includes Kathmandu, Lalitpur and Bhaktapur districts, constitutes the biggest urban area in Nepal with five bordering cities viz. Kathmandu Metropolitan City, Lalitpur Sub-Metropolitan City, and Madhyapur Thimi, Bhaktapur and Kirtipur Municipalities. Therefore, Kathmandu Valley is notably characterized by over-population, congestion, ill-managed physical infrastructures, insufficient water supply and insufficient mechanisms for the disposal of human excreta as well as other kinds of wastes. The valley is nevertheless the most developed area and also the seat of the central government of Nepal. In such context, this study aims to gather baseline information about the conditions of toilet facilities and sanitation situation observed in the Kathmandu valley.

Material and Methods

1. Study design and setting

This descriptive cross-sectional study was designed to assess the condition of toilet facilities in the Kathmandu Valley. One toilet facility (area) in a designated premise can accommodate several toilet units, which are accessible to the public. The toilet facilities located in private households were excluded from the study. Therefore, two general categories of toilet facilities were designated; institutional (means located within schools, restaurants, public buildings, hospitals, etc.) and alone- standing public toilet facility.

One hundred randomly selected toilet facilities, including male and female toilet areas were visited. At institutions with more than one toilet area (e.g. in different storeys of an institutional building), at most one male toilet area and one female toilet area were included and counted in order to avoid repetition and increase representativeness of the study. At lone-standing public toilet areas having more than one toilet/urinal rooms, the total number of toilets and urinals were recorded, and assessment was made of one of the toilets. Of the 100 toilet areas visited, attendants/ authorities did not allow assessment of the two toilet areas. From the 98 visited toilets, 15 were alone-standing public toilet facilities and the rest were institutional toilet areas. Of the institutional toilet areas, 47 were in governmental or government-owned institutions and the rest were in non-government institutions with access to the general public, including private and co-operative institutions, among others educational, culinary and business houses. Of all the toilet areas, 42 were male toilet facilities, 22 were female toilet facilities and the rest (n=34) were gender non-specified or common toilet areas. A total of 202 toilet units for defecation and 164 urinals were covered in the assessment.

2. Data collection and analysis

Data were collected during October-November 2011 using pre-designed forms by the investigators. All toilet areas were assessed during daytime, between 11:00-17:00 hours local time. The parameters recorded were types of toilet and ventilation, observed inward traffic of toilet users in five minutes, availability of water (for hand/body-washing and rinsing), hand drying facility, waste bins as well as cleaning rosters, wastes within toilet facilities/bins. The descriptive analyses were performed in Excel 2007.

Results

1. Toilet types and ventilations

61 toilet facilities visited had squatting-type flushing toilet units, 33 had sitting-type toilet units and four had units of mixed type. The majority of them (58%) were ventilated through windows, 16% were primarily ventilated by exhaust fans (some of those with exhaust fans also had ventilator windows in addition), 15% were ventilated through gaps in the roof or through gaps between the roof and the walls of the toilet facilities. 5% of the facilities were ventilated through opening on the walls (usually a few bricks missing) while 6% of the facilities had no ventilation at all.

2. Inward traffic in five minutes

Among the toilets assessed, the maximum number of people entering within five minutes of observation was 30 for alone-standing toilet facility in the Kathmandu city center, where the facilities had seven toilet units. Analysis of the eight toilet facilities with more than 10 visitors in five minutes revealed four of them to be alone-standing public toilet areas, and the rest to be institutional toilet areas. The institutional toilet facilities included those in a shopping

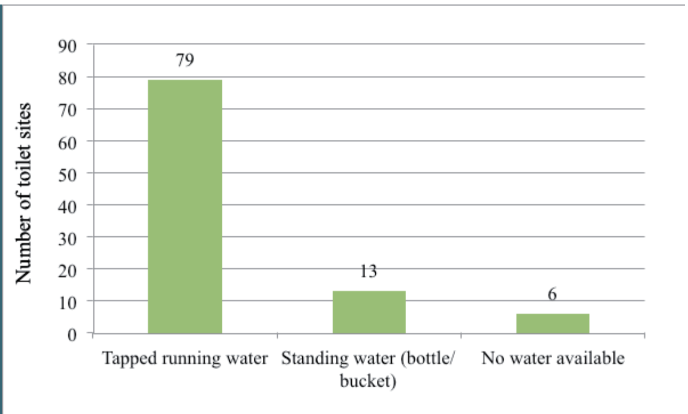

Figure 1: Availability of water in the toilet facilities

complex, two hospitals and an office of a government-owned commercial bank.

3. Water sources

81%of the toilet facilities (n=79) had tapped running water available (inside toilet units) for backside washing and flushing purposes, as well as hand washing purposes. Another 14% (n=13) of the facilities assessed had no running water but rather water standing in buckets/ mineral water bottles. No water was present in the toilet premises in six percent (n=6) of the toilet facilities assessed. Figure 1 shows the availability of water in the toilet facilities for the aforementioned purposes. Though the facilities were designed for running water uses (e.g. flushing toilet units, hand-washing basins etc.), the functionality of running water was absent largely due to unmaintained water supply.

Of the toilet facilities with standing water and no water available facilities half were institutional toilets including a district development committee office, a district police headquarters office, an office of a government-owned commercial bank, a private higher secondary school, a government office under the Ministry of Law and a women's skill-based co-operative office.

The other half of the facilities with standing water were lone-standing public toilet areas at locations including around the Central Ground of Tundikhel, and the bus parks in Gongabu, Bagbazaar, Koteshwor and Lagankhel. In the total 15 lone-standing public toilet facilities located in these areas, a total of 53 visitors were found to be availed of them in five minutes.

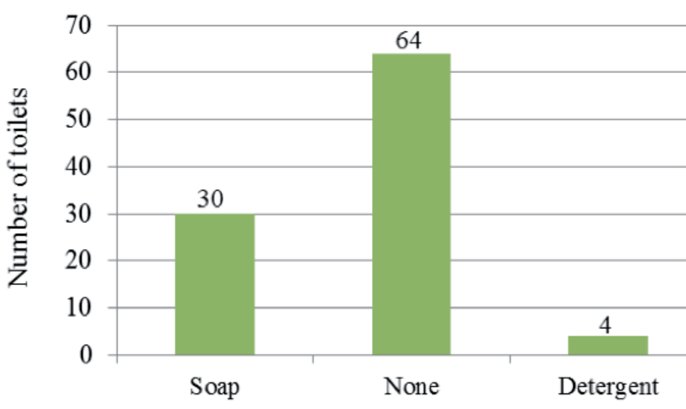

Figure 2: Provision of hand washing (hand disinfection) facility in the toilet areas

4. Hand washing and drying facilities

The presence of soap or detergent at the toilet facilities for hand washing after toilet use was assessed. Nearly 82% of the toilet areas (n=80) had wash basins for hand-washing purpose with six of them being non-functional in terms of water availability. Nearly two thirds of the toilet areas were found to be devoid of any soap or detergent for hand disinfection (Figure 2). The condition of wash basins observed is shown in Figure 3.

87 toilet facilities (89%) had no facilities for drying hands. Of the 8 toilet areas with > 10 people entering within five minutes 4 had soaps while the rest had no soap or detergent present. An electric dryer was noted in one instance while paper towels were documented in 4 of the cases. In all 9 of the toilets that had clothes towels, the towels looked worn and overused.

