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NaWaTech

Natural Water Systems and Treatment Technologies to cope with Water Shortages in urbanised Areas in India

The NaWaTech project

partner of: sustainable sanitation alliance

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Cover Photo / ***Titelbild***

Upper left and right, and Lower left: Günter Langergraber, BOKU University, Austria
Lower right: Philip Winkelmeier, Kre_Ta Landscape Architects, Germany

Editorial

During the last 3.5 year the NaWaTech project (Natural Water Systems and Treatment Technologies to cope with Water Shortages in Urbanised Areas in India, http://nawatech.net/) aimed to implement natural and compact wastewater treatment systems in urban Indian settings. All implemented systems aimed to reduce the per capita water demand by producing treated water that can be used for toilet flushing and/or irrigation. By developing the Safety and O&M Planning approach, the team aimed to guarantee long-term operation of the implemented systems. Besides implementation of pilot sites, other main activities included capacity development by establishing a Community of Practice as well as support of business development.

In Issue 25 of **Sustainable Sanitation Practice (SSP)** the highlights and main findings of the NaWaTech project are presented. The 14 papers included in this special issue show specific aspects of the project as well as an outlook on future activities.

The thematic topic of the next issue (Issue 26, April 2016) is ”*Composting*“. If you are interested to submit a contribution please inform the SSP editorial office e (ssp@ecosan.at). Contributions for issue 26 are due to 1 March 2016, the guide for authors is available from the journal homepage (www.ecosan.at/SSP). Please feel free to suggest further topics for issues of the journal 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.

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

Introduction to the NaWaTech Project

In this paper the basic concepts and ideas which form the basis of the NaWaTech project are described.

Authors: Katie Meinhold, Pawan K. Labhasetwar

Abstract

The NaWaTech project (Natural Water Systems and Treatment Technologies to cope with Water Shortages in Urbanised Areas in India) is an Indian-European Research and Development Project aimed at maximising the exploitation of natural and compact technical systems and processes for the effective management of municipal water resources, water supply and sanitation services, and the municipal water cycle as a whole in urbanised areas of India. The NaWaTech approach has been applied at six case study sites in Pune and Nagpur, India, accompanied by supporting activities such as laboratory pilot studies, the setup of a Community of Practice, or training of SMEs on the NaWaTech approach. This paper describes the general concepts which form the basis for the NaWaTech project, gives a brief overview on the NaWaTech case studies and the supporting project activities, and an outlook on the SSP NaWaTech special issue.

The general concept of NaWaTech

Providing adequate water supply and sanitation, particularly in urban areas, is a challenging task for governments throughout the world. This task is made even more difficult due to predicted dramatic global changes: Population growth, urbanisation, increasing industrialisation, climate change and a steep increase in water consumption are putting pressure on urban water resources. India, home to over 1.2 billion people, is no exception in this matter. India is currently facing a water and sanitation crisis that might hinder the economic development of the nation, with water scarcity and pollution being some of the most severe nation-wide environmental problems. Urban water supply and sanitation in the Indian context are important basic needs for the improvement of the quality of life. In urban areas water is supplied for domestic and commercial usages from surface and groundwater sources and about 80% of the water supplied for domestic use exits as wastewater. In most of the urban centres wastewater is discharged untreated on land or surface water bodies

NaWaTech - key facts:

- NaWaTech (Natural water systems and treatment technologies to cope with water shortages in urbanized areas in India) is an Indian-European Research and Development Project in water technology and management, co-financed by the European Commission within the 7th Framework Programme (Contract no: 308336) as well as the Department of Science & Technology of the Government of India (DST Sanction Order: DST/IMRCD/NaWaTech/2012/(G))
- Main activities of NaWaTech included:
  - Implementation at six intervention sites in Pune and Nagpur, India, taking into account integrated water management principles
  - Assessment of natural and compact technical wastewater treatment technologies
  - Laboratory pilot studies to enhance natural treatment technologies for the Indian context
  - Development of a safety and O&M planning approach to support long-term sustainability, efficiency and life span of the intervention sites
  - Knowledge transfer and training of SMEs active in the water sector
  - Setup of a EU-India research partnership and NaWaTech Community of Practice (CoP)
  - Student exchange programme

contaminating both of these precious water resources. According to the last census of 2011, only 72.6% of the households in urban areas had access to water closets, of which only 32.7% were connected to a piped sewer system (Census, 2011). The installed sewage treatment capacity is only around 30% (CPCB, 2009). According to NFHS-III, of the total urban households 50.4% have access to sanitary facilities (either flush or pit), but out of the total urban poor only 18.2% have access to sanitary facilities, while 62.2% of the non-slum population has access to sanitation facility (NFHS, 2008). Due to lack of proper sanitation facilities, and also poor infrastructure to deal with a city's sewage, wastewater management is an alarming problem in almost all cities across India (UNICEF, 2013).

The conventional, flush-and-forget approach to urban water management does not offer a sustainable option to solve this sanitation crisis. This approach is often associated with serious inefficiencies, such as providing high quality drinking water for all domestic purposes, large piping systems difficult to construct and maintain, large quantities of drinking water to transport human excreta, dependency on extensive energy supply for advanced treatment systems, production of large quantities of sludge and loss of useful elements with the sludge (e.g. phosphorus). Therefore, in order to cope with water shortages in urban areas in India, there is a need for a paradigm shift from conventional, centralised end-of-pipe water management to a more integrated approach. Decentralised systems and innovative technologies optimising water use and reuse, requiring little or no energy and low maintenance costs, using locally available material and human resources should be considered in order to optimise the operation, maintenance and the cost-effectiveness of future urban water management systems. The NaWaTech project is one step further in this direction.

NaWaTech, i.e. 'Natural Water Systems and Treatment Technologies to cope with Water Shortages in Urbanised Areas in India' is an Indian-European Research and Development Project initiated in July 2012 and co-financed by the European Commission under the 7th Framework Programme and the Department of Science and Technology of the Government of India (DST). The project aims to explore, assess and enhance the potential of natural and compact technical water treatment systems in order to improve their performance and reliability for the effective management of municipal water sources and to cope with water shortages in urban India. As an integrated approach, NaWaTech is based on the following axes:

(i) interventions over the entire urban water cycle (considering both wastewater and freshwater as integrated parts of water resources in general)

(ii) optimisation of water use by reusing wastewater and preventing pollution of freshwater sources

(iii) prioritisation of small-scale natural and technical systems, which are flexible, cost-effective and require low operation and maintenance.

Natural water systems, such as constructed wetlands, vertical gardens, short rotation plantations and sub-soil filtration and storage via soil aquifer treatment and bank filtration, are such small-scale systems. In addition,

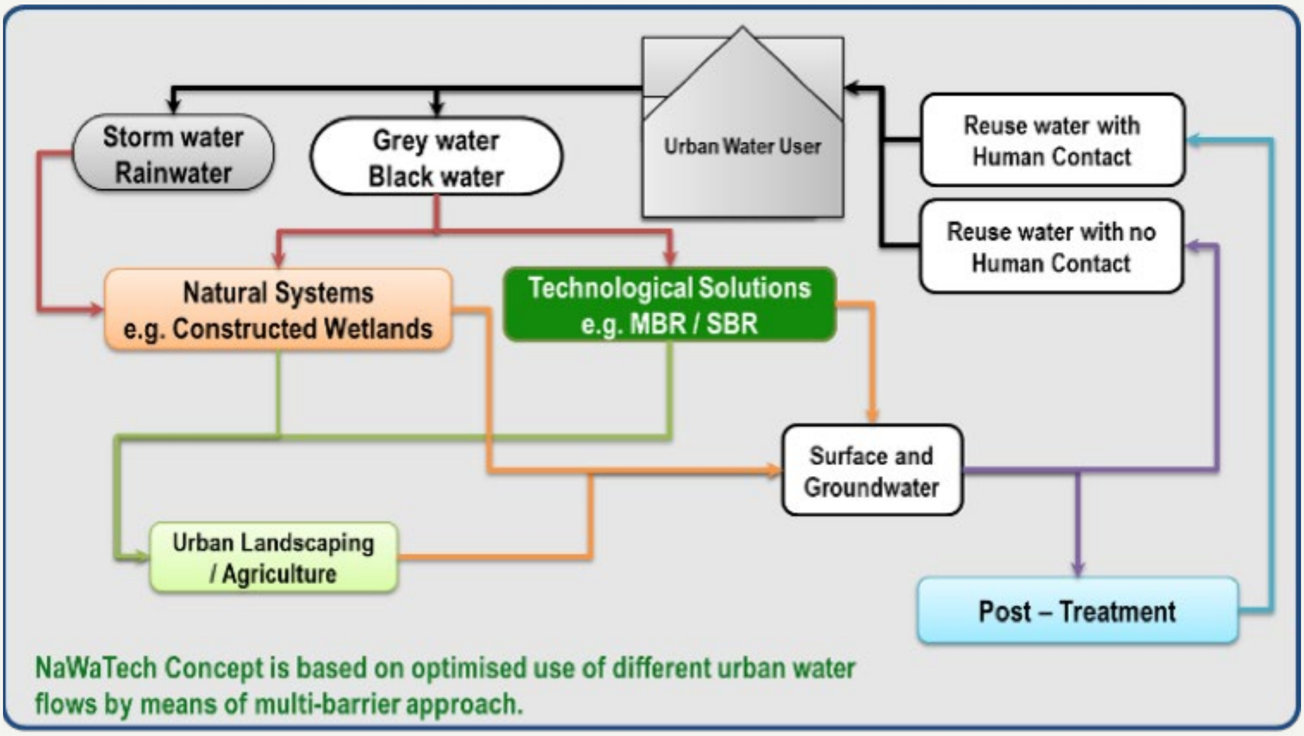

Figure 1: The NaWaTech approach

compact technical systems such as SBRs and MBRs have made a great development step in the last years, particularly for urban areas due to their low land footprints. These systems can absorb highly and widely varying pollution loads, buffer seasonal fluctuations in the availability of water; and can be integrated into urban planning as green infrastructures providing additional socio-economic benefits such as amenity or health improvements. Furthermore, they show a high potential due to their cost-efficiency and low requirements for building, operation and maintenance and energy supply. In Europe, such systems have been developed for many years and their potential for the application in developing and newly-industrialised countries is widely accepted. However, warmer climate zones in India offer different environmental conditions for operating natural wastewater treatment systems. Moreover, demand for compact wastewater treatment systems particularly for residential and commercial complexes in India is increasing in urban areas due to competing land requirements.

Taking these issues into account, the project NaWaTech aims at maximising the exploitation of natural and compact technical systems and processes for the effective management of municipal water resources, of water supply and sanitation services, and of the municipal water cycle as a whole in urbanised areas of India. The use of different urban water flows is optimised by treating each of these flows via modular systems taking into account the different nature and degree of pollution of the respective water sources as well as the different requirements for different usages (see figure 1). For instance, blackwater and greywater (as separated streams or mixed) can be treated through the combination of an anaerobic process (producing energy and biogas) plus constructed wetlands (CWs) or treated through aerobic technical water treatment systems (SBR or MBR). In both cases treated wastewater can either be discharged to the surface waters or reused in urban agriculture or landscaping. Storm water can be collected and pre-treated in CW before it is filtered through the soil and stored in the aquifer. Rainwater can be collected on rooftops and parking lots and used in the households or fed into the aquifer. In addition, a cost-effective and viable post-treatment option can be developed based on different steps depending on the use to be given to the stream, and therefore water quality requirements.

Ideally, every available water source should be reused locally minimising the dependency on external freshwater sources and minimising the pollution of downstream water users. This holistic approach minimises the urban water footprint and enhances the water security of the area, as the water cycle is closed at a local level. It also minimises the pollution of ecosystems and water sources for downstream users, as only minimal amounts of freshwater get polluted and polluted water is treated and reused locally. Thus, it will cost-effectively improve the water quality of urban surface water and restore depleting groundwater sources.

An international team composed of seven European partners, coordinated by ttz Bremerhaven and seven Indian partners, coordinated by the CSIR National Environmental Engineering Research Institute (NEERI), collaborated on the adaptation of different natural and compact water systems to the Indian context during the

Figure 2: The NaWaTech consortium

three and a half year time frame of NaWaTech, including research centres, universities, NGOs, governmental organisations, associations and SMEs (see figure 2). Besides the research institute ttz (Germany), the European team is constituted of the University of Natural Resources and Life Sciences, Vienna (BOKU, Austria), the Technical University of Catalonia (UPC, Spain), Iridra Srl. (Italy), BioAzul S.L. (Spain), Seecon international GmbH (Switzerland), and Kre_Ta Landscape Architects (Germany). The Indian team consists, besides the coordinator NEERI in Nagpur (where two of the NaWaTech implementation sites are located) of the non-profit-organisation Ecosan Services Foundation (ESF) and the Shrishti Eco-Research Institute (SERI) (both located in Pune, where the remaining four case study sites are located). Furthermore, the Indian consortium included the Indian Water Works Association (IWWA), the Pune Municipal Corporation (PMC), Maharashtra Jeevan Pradhikaran (MJP), and Viraj Envirozing India Private Limited (VEIPL) to support the project's activities.

Overview of project activities

The NaWaTech case studies

A total of six NaWaTech systems consisting of different natural and compact technical technologies combined in a modular fashion were selected by the partners, which were implemented in Nagpur and Pune, in the Indian state of Maharashtra (see Table 1).

At the facilities of the College of Engineering Pune (COEP) Hostel Campus, which can host up to 2000 students, a full-scale demonstration project featuring greywater segregation, wastewater treatment with anaerobic pre-treatment and Vertical Flow Constructed Wetlands (VF CWs), as well as reuse of the treated water (for irrigation and toilet flushing) was realised. This is the largest site in the project treating a total of 180 cubic meters of wastewater per day in three separate units. A different configuration can be seen at the Ordnance Factory Ambajhari (OFAJ) in Nagpur, where a total of

Table 1: Overview of the six NaWaTech case study sites

NaWaTech case study site	Design overview	No. of people covered	Volume treated
Amanora Park Town, Pune	SBR (Sequential Batch Reactor) and MBR (Membrane Bioreactor) systems	400 p.e.	40 m^3/d (30 m^3 for the MBR, 10 m^3 for the SBR)
Maharashtra Jeevan Pradhikaran (MJP), Pune	Green Wall (vertical garden) for greywater treatment (2 parallel lines)	1 m^2 of Green Wall per person (5-6 m^2 of Green Wall for an Indian family)	0.24 m^3/d (0.12 m^3/day per each line)
College of Engineering Pune (COEP) Hostel Campus	- Anaerobic treatment + Vertical Flow Constructed Wetland (VF-CWs) for wastewater - VF-CW for greywater	Max. 1,500 students + personnel	180 m^3/d (100 m^3/d wastewater and 40 m^3/d greywater treated for reuse + 40 m^3/d wastewater pre-treated before discharge)
Indradhanushya Environment Education and Citizenship Centre, Pune	Eco-Filtration Bank technology with Soil Scape Filter as main treatment step	400 p.e.	40m^3/d
Ordnance Factory Ambajhari (OFAJ), Nagpur	- Main treatment line with anaerobic pre-treatment and Vertical Up-flow Constructed Wetland and Sludge Drying Reed Beds (SDRB) - Pilot line with French Reed Bed (FRB) system and Short Rotation Plantation (SRP)	1,000 p.e.	100 m^3/d
Dayanand Park, Nagpur	5 parallel Constructed Wetland (CW) systems with different CW configurations	1,000 p.e.	100 m^3/d

100 m^3/day of wastewater is being treated. The system consists of a main treatment line featuring anaerobic pre-treatment, Vertical Up-flow Constructed Wetlands, and Sludge Drying Reed Beds (SDRBs) as well as a pilot line with a French Reed Bed system and a Short Rotation Plantation (SRP). It provides recycled water for a multipurpose lawn to prevent the use of fresh water in gardening. Different combinations of horizontal flow and vertical flow subsurface wetlands are currently being established at Dayanand Park, Nagpur, a multi-utility public garden spread over seven acres of land, used by approx. 1500-2000 people daily for recreational and leisure activities. This system can supply recycled water for irrigating the park, substituting the use of groundwater or untreated sewage, which is used for irrigation in the summer months when groundwater levels are depleted. Furthermore, alongside the Indradhanushya Environment Education and Citizenship Centre in Pune a full-scale treatment system is installed to treat wastewater flowing through an adjacent open stream. Eco-Filtration Bank technology - consisting of screen, intake well, Soil-Scape Filter beds as the main treatment unit, and a treated water pond - is being used to generate recycled water for garden irrigation and toilet flushing. On the front of a representative office building (Maharashtra Jeevan Pradhikaran, Water Supply and Sanitation Department of Maharashtra state) in Pune a Green Wall (also called vertical garden) was realised in order to treat greywater and reuse the treated water for irrigation. In addition to these natural systems, a Sequential Batch Reactor (SBR) and a Membrane Bioreactor (MBR) were constructed at Amanora Park Town, Pune and have been in operation since June 5th, 2014, when the plants were officially inaugurated. Both systems are treating mixed domestic wastewater (black water and grey water) from residential buildings, which is then reused for toilet flushing and gardening.

Activities to enhance the project's impact

In order to complement the NaWaTech case studies the project includes a set of other activities with the overall intention to extend the project's impact beyond the set timeframe. Besides the implementation sites, NaWaTech produces different kinds of knowledge, guidelines and tools aimed at different kinds of stakeholders, including service providers and SMEs, research partnerships and enabling institutional environments for the application of natural water treatment systems to cope with water shortages in urban areas of India.

Assessment of technologies

The NaWaTech consortium described and assessed the technical, financial and environmental potential of natural and compact technical water treatment technologies (23 in total) to cope with water shortages in urbanized areas in India (i.e. to treat and reuse secondary urban water sources and to recharge primary water sources). Among others, design and construction principles, the operation and maintenance, cost considerations, experiences in the world and in India, as well as advantages and disadvantages of each technology were considered (Barreto Dillon et al., 2013).

Pilot studies, and Safety and O&M planning

In the frame of pilot-scale experiments, natural water treatment systems were assessed considering extreme climatic conditions and highly varying pollutions loads, in order to enhance these for the production of recycled water to supplement water sources in the Indian context. The location of India in warmer climate zones sets different environmental conditions compared to Central Europe (e.g. regarding temperature, affecting dissolved oxygen concentrations, or occurrence of floods/drought periods) and, thus, important lessons can be learnt from these pilot experiments for the implementation of natural treatment technologies in India.

Furthermore, in order to achieve a long-term sustainability, efficiency and life span of the case study sites, special attention has been given to safety planning. A methodology for safety and O&M (operation and maintenance) planning has been developed and implemented for the case study sites in Pune and Nagpur. Critical control and monitoring activities to be integrated and prioritized in day-to-day operation and maintenance of the systems in order to assure system safety have been identified for each pilot site.

Support of SMEs in the water sector

In order to ensure the take-up in practice and achieve a beneficial economic impact to the water sector, special attention has been given to SMEs active in wastewater treatment. All relevant project outcomes are compiled into a decision support kit, the NaWaKit (http://www.sswm.info/category/step-nawatech/introduction), designed to provide the needed technical and business strategy tools to support water practitioners when conceiving, launching and growing a new venture in the water and wastewater sector. Furthermore, it presents key information about technological options for the implementation of appropriate wastewater treatment systems. Moreover, capacity building activities such as trainings and international workshops were carried out, aimed specifically at SMEs, to coach them with regards to integrating NaWaTech approaches into their business plans and fostering the efficient uptake of the main tools developed in the project.

NaWaTech research partnership and Community of Practice

NaWaTech brings together researcher and practitioners from the EU and India, enabling a close collaboration in order to establish the foundations for a long-term collaboration in water technologies. In order to enhance this research partnership, activities such as joint preparation and submission of publications in relevant scientific journals, planning of the NaWaTech final conference, or a twinning programme for Indian and European MSc and PhD students were carried out. Besides the scientific partnership between EU and India, an important component of the project was to bring together all the involved stakeholders in urban water management, in order to be better able to take into account local problems and needs. A NaWaTech Community of Practice (CoP) was initiated bringing together key stakeholders from research, industry and governmental bodies in Pune and Nagpur, respectively, in order to better align the projects activities with policies and urban water plans and to facilitate the implementation of replications.

The SSP special issue

This special issue of SSP presents the highlights and key findings of the NaWaTech project. The following contributions have been included in the special issue:

- The first articles describe the main results from the implementation of the six case study sites:
    - Ordnance Factory Ambajhari, Nagpur (Pophali et al., 2016),
    - Dayanand Park, Nagpur (Masi et al., 2016a),
    - College of Engineering Pune (COEP) hostel campus, Pune (Patil et al., 2016),
    - Vertical gardens at MJP head office (Masi et al., 2016b),
    - Amanora Park Town, Pune (Zapata et al., 2016), and
    - Indradhanushya Environment Education and Citizenship Centre, Pune (Joshi and Patil, 2016).
- Two papers describe general aspects related to the implementation of wastewater treatment systems at the pilot sites:
    - Winkelmeier et al. (2016) describe the importance of incorporating landscaping aspects when implementing natural treatment systems, and
    - Nicolics and Langergraber (2016) describe the safety and O&M planning approach developed to support the long-term operation of the implemented pilot systems.
- Ávila et al. (2016) describe results of pilot experiments carried out to test constructed wetland systems under simulated Indian conditions.
- The following three articles describe activities and experiences related to business development and promotion of natural water systems and treatment technologies in India:
    - Understanding the market opportunities in the Indian wastewater sector is essential for new SMEs (Barreto Dillon, 2016b).
    - To support entrepreneurs and SMEs in the wastewater sector, NaWaTech organised trainings and developed the NaWaKit (Barreto Dillon, 2016a).
    - The NaWaTech Community of Practice was initiated to promote natural water systems and treatment technologies in India (Kale and Nagarnaik, 2016).
- The final paper of Meinhold and Labhasetwar (2016) summaries the project and gives an outlook on future activities planned.