5. Waste bins availability

Of 98 total toilet areas assessed, 61 lacked waste bins. Four-fifths of the toilet facilities were found to be free of wastes and the rest had wastes within those facilities. Plastics were the most common waste present in 6% of the toilets while cigarette stubs were present in 3% of the toilets. In the remaining toilets with wastes, paper, faecal material on the floor, cotton wools as well as menstrual pads were noted. Of 22 female toilets assessed, 12 lacked bins.

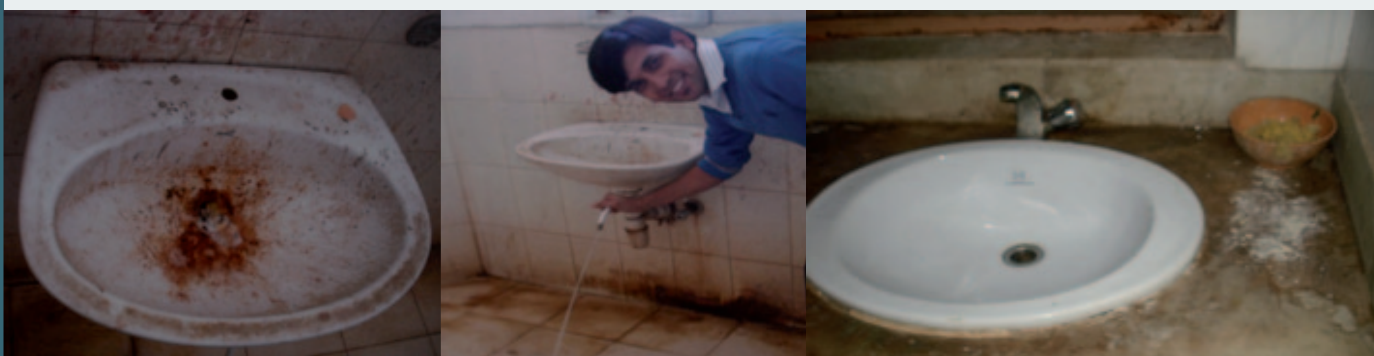

Figure 3: Pictures showing the conditions of wash basins at the toilets

Figure 4: A typical public toilet scene in Kathmandu (left) and an assessment of the condition (right)

6. Toilet cleaning and rosters

In two toilet facilities, cleaning personnel was present at the time of our assessments. Upon asking they stated they cleaned the toilets every day. In several government offices, we were told that there were separate staffs to clean the toilets. Cleaning rosters were, however, not present in any of the toilets assessed.

7. Toilet areas of different types

a. Hospitals

The hospital toilet areas assessed (11 in total) fell within six hospitals - three public and the other three private. All but one of the toilet areas were deemed to be satisfactorily ventilated. All but another one of the toilet areas had running water. However, there was no soap or detergent present in seven out of the 11 toilet areas.

b. Governmental institutions

Of the total 46 visited toilets that were within governmental or government-owned institutions, 39 had running water while 4 had standing water and 3 had no source of water at the time of assessment. Thirty five toilets of them had no soap or detergent available for hand washing. Only 10 of them had soap while one had kitchen detergent.

c. Lone-standing public toilets

Of the 15 lone-standing public toilets assessed, eight had soap while seven offered no option for hand disinfection. Similarly, all had water source; seven had standing water while eight had running water. The percentage of lone-standing public toilets with soap or detergent for disinfection was found to be greater than that of governmental or government-owned institutional toilets.

d. Restaurants

Six of the toilets assessed were within restaurants. All of them had running water. Five of the six toilets had soap present in the hand washing area.

8. General observation

While conducting the study, the caretakers of the public toilets mentioned that if soaps were placed in the toilets, they would be stolen away by the toilet users and that is why soaps were not placed! At a government office with frequent public dealings upon seeing there is no soap, we asked an employee whether that meant the personnel carried on with their work without washing hands with soap after defecation. The reply of the employee using the toilet facility while the assessment was - "What else can we do?" The situation in government offices and the attitude of helplessness in government employees gives reasons to question the government's commitment on sanitation. In most offices, obviously in government offices, senior most government officials had their own toilets attached to their offices. Such toilets were not included in the study. In some instances, in institutions frequented by public it was found that toilets were locked. Upon enquiry this was found to be for use by the staff only.

Discussion

This work generates baseline data as to the current state of toilet facilities in the most populous urban area in Nepal. The results of our study are expected to aid in realizing the problem facing the Kathmandu Valley and in designing interventions even though our study sample was of limited size. Our study revealed that even governmental institutions' toilet facilities are lacking in essentials like water supply and soap. This finding allows doubt to be cast on the commitment on the part of the government, and should help policy makers and programmers of the government realize the problem on the ground. Our study showed that nearly 2/3rd of toilet facilities were without any soap or means of hand disinfecting agent. The public toilets that we surveyed were paid type where it costs three rupees (equivalent to 0.04 US$) to get entrance into. Unavailability of soap even in such paid toilets clearly showed the excessive negligence shown by public and concerned authorities towards the sanitation practices. The evaluation of School Sanitation and Hygiene Education pilot programs in the six developing countries including Nepal has shown that the availability of soap was a major problem in most of the schools (UNICEF and IRC, 2006). In our study, the absence of hand drying facilities in most of the cases (85% of toilet facilities) further exposes another area of ill sanitation practice.

Our findings suggest that the government should work towards defining minimum requirements for alone-standing public toilets as well as toilets in institutions with public access. That should start with provision of running water and soap/detergent/hand disinfectant in all government institutions. Similarly, we visited some very busy restaurants but could not assess toilets because there were none. Whereas Nepal has an act regulating restaurants that requires separate male and female toilets to be within restaurant premises, this is clearly not the case presently.

Conclusions

A large majority of public toilet facilities in the Kathmandu Valley are aesthetically as well as sanitation-wise poor. The toilet areas have many attributes that make them high-potential zones for the origin and propagation of toilet-associated health morbidities. Therefore, there is need for better efforts from all stakeholders, especially the Nepalese government, to improve the toilet facilities to achieve better sustainable sanitation practice.

Acknowledgement

The authors are grateful to Mr. Nam Raj Khatri, WHO country office, Nepal for helping us realize this study and to Mr. Khatri and Mr. Bipin Poudel, Department of Water Supply and Sewerage, Government of Nepal for insightful comments. We also acknowledge the comments of Mr. Amrit Pandit on the manuscript.

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Response of Okra (Abelmoschus esculentus L. Moench) to different Levels of Human Urine

This was a study about the possibility of using human urine as an organic fertilizer in growing okra. The results might serve as a guide in applying human urine as an organic fertilizer.

Authors: Levy B. Arago Jr., Christian Albert R. Sarabia

Abstract

Human urine from dormitories of the Mindoro State College of Agriculture and Technology was used as organic liquid fertilizer. Its efficacy was tested in two varieties of okra (Abelmoschus esculentus). The experiment was conducted in Victoria, Oriental Mindoro, Philippines from September to December 2011 using a split-plot design with three replications. Results of the study showed varying responses of the two varieties to different urine levels. The optimum level necessary to significantly improve plant height of the Light Green is 25% urine + 75% water; the Smooth Green was not significantly affected. All urine-treated plants had significantly higher leaf area index than the untreated ones. Light Green had significantly heavier biomass than Smooth Green when applied with any level human urine. Smooth Green had significantly higher yield than Light Green when applied with 25% urine and 75% water. On the other hand, Light Green had significantly more enhanced vegetative growth than Smooth Green.