References

Ávila, C., Pelissari, C., Heleno Sezerino, P., García, J., Garfí, M. (2016): Nature-Based Solutions for Wastewater Treatment in Peri-Urban Areas of India: Pilot-Scale Experiments. Sustainable Sanitation Practice 25 (January 2016), 60-66.

Barreto Dillon, L., Doyle, L., Langergraber, G., Satish, S., Pophali, G. (eds., 2013): Compendium of Natural Water Systems and Treatment Technologies to cope with Water Shortages in Urbanised Areas in India. epubli GmbH, Berlin, Germany, 122p.

Barreto Dillon, L. (2016a): Supporting NaWaTech Entrepreneurs and SMEs Tapping the Indian Wastewater Market. Sustainable Sanitation Practice 25 (January 2016), 76-83.

Barreto Dillon, L. (2016b): Understanding the Market Opportunities of New Indian Based SMEs in the Wastewater Sector. Sustainable Sanitation Practice 25 (January 2016), 67-75.

Census (2011): Census of India, Ministry of Home Affairs, Government of India, Delhi, India.

CPCB (2009): Status of water supply, wastewater generation and treatment in Class-I Cities and Class-II Towns of India, Central Pollution Control Board, Government of India, Delhi, India.

Joshi S., Patil P. (2016): Treatment of Contaminated Ambil Stream Water and Reuse in Indradhanushya Environment Education and Citizenship Centre, Pune. Sustainable Sanitation Practice 25 (January 2016), 42-47.

Kale, S., Nagarnaik. P. (2016): NaWaTech Community of Practice (CoP). Sustainable Sanitation Practice 25 (January 2016), 84-90.

Masi F., Bresciani R., Winkelmeier P., Pophali G.R., Khilnani A., Sahu N., Kaur H., Labhasetwar P.K., Yadav S., Nagarnaik P. (2016a): Wastewater Treatment and Reuse for Irrigation in an Urban Park: the Dayanand Park Treatment Wetland System in Nagpur. Sustainable Sanitation Practice 25 (January 2016), 17-20.

Masi, F., Rizzo, A., Bresciani, R., Edathoot, A., Patwardhan, N., Panse, D. (2016b): Greywater Treatment and Reuse in a Municipal Office in Pune by Vertical Gardens. Sustainable Sanitation Practice 25 (January 2016), 28-33.

Meinhold, K., Labhasetwar, P.K. (2016): NaWaTech: Summary and Outlook. Sustainable Sanitation Practice 25 (January 2016), 90-94.

Nicolics, S., Langergraber, G. (2016): Safety and O&M Planning. Sustainable Sanitation Practice 25 (January 2016), 52-59.

NFHS (2008): National Family Health Survey (NFHS) – III, 2005-6, available at http://hetv.org/india/nfhs/nfhs3/NFHS-3-Volume-I-Front-Matter.pdf (accessed 5 January 2016)

Patil, S., Edathoot, A., Patwardhan, N., Bresciani, R., Panse, D., Masi, F. (2016): Natural and Cost Effective Way of Treating Domestic Wastewater with Reuse in Non-Potable Purposes: The College of Engineering Pune (COEP) Hostel Campus Case Study. Sustainable Sanitation Practice 25 (January 2016), 21-27.

Pophali, G.R., Sahu, N., Khilnani, A., Kaur, H., Yadav, S., Labhasetwar, P.K., Bresciani, R., Masi, F., Meinhold, K. (2016): Domestic Wastewater Treatment and Reuse in Ordnance Factory Ambajhari, Nagpur. Sustainable Sanitation Practice 25 (January 2016), 12-16.

UNICEF, FAO and SaciWATERs. (2013): Water in India: Situation and Prospects. https://coin.fao.org/coin-static/cms/media/15/13607355018130/water_in_india_report.pdf (accessed 5 January 2016)

Winkelmeier P., Kretschmer M., Tauscher A. (2016): Landscape Architecture and Wastewater Management in the Indian Context. Sustainable Sanitation Practice 25 (January 2016), 48-51.

Zapata, P., Bribián, J.L., Caballero, A., Lorenzo, A. (2016): Wastewater Treatment and Reuse in Amanora Park Town, Pune. Sustainable Sanitation Practice 25 (January 2016), 34-41.

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Domestic Wastewater Treatment and Reuse in Ordnance Factory Ambajhari, Nagpur

This paper describes the implementation of a decentralized sewage treatment system for the housing complex of the Ordnance Factory Ambajhari, Nagpur

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Abstract

This study highlights the implementation of a decentralised wastewater treatment system (DEWATS) for the housing complex of the Ordnance Factory Ambajhari (OFAJ), Nagpur. A natural treatment system comprising of an improved up-flow anaerobic filter and a vertical up-flow constructed wetland have been implemented for 1000 population equivalent (p.e.). The improved anaerobic treatment ensures substantial removal of organic matter, whereas the engineered wetlands ensure removal of remaining organic matter, fine particles, nutrients and Escherichia coli, which are harmful for human health. Anaerobic systems and engineered wetlands being natural processes are less energy intensive, do not require highly skilled manpower, have high treatment efficiency, require low operation and maintenance (O&M) costs and the latter can add to aesthetics, thus proving to be techno-economical and environmentally sustainable solutions. Additionally, sludge management through a novel sludge drying reed bed system is implemented for the first time in India. A pilot scale French reed bed system of capacity 5 – 8 m^3/d is implemented as well, to demonstrate application of this type of constructed wetlands in sewage management on a small scale in India. The treated effluent obtained from the French reed beds is utilized for development of a green belt referred to as a short rotation plantation (SRP).

Introduction

Nagpur is located at an altitude of 310 m above sea level at 21°06ʹ N latitude and 79°03ʹ E longitude. Nagpur experiences a climate that is mainly dry and slightly humid for major parts of the year. Summer season in the city begins around the month of March and lasts until June. Maximum temperature is recorded above 45°C for about 30 days per year. Nagpur experiences water scarcity in the summer season despite annual rainfall of about 1200mm, as this predominately occurs in the months of monsoon, i.e. from July to September. The present fresh water supply in the city is 470 MLD (million litres per day) (NMC, 2005) and the average rate of supply is 135 – 150 lpcd (litre per capita per day). The treatment scheme presented in this paper with a capacity of 100 m^3/day is installed in proximity to the housing premises for 1000 population equivalent (p.e.) at the Ordnance Factory Ambajhari (OFAJ) estate in the city of Nagpur, India.

Characterization of domestic wastewater

Grab samples were collected twice a day from March to May 2014. The samples of the raw wastewater were analysed in accordance with the Standard Methods for the Examination of Water and Wastewater (APHA 2009). The characteristics of the dry weather flow is presented in Table 1.

Technical data:

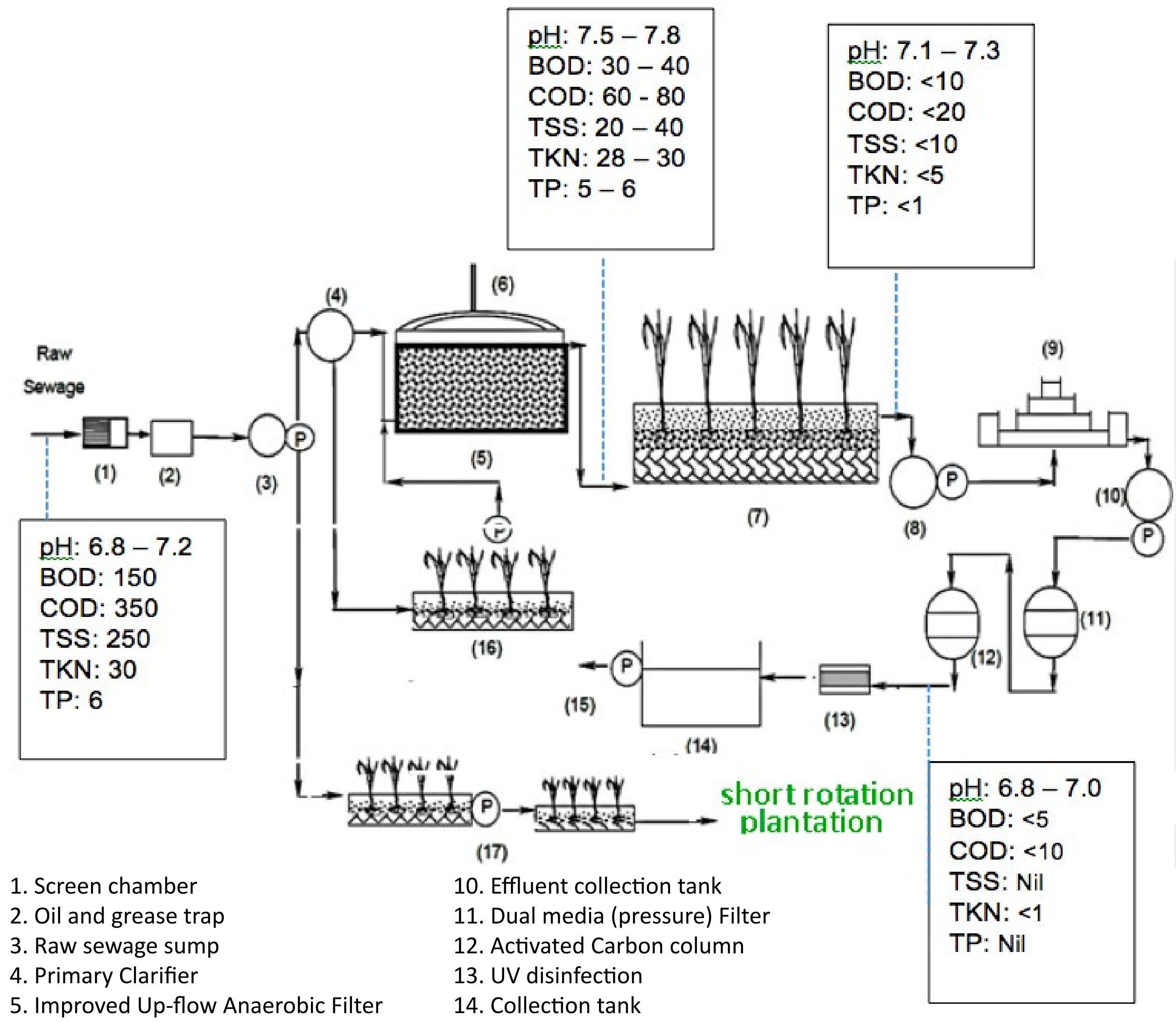
- Main treatment line for 100 m^3/d:
  - Wastewater: Sewage pumping → Primary clarifier → Up-flow anaerobic filter → Vertical up-flow constructed wetland → Dual media filter → Activated carbon columns → UV disinfection → treated water for reuse
  - Sludge: Sludge drying reed beds
  - Reuse: Irrigation
- Pilot line: French reed beds for 5 – 8 m^3/d → treated water used in short rotation plantation (with Melia dubia and Bambusa plants)

Table 1: Physico-chemical characteristics of domestic wastewater of the OFAJ residential colony (all units except pH are in mg/L)

Parameter	Range	Design values
pH	6.8 – 7.6	7.3
BOD	100 – 150	150
COD	170 – 350	350
Total Suspended Solids (TSS)	150 – 250	250
Total Dissolved Solids (TDS)	500 – 700	--
Total Solids (TS)	650 – 950	--
Alkalinity	160 – 220	220
TKN	25 – 35	30
Phosphate	2 – 6	6
Oil and grease	24 – 30	30

Rationale for selection of treatment system

Major criteria for the selection of treatment options were low O&M costs and easy to operate systems while achieving prescribed discharge standards of the state. Furthermore, the treatment system should be environmentally sustainable, require low capital costs, be less energy intensive, without chemical treatment and sludge generation, manageable with low-skilled manpower and, most importantly, aesthetically acceptable to the community. Considering all factors above, a natural treatment system comprising anaerobic systems for removing organics and engineered or constructed wetlands (CWs) have been provided.



1. Screen chamber
2. Oil and grease trap
3. Raw sewage sump
4. Primary Clarifier
5. Improved Up-flow Anaerobic Filter
6. Biogas collection
7. Vertical Up-flow Constructed Wetlands
8. Holding Tank
9. Cascade Aeration
10. Effluent collection tank
11. Dual media (pressure) Filter
12. Activated Carbon column
13. UV disinfection
14. Collection tank
15. Treated effluent reuse
16. Sludge Drying Reed Bed (SDRB)
17. French Reed Bed (FRB)

P. Pumps

Figure 1: Schematics of techno-economic treatment scheme at OFAJ

The preliminary treatment consists of oil & grease and fats removal to prevent damage to the system. The secondary treatment consists of up-flow attached growth anaerobic filters ideal for low organic loading, featuring low area footprint, low hydraulic retention time compared to suspended growth processes, and no odour and fly nuisance. It is less prone to process upset and provides better removal efficiency as compared to suspended growth processes (CPHEEO, 2013). The subsurface vertical up-flow constructed wetlands which follow are best suited for removing remaining organics and nutrients. The tertiary treatment is consists of pressure sand filters and activated carbon columns which ensure the removal of colloidal particles and residual non-biodegradable organic matter to generate reusable water.

Results and discussion

Implementation of treatment scheme

The entire treatment scheme is depicted in Figure 1.

Main treatment line

The main treatment line consists of a bar screen chamber, oil and grease trap, inlet sump, primary clarifier, improved up-flow anaerobic filter followed by subsurface vertical up-flow constructed wetland, cascade aerator, dual media and activated carbon columns. The settled sludge from the primary clarifier is treated in sludge drying reed beds (SDRB) to achieve sludge management.

The improved anaerobic filter ensures substantial removal of organic matter, wherein a specially designed filter media as shown in Figure 2 is used for microbial growth.

Figure 2: Anaerobic filter media (Pall rings) made of PP/HDPE featuring high specific surface area 150 – 200 m²/m³

The filter media is made of poly propylene (PP) or high density poly ethylene (HDPE) material and offers 150 m^2/m^3 specific surface area. The anaerobic reactor is filled with filter media 80% of its total volume and provision is made for a biogas collection system, which is proposed to be utilised as fuel.

The treated effluent from the anaerobic filter is fed by gravity into two parallel subsurface vertical up-flow constructed wetlands planted with *Typha latifolia* and *Canna indica* with a plant density of 4 plants per m^2. The vertical up-flow constructed wetlands ensure removal of remaining organics and nutrient reduction.

Thereafter, treated wastewater is pumped to the cascade aerator to infuse dissolved oxygen and enhance the quality of effluent. The aerated wastewater is then conveyed for tertiary treatment comprising dual media filters followed by granular activated carbon columns for removal of colloidal solids and non-biodegradable organics as well as pharmaceutical and personal care products (PPCPs). Disinfection via UV is provided to the final treated effluent which is then ready to be recycled and reused for various non-potable uses of the community.

The decentralised wastewater system is designed for a flow rate of 100 m^3/day (1000 P.E.). The detention time in the anaerobic filter and engineered wetlands is 24 hrs. The anaerobic filter consists of two tanks with the size of each tank being 4.5 x 4.5 x 2.5 m. The filter media is of cylindrical shape with size in the range of 37.5 – 50 mm, providing a specific surface area of 150 m^2/m^3. The size of the two wetland beds is 12.5 x 5 x 0.8 m each with the filter media ranging from 2– 60 mm.

The expected performance of this improved treatment system indicates that treated effluent with less than 5 mg/L BOD and TSS; < 10 mg/L COD will be obtained. Removal of PPCPs through wetlands and activated carbon columns shall also be monitored. Among the major advantages of the treatment system are requirement of low operation & maintenance cost, low energy intensity, manageable with unskilled manpower and highly efficient in removing primary, secondary and tertiary pollutants.

In order to ensure efficient sludge management, the SDRB is divided into three sectors, which are hydraulically connected. The different sectors will be loaded intermittently observing a rest period to permit dewatering before new loading. The loading of a respective sector will occur in batch mode, ensuring a resting period between every loading day per sector of approximately 45 days; this means that approximately every 15 days one sector is loaded. The beds will be planted with *Phragmites, Karka* or *Typha latipholia* with a plant density of 4 plants per m^2. The size of the three wetland beds is 5.5 m x 3.5 m x 0.55 m each with filter media comprising of gravel and sand ranging from 12– 60 mm and 0.2– 4.75 mm, respectively.

Pilot line

In addition to the main treatment line, a pilot line for treatment of 3 – 8 m^3/d wastewater with a French reed bed (FRB) system is installed. The treated wastewater is utilised in a short rotation plantation (SRP).

The pilot line aims to demonstrate the applicability of the FRB system in the Indian scenario. The FRB system is a 2-stage CW system: the first stage comprises 3 parallel operated vertical flow beds (total surface area 21 m^2), the second stage a vertical flow bed with 15 m^2 surface area. This treatment scheme can offer several advantages such as the minimum possible footprint for passive natural treatments or the absence of primary sedimentation, meaning no production of primary sludge (as generally the case in “classic” CW configurations); the raw wastewater upstream of the primary clarifier is fed directly into the 1st stage bed, after only passing a screen chamber and an oil and grease trap. Solids and the surplus of biomass remain on the top of the gravel surface, forming an active layer that enhances performance and permits sludge dehydration and stabilization. This active layer can grow 1-2 cm every year, until the hydraulic conductivity is too reduced and the sludge layer has to be removed. The emptying and the disposal of sludge can be programmed at intervals of approximately ten years and sludge volumes are very much smaller than with activated sludge, and smaller than with classic CWs. The sludge is suitable as soil conditioner on agricultural land. The beds are planted with *Phragmites, Karka* or *Typha latipholia* with a plant density of 4 plants per m^2, with filter media comprising of gravel of size 2 mm – 60 mm with depth 0.9 m in the 1st bed and gravel and sand ranging from 12 mm – 60 mm and 0.2 mm – 4.75 mm with depth 0.85 m in the 2nd bed, respectively.

The SRP was installed first, to allow its plants to accommodate before irrigation with the effluent from the FRB starts. The size of the SRP was adapted to the generated amount of effluent under consideration of the PET (potential evapotranspiration). SRPs are plantations of fast-growing trees regularly harvested in short intervals for the production of mainly fuel- and pulpwood. The fast growth leads to a high uptake of nutrients from the wastewater (high treatment efficiency).For the SRP wastewater treatment system in Nagpur local species suitable for wastewater treatment were selected: *Melia dubia* and *Bambusa bambos.* The treated wastewater will be applied to the SRP via drip irrigation. Only in the dry season irrigation will take place, no wastewater application will occur during monsoon.

Figure 3, 4, and 5 depict different components of both the main and the pilot line at OFAJ.

Figure 3: Aerial view on the vertical –up-flow constructed wetlands of the main treatment line (before plantation, left) and short rotation plantation (SRP, right) at OFAJ Site, Nagpur

Figure 4: Overall view of main treatment line at OFAJ, Nagpur after completion of the implementation

Figure 5: Aerial view of SDRB and FRB Systems (before plantation)

Summary

The implemented treatment system at OFAJ showcases natural treatment systems for treating domestic wastewater under Indian conditions. The main treatment line for 100 m³/d comprises an anaerobic pre-treatment and a vertical up-flow constructed wetland. Sludge from the main treatment line is treated in a sludge drying reed bed. The pilot line for 5-8 m³/d demonstrates a French reed bed system for treating raw wastewater. Treated wastewater from the pilot line is utilized in a short rotation plantation. Three of the technologies showcased at OFAJ are novel under Indian conditions: Sludge Drying Reed Bed, French Reed Bed, and short rotation plantation. The implementation of the treatment system was finalised and operation started in December 2015.

References

APHA (2009): Standard Methods for the Examination of Water and Wastewater 2009 21st edition, American Public Health Association/ American Water Works Association/Water Environment Federation, Washington DC, USA.

CPHEEO, 2013 Manual on Water Supply and Treatment. Ministry of urban Development, Government of India, Delhi, India, http://moud.gov.in/advisory/manual_ws (accessed 5 January 2016).

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Wastewater Treatment and Reuse for Irrigation in an Urban Park: the Dayanand Park Treatment Wetland System in Nagpur

This paper shows how natural treatment systems can provide ecosystem services such as the treatment of a local alternative water source in a typical Indian urban park.