Introduction

Okra (*Abelmoschus esculentus L. Moench*) is a very nutritious vegetable and is popular in the Philippines due to its many uses. It is also resistant to drought and water logging and can be grown throughout the year as a stand-alone crop or in mixture with other staple crops (Odeleye, et al., 2005). Due to its popularity and the increasing demand for organically grown food products, the prospect of using organic fertilizer in growing this crop is very bright. One such organic fertilizer which is in abundance and at the same time, if not properly disposed, poses health hazard is human urine. Since most of the nutrients absorbed by our body from the food we eat is excreted via urine, it is rich in valuable nutrients in ionic form, e.g. 75-90% of nitrogen from urine is in the form of urea and most of the minerals especially potassium and sulphur which are present as free ions are directly available to plants without processing (Jönsson et al, 2004). As a fertilizer, it is fast-acting in nourishing plants (Kvarnström et al, 2006). Studies have also shown that the availability of plant nutrients from urine is comparable with those in chemical fertilizers (Mnkeni et al., 2005). Studies in different countries resulted to comparable yields in many different crops when equivalent amounts of chemical and urine fertilizer was used (Richert et al, 2010). In Sweden this was tested for barley (Johansson et al., 2001; Rodhe et al., 2004) and leeks (Båth, 2003); in the Philippines for sweet corn, eggplant and pechay (Gensch and Miso, 2011) and in India for maize (Sridevi, 2009) and Poovan banana (Jeyabaskaran, 2010). The use of urine as a fertilizer instead of the commercial fertilizer will thus reduce production cost (Germer et al, 2009). In addition, it also contains very few pathogens, hence it is easy and safe to use as organic fertilizer (Esrey et al, 2001).

Premises considered the response of two okra varieties to the application of different urine levels in terms of growth and yield components needs to be investigated.

Key findings:

- To ensure that human urine is not contaminated with pathogens a withholding period before application is needed to allow the pathogen to die-off. Urine should be stored undiluted in a sealed PVC container for several months.
- Human urine should be applied to Smooth Green okra variety at a mixing ratio of 25% urine to 75% water at the rate of 250 mL; the rate should be increased by 50 mL every week until it reach 500 mL; the initial application should be done three weeks after planting.
- The last application of urine should be at least one month prior to harvesting and urine should be applied into the ground if the edible parts of the plant grow above the soil surface.

Methodology

A Split Plot Design with three replications was used in this study. The level of urine was assigned as Factor A (A_1: no urine; A_2: 25% urine + 75% water; A_3: 50% urine + 50% water; A_4: 75% urine + 25% water; and A5: 100% urine) and the varieties of okra was assigned as Factor B (B_1 – Smooth Green; B_2 – Light Green).

A basal application of 6 kg of organic fertilizer per experimental unit was made. After the basal application of the fertilizer, each plot was covered with plastic mulch.

The human urine was collected every morning from the dormitories of the Mindoro State College of Agriculture and Technology, in Victoria, Oriental Mindoro, Philippines. It was prepared as a liquid fertilizer based on the mixing ratio proposed in the study. The liquid fertilizer was applied twice a week, around the base of the okra plants by drenching at the rate of 250 mL/plant. The amount of liquid fertilizer applied per plant was increased by 50 mL every week until it reached 500 mL. Urine application started three weeks after planting.

The data collected were analyzed using ANOVA for Split Plot Design tested at 5% and 1% levels of significance as described in Gomez and Gomez (1984). Mean comparison for significant differences was done using the Duncan's Multiple Range Test (DMRT) and was tested at 5% level of significance.

Findings

Height of the Plants

Highly significant variations in plant height were observed among plants treated with different urine levels. The specific test (Table 1) showed that in the Light Green variety, those treated with 25% urine and 75% water produced significantly taller plants, 88.7 cm, than the untreated plants and the others treated with higher levels as indicated by the letter notations that followed the data. The result implied that in using human urine as a fertilizer, the application of 25% urine and 75% water is the optimum level necessary to increase plant height of the okra Light Green variety. The effect of the different treatment combinations on the Smooth Green variety had no definite pattern i.e. the height of plants were comparable.

Leaf Area Index (LAI)

Variance analysis showed highly significant variations in LAI among plants treated with different urine levels, between varieties and the interaction between the two variables. Specific test (Table 2) showed that the plants in both varieties treated with 25% urine and 75% water had significantly higher LAI than the untreated ones and those treated with higher levels of urine. The significantly higher LAI of the Light Green plants in all treatments than their Smooth Green counterparts was an indication of differences in varietal characteristics.

Table 1: Specific test for plant height (cm)

Treatments (A)	Variety (B)		A-Mean	Difference
	Smooth[1]	Light[1]		
No Urine	78.7 a	73.7 c	76.7	5.0*
25U : 75W	75.3 b	88.7 a	82.0	-13.3*
50U : 50W	77.0 ab	84.0 b	80.5	-7.0*
75U : 25W	79.7 a	73.0 c	76.4	6.7*
100% Urine	77.7 ab	73.3 c	75.5	4.3*
B-Mean	**77.7**	**78.5**	**78.1**	**-0.9**

[1]Means followed by a common letter are not significant at 5% level by DMRT. *Significant difference.

Table 2: Specific test for leaf area index

Treatments (A)	Variety (B)		A-Mean	Difference
	Smooth[1]	Light[1]		
No Urine	0.73 c	0.85 d	0.79	-0.1*
25U : 75W	1.28 a	1.41 a	1.35	-0.1*
50U : 50W	0.76 c	1.20 b	0.98	-0.4*
75U : 25W	0.93 b	1.03 c	0.98	-0.1*
100% Urine	0.88 b	1.10 c	0.99	-0.2*
B-Mean	**0.92**	**1.12**	**1.02**	**-0.2***

[1]Means followed by a common letter are not significant at 5% level by DMRT. *Significant difference

Table 3: Specific test for biomass (g)

Treatments (A)	Variety (B)		A-Mean	Difference
	Smooth[1]	Light[1]		
No Urine	212.9 a	146.9 c	179.8	65.9*
25U : 75W	250.0 a	225.0 ab	237.5	25.0^{ns}
50U : 50W	203.1 a	168.8 bc	185.9	34.4^{ns}
75U : 25W	206.3 a	200.0 abc	203.1	6.3^{ns}
100% Urine	218.8 a	249.4 a	234.1	-30.6^{ns}
B-Mean	**218.2**	**198.0**	**108.1**	**20.2^{ns}**

[1]Means followed by a common letter are not significant at 5% level by DMRT. *Significant difference; ^{ns} insignificant difference.

Biomass

Variance analysis for biomass showed that the mean difference between varieties and the interaction between the urine level and variety was highly significant. Further test showed that in the Light Green variety, the plants applied with pure urine had significantly heavier biomass (249.4 g) than the untreated plants (146.9 g) (Table 3). This implied that human urine can significantly enhance the vegetative growth of Light Green variety of okra. For the Smooth Green variety, however, the application of different levels of urine did not have significant effect on biomass.