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Abstract

Natural treatment systems, i.e. constructed wetlands (CWs), are used to provide an alternative water source in a typical Indian urban park. Raw water consists of municipal wastewater pumped from the sewer. The treatment system is composed by 5 parallel lines, each one able to treat up to 20 m³/d of wastewater. Every line has a different configuration for the purpose of demonstrating different CW types. These types include HF-HF, HF-VF, VF-HF, VF-VF and aerated engineered wetland (AEW). The treated effluents are used for landscaping during the dry season and the entire system adds a thoughtful aesthetic insertion into the park architecture and social functions. Results from the experiments shall help adapting CW designs to Indian conditions.

Introduction

Dayanand Park is a multi-utility public garden spread over 7 acres of land mainly planted with grass and trees. It is the one of the well maintained parks of the Nagpur Improvement Trust (NIT), the Development Authority of Nagpur. About 1,500-2,000 people use the garden daily for recreational and leisure activities, such as yoga, laughter club, jogging and play area for children (Figure 1). The water requirement to maintain the garden is approx. 100 m³/d. Currently, groundwater from a nearby dug well is being used for irrigating the garden. However, due to depletion of groundwater level, water is not available for irrigation in the dry season, i.e. from February to June. During the summer season untreated sewage is used for irrigating the garden which poses a huge health risk for the park users.

The aim of this project is to treat the needed water before usage in order to improve the population and workers safety and health. The solution proposed is a natural treatment technology integrated into the existing landscape. Such solutions can then be replicated at other gardens or parks in a modular fashion in the city and country.

System description

The general conditions for the treatment system implemented at Dayanand Park are:

Technical data:

- Capacity: 100 m³/d
- Primary treatment: three stage septic tank
- 5 parallel lines based on different configurations of CWs integrated into the existing landscape
- CW configurations: HF-HF, HF-VF, VF-HF, VF-VF and aerated engineered wetland (AEW), each of equal capacity (HF = Horizontal flow; VF = vertical flow)
- Tertiary treatment: UV disinfection
- Treated water will be reused for park irrigation

- Tropical wet and dry climate with dry conditions prevailing for most of the year. It receives an annual rainfall of 1,205 mm from monsoon rains during June to September. The average annual high and low temperatures are 34 and 20 °C, respectively.
- About 1,500-2,000 users daily. Most users of Dayanand Park are people with at least a high school education level completed and almost 1/3 of the users have a university degree. Men are typically employed or students, while the over 60 users are retired. More than 40% of the women are housewives, even if most of them have a university degree.
- Currently groundwater and raw sewage are used for gardening.
- Water requirement is approx. 100 m^3/d.
- NIT is the responsible authority and key stakeholder for project implementation. Other important stakeholders include the park users such as the laughing club.

The system can treat 100 m^3/day which is the water needed for irrigation. The CW combinations of VF and HF beds implemented are HF-HF, HF-VF, VF-HF, VF-VF as well as an aerated engineered wetland (AEW), each of equal capacity (20 m^3/day). The selected primary treatment is a three stage septic tank. The tertiary treatment before reuse is UV disinfection. Table 1 illustrates major parameters of both the raw sewage and the expected effluent quality as well as discharge standards set by the Central Pollution Control Board (CPCB).

Figure 1: Schematic of the treatment system (source: Iridra and Kreta, 2014)

Table 1: Influent quality parameters and CPCB discharge standards

Major parameters	Raw sewage	Proposed treated effluent quality	Discharge standards for inland surface water
pH	6.75 – 7.0	6.8 – 7.2	5.5 – 9.0
BOD	70 – 90	<30	30
COD	72 -144	50 – 60	250
Suspended Solids	76 - 110	20 – 30	100
Oil & grease	32 – 36	<10	10

Treated water will be used for park irrigation and replace current usage of groundwater and/or untreated sewage which is used during the summer season. Thanks to the implemented system, it will be possible to irrigate the garden daily with 100 m^3 using treated and safe water.

The main part of the capital costs (about 105'000 EUR) will be funded by the NaWaTech project, with NIT also funding part of the construction works. NIT and NEERI will be in charge of the O&M costs (about 16'000 EUR per year including costs for sampling and analysis). Initially the treatment system shall be maintained by NEERI, through third party outsourcing and later it will be handed over to NIT. After handing over, the treatment system will be maintained by NIT.

The NaWaTech consortium developed research and evaluation plans as well as a framework for Safety and O&M planning. O&M guidelines were developed by identifying and assessing potential hazards unit wise which could lead to poor functioning of the wastewater treatment systems.

Stakeholder involvement

A first assessment carried out by interviewing park users before system implementation pointed out that:

- The majority of interviewees agreed with the construction of a CW system for wastewater treatment in Dayanand Park;
- Some users highlighted the importance of NIT involvement in order to ensure a correct implementation, operation and maintenance of the system;
- Around 95% of interviewees agreed with water reuse for irrigation;
- The main issue is that around 55% of the interviewees did not know the importance of wastewater reuse. So it can be concluded that more awareness about water scarcity is needed;
- Around 60% of interviewees were not informed about wastewater treatment and management in the city, and a high proportion of these people were also unconscious about river pollution. This demonstrates a low environmental awareness.

Based on the results of this assessment, workshops, campaigns and other participatory activities were conducted in order to increase users' environmental awareness and their knowledge about wastewater treatment and reuse.

Lessons learnt

The following lessons learnt were identified:

- Stakeholder selection and participation is essential. In this case the NIT was the main stakeholder, with high interest in the site. Communication and capacity building with the stakeholders had to be guaranteed to create an overall supportive environment. As Dayanand Park is a public park, the consultative processes were highly important in order to create awareness amongst the park users and gain their willingness, acceptance, and support. Involvement of stakeholders needs to continue after the implementation (e.g. by means of training for O&M for involved personnel). Park users should also be involved in the monitoring (e.g. reporting potential smells or leakages of the system).
- A proper design must be considered. Collaboration between landscape architects and engineers was of great importance. The entire system should not interfere with the activities of the park users. System should occupy a relatively small area. It was very helpful that for this site geotechnical profiling was carried out and groundwater level was identified. It is important to know the status of electricity availability in public sites before system implementation.
- Regarding tendering requirements, proper material management and procurement were important for contractor selection. Moreover, legal arbitration issues should be avoided as much as possible.
- Health and safety represent a core issue. It needs to constantly be considered during construction as well as during the entire lifetime of the site as it is located in a public area.

These lessons should help implementing sites at other public areas.

Summary

The main objective of this project is to treat the water before usage for improving the population and workers safety and health. The solution with natural treatment technologies integrated into the existing landscape can then be replicated in other gardens or parks in a modular fashion in the city and country.

A secondary objective of the proposed approach is to offer an opportunity for research, because it will be possible to monitor and compare five different treatment schemes treating the same wastewater. Additionally, the system is a good example of how landscaping can transform treatment units into ecosystem services with a high fruition potential and direct positive effects on quality of life. With regards to the long-term impacts of the project, the main benefits are public health improvement (improved safety and health of park users due to the use of safe irrigation water) and the prevention of groundwater depletion.

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Natural and Cost Effective Way of Treating Domestic Wastewater with Reuse in Non-Potable Purposes: The College of Engineering Pune (COEP) Hostel Campus Case Study

The paper shows a sustainable approach to wastewater treatment with non-potable reuse in the urban Indian context.

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Abstract

Pune is facing problems of increased population and urbanisation with regards to a variety of resources, in particular water. As far as the last few years are concerned, the monsoon rainfall is continuously decreasing compared to its average value. Therefore, the balance between the demand and supply of water is getting increasingly disturbed. This article describes the work at the hostel campus of the College of Engineering Pune (COEP) where around 2000 persons are staying. The basic aim was to treat the sewage for reuse in a cost effective way. A natural wastewater treatment system which includes anaerobic settler (AS), anaerobic baffled reactor (ABR), anaerobic filter (AF) and constructed wetlands (CWs) has been installed to treat the sewage. The treated water from the system is used for non-potable purposes such as gardening, flushing, etc. This will minimise the total consumption of fresh water of the hostel campus and also reduce the pollution load on the public sewerage system.

Introduction

Pune is said to be the cultural and educational capital of the state of Maharashtra (India). With almost 5 million inhabitants, Pune shows the typical characteristics and contradictions of Indian cities, with the coexistence of high-density planned urban settlements and slum areas. Pune is located 560 m (1,840 ft) above sea level on the western margin of the Deccan plateau in the central part of India. It has a hot semi-arid climate, bordering with tropical wet and dry with average temperatures ranging

Technical data:

Characteristics of the three different treatment lines:

DTS 100:

- Domestic wastewater, capacity 100 m³/d
- Anaerobic pre-treatment
- 3 vertical flow constructed wetlands in parallel
- Reuse for toilet flushing and gardening

DTS 40:

- Domestic wastewater, capacity 40 m³/d
- Anaerobic pre-treatment
- Discharge in sewer

GW 40:

- Greywater, capacity 40 m³/d
- 2 vertical flow constructed wetlands in parallel
- Reuse for toilet flushing and gardening

between 20 and 28°C. The climate is characterized by the presence of the monsoon that causes moderate and heavy rainfall between June and October. The average annual rainfall in this region is about 720 mm.

The College of Engineering Pune (COEP) is one of the oldest and most relevant technological institutions in India. The hostel campus of the college is located in a high density urban area of Pune and can house up to 2000 persons in several buildings of different types (1, 2 or 3 floor buildings, towers). Currently, greywater and blackwater are not segregated and connected to the public sewer, but there is the possibility to separate the plumbing systems in one of the new buildings, which is 11 storied. In the campus there are many green areas and a concrete interest to wastewater reuse due to the long dry-season and the restrictions on water available for irrigation. The management of the COEP project has been conducted by the Indian non-profit organisation ESF (Ecosan Services Foundation, Pune), that identified the possibility of the intervention, followed by the design phase for the anaerobic treatment and the supervision of works; IRIDRA (Italy) designed the CW systems and supported ESF in the project. Previously, the wastewater was discharged into the sewer that reaches a central wastewater treatment facility under the Pune Municipal Corporation. Centralised sewage treatment plants (STPs) are conventional treatment plants and the treated water from it is discharged into the river Mutha.

The project has been developed during 2013; in the first phase ESF carried out a preliminary survey on wastewater quantity and quality, collecting flow data and samples for chemical analysis, permitting the characterisation of the wastewater and the greywater. IRIDRA elaborated different preliminary hypothesis, specifying the required area for constructed wetland treatment systems. The main constraint was the limited space available for the realisation of the constructed wetlands and anaerobic system, considering also the development plans of COEP in the hostel. After an accurate topographical survey and several meetings with the management of the hostel conducted by ESF, some areas distributed along the boundary of the campus were selected and a new, more compact system combining anaerobic treatments and CWs was elaborated and approved by COEP. The detailed design was concluded in November 2013, with the additional contribution of the architects of Kre_Ta Berlin that carried out the landscaping of the project. A bid was published at the end of December 2013; in January 2014 a contractor was selected and in February 2014 IRIDRA experts performed a mission to train the contractor and the supervisor on the realisation activities. The works started concretely in May 2014, after the definition of the main aspects related to the access to the area with the beneficiary. After a constrained stop during the monsoon season, the works restarted in October 2014, when a second support mission was done by IRIDRA. In June 2015 major construction works were completed and after some necessary tests the anaerobic treatment system was commissioned. The commissioning of the CW system is likely to be completed by the end of December 2015. The realisation of the pilot systems inside the campus constitutes a great opportunity for research and dissemination on the proposed approach, besides guarantying the availability of water for irrigation during the summers.

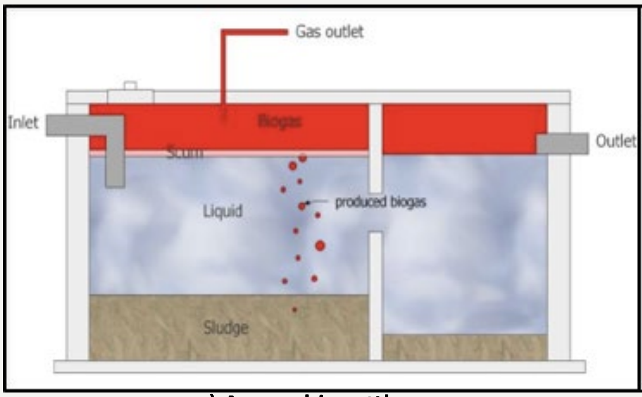
Theoretical concept

The quality and quantity of wastewater are two of the most important factors in deciding the treatment system. Domestic wastewater is generally categorized as blackwater (toilet wastewater) and greywater (household wastewater not in contact with faecal matter, e.g. from kitchens, sinks, washing, etc.). There are about 2000 people staying in the hostel campus in about 10 blocks. As the per capita per day consumption of fresh water is about 100 litres, the theoretical wastewater generation is about 180 m^3/day.

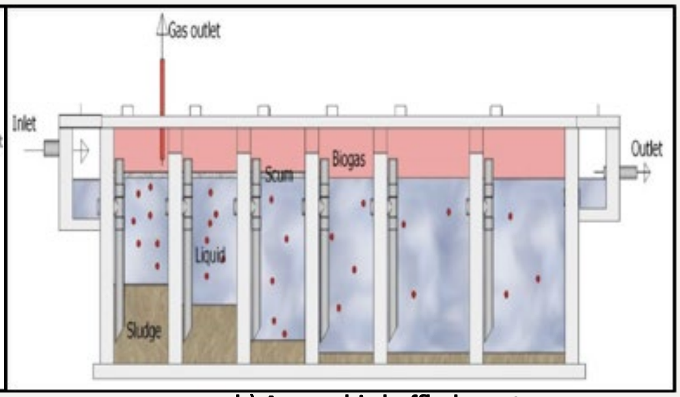
For the COEP site the use of wetland systems was foreseen. However, due to the limited space available, anaerobic pre-treatment was required to reduce the specific surface area requirement of the vertical flow (VF) CW systems. Greywater will be treated entirely with a VF CW. The anaerobic treatment is composed by a primary anaerobic settler, an anaerobic baffled reactor followed by an anaerobic filter. On the basis of the expected high temperatures along the entire year, the system should be very effective not only in suspended solid reduction but also in organic degradation (60-80% of BOD_5 is expected). Figure 1 shows the schematic diagrams of the units of the anaerobic treatment system (AS, ABR and AF).

The CW or planted gravel filter (PGF) is made of planted filter bodies consisting of fine gravel. The bottom slope is 1 %. The flow direction may be horizontal or vertical. The filter is normally planted with easily available plants such as Canna indica, Typha and Phragmites etc. The main removal mechanisms are biological conversion, physical filtration and chemical adsorption. Mechanisms of BOD removal are mainly aerobic and anoxic. The function of the PGF is mainly post treatment. Reduction rate of BOD is between 75 - 90%. Reduction of pathogens organisms is over 95%. Operation and maintenance of the system is simple (mainly garden works). Figure 2 shows the schematic diagram of a VF CW.

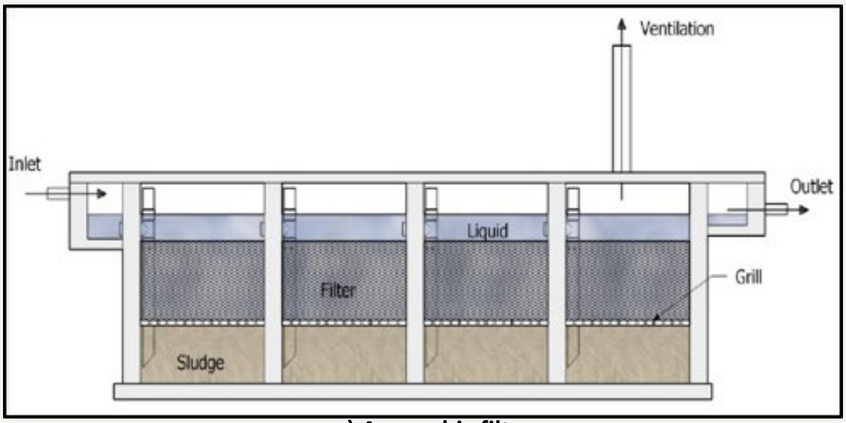
Surely the limited space and the high urban density is a constraint to the application of CWs in Indian urban areas; the segregation of grey water (for which the ratio wetland surface / p.e. is lower), the combination of CW with anaerobic treatment systems (which are quite largely diffused and well known by the Indian experts in sanitation) and the recourse to VFCW systems (more efficient in terms of required space than horizontal flow HF systems) are interesting options. Table 1 shows the basic design assumptions for the water quality to be treated.



a) Anaerobic settler



b) Anaerobic baffled reactor



c) Anaerobic filter

Figure 1: Schematic diagrams of the units of the anaerobic treatment system

Table 1: Basic design assumptions for the water quality

Description	Volume (m^3/day)	BOD_5 (mg/l)
Total Wastewater	**180**	**279**
Left side WW (black- and greywater)	100	287
Right side greywater	40	150
Right side blackwater	40	457

Design considerations

Considering that the irrigation demand was lower than the total wastewater production, 20-25% of the wastewater was decided to be treated solely by primary treatment and then discharged into the sewer as at present there is limited reuse potential on the site. Thus, to treat the blackwater produced in the girl's hostel building (East side of the campus) an anaerobic treatment was designed for 40 m^3/day (referred to as DTS 40). To treat and reuse 40 m^3/day of greywater produced in the Girl's hostel building (East side of the campus), where the segregation from blackwater was possible, the treatment scheme provides a preliminary treatment (degreaser, capacity 10 m^3) followed by two VF CWs in parallel with a total surface of 133 m^2; it is possible to alternate the loading cycle and stop temporarily one basin. This treatment system is referred to as GW40, while the wetland unit is referred to as PGF 1 (VF). The treated water will be stored in a tank and disinfected treated water used to flush the toilets in the Eastern side of the campus thanks to a new dual network designed within the project.

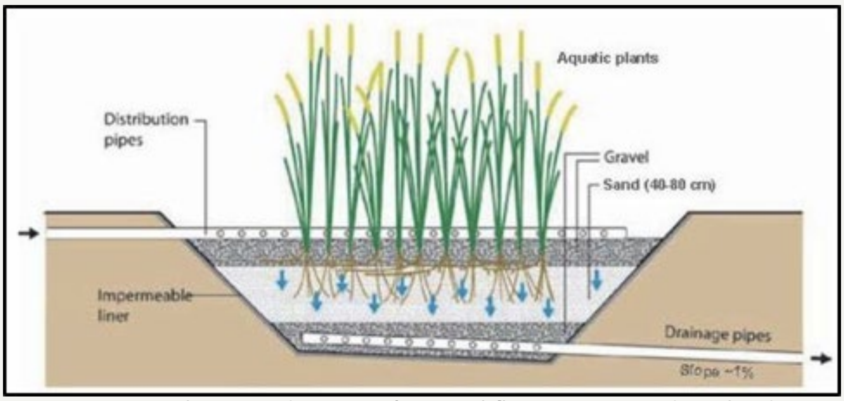


Figure 2: Schematic diagram of vertical flow constructed wetland

To treat and reuse 100 m^3/day of wastewater produced in the Western part of the campus, where no segregation of grey- and blackwater was currently possible, the treatment scheme provides an anaerobic primary and secondary treatment (AT) - referred to as DTS 100. In order to achieve the quality for reuse, a tertiary treatment, constituted by three VF CWs with a total surface of 405 m^2 has been provided. This unit is referred to as PGF 2, which is subdivided into three parallel beds viz. VF1, VF2 and VF3. The treated and disinfected water will be pumped towards several tanks on the roofs of the buildings and reused to flush the toilets and garden irrigation. The VFs are loaded with 3 independent pumps, ensuring an alternate loading and permitting eventually to stop periodically one basin for limited periods: this practice preserves the hydraulic conductivity of the VF filters and permits to recover the functionality in case of temporary clogging of the substrate. Figure 3 shows the flow chart of the total treatment system.

The design methodology for anaerobic treatments and constructed wetlands considered international literature indications and accepted guidelines of several countries. COEP has a number of hostel blocks in the campus which are also heritage structures. These blocks along with new buildings leave very little room for any other provisions. Due to this, the overall design was a challenge. The COEP hostel campus is located near the Pataleshwar Caves which is an archaeological site. Therefore, there are restrictions to any kind of construction and only part of the campus was available for construction of the treatment system. The campus has a large number of old trees and green cover is spread across the entire area. Any diversion of green cover/ cutting of trees requires approvals through government processes. The treatment system was to be planned in such a way that the green cover is not disturbed. Considering all these factors the dimensions of all treatment units were finalised. Anaerobic treatments were realised on site by using reinforced concrete and brick masonry for internal baffles, coating the walls with epoxy paint to improve the resistance of the concrete to chemical corrosion. The installation is underground and the tanks are covered by concrete slabs, avoiding any risk of odours and guarantying the safety of the people. Table 2 explains the dimensions of anaerobic treatment and Figure 4 shows the photograph of the AT system.

For the dimensioning of PGF (1 & 2) the German Guidelines (ATV) were considered and the oxygen balance chosen as verification method, assuming the oxygen transfer rate from literature. PGFs are obtained excavating the soil and waterproofing the basins with EPDM liner, available in the Indian market and easy to weld on site. The basins are filled for a total height of 0.85 m with gravel and sand: from the bottom, 15 cm coarse gravel, 10 cm medium gravel 12 mm, 50 cm sand 0.2-5mm, 10 cm medium gravel 12 mm.

The design of the PGFs was adapted to the site conditions:

- to limit odours and mosquito diffusion, the distribution pipes are laid under a thin gravel layer avoiding any exposure of the water;
- for a better landscaping and to reduce the excavation volumes, the basins are partially over ground, surrounded by a brick wall that can also constitute a sitting area for students;
- The aquatic plants were selected to obtain a pleasant aesthetic effect with the combination of *Typha* and *Phragmites*, typically used in CWs, with other ornamental plants such as *Canna Indica* and *Iris*.

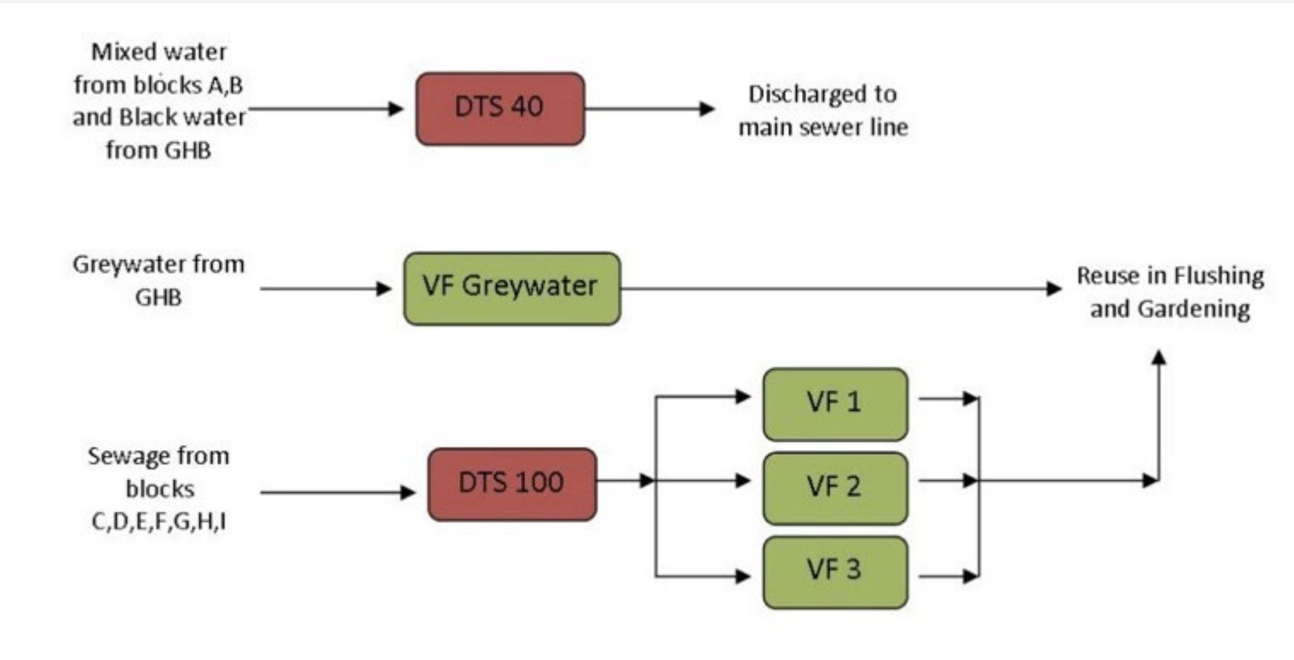


Figure 3: Flow chart of the treatment & reuse system (source: ESF; 2014)

Table 2: Details of anaerobic treatment system

Sr. No.	Description	Treatment units	
		DTS 100	DTS 40
1.	**Anaerobic settler**		
	Width (m)	6	4
	Length (m)	4.25	3.25
	Water level (m)	2.20	2.20
	Volume (m^3)	56	28.6
2.	**Anaerobic baffled reactor**		
	Width (m)	5	4
	Length (m)	9	5.48
	Water level (m)	2,1	2,1
	Volume (m^3)	94.5	46
3.	**Anaerobic filter**		
	Width (m)	5	4
	Length (m)	4	3.9
	Water level (m)	2.05	2.05
	Volume (m^3)	41	32
4.	**Total treatment volume (m^3)**	**191.5**	**106.6**
5.	**HRT (days)**	**1.92**	**2.66**

a) DTS 40 **b) DTS 100**

Figure 4: Anaerobic treatment systems at COEP hostel campus

Particular attention was given to the substrate material selection, particularly the sand layer, both in the design phase to guarantee the high hydraulic loading rates and in the realisation phase to verify the quality of the material. The supervisor was trained on the on-site verification tests and on the verification of the design grain curves. ESF conducted a survey on the available quarries in the area, selecting those that can ensure the desired quality; this is very important in India considering that not all the quarries are equipped with proper mechanical and washing devices and the spread of illegal mining of river sand. All the used materials were easily available in the local market. The main design parameters for CWs are reported in Table 3. Photographs of PGF 1 and PGF 2 are shown in Figure 5.

Research & reuse plan

As soon as the commissioning of the system is finished monitoring of the system will get started. It will be carried out for about 6 months by ESF. In this period water consumption calculation, reuse efficiency etc. will be measured and analysis of inlet and outlet water of the treatment units will be carried out. Parameters such as pH, electric conductivity, BOD, COD, TSS, DO, Sulphates as SO_4,

Table 3: Basic design assumptions for the CW treatment

Planted gravel filter (constructed wetland)	PGF 1 (Greywater)	PGF 2 (Grey- + blackwater)
Daily flow (m^3/day)	40	100
AT and pre-treatment removal	0.25	0.75
Total surface area (m^2)	133	405
COD loading rate (g COD/m^2 per day)	39	29
Hydraulic loading rate (litre/m^2 per day)	325	252
Expected outlet BOD_5 concentration (mg/l)	9	14
Expected outlet SST concentration (mg/l)	15	15

a) PGF 1 b) PGF 2

Figure 5: Planted gravel filters (constructed wetlands) at COEP hostel campus

Ammonia as NH_4, Phosphates as PO_4, Nitrates as NO_3, TKN, Oil & Grease and TDS will be checked on a weekly basis. Continuous monitoring and observations will be done on the basis of the treatment process and the results of analysis. As per now, the monitoring of the DTS 40 (AT) unit has already started. As far as the other units are concerned the commissioning of the other units i.e. DTS 100, PGF 1 and PGF 2 was completed by the end of December 2015.

The system will permit to reuse approximately 85 thousand and 30 thousand litres per day for toilet flushing and garden irrigation, respectively. Considering the evapotranspiration rate of the wetlands; reuse for WCs will be spread over the whole year, whereas the reuse for irrigation is concentred in the dry season, approximately between November and May. It is proposed to implement a hydro pneumatic system for toilet flushing and the procedure towards completing it has been started.

Basic design criteria for natural wastewater treatment units used in this case study:

- Anaerobic settler:
  - Area required = 0.5 to 1 m^2 /m^3 of volume,
  - HRT (Hydraulic retention time) > 2 hours,
  - Desludging interval > 1 year,
  - Volume of 1st compartment = 2/3 of entire tank volume
- Anaerobic baffled reactor:
  - Up flow velocity = 1.4 to 2 m/hr
  - HRT > 12 hours,
  - Organic load < 3 kg BOD/m^3.day,
  - Number of chambers = 4 to 8 nos.
- Anaerobic filter:
  - Up flow velocity < 2 m/hr,
  - HRT = 24 to 48 hrs,
  - Surface area of filter media = 80 to 120 m^2/m^3,
  - Voids in filter media = 30 to 45 %,
- Vertical flow constructed wetland:
  - Area required = 4 m^2/m^3,
  - Bed slope = 0.5 to 1%,
  - Total depth of bed = 70 cm

Table 4: Performance of DTS 40 (Nov & Dec. 2015)

Parameter	Unit	Inlet	Outlet
pH	-	6.95	6.93
Electrical Conductivity	µS/cm	825	856
Biological Oxygen Demand (BOD_3) at 270C	mg/l	222	65
Chemical Oxygen Demand (COD)	mg/l	556	175
Total Suspended Solids (TSS)	mg/l	256	66
Sulphates as SO_4	mg/l	6.77	1.2
Phosphates as PO_4	mg/l	9.88	5.49
Nitrates as NO_3	mg/l	35.2	14.2
Ammonia as NH_3	mg/l	68.5	45.4
Total Kjeldahl Nitrogen as N	mg/l	78.5	46.1
Total Oil & Grease	mg/l	28.1	11.6
Total Dissolved Solids	mg/l	482	498

First results

As mentioned above the analysis of DTS 40 has been started in September 2015. The performance of DTS 40 in the months November and December 2015 is summarized in Table 4. An anaerobic treatment system takes 3 to 6 months to get stabilized; the DTS 40 is currently showing satisfactory performance, the reduction for BOD_3 and COD is about 70 % and for TSS about 75 %, respectively

Summary

The results of the analysis shows that the anaerobic treatment system of DTS 40 is stabilizing in an appropriate way, nevertheless, it will still take some more time to stabilize completely. Despite the fact that the outlet of DTS 40 is not being reused for any purpose, the system is proving a helping hand in discharging partially treated water to the public sewer. The partially treated water from DTS 40 is well within the discharge limits to the sewer. The experience of stabilizing the anaerobic treatment system is very interesting and will be helpful for us in further projects.

The combined use of anaerobic treatment and constructed wetlands is promising for India as it requires only limited O&M requirements. As per the reuse plan, approximately 140 m^3 of water will be available for reuse in toilet flushing and irrigation (gardening). This will significantly reduce the fresh water consumption and , therefore, the costs of the COEP hostel campus.

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Greywater Treatment and Reuse in a Municipal Office in Pune by Vertical Gardens

Vertical gardens or green walls can be used for treating greywater permitting a close-loop reuse.

Author: Fabio Masi, Anacleto Rizzo, Riccardo Bresciani, Ajith Edathoot, Neha Patwardhan, Dayanand Panse

Abstract

An innovative way to treat and reuse greywater has been implemented in Pune. This pilot system is able to treat 125-250 litres per day of greywater originating from the toilets of the Maharashtra Jeevan Pradhikaran (MJP) head office in Pune, recovering them for garden irrigation. MJP is the water supply and sanitation department in Maharashtra (http://www.mjp.gov.in/). The pilot aims to demonstrate the applicability of modified green vertical bio-walls for greywater treatment, adding a new interesting tool to the sustainable water management technologies in urban high-density areas. The green bio wall is divided into two parallel lines, each constituted by two stages in series; every stage is constituted by 12 parallel frames and every frame is constituted by 6 pots in series. The experimental analysis has been divided into two phases. The first phase analysed the results from green walls filled only with lightweight expanded clay aggregates (LECA). Since results from the first phase were not satisfactory enough, a second phase was developed. In this phase, LECA plus sand and LECA plus coconut fibres were tested as porous media in order to increase residence times and consequently the treatment performances. The expected improvements in treatment efficiency have been confirmed by the wider range of observed removal rates between phase I (COD 16–20%) and phase II (i.e. COD removal in the order of 14 - 86% and 7 - 80% for LECA-coconut and LECA-sand, respectively), denoting higher treatment potentialities for the new configurations. The obtained effluent quality was fulfilling the Indian law specifications for reuse in irrigation for all the analysed samples, yet only the last samples collected during phase II were showing an appropriate quality for reuse in flushing toilets.

Introduction

Green walls (also called bio walls, green bio walls or vertical gardens) have already been adopted by architects to reduce energy costs, increase biodiversity, reduce noise pollution, increase building longevity, and improve building aesthetics. However, green walls are living ecosystems in which practically the same processes take place as in a constructed wetland, therefore, their efficiency in wastewater treatment, and particularly greywater treatment, is an interesting additional benefit which is currently under investigation by the scientific community.

Principles of source separation of wastewater classify domestic wastewater into blackwater and greywater. Blackwater comprises the discharge from kitchen and toilets whereas greywater is less polluted wastewater from bathtubs, showers, hand washing basins and washing machines (Nolde, 1999). In residential buildings blackwater generation is generally a very low fraction, less than 30% of the total, in non-residential buildings (commercial, offices, etc.) even less (Scheumann et al., 2009; Li et al., 2009). Hence, greywater treatment can be

Technical data:

- 2 pilot green walls installed to test the efficiency in treating greywater for irrigation reuse
- Degreaser (125l) as pre-treatment
- Each pilot green wall has 12 parallel frames; every frames constituted of 6 pots in series; Total vertical area covered 1.8 m x 0.9 m (1.6 m^2)
- Lightweight clay aggregates used as filling media mixed with coconut fibres in a pilot unit and with sand layers in the other
- Expected treatment capacity of 125-250 l per day

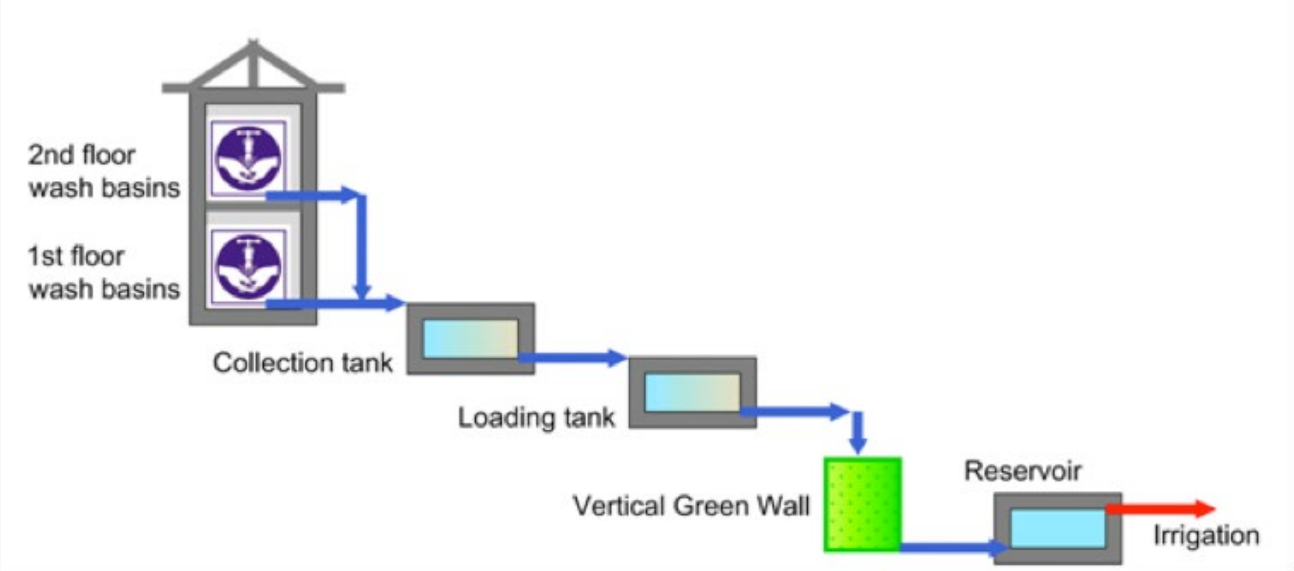

Figure 1: Sketch of the greywater treatment unit

used for recycling most of the wastewater generated by a close loop cycle (Dixon et al., 1999).

While many technologies are available for greywater treatment, natural systems such as constructed wetlands have shown advantages of low energy requirements together with simple and cheap maintenance (e.g. Masi et al., 2010; Li et al., 2009). In NaWaTech, the potential of green walls has been explored as a viable greywater treatment system that can substantially minimise the treatment footprint and provide a series of benefits in the urban landscape (greening, CO_2 trapping, O_2 production, microclimate effects, house insulation, etc.; see Francis & Lorimer, 2011). If the concept of recycling greywater at building or block level could be applied on large scale in a city, this approach could strongly reduce the dependency on very expensive infrastructures such as sewer systems and end-of-pipe large wastewater treatment plants, optimising by an effective decentralised treatment the overall wastewater management and operative conditions for the treatment itself. The urban development strategy planners could therefore make use of different values for the usual pro-capita parameters when designing lighter sewer networks and optimised treatment units, better focused on the recovery of resources conveyed in the black water fraction.

Technical aspects of the pilot installation

Two pilot green walls units have been installed at the MJP head office (Water Supply and Sanitation Department of Maharashtra) in Pune, India to investigate the greywater treatment efficiency.

The office houses 125 fixed staff and has a daily visitor count of 65. Dual plumbing was installed in the first and second floors of the building used by approximately 60 staff and 25 visitors and connected to a collection tank of 300 L capacity (Figure 1). The pilot green wall consist of two parallel units on either side of the entrance. The inflow from the collection tank is stored in two intermittent loading tanks of 100 L capacity each whose outflows are controlled by a timer based solenoid valve. The feeding of the treatment unit happens through an hourly flush of 10 L of greywater. The discharge is directly allowed to flow into the garden next to the walls. The system is designed to treat from 125 up to 250 L per day.

Each individual treatment unit consist of a 12 x 6 matrix of pots (6 pots in a column and 12 pots in a row). Each pot has a top surface of 0.01 m^2.

The frames are fixed to the wall by stainless steel screws, drilling the coverage and reaching the concrete structure. The frames and the pots for the realisation of the green wall are produced by the Indian company Bajnath and their characteristics are shown in Figure 2. Each pot was initially filled with LECA and planted with different species (genus Abelia, Wedelia Portulaca, Alternenthera, Duranta, and Hemigraphis; see Figure 3).

A perforated pipe is used for loading the first row of pots. The water flow is hence divided along the columns of the matrix arrangement and is collected at the bottom by a drain pipe.

The experimental analysis has been divided into two phases. Initially, the pots have been filled with an inert planting material – LECA – to ensure that the only nutrient source for the plants is the greywater. In this first phase samples of the inlet and outlet have been collected weekly and analysed in terms of organic content (BOD_5 and COD). Since results have not been satisfactory enough, this phase was ended (lasting from 12th of February to 27th of April 2015) and a second experimental phase was started (from 30th of April up to 5th of

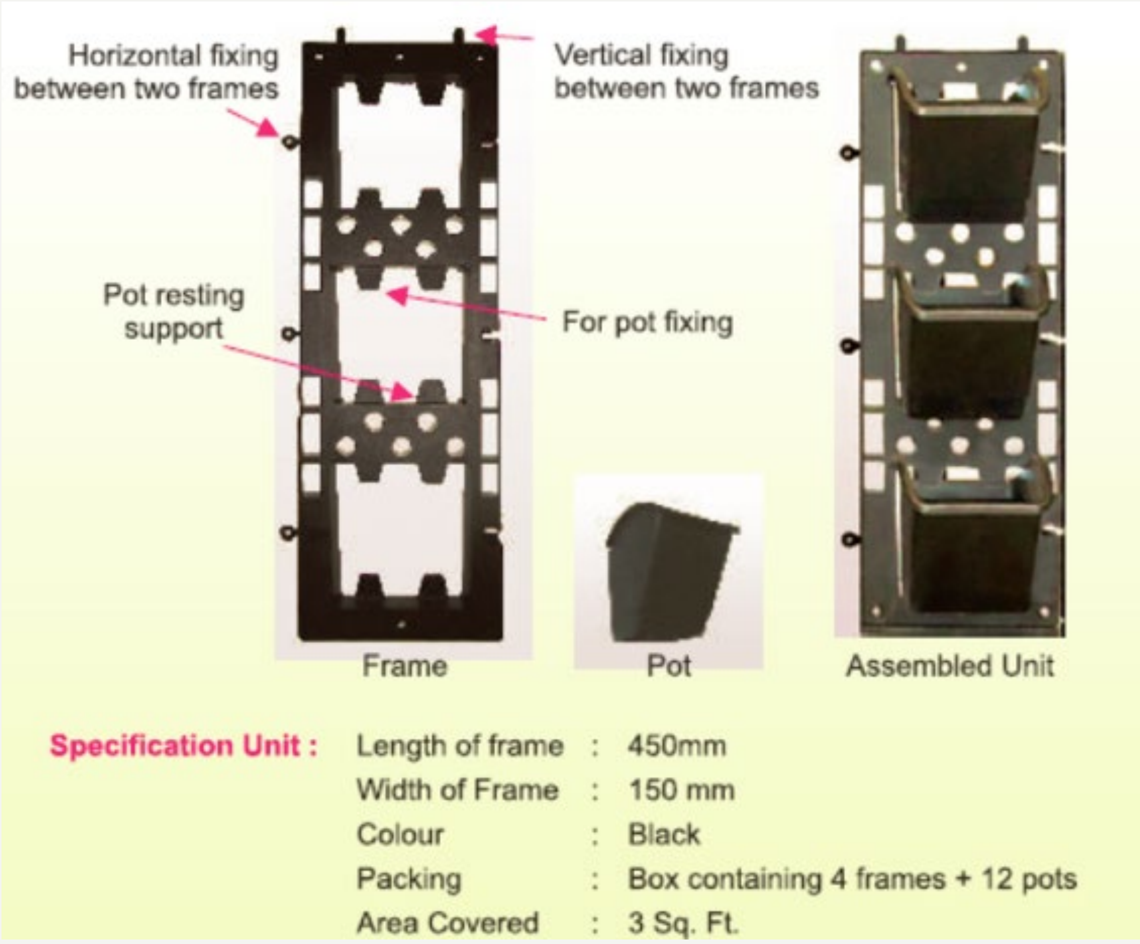

Figure 2: "Biowall" characteristics, produced by the company Bajnath

October). In the second phase the LECA (4-10 mm) was mixed with two different other mediums (sand and coconut fibres, respectively) for the two different pilot green wall units. The aim of the second phase was to slow down the water flow, increase residence time, and favour a greater biofilm development. Coconut shell has been adopted due to its high local availability in India, and the lower cost and weight compared to sand. During the green wall lifespan, coconut is expected to disappear due to degradation, but slow enough (high proportion of lignin based compounds) to allow a full development of plant roots which would guarantee a proper green wall functioning. Samples for the analysis of SS, BOD_5, COD, NH_4+-N, TKN, PO_4^{3-}, MPN and E. coli have been collected during the second phase. The results of the first phase as well as

Figure 3: Demonstrative pilot green wall installed at MJP head office in Pune (India)

preliminary results of the second phase are reported in the following section.