Number of Fruits (5 Harvests)

Variance analysis showed no significant difference among the treatments and between the two varieties. However, a significant interaction between the treatment and variety was observed. The Smooth Green variety responded to varying levels of urine, e.g. the application of 25% urine and 75% water significantly increased yield as compared to the application of pure urine; Light Green was not affected significantly.

Weight of Fruits (Five harvests)

No significant variation among the treatments and between the two varieties was noted. However, there was a significant interaction between the treatment and variety, i.e. the Smooth Green plants treated with 25% urine and 75% water produced significantly heavier fruits (516.7 grams) than the untreated ones (Figure 2). This finding shows a parallelism with the findings on the number of fruits.

Conclusions

The response to urine treatment of different varieties in terms of plant height varied significantly, i.e. the optimum level that could significantly increase plant height of Light Green variety is 25% urine and 75% water; the Smooth Green variety had no significant response to urine application. In terms of LAI, all plants in both varieties fertilized with urine had significantly higher LAI than the untreated ones. In terms of biomass, urine application did not affect the Smooth Green variety; the application of pure urine to the Light Green variety resulted to significantly heavier biomass, suggesting that its effect is variety specific. In terms of yield, the application of 25% urine and 75% water to Smooth Green variety of okra

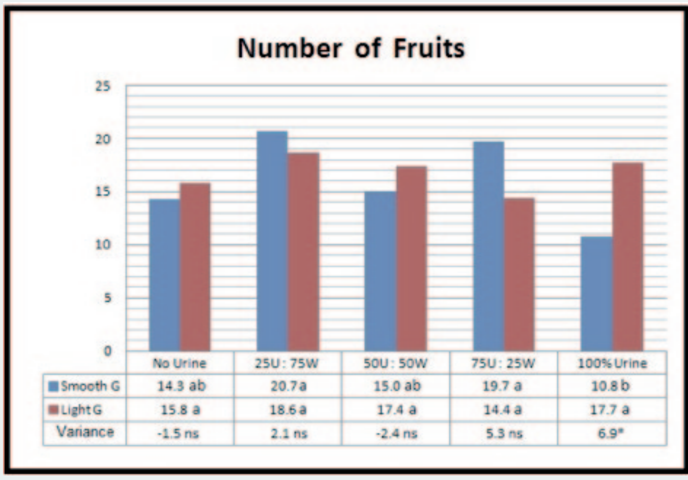

Figure 1:Number of fruits after 5 harvests and specific test

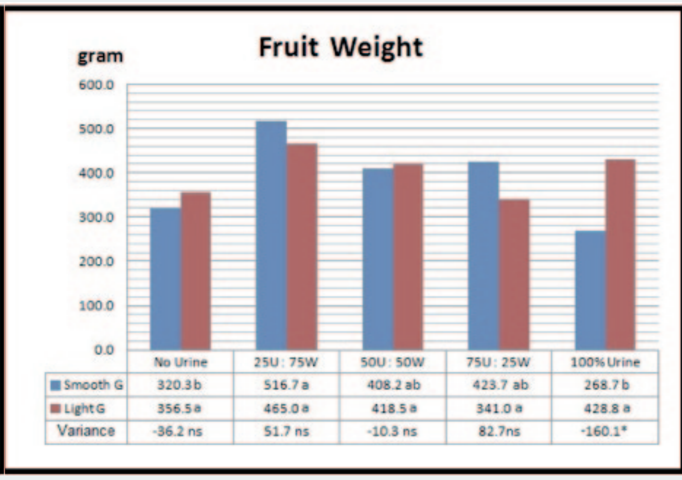

Figure 2 Weight of fruits (g) after five harvests and specific test

could significantly increase the number and weight of its fruits but not for the Light Green variety. The result indicates that application of varying levels of urine could enhance the vegetative growth of the Light Green variety. For the Smooth Green variety, however, the application level of 25% urine and 75% water could increase yield but beyond this point, the yield begun to decline.

Based on the results of this study, human urine could be used as an organic fertilizer for Smooth Green variety of okra and possibly other crops. Being organic in nature, the use of human urine as a crop fertilizer is economically viable, socially acceptable, technically and institutionally appropriate and environment-friendly.

Recommendations

1. Apply human urine as an organic fertilizer twice a week by drenching to Smooth Green okra variety at a mixing ratio of 25% urine to 75% water at the rate of 250 ml, gradually increasing the rate by 50 ml every week until it reach 500 ml. The initial application should be done three weeks after planting.
2. The collection of urine should be done by implementing appropriate urine separation techniques. The drain of urinals in male toilets should be designed to end in PVC containers and not in septic tank for ease in urine collection; toilet bowls that has a separate drain for liquid (urine) and solid (faeces) wastes, e.g. Chinese squat type urine-diverting toilet bowl should be installed in toilets.
3. On the perspective of health, to insure that the human urine intended for agricultural use is not contaminated with pathogens, there should be a withholding period before application to allow the pathogens to die-off. It should be stored undiluted in a sealed PVC container (prevents nitrogen loss) from 1-6 months at a temperature of 4-20 OC. This condition will provide a harsh environment for the pathogens. Moreover, the last application should be at least one month prior to harvesting and that it is applied into the ground if the edible parts of the plant grow above the soil surface.
4. Try varying levels of human urine as fertilizer for other crops.

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Removal of Selected Pharmaceuticals from Urine via Fenton Reaction for Agriculture Reuse

Fenton and Fenton-like oxidation treatments have been researched to remove pharmaceutically active compounds from urine.

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Abstract

Pharmaceutically active compounds (PhACs) are excreted by humans mainly with urine and, to a lesser extent, with faeces. This study investigates the effect of Fenton's oxidation on the degradation of three PhACs, namely levofloxacin, ibuprofen and atorvastatin in combination. Therefore, aqueous solution and urine spiked, separately, with the selected PhACs. Fenton and Fenton-like oxidation treatments, namely: H_2O_2 and $FeSO_4$, H_2O_2 and CuCl, and H_2O_2 and Activated Carbon were examined in batch reactors. Results showed that the removal rate ranged from 95 to 99% for PhACs and from 97 to 98% for COD in the aqueous solution. For the artificially contaminated urine, the removal rate ranged from 95 to 99% for PhACs and from 97 to 99% for COD. Biodegradability (BOD_5/COD ratio) improved from 0.09 to 0.7, indicating that the effluent was amenable to biological treatment.

Introduction

Pharmaceutically active compounds (PhACs) have been observed in surface water (Vieno et al., 2007), groundwater (Abdel-Shafy et al., 2008), sewage effluents (Ternes et al., 2004), drinking water and solid waste (Musson and Townsend, 2009). The drug concentrations detected in the environment were generally in the ng/L to µg/L range (Vieno et al., 2007). PhACs can reach the aquatic environment through various sources including pharmaceutical industry, hospital effluents and excretion from humans and livestock (Yanga et al., 2008). PhACs in surface waters is an emerging environmental issue and provides a new challenge to drinking water, wastewater and water reuse treatment systems (Ikehata et al., 2006). Generally, approximately 70% of PhAC forms are excreted with urine (metabolites, conjugates) excreted from human body while 30% with feaces (Lienert et al., 2007). Separate collection and processing of human urine is gaining interest for three important reasons. Firstly, human urine contains the largest fraction of nutrients: nitrogen (80%), phosphorus (50%) and potassium (70%) emitted from households (Vinnerås and Jönsson, 2002). These could be used, after an appropriate treatment if required, as fertilizers in agriculture. Secondly, to reduce the amounts of residual PhACs that are currently discharged through sewer overflows and by wastewater treatment plants (WWTPs) that are not designed to efficiently eliminate these compounds. Thirdly, disconnection of the urine stream (or part of the stream) from the sewer would enable to save energy at WWTPs (Wilsenach and van Loosdrecht, 2006), spent for nitrification of ammonium mainly originating from urine.