Some initial issues followed by technical improvements and positive results

The pilot system started operating at the beginning of February 2015. The greywater produced by the office building is quite lightly polluted in terms of concentrations, with BOD_5 and COD in the range of 6-47 mg/L and 20-100 mg/L, respectively and with average values almost equal to 25 mg/l and 60 mg/l. The hydraulic loading rate (HLR) and the organic loading rate (OLR) on the first line and on the entire infiltration area resulted in 1000 l/m^2/d, 96 g/m^2/d and 167 l/m^2/d, 10 g/m^2/d, respectively. The maximum HLR for treatment of black water with vertical subsurface flow constructed wetlands is equal to 50 l/m^2/d in summer (DWA, 2006); this value can be considered in accordance with the HLR of the total infiltration area for the green wall, which treats wastewater with a lower pollutant content (greywater) compared to the black water or mixed wastewater. The average BOD_5/COD ratio is equal to 0.43. The low contamination with organic matter compared to typical greywater can be explained by the fact that only greywater from hand washing basins is collected in this particular situation. The usually stronger contaminated greywater fractions, i.e. from kitchens and washing machines, are not present in the MJP office buildings.

During the first phase the system has shown a low average removal efficiency of 18.3% and 24.6% for COD and BOD_5, respectively (Table 1). These results suggest a scarce biofilm development, with removal mainly driven by filtration processes only, and a quite fast percolation of the water throughout the LECA layer that did not allow for an appropriate contact time between the solution and the active agents involved in processes such as adsorption and biosorption. The top layer in the pots in phase I was still completely unclogged and the biofilm was starting to develop after a few weeks. These results could also be explained by a concentration effect created by the evaporation and evapotranspiration of the water from inside the pots. The slow biomass growth can also be justified by the very low content of nutrients (C, N, P) in the inlet.

Relating to the second phase, COD, BOD_5, SS, NH_4+-N, TKN influent and effluent concentrations have been observed for a 2 months period with weekly sampling. The unit filled with mixed LECA and coconut fibres has shown a release of carbon generated by the more biodegradable fraction of the coconut fibres up to the 19th of June, with alternate higher and lower influent, compared to effluent concentrations for COD, BOD_5, SS, NH_4+-N, and TKN. At the end of this start-up period, a proper biofilm seemed to have developed, since effluent concentrations always resulted in lower values than influent ones in the subsequent samples up to the end of the second phase. With regards to the unit filled with LECA and sand, interesting removal efficiencies have been observed for all the studied parameters, with higher performances for COD, BOD_5, and NH_4+-N when compared to SS and TKN. Coconut fibres seem to perform better than sand and this aspect can be related to the longer retention time provided by the adoption of this filling material in the pots: a complete fill and drain cycle has a duration of 12 minutes in the LECA-sand unit while instead it goes up to about 40 minutes in the LECA-coconut unit (Masi et al., 2015).

One common situation of dense urbanised areas in developing countries is the lack of proper treatment of domestic wastewater. This is due both to the common lack of classical centralised treatment (e.g. activated sludge) due to high construction and management costs, and to the scarce available area to adopt natural treatment solutions. At the same time, fast developing urban areas are facing the scarcity of high quality water sources for the increasing urban demand. The solution here proposed, green wall for greywater treatment and reuse, has the potential to respond to these issues with a single solution: (i) adoption of low cost natural treatment solution in dense urbanised area, due to high availability of vertical concrete surfaces in common developing country urban centres; (ii) recovering a huge amount of treated greywater (100 l/PE/d

Table 1: Influent and effluent concentrations from the two experimental phases

	Phase I LECA		Phase II LECA-Coconut*		Phase II LECA-Sand**	
	Influent [mg/l]	Effluent [mg/l]	Influent [mg/l]	Effluent [mg/l]	Influent [mg/l]	Effluent [mg/l]
COD	84.9±2.5	69.4±1.7	48.8±24.6	21.4±15.3	43.9±22.6	27.7±21.2
BOD_5	39.7±3.2	29.9±2.5	17.1±7.9	6.7±2.7	18.6±10.2	11.0±8.3
NH_4+-N	–	–	3.4±1.7	1.7±0.7	3.5±0.8	1.1±0.5
TKN	–	–	4.6±0.8	3.5±3.4	4.6±1.2	3.9±3.0
SS	–	–	58.8±12.9	45.6±20.0	53.8±18.4	48.1±20.1
n° samples						

* From 19th of June (only after the end of coconut fibres organic fraction release)
** From 30th of April (all samples for LECA-sand green wall in Phase II)

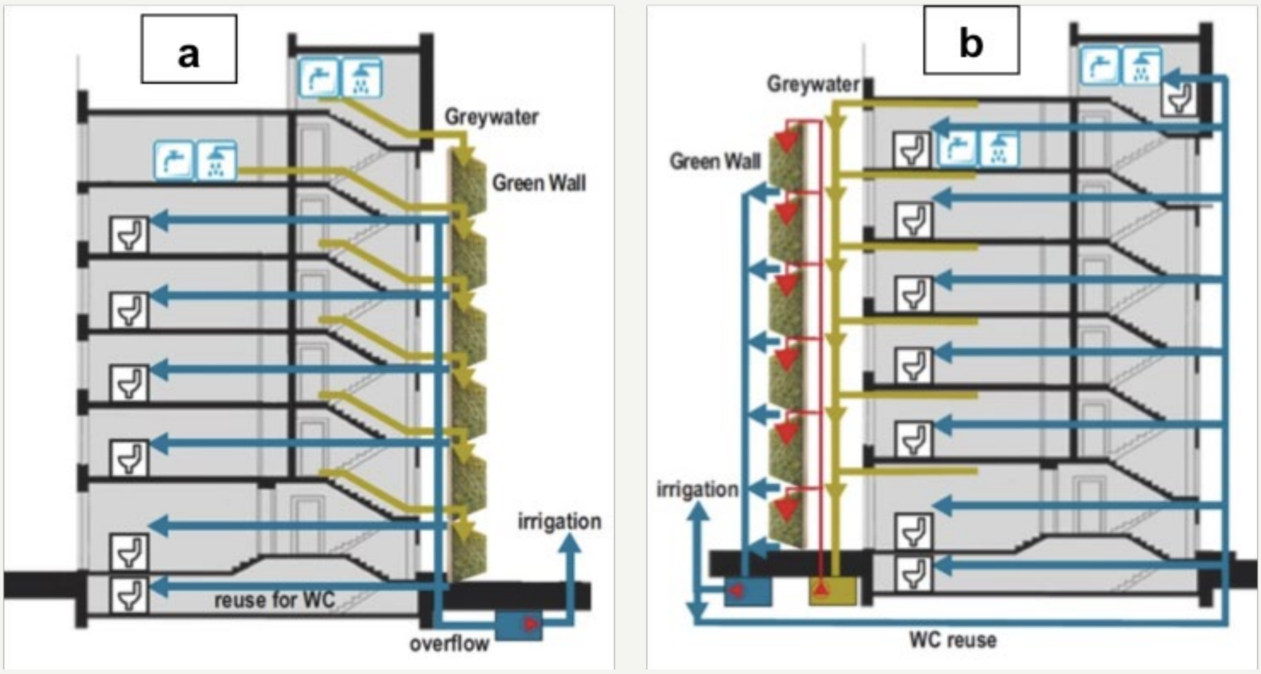

Figure 4: Possible implementation schemes for greywater collection, treatment, and reuse in the same building with green walls: a) floor-by-floor and b) unified.

– up to 70–75% of the total daily domestic wastewater) as a new source for activities requesting water with lower quality (e.g., WC flush, irrigation), facing the increasing water demand. Moreover, green walls are already adopted principally for aesthetic reasons, but also for different ancillary benefit such as the air filtration (O2 production and CO2 storage), thermal insulation of building, and reduction of noise pollution. Consequently, greywater treatment and reuse could be a very promising additional service provided by green walls.

The results exposed in this work highlight that the current set up of the tested green wall could be ready to upscale and adopted to real cases. Indeed, the effluent quality was in all samples already suitable for reuse for land irrigation according to the Indian regional and national regulations; in the last samples collected in Phase 2 the effluent reached an appropriate quality for reuse in flushing toilets (considering in the treatment scheme a further disinfection by an UV lamp).

Two possible implementation schemes could be adopted to collect, treat, and reuse in the same building the greywater generated from showers and washbasins with green walls. The first scheme (Figure 4-a) adopts a “floor-by-floor approach”, in which the greywater from the above floor is collected, treated by the green wall of the below floor, and reused in the WC flush tanks of the below floor. An overflow pipe needs to be installed to collect and properly discharge in the sewer the not treated greywater. A storage tank is installed to collect the treated but not reused within the building greywater, which could instead be reused for irrigation. The second scheme (Figure 4-b) follows a “unified approach”. The greywater from the all floors is collected in a storage tank, and uniformly pumped to all the green walls. The treated greywater is collected in a second tank where a fraction is pumped to the floors for reuse in WC flush tanks and another fraction is reused for irrigation. The social acceptance is higher with the “unified approach” instead of the “floor-by-floor approach”, since the source of the effluents becomes more unlinked to specific producers. From a technical point of view, the “unified approach” allows an easier hydraulic and treatment management. The hydraulic design is easier since the need of an overflow pipe for each green wall could be avoided. Moreover, the unified treatment of all the greywater guarantees higher buffer capacity and removal efficiencies to sudden loads. The “floor-by-floor approach” could be adopted when a minimization of operational costs is requested, due to the avoidance of the double pumps needed by the “unified approach”.

Assuming a greywater hydraulic load of 70–100 l/d/PE typical for the Indian context, the footprint results equal to 1 m^2 of green wall per person. For a typical Indian the requested area would be of 5–6 m^2, with costs of about 500–800 USD (including degreaser, pumps, piping). Hence, the solution results economically feasible, with a payback time estimated in about 10 years. Moreover, the cost evaluation should also consider that the green wall provides multiple services further than greywater treatment, i.e. aesthetical improvement of concrete surfaces, increase of urban biodiversity, thermal insulation of the building and related energy savings (i.e. less air-conditioning), improvement of urban air through CO2 sequestration. The cost would be cheaper for the conversion to greywater treatment of an already existed green wall.

References

Dixon, A., Buttler, D., Fewkes, A. (1999). Water saving potential of domestic water reuse systems using grey water and rainwater in combination. Water Science and Technology 39(10), 25–32.

DWA A 262, (2006). Principles for the Dimensioning, Construction and Operation of Planted Soil Filters for Urban Wastewater. German Association for Water, Wastewater and Waste.

Francis, R.A., Lorimer, J. (2011): Urban reconciliation ecology: The potential of living roofs and walls. Journal of Environmental Management 92(6), 1429-1437.

Li F., Wichmann K., Otterpohl, R. (2009): Review of the technological approaches for grey water treatment and reuses. Science of the Total Environment 407, 3439-3449.

Masi, F., El Hamouri, B., Abdel Shafi, H., Baban, A., Ghrabi, A., Regelsberger, M. (2010): Segregated black/grey domestic wastewater treatment by Constructed Wetlands in the Mediterranean basin: the Zer0-m experience. Water Science and Technology 61(1), 97-105.

Masi, F., Bresciani, R., Rizzo, A., Edathoot, A., Patwardhan, N., Panse, D., Langergraber, G. (2015): Green walls for greywater treatment and recycling in dense urban areas: a case-study in Pune. Journal of Water, Sanitation and Hygiene for Development, submitted December 2015.

Nolde, E. (1999). Greywater reuse systems for toilet flushing in multi-storey building-over ten years experience, in Berlin. Urban Water 1, 275–284.

Scheumann, R., Masi, F., El Hamouri, B., Kraume, M. (2009): Greywater treatment as an option for effective wastewater management in small communities. Desalination and Water Treatment 4, 33–39.

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Wastewater Treatment and Reuse in Amanora Park Town, Pune

Treatment and reuse of mixed domestic wastewater from residential buildings in an existing urban area - pilot scale study Amanora Park Town, Pune.

Author: Pilar Zapata, José Luis Bribián, Alejandro Caballero, Antonia Lorenzo

Abstract

Matching the current demand of adequate water and sanitation systems is a challenging task for governments all around the world, especially in urban areas of countries suffering from water shortages. The main motivation for this project is to address these problems within the Indian context by implementing, assessing and optimising medium-scaled compact and robust SBR and MBR systems, which allow treated water reuse, in a residential area within Amanora Park Town in Pune City; with the additional objective to minimise the urban water footprint and enhance the water security of the area. Moreover, the results are relevant for other Indian regions as well as for EU countries facing similar challenges (e.g. rapid urbanisation or failure of conventional water treatment systems) and are expected to contribute to the reduction of freshwater abstraction and pollution, more efficient use of limited water resources and improved resilience to water shortages and climate change.

Introduction

Within the context of the NaWaTech project, BIOAZUL designed, implemented and currently monitors in collaboration with ESF (Ecosan Services Foundation) two medium-scaled compact and robust SBR and MBR systems which allow treated water reuse in a residential area within Amanora Park Town in Pune City. Thanks to this experience, the potential of compact wastewater treatment systems is being explored, assessed and enhanced.

Moreover, taking into account the special conditions of the available area to install the systems, which was quite reduced, it was decided to optimise the combination of SBR and MBR (SMBR), minimising the urban water footprint and enhancing the water security of the area.

Key facts:

Technical data:

- Number of people covered: 200-300 population equivalent (p.e.)
- Size of treatment plant: 52 m^2 of land footprint (including housing for the equipment)
- Wastewater is treated in a SBR (10 m^3/day) and in a MBR (30 m^3/day)
- Type of reuse: gardening and flushing
- Energy supply: 380 V/3 Phases/50 Hz

Key aspects for operating SBR and MBR plants in India:

- MBR and SBR systems are suitable for most of urban settings in India
- Electrical short power cuts may cause some problems, especially in the SBR
- Local climate conditions are not expected to have any impact on the treatment performance, although specific parameters such as MLSS in reaction tanks must be carefully monitored during the monsoon period
- Operators on site usually work on a memory basis and thus may not record operational issues on a regular basis or use extensive O&M manuals
- Training of operators is needed in their working environment (hands-on)

Figure 1: Surrounding buildings of selected test site in Amanora Park Town (source: BIOAZUL, 2014)

Location and conditions

The selected site is a residential area within Amanora Park Town, a sprawling 400 acre township located in Pune City (the second largest city of the state of Maharashtra). The surrounding area consists of several towers for apartments, buildings, school, hospital, fire station, parks, and power and water supply stations. The township has been awarded with many recognitions/awards in categories such as urban design, green projects and women empowerment. Amanora Park Town also has a local sewage treatment plant (STP) treating 3.5 MLD at present.

The region has a hot semi-arid climate bordering with tropical wet and dry, offering an average temperature range between 20 and 28 ºC. Three seasons take place in the region: summer (March-May), monsoon (June-October) and winter (November-February). Most of the 722 mm of annual rainfall in the city of Pune falls during the monsoon period. According to the World Health Organization (WHO), Maharashtra is the state of India with the highest risk related to floods.

Amanora Park Town is also part of the Hadapsar suburb, an IT, manufacturing and entertainment hub of Pune city, which has emerged as the cultural capital of the state of Maharashtra. Moreover, Pune city represents the sixth highest income per capita in the country.

However, the city is also an example of the water crisis suffered in urban areas of India, as a result of the increasing automobile and IT industry, the rapidly increasing population, and the growing demand for drinking water. It is estimated that 17 million inhabitants in the state of Maharashtra have no or unsafe access to water. In addition to this, only 68% of the wastewater generated in Pune is treated, contributing to water pollution in the Mula and Mutha Rivers.

Project history

BIOAZUL, partner in charge for designing this wastewater treatment plant, visited the site in April 2013. The construction of the treatment system started in May 2014 and was finalised in June 2014, starting to operate straight afterwards. The systems used for wastewater treatment were first delivered in Spain and tested by BIOAZUL, and then shipped to India for installation. Currently, the project is running and treated wastewater is stored prior entering the reuse network.

Some hindering aspects considered prior implementation of the system were related to certain local conditions, including features such as wastewater pollution load, power supply or area available. These issues were tackled by researching and implementing adapted technology to the region, demanding less energy and adjusting equipment to be financially feasible. For the near future, trained personnel is required for operation and maintenance of the treatment systems.

Technologies applied

The selected treatment systems – Sequential Batch Reactor (SBR) and Membrane Bioreactor (MBR) - are currently treating mixed domestic wastewater (black water and grey water) collected for the existing STP, and

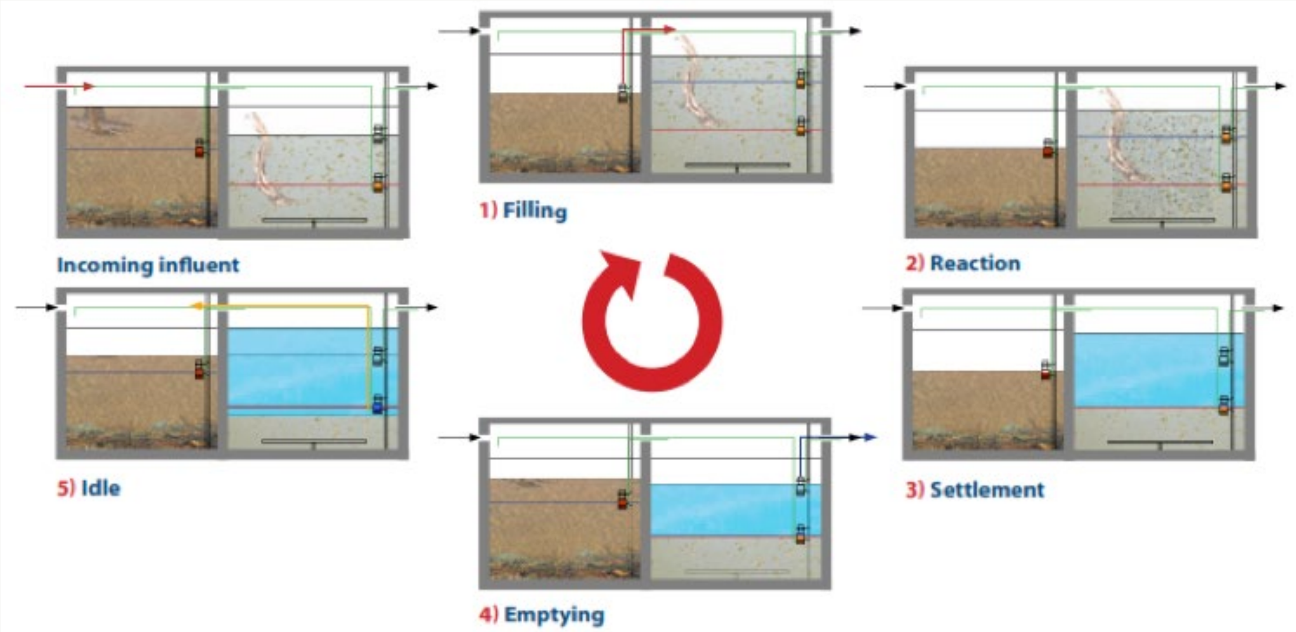

Figure 2: Overview of Sequential Batch Reactor (SBR) system (source: BIOAZUL, 2014)

they are designed to generate an effluent to be reused in toilet flushing and gardening. SBR and MBR systems represent intensive water treatment systems, allowing the effective treatment of heavily contaminated municipal wastewater, as stand-alone systems or in combination with natural extensive systems.

- SBRs (Figure 2) are a variation of the well-known activated sludge system, but undertaking carbon degradation, conversion of ammonia to nitrate (nitrification) and conversion of nitrate to nitrogen gas (denitrification) in a single reactor tank. All steps occur along a specified sequence of aerobic and anoxic periods, followed by settling and decanting to separate treated water from active biomass. Phosphorus removal is possible as well. The entire cycle ends when treated water is pumped to a treated water tank passing through a sand filter, which removes remaining suspended solids. Then the plant is ready for starting a new treatment cycle. The system is easy to control; it has a small land footprint, and a reliable performance for various raw wastewater qualities.
- MBR (Figure 3) is a combination of biological treatment (normally aerobic, although anaerobic is also possible) with membrane filtration. The retention of biomass is not achieved by settling, but by using a membrane as a physical barrier. Not only biomass is retained but also viruses and bacteria (depending on pore size). The permeate pump drives water from the MBR tank to the treated tank through the membrane, achieving a water quality good enough for reuse, considering

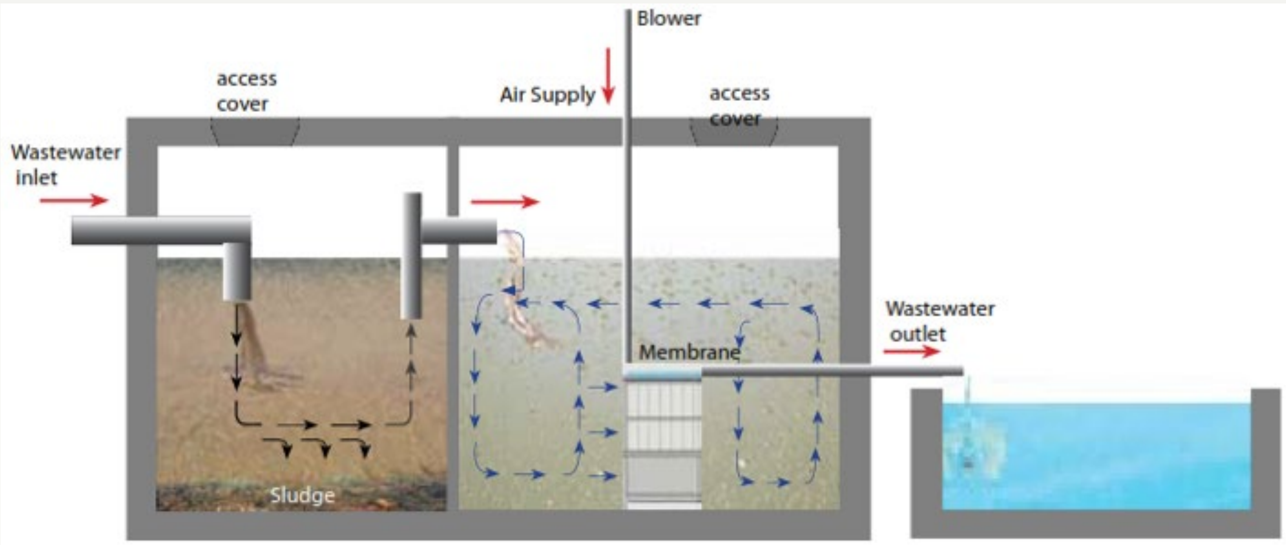

Figure 3: Overview of Membrane Bioreactor (MBR) system (source: BIOAZUL, 2014)

Table 1: Average contaminant load of untreated wastewater and expected results after treatment for certain parameters.

	Contaminant load (mg/l)	Expected results (mg/l)	Performance (%)
SS	198	35	95
BOD[5]	210	25	95
COD	470	125	90
Grease	10	1.0	90
N	12.3	2.0	80

that the treated water tank is equipped with an UV lamp working in continuous recirculation to assure a good disinfection rate. Very small footprints and stringent treatment requirements can be achieved with this system.

Both systems share a buffer tank since they are placed at the same location. Inside the buffer tank, pre-treated wastewater is collected and stored before undergoing the selected treatment. The buffer tank is used in order to reduce space, to ensure the continuous availability of wastewater and to make a previous oxidation of the organic matter before undergoing the main treatment in each reactor. The systems has been installed close to an existing wastewater treatment plant, from where the pre-treated water has been pumped to the buffer tank. A rotary screen is installed at the beginning of the treatment so that large particulate matter such as toilet paper and other solids are removed. Waste sludge removed from SBR and MBR systems is sent to the existing STP for further treatment.

The two systems have been selected and adjusted considering characteristics of the area such as amount of wastewater to be treated, wastewater pollution, area available and effluent requirements. Table 1 shows the average contaminant load of untreated wastewater as well as the expected results after passing this treatment system.

The reason for the inclusion of this combined system is the demand for water re-use at high quality requirements in the urban context as well as the targeted removal of trace contaminants (micro pollutants) that would pass other stages. Both systems are also seen as complementary components of the natural systems to enlarge the modular flexibility.

Design information

The adaptation of the technology was essential to enhance its applicability. Research and development for designing both systems was concentrated on reduced energy demands and lower maintenance requirements. Low energy membranes, hydrostatic filtration and simplified reactor designs have been considered in this project.

For the design of the SBR, the information considered was the following:

- Water resources: 120 L/p.e./d & 30 g BOD/p.e./d
- People equivalent: 85
- Flow: 10 m^3/d

Taking into account the capacity of the SBR in terms of daily flow (10 m^3), at least 25% of this (2.5 m^3) is needed in order to store enough water during the low sewage production periods. Since denitrification step occurs in the same tank, an additional tank for nitrogen removal is not necessary.

For the design of the MBR, the following data was considered:

- Water resources: 120 L/p.e./d & 30 g BOD/p.e./d
- People equivalent: 250
- Flow: 30 m^3/d

Considering the capacity of the MBR in terms of daily flow (30 m^3), at least 25% of this volume (7.5 m^3) is needed in order to store enough water during low sewage production periods. In order to avoid that nitrogen level of treated effluent could exceed allowed values recommended by the World Health Organisation, a denitrification tank has been considered and installed.

Both systems share a buffer tank as they are placed in the same area. The total volume of the buffer tank is 10 m^3, which is enough for feeding 30 m^3/day to the MBR and 10 m^3/day to the SBR. The total footprint of the combined treatment system (including housing for the equipment) has resulted in 52 m^2 (1.3 m^2/m^3 of treated water; Figures 4 through 7).

All construction materials and most of the equipment used for this treatment system (e.g. pumps, motors, blowers, probes, etc.) were available in India. Only specific parts such as tailor made membranes (for MBR) were shipped from Europe.

Type and level of reuse

For this project, domestic grey water and black water are mixed and treated for direct reuse applications. After wastewater is collected and treated, effluents are stored in a separated tank and are fully available to feed the reuse

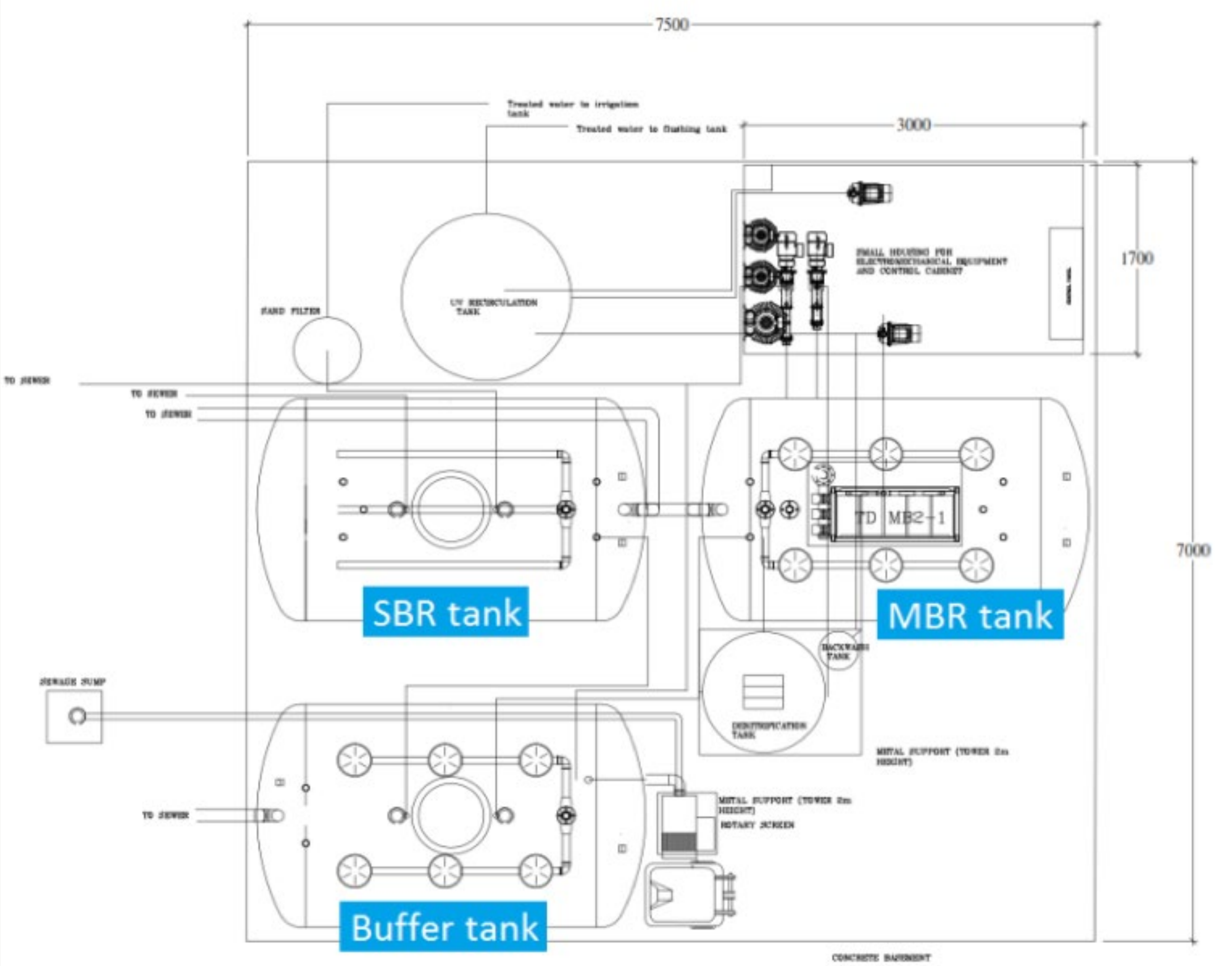

Figure 4: General overview of the systems (source: BIOAZUL, 2014)

Figures 5, 6 and 7: Combined wastewater treatment system (SBR and MBR) for wastewater reuse in Amanora Park Town (source: BIOAZUL, 2015)

network. The two different types of reuse are irrigation and urban reuse. Specifically, the activities considered for reuse are gardening irrigation and toilet flushing, which are supposed to take place in the proximities of the treatment plant and residential buildings.

Operation and maintenance

SBR and MBR systems require trained personnel for operation and maintenance. For this purpose, BIOAZUL S.L. has trained Amanora staff to be responsible for operation and maintenance of the systems, following the “NAWATECH O&M Manual MBR + SBR systems” together with the treatment plant components provided by BIOAZUL S.L.

Maintenance for MBR technology is quite similar to other secondary treatment systems, with the particularity of membrane cleaning, which takes place one/twice per year. Normal maintenance of pumps and motors following manufacturer instructions is required as well. A remote control of the system is highly recommended as the maintenance staff can monitor and manage the plant from the same place.

Table 2. Investment, O&M and total treated water costs (in EUR) per treatment system

COST	MBR	SBR
Investment (equipment)	60,800 EUR	34,200 EUR
Operation & maintenance*	0.1 - 3.5 EUR/p.e./year	0.065 - 2 EUR/p.e./year
Total treated water *	7.5 - 20 EUR/p.e./year	5.5 - 15 EUR/p.e./year

*Estimated costs from European prices

As for the SBR, despite the system being fully automated, maintenance activities are mainly related to solve problems with flow meters reading, level transmitter or pressure sensors.

The institutions responsible for the coordination of the safety planning process (planning, implementation, revision) are ESF and SERI (during the project duration), and Amanora staff (after hand-over). Furthermore, ESF is responsible for the performance of foreseen analyses.

Costs and economics

Detailed information regarding investment, operation and maintenance costs is illustrated in table 2.

Practical experience

The systems installed in Amanora Park Town were inaugurated on June 5th, 2014, and they have been running for one year and a half under monitoring phase. The sampling process has not been fully harmonised yet, but independently on this, some valuable experiences can already be described.

As explained when describing the key factors for the operation, surface area available, volume of wastewater to be treated, reuse activities expected, power supply or hydraulic connections are just some of the local features to be carefully considered. Electrical short power cuts may cause some problems, especially in the SBR, and internet connection is an indispensable feature, but these have never been a problem in Amanora, and it is not expected to have them as the profile identified as key customer for these kinds of technologies coincides with urban settlements similar to Amanora Township.

In general, spare parts needed for the construction of both technologies are locally available (providers can supply the needed equipment both in Europe and in India). Customs duty can be a problem, as costs of the material sent can be increased a lot (occasionally, up to 150%). Therefore, local manufacturers should be preferred (for instance, there is a good membrane manufacturer close to Pune). For Amanora, critical parts such as the membrane or the control panel were brought from Spain, although they are also available in India. Regarding the control panel, perhaps some specifications would be necessary when using an Indian provider, but this should be possible. In addition, the existing local technical service is suitable for reparation and maintenance.

For the installation phase of the equipment, minor problems occurred due to certain delay of materials to be delivered (e.g. tanks and motors) and the construction of the basement. As a consequence, the construction process suffered some delay although it did not affect the inauguration date for the plant. This made us learn that the time to be considered for design, land preparation, construction and commissioning, has to be increased in comparison to the European context. Sometimes there can be some incidences with providers, permits to be conceded by the authorities, etc., or the needed times for any of these tasks are simply longer in India. Thus, taking this into account, delay can be avoided when calculating the project delivery date.

Due to the fact that NaWaTech is a collaboration between international partners (Indian and EU), it was important to make sure all stakeholders used the same nomenclature regarding equipment, construction materials, etc. This was very useful to avoid potential misunderstandings. Regarding gender aspects, NaWaTech principles were followed to contribute with the enrolment of women in the research and development sector in India.

Up to now, the acceptance of the technology implemented has not been an issue for any of the stakeholders involved. The SBR operation requires less technical skills to be operated than MBR, what in principle would make it more suitable for India. Nevertheless, the profiles of typical costumers for using these technologies are those from townships like Amanora, where skilled operators can be hired, so we realised there is no objection for any of the systems. Moreover, considering concretely the Amanora case study, they prefer the MBR to the SBR as they can train already skilled personnel to operate the MBR, it takes less space and its efficiency is better.

Committing mistakes with the MBR can be much more serious than with the SBR; however, the MBR gives faster responses in adaptation when the operation conditions have to be re-established (such as when the plant has to be restarted). This is therefore another reason justifying Amanora's preference for the MBR.

During this operation and monitoring stage, no crucial problems have occurred. Most of them dealt with inexperience of the operators when running the systems or with mechanical problems of some of the systems' components, usually pumps and check valves. These problems have required that the pumps and valves were took from the plants and checked manually, and afterwards re-installed in the plant when fixed or replaced by new ones. The communication with the operators was of vital importance at this point, as their tendency was switching off the whole plant when a problem was detected, and maybe this problem was just due to a wrong adjustment of a pump, for example. Switching off the plant can cause serious incidences, as once it is switched on again, the operation conditions have to be re-established, what takes some time and therefore leads to a lack of treatment during this time. They are fully aware now that switching off the plant must not be a decision to be taken easily. An additional problem occurred with the programming of the control panel, but this was due to an erroneous configuration of the provider and was solved causing no more incidences.

Recommendations/conclusions

Based on the work performed and the lesson learnt, some recommendations and tips have been summarised below:

- In order to facilitate the implementation of the selected technology, local site conditions must be identified and analysed from the early stages. In this sense, surface area available, volume of wastewater to be treated, reuse activities expected, or power supply are just some of the local features to be considered.
- MBR and SBR systems are suitable for most of urban settings, only power supply and hydraulic connections must be carefully considered. Electrical short power cuts may cause some problems, especially in the SBR, as it may mean that the process is stopped in the middle of a concrete stage. Nevertheless, such kind of incidence has not occurred and is not expected in Amanora Park Town. In addition, internet connection has to be considered as an indispensable requirement and its availability should be checked in all potential installation sites from the planning stage, as it is required for carrying out the remote control. Once more, this has never been a problem in Amanora, and it is not expected to have them as the profile identified as typical customer for these kinds of technologies coincides with urban settlements similar to Amanora Township. Other than these, no special requirements were needed since shape and size of the systems were adapted to land surface available.
- In general, all parts needed for the construction of both technologies are locally available and local manufacturers should be preferred, as customs duty can be a problem. The existing local technical service is suitable for reparation and maintenance works.
- In comparison with the European context, design, land preparation, construction and commissioning may require more time which needs to be considered in order to correctly calculate the delivery date.
- Possible hazards with regards to technical components and their impacts are related to membrane clogging and puncturing, break-down of software/control panel, break-down of pumps, break-down of valves, and contamination of drinking water distribution pipes.
- Local climate conditions are not expected to have any impact on the treatment performance, although specific parameters such as MLSS (mixed liquor suspended solids) in reaction tanks must be carefully monitored during monsoon periods.
- Due to ongoing collaboration between international partners (Indian and EU), it is important to make sure all stakeholders use the same nomenclature regarding equipment, construction materials, etc. in order to avoid potential misunderstandings.
- Up to now, the acceptance of the technology implemented has not been an issue for any of the stakeholders involved. The SBR operation requires less technical skills to be operated than MBR, what in principle would make it more suitable for India. Nevertheless, the profiles of typical costumers for using these technologies are those from townships like Amanora, where skilled operators can be hired, so we realised there is no objection for any of the systems. Moreover, considering concretely the Amanora case study, they prefer the MBR to the SBR as they can train already skilled personnel to operate the MBR, it takes less space and its efficiency is better.
- Regarding operation and maintenance, it was clear that it is much easier and fluent when dealing directly with the client. Operators on site usually work on a memory basis, and not using extensive manuals where all answers can be found. We realised they can be very useful, but what is of vital importance is to focus on teaching and learning besides providing and having all needed information available. Training is needed not on an academic basis, but interacting with the operators in their working environment (hands-on). It is important to always consider who your end user is.
- Short reaction times for solving punctual problems with the systems are required, so appropriate responsibilities have to be established from the very beginning (it is needed to fix which operator is in charge of what).
- Committing mistakes with the MBR can be much more serious than with the SBR; however, the MBR gives faster responses in adaptation when the operation conditions have to be re-established (e.g. when the plant has to be restarted). This is another reason justifying Amanora's preference for the MBR.

- Decisions taken to solve any anomalous circumstances have to be in line with the manufacturers' guidelines, which have to be known and frequently used by the operators.
- Finally, regarding sampling, taking into account that in our case study the outflow from both systems goes to one common tank, the different parameters should be measured more strictly.

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Treatment of Contaminated Ambil Stream Water and Reuse in Indradhanushya Environment Education and Citizenship Centre, Pune

The use of an eco-technological treatment system (eco-filtration bank technology with soil scape filter as main treatment step) for stream water and reuse at the Indradhanushya Environment Education and Citizenship Centre, Pune is presented.

Author: Sayali Joshi, Pallavi Patil

Abstract

The ever growing Indian cities are putting pressure on the limited natural resources. There is increasing demand of fresh water for domestic and industrial uses. Due to unplanned growth the storm water drains in urban cities are serving as sewerage lines; the Ambil stream flowing through the central part of Pune city is a classic example of the same. We require sustainable and cost effective technologies to keep our surface water bodies' clean.The main motive behind the Indradhanushya project is to demonstrate that after treatment, the reuse of polluted water flowing through such streams and rivers is possible for flushing of lavatories in adjacent public places, watering plants in nearby gardens, and other non-consumptive uses. The reuse will help to reduce the load on fresh water supply. An eco-technology (eco-filtration bank (EFB) system) is applied with advantages such as no chemical addition, less electricity requirement and minimum maintenance needs of the treatment plant. EFB is comprised of screen, intake well, soil scape filters and treated water pond.

Introduction

Strom water drains carrying sewage from the alongside residential and commercial settlements is a common scenario in developing countries. This water if treated with cost effective, sustainable technology and reused for non-consumptive uses by the local authority, such as flushing in public toilets and irrigating the parks and gardens maintained by the local authorities, can tremendously reduce the pressure on fresh water demand and will help a lot in urban water planning of the developing countries.

Study area

The Indradhanushya Environment Education and Citizenship Centre is one of the sites selected under the NaWaTech project. An Eco-filtration bank (EFB) system is installed in the garden of the centre to treat wastewater for being recycled for non-consumptive purposes. Shrishti Eco-Research Institute (SERI) has designed the system and Ecosan Services Foundation (ESF), Pune is the project coordinator.

Technical data:

Mixed domestic wastewater flowing through the Ambil stream which is encircling the premises of Indradhanushya center is treated:

- Flow of Ambil Stream : 70 MLD (Non-monsoon flow)
- Size of treatment plant: 50 m^2 for main treatment unit, i.e. soil scape filter bed, additional area for collection tank and treated water pond (48 m^2)
- Quantity of treated water : 40 m^3/day
- Type of reuse: gardening and flushing
- Operation time of the system: 8 hours per day

Figure 1 - Indradhanushya Environment Education and Citizenship Centre

Figure 2 - Ambil stream encircling the Indradhanushya Centre, Pune (Photo taken by SERI Team in April 2014)

The Indradhanushya Environment Education and Citizenship Centre (Figure 1) is a public facility of the Pune Municipal Corporation to create awareness among the people about environment and sustainable development. The main objective of the Indradhanushya centre is to spread the message of environment conservation in society and develop skills and mind set among the citizens which could improve their environment literacy and and overall performance of the city.