Key factors:

- Pharmaceuticals are consumed in high quantities worldwide and the expectations are that these amounts will continue increasing because of improving health care system and longer life expectations of people.
- Approximately 70% of pharmaceuticals are excreted with urine (metabolites, conjugates) from human body while 30% with feaces.
- Fenton's oxidation achieves high removal efficiency of pharmaceuticals from urine, particularly for the non-biodegradable portions, and it is highly dependent on the concentration of oxidant and catalyst.
- Fenton's treatment is rated as uneconomical for treating large volumes of urine. For pre-treatment, lower dose of Fenton's reagents can be used.
- For the elimination of the selected PhACs the tested catalysts (Fe^{2+} or Cu^{1+}) have been more efficient than Activated Carbon

Usage of urine includes the risk of transfer of pharmaceutical residues to agricultural fields. Little is known on the fate of pharmaceuticals regarding their accumulation in soils, transfer to groundwater, and incorporation by plants. The uptake of pharmaceuticals in plants and the effects they exaggerate on plant physiology and development were of major interest when crops are fertilized with urine. Uptake of organic compounds by plants is correlated with their molecular weight (Winker et al., 2008). It is assumed that molecular weight of >1000 (Da) makes the absorption by cellular membranes impossible (Sanderson et al., 2004). Additionally, uptake of pharmaceuticals by plants can affect their growth when dosed in sufficient concentrations (Dolliver et al., 2007).

Treatment of pharmaceutical wastewaters for the removal of PhAC's is a challenging task due to the wide variety of chemicals produced in drug manufacturing plants, which lead to wastewaters of variable compositions (Zwiener and Frimmel, 2000). Likewise, most of the substances related to pharmaceutical industry are resistant to the biological degradation. Therefore, chemical treatments or pre-treatments to increase the effect of biological depuration are necessary. Chemical processes, like Advanced Oxidation Processes (AOPs) have been successfully used for the removal or degradation of recalcitrant pollutants present in wastewater coming from different industries (Klavarioti et al., 2009, Abdel-Shafy et al., 2010). These processes involve the generation of hydroxyl radicals ($HO^{\bullet}$) with high oxidative power. Among AOPs, Fenton´s reagent, has emerged as an interesting alternative for the treatment of dissolved organic pollutants in wastewater streams(Klavarioti et al., 2009). Other examples of AOPs include photo-Fenton and electro-Fenton (Mira et al., 2011).

Fenton Reaction

Under acidic conditions, in the presence of hydrogen peroxide (H_2O_2), Cu^{1+} or Fe^{2+} and organic substrate (RH), the following redox reactions take place:

$$Fe^{2+} \text{ or } Cu^{1+} + H_2O_2 \rightarrow Fe^{3+} \text{ or } Cu^{2+} + HO^- + HO^{\bullet} \quad (1)$$
$$HO^{\bullet} + Fe^{2+} \text{ or } Cu^{1+} \rightarrow Fe^{3+} \text{ or } Cu^{2+} + HO^- \quad (2)$$
$$HO^{\bullet} + RH \rightarrow H_2O + R^{\bullet} \quad (3)$$
$$R^{\bullet} + Fe^{3+} \text{ or } Cu^{2+} \rightarrow R^+ + Fe^{2+} \text{ or } Cu^{1+} \quad (4)$$

Reactions (1) and (2) are initiation and termination reaction, while reactions (3) and (4) are propagation reactions.

Activated carbon (AC) is known to decompose H_2O_2. Presumably, the process involves the exchange of a surface hydroxyl group with a H_2O_2 anion (Reaction 5) The formed surface peroxide is regarded as having an increased oxidation potential which enables the decomposition of another H_2O_2 molecule with release of oxygen (O_2) and regeneration of the AC surface (Reaction 6). Beside this decomposition reaction, H_2O_2 can obviously be activated on the AC surface involving the formation of hydroxyl radicals ($HO^{\bullet}$). AC is considered to function as an electron-transfer catalyst similar to the Haber–Weiss mechanism known from the Fenton reaction, with AC and AC^+ as the oxidized and reduced catalyst states (Reactions 7 and 8). The AC/H_2O_2 process can lead to decay of organic contaminants in aqueous solution (Georgi and Kopinke, 2005).

$$AC\text{–}OH + H^+ OOH^- \rightarrow AC\text{– }OOH + H_2O \quad (5)$$
$$AC\text{–}OOH + H_2O_2 \rightarrow AC\text{– }OH + H_2O + O_2 \quad (6)$$
$$AC + H_2O_2 \rightarrow AC^+ + HO^- + HO^{\bullet} \quad (7)$$
$$AC+ + H_2O_2 \rightarrow AC + HO_{2\bullet} + H^+ \quad (8)$$

Afterwards, the hydroxyl radicals are oxidizing the pollutants. The hydroxyl radicals can react according to 4 kinds of reactions with the pollutants:

$$\text{Addition: } HO^{\bullet} + C_6H_6 \rightarrow (OH)\, C_6H_6 \quad (9)$$
$$\text{Hydrogen Abstraction: } HO^{\bullet} + CH_3OH \rightarrow CH_2OH + H_2O \quad (10)$$
$$\text{Electron Transfer: } HO^{\bullet} + [Fe(CN)_4]^{4-} \rightarrow [Fe(CN)_6]^{3-} + HO^- \quad (11)$$
$$\text{Radical Interaction: } HO^{\bullet} + .\,OH \rightarrow H_2O_2 \quad (12)$$

During the Fenton's reaction all the parameters are adjusted to promote the two first reactions (Reactions 9 and 10) between the pollutant and the hydroxyl radicals. The Fenton process usually involves four stages: pH adjustment, oxidation, neutralization, coagulation and precipitation (Geisslinger et al., 1989).

The aim of the present study is to investigate the removal efficiency of selective PhAC's from urine for the purpose of safe urine reuse in agriculture. In this study the laboratory batch investigations were conducted to determine the potential and efficiency of Fenton's oxidation process H_2O_2 and $FeSO_4$, H_2O_2 and CuCl, and H_2O_2 and AC on the degradation of selective PhACs.

Material and Methods

Selected Pharmaceutical Compounds

For a selection of test compounds a number of criteria were taken into account: consumption, occurrence in aquatic environment, differences in physical-chemical properties (e.g. polarity, hydrophobicity) and suspected biological degradability (persistent, biodegradable), potential eco-toxicological effects and availability of analytical methods. The optimum dose was determined according to the maximum removal of both the selected PhACs and chemical oxygen demand (COD) by using of Fenton's oxidation process. Analysis of the selected PhACs samples using UV-Vis spectrophotometer instrument were carried out.