The sewage contaminated Ambil stream (Figure 2) encircles the elevated premises of the Indradhanushya building. It is just 320 m upstream from the confluence of the Ambil stream and Mutha River. The height of the Indradhanushya centre is 555 m above the mean sea level (MSL). The total plot area of the Indradhanusya centre is 3723 m² while area under green belt is 2458 m².

The Ambil stream (rivulet) drains a catchment of 30.02 km². It is located to the south of Pune City between 18°23’40’’ N to 18°30’33’’ N latitudes and 73°50’20’’ E to 73°53’30’’ E longitudes. The rivulet originates at an elevation of 1100 m above MSL near the off shoot Western Ghats and flows towards a North North-West direction to join the Mutha River (Figure 3).

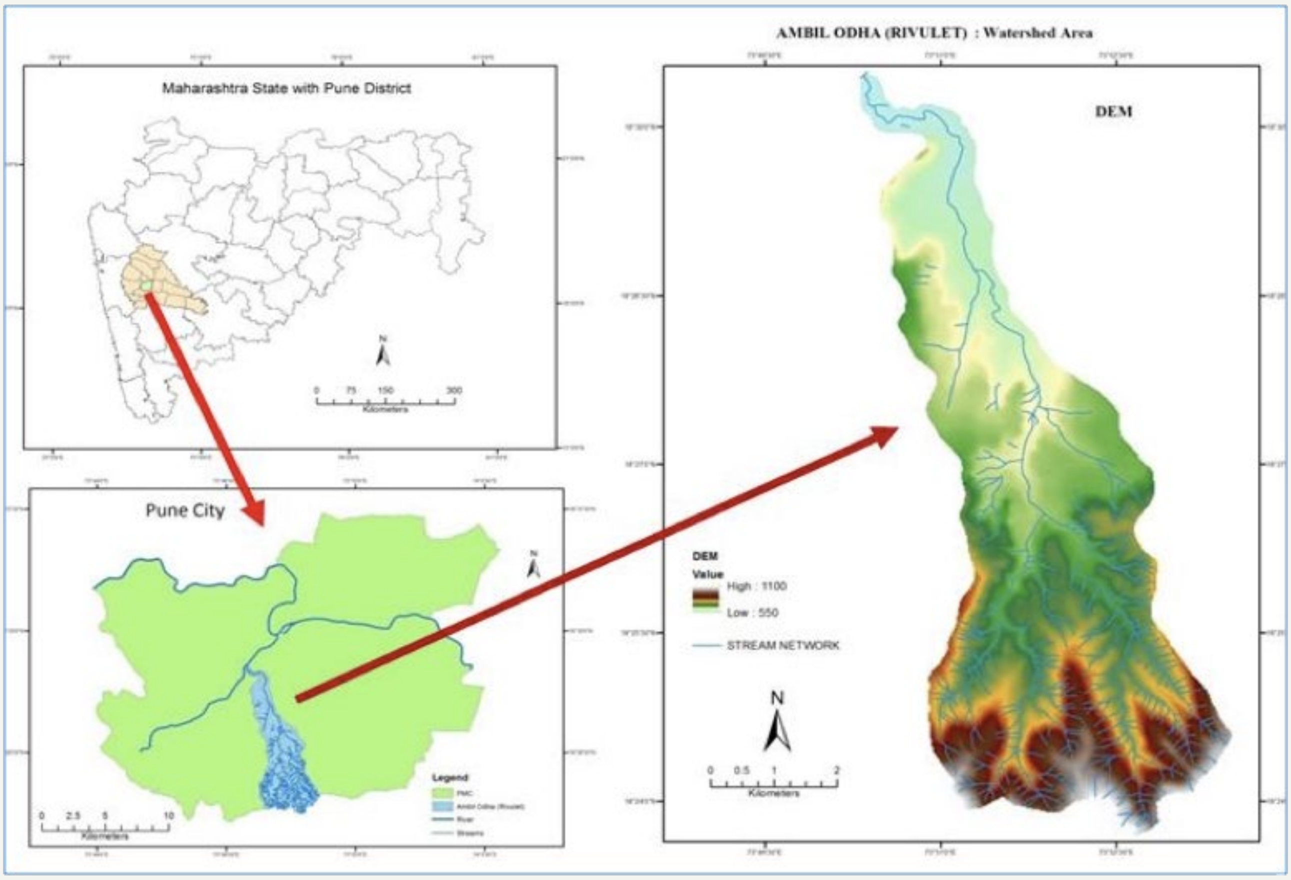

Figure 3 - Catchment area of the Ambil stream

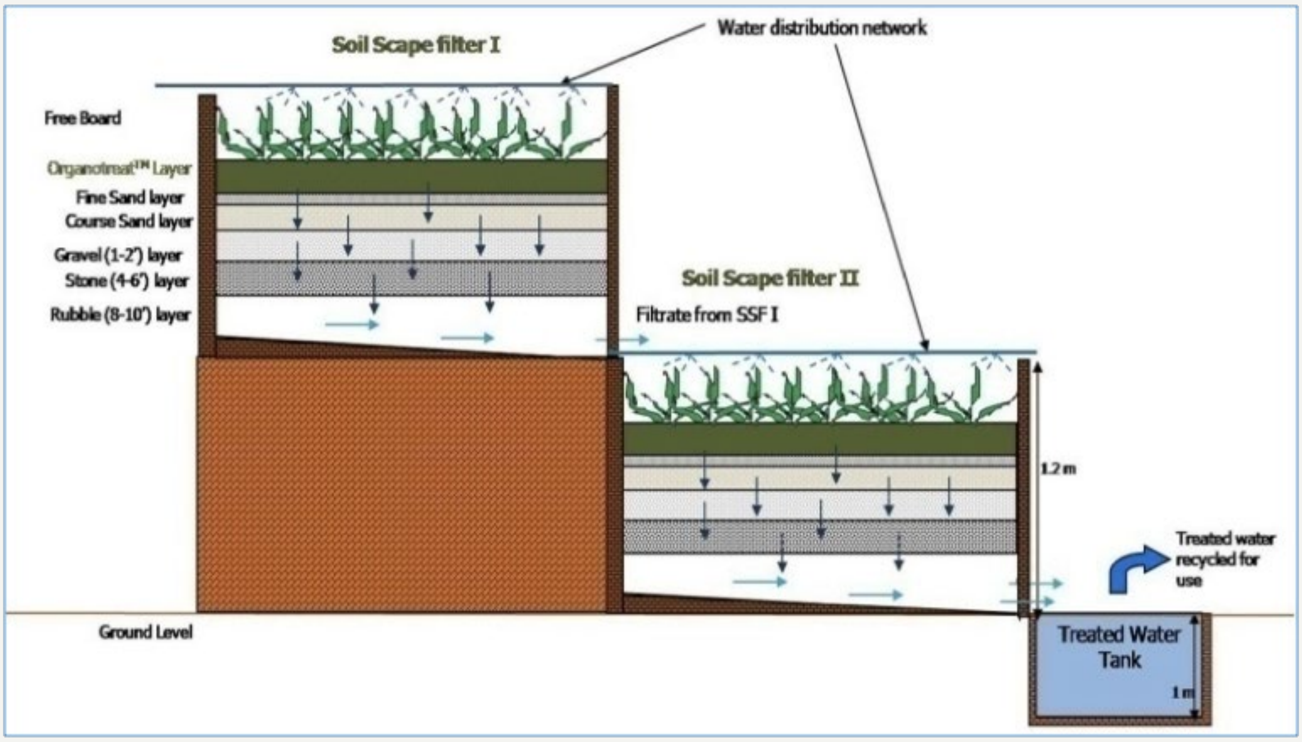

Figure 4 - Cross section of soil scape filter units

The non-monsoon flow of the Ambil Stream is around 70 MLD. The Indradhanushya centre has been selected for installation of an EFB system. For the EFB system, 50 m³/d of river water will be taken for treatment, to be recycled for gardening and flushing purposes.

The treatment system

According to the garden area, 12 m³/day and 15 m³/day water is required for the garden in the Indradhanushya premises and along the Sachin Tendulkar Jogging track, respectively to maintain their green cover. The remaining 10-15 m³/day water will be used for flushing of public toilets adjacent to the Indradhanushya building, therefore, the total water requirement is around 40 m³/day.

The technical details of the treatment system are as follows:

a. Flow of Ambil stream: 70 MLD (Non-monsoon flow)
b. Proposed quantity of wastewater to be treated: 50 m³/day
c. Details of soil scape filter tanks: Linearly placed 2 tanks, 25 m² surface area for each tank with effective depth of tank being 1.2 m (10 m length x 2.5 m width of each SSF bed)
d. Operation time of the system: 8 hours per day
e. Quantity of treated water : 40 m³/day
f. Quality of treated water: Complying State and Central Regulatory Discharge Norms (reuse in land application and remaining for flushing purposes).

<u>The process</u>

The required quantity of contaminated water from the Ambil stream is diverted into the intake well by gravity. Water from the intake well is pumped out and distributed on to the soil scape filter beds uniformly. The wastewater passes through the different layers of the filter bed and finally filtered water is collected in the treated water pond. The water flows from the stream to the intake well by gravity. From the intake well the water is lifted by an electric pump to spread it on the soil scape filter beds. From the soil scape filter beds to the treated water tank water flows by gravity again.

The intake well is comprised of an inlet chamber with screen, conduit and collection/storage well. Non-biodegradable solid waste flowing through the Ambil stream is trapped in the screening chamber of the intake well. The trapped solid waste is removed daily to be collected and transported to the dumping site of the local authority. The collection well of the intake system has been designed to collect the desired amount of stream water.

The EFB comprises soil scape filters (SSF) as the main treatment unit (figure 4). This ecological treatment process involves the filtration of wastewater through the biologically activated filtration medium supported by sand and gravel. It harnesses the ecological principles of biodegradation, biotransformation and bioconversion occurring at various tropic levels in the detritus food chain to treat, transform and detoxify the pollutants using solar energy. Bio-fertilizer and treated water are the products of this process. This technology was invented by late Prof. Sandeep Joshi (e.g. Joshi, 2013).

Figure 5 - Overview of treatment system (left) and treated water pond (right) under construction.

Figure 6 - Construction of intake well (left) and soil scape filter beds (right).

In a SSF, a combination of green plants and bacterial culture is used to remove organic matter and pollutants. Soil scape filtration is vertical eco-filtration of water or wastewater through the layers of bio-active (i.e. biologically activated) soil including microbial consortia such as Organotreat™ (developed from non-toxic and non-hazardous organic matters, bacterial cultures) and fragmented rock materials. As the wastewater passes through these layers of biologically activated filtration medium the pollutants are absorbed and degraded. This biodegradation process releases nutrients in simple forms which can be absorbed by the plants for their growth. So there is no production of any kind of sludge in this treatment system.

<u>Operation and maintenance</u>

SSF systems require unskilled but trained personnel for routine operation and maintenance. An O&M Manual and Safety Plan with the necessary instructions for the management of the plant and for the troubleshooting has been submitted to the O&M team.

Normal maintenance of pumps and motors following manufacturer instructions is required. Periodic analysis of the incoming and treated water quality to monitor the changes in the process is suggested which will help in trouble shooting.

For the intake well, maintenance activities are mainly related to removal of silt deposited in the collection well and monitoring the flow meters readings.

<u>Expected results</u>

During preparation of the manuscript the system was still under construction. So water quality analysis were not available. The expected untreated wastewater concentrations and treatment results (based on SERI‘s experience) are given in Table 1.

Figure 7 - Landscape design of the Indradhanushya project (Souce: Kre_Ta, 2015)

Table 1- Average untreated wastewater concentrations and expected results after treatment

Parameter	Average values of Ambil stream water	Proposed treated effluent quality	Discharge standards for irrigation water*
TSS	120 mg/l	< 30	200
BOD	140 mg/l	< 30	100
COD	260 mg/l	< 80	NA
Oil & Greases	10 mg/l	**	10
Fecal coliforms	105 CFU/ml	< 1 CFU/ml	NA

* Not Available as per CPCB standards
** Below limit of detection

For 50 m³ per day, the present cost of fresh water is approx. 150 EUR, the expected costs of the treatment system to produce the same amount of non-potable recyclable water are approx. 10 EUR. Thus the daily savings are expected to be around 140 EUR.

Conclusions

The major advantages of the treatment system are low operation & maintenance cost, low energy demand, manageable with unskilled but trained manpower and high efficiency in pollutants removal. Although this Indradhanushya project is still in the construction phase, based on previous installations, the following conclusions can be drawn:

- In India cost of land is very high. SSF is a compact system with minimum land footprint. The surface area is critical and not the shape of the filter tank. Depending on the availability of space it can be constructed in any shape and size, hence it can be called a “tailor-made” system.
- It is suitable for populations ranging from one family (4- 5 persons) to 1000 families. It is effective for the treatment of grey water and black water separately or combined.
- SSF systems require unskilled but trained personnel for routine operation and maintenance.
- The whole system can function by gravity, except small pumps for loading of wastewater on to the filter beds from the collection tank, with measured flow for the designed time frame, in case gravity benefit is unavailable. The electricity savings will be more than 90% as compared to conventional aerobic treatment systems. No breakdowns since almost all components are natural systems. There is no need of any chemicals for the process.
- This system uses natural processes which save a lot of mechanical and electrical energy contributing to minimize global warming.
- It is very effective in the tropical environments of Indian cities as the process is based mainly on bioremediation and phytoremediation. The bacterial

consortia used for the treatment of wastewater perform effectively in a wide range of temperature (2 to 50oC). In this favourable environment the naturally isolated culture of bacteria gives highest performance.

- Gives aesthetic look to the premises due to flowering plants and ponds.
- It can take up shock loadings, treat toxicants in a safe manner and restore itself in a short span of time.
- The plants selected for the treatment are native and are easily available in all states of India. Furthermore, all construction material and layering supportive material in the filter bed is readily available in India.

References

Joshi S. (2013): Water and Wastewater: Filters. In: S.E. Jorgensen, ed: Encyclopedia of Environmental Management Vol.IV, Taylor & Francis: New York, pp.2740-2754.

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Landscape Architecture and Wastewater Management in the Indian Context

This paper outlines the interactions of landscape architecture and wastewater management based on the experience of the NaWaTech case studies.

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Abstract

During the NaWaTech project five case studies were implemented in India to treat wastewater with natural treatment systems. Landscape architects accompanied the planning and construction process in order to combine the technical design of the treatment plants with aesthetic aspects. This paper presents some experiences of this undertaking. The case studies of the NaWaTech project can provide an example how sustainable design criteria can be applied in the field of wastewater management in the Indian urban context.

What is landscape architecture?

Landscape architecture is a multi-disciplinary planning practice specialised in the design of outdoor spaces to achieve environmental, social-behavioural and/or aesthetic outcomes. The scope of landscape architecture ranges at all varying scales from strategic framework masterplans to the applied scale of streetscapes, parks, plazas and gardens. The landscape architect follows the project from the site analysis via the designing and approval process up to the construction work.

Implementation in the NaWaTech case studies

The design and implementation of wastewater treatment systems in India and Europe are normally in the hands of engineers and administrative staff. This very often leads to isolated technical systems which are hidden from the public with no access and interrelations with the users/ residents. These systems are technical functioning but not fulfilling any aesthetic standards or opportunities of use for the residents. This procedure is part of the common understanding that treatment and reuse of wastewater is a "dirty and smelling" business which should be hidden and take place far away from any other human activities.

The NaWaTech approach follows an entirely different methodology. By integrating from the first moment local

Key messages/ key facts:

- Landscape architects accompanied the planning and construction process of the NaWaTech case studies
- Sustainable design criteria were applied in the field of wastewater management
- Multi-use solutions are required
- Public acceptance and educational value can be achieved by integration of stakeholders from the very beginning
- Treatment systems should be accessible and self-explaining
- Detailed landscape analysis of the site conditions is required for a solid project planning
- Main challenge of the different NaWaTech test sites was to implement natural wetland systems in a very dense urban context
- The role of landscape architects is to mediate, translate and synthesize
- The construction of wetlands and other new approaches of wastewater management can emerge with aesthetic value and revaluation of the living environment

stakeholders such as residents, users and local authorities as well as experienced landscape designers an open, integrated and user-accepted concept is targeted. By creating a multi-use solution which is integrated into the open space used on a frequent basis by the local residents important objectives such as public acceptance or educational value can be achieved. The NaWaTech treatment systems should be accessible, self-explanatory and the reuse of water should have an additional positive effect for the site (e.g. for irrigation, toilet flushing, etc.).

For the implementation of constructed wetlands in the different NaWaTech test sites the landscape analysis consisted of research on local conditions and collection of required data such as local climate, soil structure, rainfall and precipitation. In India the monsoon season, water supply and rainwater levels need to be considered. Furthermore, the existing infrastructure should be thoroughly evaluated with a particular attention to all technical equipment such as pipes, siphons and sewers which are not necessarily documented.

Additionally, research on locally available plants and flowers and on regional traditional design of parks and gardens is required as well as a collection of basic information for the first design such as maps, photos and graphics.

The early analysis included a mapping of all stakeholders and their requirements, the interrogation of user needs plus the legal framework. Public stakeholder participation is an important part of these planning processes as it lays the foundation for increased citizen engagement and satisfaction as well as reduced vandalism and provides an indication about the usage of a site. After consideration of all interests, a creative process is started; a first draft of the planning is prepared for the purpose of early stakeholder participation, alignment with involved parties (such as land and building owner, constructor, residents, visitors and project partners) and approval processes with the authority. With the results an execution planning is created describing the details as needed for the construction.

During the construction, supervision by the Indian NaWaTech partners insured the correct realisation of the project.

The particular challenge for the different NaWaTech test sites was to implement natural wetland systems in a very dense urban context with a high number of users/visitors. The available space was strongly limited and there is an ongoing high pressure of use. The recreational purposes for all local residents has been considered in the planning and the implementation, e.g. by using questionnaires and interviews.

Key landscape challenges at NaWaTech case studies have been:

- The College of Engineering Pune (COEP) hostel campus, Pune (Figure 1; Patil et al., 2016): The very

Figure 1: COEP hostel campus, Pune

Figure 2: Indradhanushya Environment Education and Citizenship Centre, Pune

dense habitat for students and few recreational space available led to the development of a concept that does not restrict the recreational area of the garden, but adds a new value in the front yard of the student‘s hostel.

- Indradhanushya Environment Education and Citizenship Centre, Pune (Figure 2; Joshi and Patil, 2016): The treatment system had to be integrated into the garden of the museum and demonstrates an opportunity to stage it for educational purposes.
- Dayanand Park in Nagpur (Figure 3; Masi et al., 2016): The project had to deal with the very high pressure on the available public space and proposes a multi-usage solution.

The integration of the technical infrastructure of the treatment systems into the public spaces was carried out through an aesthetic improvement of the living environment in order to reach a higher acceptance, understanding and ecological consciousness of the users. This educational effect is underlined by a very direct reuse of the treated water, either for toilet flushing or irrigation on site.

The technical integration of the treatment systems should not reduce the available space but create new opportunities and values (multi-use approach). Besides water purification, educative and aesthetic aspects should be proposed to the habitants and users. The plants can potentially offer shade and influence the local climate conditions in a positive way.

High risk of theft in public areas requires the use of materials without major resale value. Security should be considered and interesting objects should be invisible.
The design should pay attention to the local culture and aesthetics. In India, since the beginning of landscape architecture more than 2000 years ago decorative, symbolic, medical and evergreen plants have been in the centre of interests. Although modern and western influences have taken over in many public places, typical Indian signs such as specific trees, plants in general and ensembles can still be found. In order to underline the symbioses between traditions and sustainable water treatment several typical Indian signs have been integrated in the landscape design.

Urban sustainable sanitation is one of the big challenges of our time and actually offers an exciting opportunity to redefine quality of life in our cities. The construction of wetlands and other new approaches of wastewater management requires changes in the public and private open space. These changes can bring a lot of benefits socially, culturally and environmentally - for instance by using short rotation plantations (SRP) local value chains (e.g. bamboo production) can emerge with aesthetic value and revaluation of the living environment (Ordnance Factory Ambajhari, Nagpur; Pophali et al., 2016).

Summary

The role of landscape architecture in the field of wastewater management is to mediate, translate, synthesize and communicate between scientists, politics, engineers and all remaining stakeholders in order to develop visions of new relations between human habitation and sanitation systems. In a creative process the landscape architect develops solutions for and discovers hidden potentials of a specific site. Therewith additional aesthetic and other

Figure 3: Dayanand Park, Nagpur

sustainable values for a higher acceptance of the project are created. In the words of the landscape architect Herbert Dreiseitl: „Perhaps most importantly, we would benefit from the creation of a stronger emotional and spiritual connection to water. This could be done in artworks that celebrate the value of water and designs that emphasize its boundless properties." (Margolis and Chaouni, 2015)

References

Joshi S., Patil P. (2016): Treatment of Contaminated Ambil Stream Water and Reuse in Indradhanushya Environment Education and Citizenship Centre, Pune. Sustainable Sanitation Practice 25 (January 2016), 42-47.