The selected PhAC's were levofloxacine (LEF), ibuprofen (IBP) and atorvastatin (ATV); extra pure (98%) assays were purchased from Merck (Germany). Characteristics of the selected pharmaceutical compounds:

- Atorvastatin (ATV) is a calcium salt under the trade name Lipitor, is a member of the drug class known as statins, used for lowering blood cholesterol. It also stabilizes plaque and prevents strokes through anti-inflammatory and other mechanisms. The drug has topped the list of best-selling branded in pharmaceutical history, for nearly a decade, since it was approved in 1996, and it exceeds US$125 billion (McCrindle et al., 2003). It is a white to off-white crystalline powder that is insoluble in aqueous solution of pH 4 and below; it is very slightly soluble in water and slightly soluble at pH 7.4 phosphate buffers and acetonitrile, slightly soluble in ethanol and freely soluble in methanol.

- Levofloxacin (LEF) is a synthetic chemotherapeutic antibiotic of the fluoroquinolone drug class and is used to treat severe or life-threatening bacterial infections or bacterial infections that have failed to respond to other antibiotic classes (Nelson et al., 2007). Levofloxacin is associated with a number of serious and life-threatening adverse reactions as well as spontaneous tendon ruptures and irreversible peripheral neuropathy. Chemically, LEF, a chiral fluorinated carboxyquinolone, is the pure (-)-(S)-enantiomer of the racemic drug substance ofloxacin. In solid form, is an odourless, white to yellow, crystallized powder with a melting point of 228.6°C. Its molecular weight is 361. LEF is practically insoluble in water, but is soluble in ethanol and chloroform, and also in ethanol–water mixture,
- Ibuprofen (IBP), from the nomenclature iso-butyl-propanoic-phenolic acid, is a non-steroidal anti-inflammatory drug (NSAID) used for relief of symptoms of arthritis, fever (Van Esch et al., 1995) as an analgesic (pain reliever), especially where there is an inflammatory component, and dysmenorrhea. Ibuprofen is known to have an antiplatelet effect, though it is relatively mild and somewhat short-lived when compared with aspirin or other better-known antiplatelet drugs. Ibuprofen is a ‚core' medicine in the WHO Model List of Essential Medicines, which is a list of minimum medical needs for a basic healthcare system (Su et al., 2003). It is insoluble in water but is soluble in ethanol and acetone. At standard temperature and pressure it is a crystalline solid with a white/off-white colour.

Experimental procedure

Distilled water was artificially contaminated with the selective PhAC's at a concentration of 40 mg/L each (in order to ensure analytical detection limits of UV-Vis spectrophotometer). The experiments were conducted in a jar-test apparatus at room temperature as batch reactors (for each drug separately and/ or in combination). The initial pH of the contaminated water was adjusted to 3 using 0.1 M H_2S0_4. The experiment was started by adding H_2O_2 at variable concentrations to the examined water (to initiate the oxidation reaction) under flash mixing (500 rpm). Furthermore, the catalyst (namely, Fe^{+2}, Cu^{+1}) and / or powdered activated carbon (PAC) was added to the reactors followed by slow mixing (100 rpm). The reaction was allowed to continue for 60 min. Fenton reactions cannot occur at pH > 10. Therefore, the reaction was stopped instantly and thereafter, pH was elevated to more than 10 by adding 1M NaOH under flash mixing for 5 min. at 200 rpm, for the precipitation of iron or copper and the decomposing of residual H_2O_2 before analysis (Talinli and Anderson, 1992). The jar-test was setup for flocculation at 30 rpm for 20 min followed by 60 min for sedimentation.

After determining the optimal dose of H_2O_2 variable concentrations of the catalysts and/or chemicals (namely Fe^{+2}, Cu^{+1} or AC) were added at the pre-determined H_2O_2 dose. Similar experiments were carried out on real urine samples that were artificially contaminated by the selected PhACs in combination.

Artificially Contaminated Urine (ACU) Samples

Urine was collected from urine diversion toilets (Figures 1) implemented in the National Research Centre pilot plant in Cairo, Egypt. None of the toilet users was under any medication with the selective PhACs or any other drugs.

The urine samples were artificially contaminated with an initial concentrations of 40 mg/L for the three selected pharmaceuticals. Fenton oxidation process was applied to this ACU using Fenton's reagents H_2O_2 and $FeSO_4$, H_2O_2 and CuCl, and H_2O_2 and AC.

Analytical Methods

The concentration of drugs in the artificially contaminated water or urine was detected immediately at the end of each experiment using UV-VIS double beam spectrophotometer. The pH and the COD were determined according to the standard methods. Final COD was quantitatively corrected for hydrogen peroxide interference according to the correlation equation (Kang et al., 1999).

Result and Discussion

Factors affecting the Performance of Fenton's process

Effect of pH

Results indicated that the optimum pH of Fenton's Oxidation ranged from and 3.0 to 3.5. This is in good agreement with (Tekin et al., 2006). When pH > 3, oxidation efficiency rapidly decreases due to auto decomposition of H_2O_2 affecting the production of OH radicals (Tekin et al., 2006) and deactivation of ferrous catalyst with the formation of ferric hydroxide precipitates (Luis et al., 2009). It was confirmed that there is a decrease in oxidation potential of hydroxyl radical by increasing the pH value (Lucas and Peres, 2006). When pH is < 3, the reaction of H_2O_2 with Fe^{2+} was seriously

Figure 1: Urine diverting toilet.

affected to reduce hydroxyl radical production and water was formed by the reaction of OH radicals with H^+ ions (Lucas. and Peres, 2006) and also there was an inhibition for the radical forming activity of iron (Luis et al., 2009).

Effect of H_2O_2 and Ferrous Sulphate

The overall effect of sulphates on degradation rates is much lower in comparison to chloride ions. Moreover, ferrous sulphate is more reactive towards hydrogen peroxide than ferrous ions alone that can additionally balance inhibitory potential of the sulphate ions (Laat et al., 2004)

To investigate the optimum dose of H_2O_2, variable H_2O_2 concentrations ranging from 150 to 800 mg/L were added at constant iron concentrations (150 mg/L). The optimum dose of H_2O_2 was found to be 750 mg/L at which the removal rate of the selected PhACs and COD reached the maximum (Table 1 and Figure 2).
The experiment was extended to investigate the optimum dose of Fe^{2+}. Therefore, variable Fe^{2+} concentration ranging from 10 to 150 mg/L, at optimum concentrations of hydrogen peroxide (750 mg/L) were examined (Table 2). The optimum dose of Fe^{2+} was found to be 130 mg/l at which the optimum removal rate of PhACs and COD was achieved (Table 2).

Effect of H_2O_2 and CuCl

Variable doses of CuCl ranging from 10 to 150 mg/L were examined at the predetermined optimum dose of H_2O_2 (750 mg/L) for the determination of the optimum dose of CuCl. The results showed that the optimum dose of the CuCl is 100 mg/L Cu^{+1} at which the removal rate ranged from 95 to 98% for the PhAC's and 97% for the COD (Table 3).

Effect of H_2O_2 and AC

Variable doses of the H_2O_2 ranging from 500 to 5000 mg/L, at a constant dose of PAC (4000 mg/L) were examined to determine the optimum dose of H_2O_2 (Figure 3). It was found that 4000 mg/L H_2O_2 is the optimum dose (Table 4). To determine the optimum dose of AC different doses of AC varying from 100 to 4000 mg/L, at the predetermined optimum concentrations of H_2O_2 (4000 mg/L) were investigated. Results indicated that the optimum dose of AC is 3000 mg/L at which the removal rate ranged from 97 to 99% for the PhACs and 97% for the COD (Table 5).

Artificially contaminated urine (ACU):

Urine samples were artificially contaminated with 40 mg/l of each of the selected PhACs in combination. By contaminating the raw urine, increase in the COD was recorded. Correlation between the chemical characteristics of the raw urine and the ACU (Table 6) showed an increase from 6660 to 13400 mg/l for the COD (total) and from 4130 to 7150 for COD (dissolved) (Table 6). The rest of characteristics remained the same.

Effect of the predetermined doses on the ACU

These predetermined doses are: (750 mg/L H_2O_2 & 130 mg/L $FeSO_4$) as combination (1), (750 mg/L H_2O_2 & 100 mg/L CuCl) as combination (2) and (4000 mg/L H_2O_2 & 3000 g/L AC) as combination (3). When combination (1) was examined unsatisfied removal rate was obtained namely, 86.2%, 45.8%, 70% and 80% for the COD, LEF, IBP and ATV respectively (Table 7). Similar unsatisfied removal rates were obtained by using either combination (2) or combination (3) (Table 7).

The impact of these predetermined doses on the characteristics of the ACU is given in Table 6. Results exhibited decrease in CODT, CODD, BOD_5, TP, NO_3, NO_2, k and Na due to the effect of oxidation. Slight increase in the Ca concentration was recorded which could be attributed to the release of Ca from the oxidation of atorvastatin (as being a calcium salt).

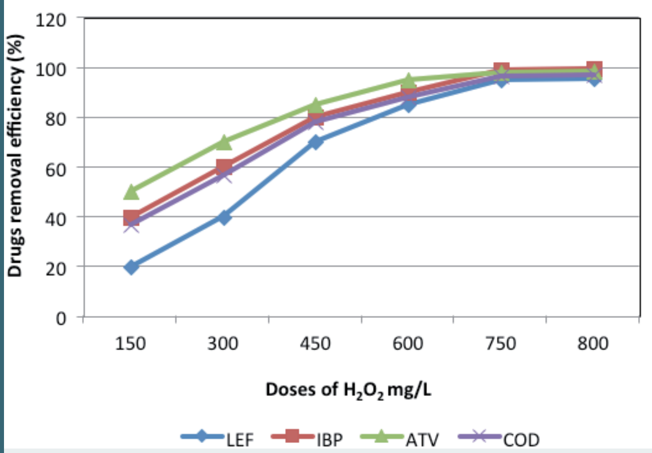

Figure 2: Effect of Fenton process (at different H_2O_2 doses) and constant dose of $FeSO_4$ (150 mg/L) on the removal of the selective PhACs and elimination of COD from water.

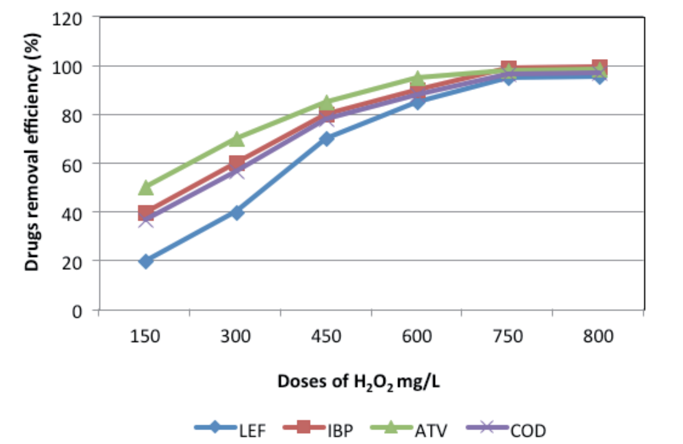

Figure 3: Effect of different doses of hydrogen peroxide in combination with constant dose of powdered activated carbon (AC = 4000 mg/L) on the removal of PhACs and COD from aqueous solution.

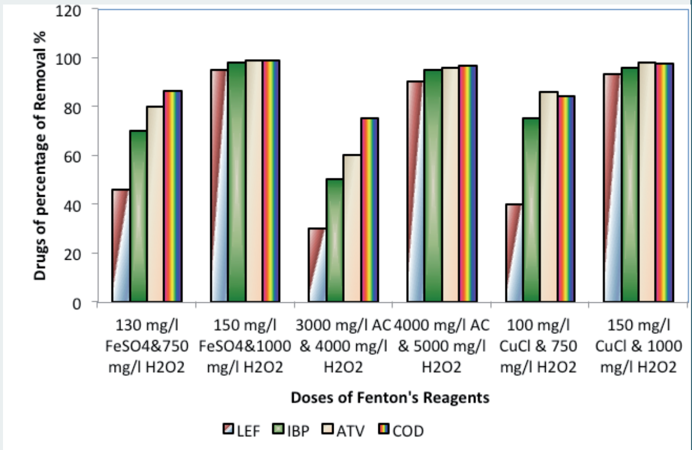

Figure 4: Effect of different Fenton reagents on the elimination of PhACs and COD from artificial contaminated urine sample.

Effect of Higher Doses on the Artificially Contaminated Urine

Higher doses namely, (1000 mg/L H_2O_2 &150 mg/L $FeSO_4$) as combination (4), (1000 mg/L H_2O_2 & 150 mg/L CuCl) as combination (5) and (5000 mg/L H_2O_2 & 4000 mg/L AC) as combination (6) were examined to improve the removal rate of the PhACs. Results obtained showed that removal efficiency of PhACs was notably increased (Table 7). When combination (4) was employed the achieved elimination rate increased from 86.2 to 98.6% for COD, from 45.8 to 95% LEF, from 70 to 98% for IBP and from 80 to 99% for ATV. Similar improvements were achieved by employing the other combinations (5) and (6) (Table 7).

Impact of these higher doses on the chemical characteristics of ACU indicated further decrease in CODT, CODD, BOD_5, TP, NO_3, NO_2, k and Na (Table 6). However, higher increase in the Ca concentration as a result of higher release from the atorvastatin (Table 6).

It is worth mentioning that combination (4) and combinations (5) are at the same concentration. However, combination (4) was slightly more efficient in the elimination of the PhACs. Therefore, combination (4) is more preferable than combinations (5) (Figure 4).

The overall results indicate that the Fenton‘s oxidation process gives high removal efficiency when applied on the artificial contaminated urine, where 95%, 98%, 99% and 98.6% removal efficiency of levofloxacin, ibuprofen, atorvastatin and COD respectively, were achieved under operating condition: pH 3 and combination (4) (Table 7). When combinations (5) was examined at pH 3, less slight removal rate was achieved, namely 93%, 96%, 98% and 97% for levofloxacine, ibuprofen, atorvastatin and COD respectively. By employing AC at combinations (6) and at pH 3, removal efficiency reached 90%, 95%, 96% and 96.8 % for levofloxacine, ibuprofen and atorvastatin and COD, respectively (Figure 4). In the case of AC the removal is due to both adsorption (Eq 5,6) and catalytic reaction (Eq 7,8) (Georgi and Kopinke, 2005).

Conclusion

Fenton’s treatment may be rated as uneconomical for the large volumes of urine. However, Fenton oxidation is preferable as an effective pre-treatment method for the non-biodegradable portions, which renders them more biodegradable for following biological processes. In the case of pre-treatment, lower dose of Fenton’s reagents can be used. Therefore, urine can be used safely for agriculture purpose without the hazard of pharmaceuticals. It is worth mentioning that the catalysts (Fe^{2+} or Cu^{1+}) are more efficient than AC for the elimination of PhACs as lower concentrations of H_2O_2 are required.

Table 1. Efficiency of Fenton treatment at variable doses of H_2O_2 and constant dose of $FeSO_4$ (150 mg/L) for aqueous synthetic sample

Doses of H_2O_2 (mg/L)	COD		LEF		IBP		ATV	
	(mg/L)	(%) removal	(mg/L)	(%) removal	(mg/L)	(%) removal	(mg/L)	(%) removal
0	7200	0	40	0	40	0	40	0
150	4536	37	32	20	27.2	40	20	50
300	3132	56.6	24	40	16	60	12	70
450	1584	78	12	70	8	80	6	85
600	864	88	6	85	4	90	2	95
750	252	96.5	2	95	0.4	99	0.8	98
800	216	97	1.8	95.5	0.2	99.5	0.6	98.5

Table 2: Efficiency of Fenton treatment at variable doses of $FeSO_4$ in combination with the optimum dose of H_2O_2 (750 mg/L) for aqueous synthetic sample

Doses of $FeSO_4$ (mg/L)	COD		LEF		IBP		ATV	
	(mg/L)	(%) removal	(mg/L)	(%) removal	(mg/L)	(%) removal	(mg/L)	(%) removal
0	7200	0	40	0	40	0	40	0
10	3384	53	28	30	16	60	12	70
40	2475	65.6	20	50	12	70	8	80
70	1584	78	12	70	8	80	6	85
100	792	89	6	85	2.8	93	4	90
130	231	96.8	2.2	94.5	0.6	98.5	1	97.5
150	216	97	2	95	0.4	99	0.7	98

Table 3: Efficiency of Fenton treatment by addition of different doses of CuCl at optimum dose of H_2O_2 (750 mg/L) for aqueous synthetic sample.

Doses of CuCl (mg/L)	COD		LEF		IBP		ATV	
	(mg/L)	(%) removal	(mg/L)	(%) removal	(mg/L)	(%) removal	(mg/L)	(%) removal
0	7200	0	40	0	40	0	40	0
10	4104	43	32	20	20	50	16	60
40	2520	65	20	50	12	70	10	75
70	1368	81	12	70	6	85	5.2	87
100	216	97	2	95	1.2	97	1.2	98
130	144	98	1.6	96	0.8	98	0.8	97
150	108	98.5	1.2	96.5	0.6	98.5	0.5	97.5

Table 4: Efficiency of Fenton treatment process using variable doses of H_2O_2 at constant dose of AC (4000 mg/L) for aqueous synthetic sample.

Doses of H_2O_2 (mg/L)	COD		LEF		IBP		ATV	
	(mg/L)	(%) removal	(mg/L)	(%) removal	(mg/L)	(%) removal	(mg/L)	(%) removal
0	7200	0	40	0	40	0	40	0
500	5292	26.5	36	10	28	30	24	40
1000	3240	55	24	40	16	60	14	65
2000	1548	78.5	12	70	6	85	8	80
3000	648	91	6	85	2.8	93	2	95
4000	144	98	1.48	96.3	0.8	98	0.6	98.7
5000	108	98.5	1.4	96.5	0.6	98.5	0.4	99

Table 5: Efficiency of Fenton treatment process at different doses of AC in combination with the optimum dose of H_2O_2 (4000 mg/L) for aqueous synthetic sample.

Doses of AC (mg/L)	COD		LEF		IBP		ATV	
	(mg/L)	(%) removal	(mg/L)	(%) removal	(mg/L)	(%) removal	(mg/L)	(%) removal
0	7200	0	40	0	40	0	40	0
100	3672	49	25	37.3	20	50	16	60
500	1764	75.5	11.6	71	10	75	8	80
1000	432	94	2.8	93	2.16	94.6	2	95
2000	288	96.5	2	05	1.6	96	1.2	97
3000	144	98	1.2	97	1	97.5	0.4	99
4000	108	98.5	1	97.5	0.8	98	0.32	99.5

Table 6: Characteristic of urine before and after treatment using (FeSO4 and H2O2), (AC and H_2O_2) and (CuCl and H_2O_2) (as mg/l).

Parameter	Natural human urine	Artificially contaminated urine	Fenton's reagents doses (mg/L)					
			750 H_2O_2 130 $FeSO_4$ Comb. (1)	1000 H_2O_2 150 $FeSO_4$ Comb. (4)	750 H_2O_2 100 CuCl Comb. (2)	1000 H_2O_2 150 CuCl Comb. (5)	4000 H_2O_2 3000 AC Comb. (3)	5000 H_2O_2 4000 AC Comb. (6)
pH	4.95	4.14	9.5	9.5	9.5	9.5	9.5	9.5
COD_T (mg/L)	6555	13355	1840	188	2100	346	3970	415
COD_D (mg/L)	4130	7153	1160	118	1320	218	3300	260
COD_D (mg/L)	1200	1205	370	144	362	180	421	241
BOD_5/COD	0.18	0.09	0.20	0.76	0.17	0.52	0.10	0.58
T.P. (mg/L)	449	450	90	17	113	41.1	130	32.8
NO_3 (mg/L)	4.46	4.47	0.107	0.028	2.990	2.480	2.233	1.781
NO_2 (mg/L)	17.56	18	3.6	0.3	4.3	1.2	5.2	2.3
K (mg/L)	13886	13890	7630	1888	6500	1586	2057	773
Na (mg/L)	14760	14770	8410	1745	*7800*	1615	2610	831
Ca (mg/L)	5825	5820	6015	9240	5900	8610	8255	4940

Table 7: Efficiency of Fenton treatment process on the removal of PhACs from artificial contaminated urine sample using different Fenton's reagents.

Doses of Fenton's reagents			COD		LEF		IBP		ATV	
H_2O_2 (mg/L)	Reagent	Combination	(mg/L)	(%) removal	(mg/L)	(%) removal	(mg/L)	(%) removal	(mg/L)	(%) removal
0	0	-	13355	0	40	0	40	0	40	0
750	130 mg/L $FeSO_4$	1	1840	86	21.7	46	12	70	8	80
1000	150 mg/L $FeSO_4$	4	188	99	2	95	0.8	98	0.4	99
750	100 mg/L CuCl	2	2100	84	24	40	10	75	5.6	86
1000	150 mg/L CuCl	5	346	97	2.8	93	1.6	96	0.8	98
4000	3000 mg/L AC	3	3300	75	28	30	20	50	16	60
5000	4000 mg/L AC	6	415	97	4	90	2	95	0.6	96

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Notes

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Next issue:

Issue 18, January 2014: **„Outcomes from the UFZ wetland workshop“**

Issue 19, April 2014: **„The CLARA project“**

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