Margolis, L., Chaouni, A. (2015): Out of water - design solutions for arid regions. Birkhäuser, Basel, Switzerland.

Masi F., Bresciani R., Winkelmeier P., Pophali G.R., Khilnani A., Sahu N., Kaur H., Labhasetwar P.K., Yadav S., Nagarnaik P. (2016a): Wastewater Treatment and Reuse for Irrigation in an Urban Park: the Dayanand Park Treatment Wetland System in Nagpur. Sustainable Sanitation Practice 25 (January 2016), 17-20.

Patil, S., Edathoot, A., Patwardhan, N., Bresciani, R., Panse, D., Masi, F. (2016): Natural and Cost Effective Way of Treating Domestic Wastewater with Reuse in Non-Potable Purposes: The College of Engineering Pune (COEP) Hostel Campus Case Study. Sustainable Sanitation Practice 25 (January 2016), 21-27.

Pophali, G.R., Sahu, N., Khilnani, A., Kaur, H., Yadav, S., Labhasetwar, P.K., Bresciani, R., Masi, F., Meinhold, K. (2016): Domestic Wastewater Treatment and Reuse in Ordnance Factory Ambajhari, Nagpur. Sustainable Sanitation Practice 25 (January 2016), 12-16.

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Safety and O&M Planning

Development of a safety and O&M planning approach to support long-term operation of the implemented pilot systems.

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Abstract

A safety and O&M planning approach was developed to support the long-term operation of the implemented pilot systems. Using a risk-based approach adapted from WHO Water and Sanitation Safety Planning, it builds the basis for developing O&M schemes, general spare-part management and trouble-shooting routines including user-friendly O&M materials for operators and supervisors. Besides presenting the safety and O&M planning approach, we summarise general considerations on O&M planning, the implementation of the approach at the NaWaTech pilot sites, and experiences gained during implementing the approach.

Introduction

Efficient and effective operation and maintenance (O&M) is necessary in order to guarantee the long-term operation of any sanitation system. Maximum health and environmental benefits can only be achieved in case the facilities operate continuously and at full capacity, while complying with acceptable quality standards (Müllegger et al., 2012).

One main aim of the NaWaTech project was to support long-term sustainability of the implemented treatment plants through systematic O&M management. This includes taking into account that various technologies are implemented in quite different stakeholder contexts. Some of the pilot sites are managed by well-experienced plant managers, while others will be managed by staff with no wastewater management background at all. Thus, an O&M planning and management approach was developed and implemented that is flexible enough to be applied in various contexts. For being able to replicate NaWaTech solutions, the aim was to provide a generic approach for O&M planning which is practice-oriented, simple, and does not require complex data collection and processing. In the NaWaTech project, O&M planning was initiated as early as during the planning and design phase by sensitising the system designers for O&M and safety requirements.

Water and Sanitation Safety Planning promoted by WHO (Davison et al., 2005; Bartram et al., 2009; WHO, 2015), are risk-based management concepts that recognise the importance of institutionalising good O&M practices (NIPHJ/IWA, 2015). However, the miss-perception of the concept being an “additional” activity to existing managerial or operational tasks or the missing integration of planning results into day-to-day routines due to financial or institutional barriers can limit the success and the practical implementation of the concept (Williams and Breach, 2012). Since sanitation safety planning is still rather new to the sector and only few case studies are available, lessons learnt from water safety planning are taken as a basis for further developing safety planning as a means for O&M management in the sanitation sector. Through simplifying and adapting principles of WHO Water and Sanitation Safety Planning, preventative, technology-focused O&M schemes are developed and

Key facts:

- Sanitation systems only work and have the expected benefit to humans and environment if they are operated and maintained properly
- The NaWaTech safety and O&M planning approach
  - was developed to support sustainable long-term operation of sanitation systems
  - is based on key elements form WHO Water and Sanitation Safety Planning approaches
  - facilitates definition of clear responsibilities for O&M (e.g. for operators and supervisors)
  - supports development of O&M schemes and materials

stakeholder involvement was initiated at each pilot site. Major objectives are to overcome shortcomings of conventional approaches to O&M which are often rather trouble-shooting oriented and to establish effective and more informed and target-oriented preventive O&M. The underlying idea of using a risk-based planning approach is to make use of the way of thinking to tackle O&M through „prevention instead of reaction".

The safety and O&M planning approach

In general, safety and O&M planning shall support the development of effective O&M routines and improve their formalisation. Starting to plan O&M activities in an early project phase instead of only addressing it once systems are already in place shall allow to systematically face the aspects mentioned above.

Depending on the setting of each project and involved parties, this task can be carried out either by the system designers, the O&M contractor or an external stakeholder providing this as a service for one of these parties. Ideally, O&M planning should be initiated as early as possible during the design phase and continued along with the implementation and of course the operation phase. However, in the majority of projects, discussions around O&M only start when the systems are close to commissioning or even already handed over for operation. Thus, the actual implementation of the planning process can look very different from project to project.

Systematic safety and O&M planning targets at:

- Identifying all relevant stakeholders and initiating stakeholder involvement at all levels (authorities, management, operative level) for fostering agreements and understanding on the different roles and responsibilities involved in O&M and system monitoring
- Identifying and understanding critical O&M requirements – both technical and institutional/organisational - which need to be addressed during the design, construction and operation phase; plus integrating these into the design and construction process as well as into standard routines for normal operation conditions
- Preparing general routines for incidents to shorten the time until returning back to normal operating conditions
- Identifying critical monitoring tasks involving both inspections and quality measurements
- Supporting the preparation of O&M materials and routines. E.g.: providing lists of critical O&M activities can serve as a basis for the development of the O&M manual and additional supporting materials for operators and supervisors (such as work plans, checklists and documentation forms)
- Identifying site-specific focus topics for trainings of operators and supervisors

The approach developed in the NaWaTech project breaks down key ideas of safety planning to six practical steps:

1. Establishment of the safety and O&M planning team

A core-team coordinating and initiating the safety and O&M planning needs to be assembled. Ideally, this team should involve representatives of all relevant stakeholder levels:

- Safety and O&M planning coordinator: initiating the stakeholder involvement and discussions; steering of planning process and documentation integration of outcomes in day-to-day operation and plant monitoring.
- Operational staff: staff directly involved in day-to-day operations and their supervision; provision of operational experiences and technical knowledge for hazard identification and definition of O&M and monitoring measures; execution of O&M activities.
- Management staff representative: in decision-making position, and in the ability to assign budget; being able to foster implementation of agreed activities and follow-up.

This core team will be extended for some planning tasks, e.g. during hazard identification or identification of control and monitoring measures. Ideally, other technical experts with long-term practical experience can be involved in the discussions as well.

Team members might change over time, thus team-build up needs to be revised on a regular basis.

2. Definition of system boundaries, stakeholder identification, and system description

One of the first tasks of the safety planning team is to define the boundaries of the planning process. This includes the physical boundaries ("Which technology units will be considered?"), the political, administrative and legal boundaries ("What are the regulations/standards that need to be taken into account when formulating O&M and monitoring activities and defining critical limits?"), as well as the financial boundaries ("How und who will cover costs for O&M and monitoring activities?").

In a next activity, a system description needs to be prepared. In this description, the main functionalities of the involved technologies are lined out as basis for a general understanding of the processes involved. This description should also break down the system into system units, e.g. along the sanitation chain following the sanitation system approach (Tilley et al., 2014), in order to have a systematic baseline ("skeleton") for the planning activities. This can be done based on the development of simple flow diagrams. An example for a system description including flow diagrams is available in the NaWaKit (2015). Moreover, a stakeholder mapping needs to be carried out to identify all people and institutions directly or indirectly relevant for O&M and safety planning and implementation. Along the project progress, these stakeholders should agree on various roles and responsibilities in context

Figure 1: Identification of roles and responsibilities for O&M during a stakeholder workshop at the COEP hostel campus site.

of long-term system operation and maintenance and monitoring and be assigned to them accordingly (Figure 1). A genuine list with main roles and responsibilities is available in the NaWaKit (2015).

3. Identification of hazards, risk assessment and prioritization

The objective of the next step is to identify functional bottlenecks of the (planned) treatment system. These bottlenecks are referred to as "hazards" and "hazardous events, with:

- "hazards" being specifically defined as "failure modes of treatment units and supporting units" (e.g. pumps, monitoring devices, etc.), and
- "hazardous events" being defined as "circumstances favouring these mal-functions or failure modes"

The identification and understanding of these bottlenecks represents the centrepiece of the "safety" thinking – and builds the basis for systematically identifying relevant prevention and monitoring measures.

Hazards need to be identified for each system component. Here, it can be distinguished between hazards and hazardous events that are linked to the design, construction and operation phase. During the NaWaTech project, template hazard lists were compiled for all components implemented in the NaWaTech pilot sites. These template lists can be used as a discussion baseline in planning activities and are available in the NaWaKit (2015).

Once potential hazards are listed, the risk of each hazard can be assessed taking into account its probability and severity. Based on the risk assessment, the criticality of each hazard can be evaluated.

In the NaWaTech project, this activity was carried out following a semi-quantitative risk scoring approach which not only takes into account the criteria of probability (P) and severity (S), but also the detectability (D) of each hazard. Each identified hazard was assessed using the semi-quantitative risk-scoring matrix shown in Table 1. Once the risks are assessed, risk ranking helps prioritising risks and evaluating the "tolerability of a risk". The ranking is based on calculating risk scores (R) with $R = P*D*S$. Results of the risk scoring were then grouped in two ranking classes indicating the criticality of the estimated risk. A risk is

Table 1: Semi-quantitative risk score matrix for NaWaTech safety and O&M planning

Score	Probability (P) (of the hazardous event)	Detectability (D) (of the hazard)	Severity (S) (of the consequence of the hazard)
1	Occurs less than once in 5 years	Hazard is detected based on visual inspections	Will not result in major system degradation and will not produce system functional damage
2	Occurs once a month to once a year	Hazard detection requires stepwise analysis (e.g. sampling required)	Will degrade system performance but can be counteracted or controlled without major damage
3	Occurs more often than once a month	No detection in normal operation; problem analysis is stepwise and complex	Will (severely) degrade system performance by substantial damage (component failure), interrupt system feeding, requiring immediate corrective action for system survival.

Table 2 Selected hazards and risk assessment applied

		Hazards and their effects		Risk Assessment			
Component	**Project Phase**	**Hazardous Event (Failure cause)**	**Hazard (failure mode)**	**P**	**S**	**D**	**R**
Screen	3	Insufficient cleaning of screen, build-up of solid material	Reduction of flow; eventually choking; overflow of screen chamber	3	1	1	3
Pump	3	Malfunction of lower floating valve	Pump doesn't stop after reaching the minimum level	2	3	2	12
Anaerobic Settler	3	Insufficient removal of sludge	Reduction of effective volume; non-adequate removal of SS	2	1	2	4
HF CW	2	Use of low-quality or unwashed filter material	Uneven distribution of WW in wetland; clogged zones in filter bed	-	2	2	-
General	3	Frequent staff rotations	Knowledge management impeded; Loss of experience; temporary/long-term understaffing	2	3	1	6

Project phases: (1) design (2) construction (3) operation; HF CW = horizontal flow constructed wetland

considered critical if R > 7, P = 3, or S = 3 (adapted from Mayr et al., 2012). In order to limit the subjectivity of this scoring method, it is essential to carry out the scoring iteratively and to involve several stakeholders/stakeholder groups. In NaWaTech, scoring of the three risk criteria were based on several expert discussions within the project consortium. In future replications, this joint risk assessment should ideally be carried out in group discussions involving the whole safety planning team.

Table 2 shows examples of hazards and their risk assessment for different technical components as well as for general hazards. General hazards are hazards that do not concern a system component specifically, but the whole system. The column "project phase" indicates whether the respective hazard is controllable during the design, construction or operation phase. For hazards controlled during design or construction phase, no likelihoods are assessed.

4. Identification of risk prevention and risk reduction measures (control measures)

Following the risk assessment, for each identified hazard (hazardous event) control measures are defined. A control measure is a preventive activity aimed at eliminating potential component failures, respectively, the probability of their occurrence. If a hazard cannot be fully eliminated or reduced, also monitoring of the hazards (e.g. in form of inspections) is considered a control measure.

Typically, control measures are regular maintenance activities and inspections and can be linked to O&M routines proposed by system designers or by technology providers. However, approaching the definition of these activities though risk-based planning helps to systematically list out critical O&M activities and helps understand the importance and effect of each activity and identify additional activities necessary, respectively, adapt the frequencies of existing O&M routines.

5. Monitoring measures for surveying the efficacy of the control measures

In a next step, monitoring measures are defined to check whether the control measures, respectively, the treatment system, are operating as intended and to describe what to do if they are not. To define when a measure is considered unsuccessful, respectively, system safety is at risk, critical limits have to be defined. These critical limits are used to define at which point or under which condition corrective measures ("trouble-shooting") have to be initiated.

6. Formulation of a generic trouble shooting and communication routine

Since required trouble-shooting is problem-specific and often requires detailed analysis of a failure, preventive planning cannot detail each trouble-shooting step, but rather give guidance on some general actions to be taken when the "critical limit" is exceeded and/or a deviation from regular operation conditions is observed. This can for example be the proposition of a general line of action, e.g.: who needs to be informed and when, which immediate action needs to be taken (e.g. diversion of inflow prior to the failing component) and what to do after the problem is solved (e.g. documentation and review of routines).

Implementation at NaWaTech pilot sites

In this chapter, we present the results from implementing the illustrated safety and O&M planning approach at three pilot sites, i.e. Amanora Park Town (Zapata et al., 2016) and COEP hostel campus (Patil et al., 2016) in Pune, and Ordnance Factory Ambajhari (OFAJ, Pophali et al., 2016) in Nagpur. At all tree sites two treatment lines have been implemented. More details on the implementation of the safety and O&M planning approach are presented in Nicolics et al. (2015a,b). Table 3 shows a summary of the results for hazard identification and risk assessment for the six treatment lines

Table 3: Overview of main results for hazard identification and risk assessment for two technical and two natural treatment lines.

Treatment Line	Implemented system	# components	# hazards	# critical hazards	Hazards with R≥7	Hazards with P=3	Hazards with S=3
Amanora 1	SBR	**11**	88	**51**	27	3	21
Amanora 2	MBR	**10**	87	**58**	22	3	33
COEP 1	Anaerobic pre-treatment + VF CWs (domestic wastewater)	**11**	83	**38**	19	6	13
COEP 2	VF CW (greywater)	**7**	65	**35**	18	4	13
OFAJ 1	Anaerobic pre-treatment + vertical up-flow CW	**16**	106	**47**	25	0	22
OFAJ 2	French reed bed	**8**	66	**24**	12	0	12

at the three pilot sites. Besides the number of technical components, the total number of hazards and the number of critical hazards are given. The critical hazards were identified as described above, i.e. R > 7, P = 3, or S = 3.

When taking into account the number of components involved, there is not a big difference in the total number of hazards identified for the different treatment lines. However, the number of critical hazards is higher for those lines that have compact systems (SBR and MBR) – meaning they have more hazards which can cause severe system performance degradation, substantial damage (component failure) or interruption of the system feeding, and/or hazards which are very likely to happen or rather complex to detect. This indicates the higher risk of failure of and higher O&M effort required for technical systems.

It has to be noted that for the lines with natural treatment options the majority of critical hazards are linked to pump operation. I.e. for COEP Line 1, 21 of the 38 identified critical hazards are linked to the three pumps used for intermittent loading of the constructed wetlands. In comparison to that, for the MBR treatment line, pump-related critical hazards are 30 out of 58. Further 12 critical hazards are linked to MBR operation itself.

In comparison with technical systems, the following aspects can be highlighted for natural treatment options:

- The need for regular and reliable O&M of the screen to prevent coarse materials from entering the systems, as well as the considerable number of “bottle-necks” related to pump operation.
- Thus, a reasonable number of critical hazards can be eliminated when designing/positioning the treatment lines in a setting that allows substituting pumps by syphons.

However, it has to be noted that for both technical and natural treatment systems training of the involved staff (operators and supervisors), the preparation of knowledge transfer and the organisation of re-fresher trainings, but also the planning for staff rotations are further critical control measures as well as the preparation of spare part management.

Trouble shooting routines identified underlined the importance of reviewing O&M routines after major incidents - besides the actual technical measures for remediation. Thus, communication between the different levels of staff involved in system operation and maintenance is foreseen in all defined trouble-shooting routines. Only through systematic re-fresher trainings and joint discussions with operational staff, a learning process for system improvement can be established. Similar as in case of the control measures, trouble-shooting routines defined in the safety planning should be linked to more detailed step-by-step work descriptions contained in the O&M manuals provided by system designers and component manufacturers.

Table 4 shows an overview of outcomes of the safety and O&M planning activities. After discussion of potential hazards, the design at COEP has been amended in the early phase to eliminate some of the hazards (e.g. installation of gas collection pipes, drainage channels surrounding sub-terrain structures, and float switch for manually operated pumps). The existing staff at Amanora Park Town has been involved in identifying the O&M materials and tools they prefer. At all sites, O&M manuals and supporting materials such as checklists and workplans have been developed together with the stakeholders. Also OFAJ site staff, which already has experience in operating the wastewater treatment plant of the production facility, underlined the importance of materials which are easy to understand and practical for use.

Lessons learnt

General challenges concerning O&M of sanitation systems in India are listed in Table 5, lessons learned from applying the safety and O&M planning method in the NaWaTech project in Table 6.

Table 4 Safety and O&M planning outcomes.

Safety and O&M planning outcomes	Amanora	COEP	OFAJ
Design adaptations based on hazard identification in discussions with designers	-	X	X
Fostering O&M roles and responsibilities in stakeholder workshops	-	X	X
Prioritization of critical control and monitoring measures to be integrated in O&M work plans for operators and supervisors / skilled and unskilled workers	X	X	X
Input for technical trainings: focus topics, cause-effect chains	X	X	X
Development of or adaptation of O&M manuals and supporting materials	X	X	X
Identification of operator-friendly O&M materials and tools	X	-	-
Introduction of failure-reporting documentation	X	X	X

Table 5: General challenges related to O&M

Challenge	Solution
Lack of awareness for need of O&M resulting in limited interest in O&M management	• Trainings on understanding system functioning should create awareness for O&M and shift mind sets • Include "mogdrill" ("in-case-of-failure") demonstrations into trainings; practical hands-on trainings instead of class-room training to foster understanding why certain O&M activities are important • Promotion of preventative O&M and monitoring routines based on risk-oriented thinking → preventive O&M and monitoring of prevention measures instead of "end-of-pipe-checks" only focusing on the effluent • Create incentives besides wastewater treatment that can help fostering O&M, e.g. by designing systems that have additional benefits (such as producing water for reuse or other products like compost) • Establish performance-based "construct-and-operate" contracts to increase interest of contractors in not only constructing the facilities, but also operating them appropriately
Institutional/organisational barriers: lack of capacities to monitor decentralized plants	• Consider O&M requirements already in design phase so that receiving stakeholders (e.g.: project employees) are better prepared for the operation phase and foster "internal auditing" instead of relying on "external auditing" through authorities • Line out clear responsibilities of all involved stakeholders
Lack of funding for O&M	• Consider O&M requirements in the design phase and plan O&M activities prior to system commissioning → more realistic and target-oriented budgeting for O&M.
Lack of capacity of organisations/ persons responsible for O&M	• Initiation of business development and capacity development of private contractors towards integrating O&M as one of their services; O&M as a business (e.g. one company carries out O&M for several plants) • Establishment of "Construct-and-Operate" contracts and/or "Design-and-Operate contracts" (e.g. for 5 years)

Table 6: Learnings from safety and O&M planning within NaWaTech

Challenge	Solution
Lack of capacities and resources for O&M limit the number of people willing to contribute to the safety planning	• Underlining the benefits of preventive O&M could help raising the interest in the activities • Supporting materials (e.g.: template hazard lists, example control measures etc.) can facilitate the process and limit the necessary resources
The identification of hazards is a delicate topic – especially when confronting system designers with it. Thus, the willingness to discuss potential bottlenecks openly or vulnerabilities can be limited.	• Stakeholder discussions need to be carried out sensitively and should be based on the understanding that the activity is of mutual interest to ultimately optimise system operation and safety – not for blaming system weaknesses • The process can be facilitated if the discussions do not start from scratch, e.g. based on template hazard lists
Some O&M manuals follow a "reactive" thinking by putting trouble-shooting at the centre of their focus with only a minor preventive perspective	• Risk-based planning can help to shift the mind set to a more preventive thinking through pointing out cause-effect relationships between O&M activities and failures-to-be-prevented
The roles of different stakeholders in the context of O&M are not clear to all. O&M is often limited to "day-to-day" O&M activities at the plant rather than acknowledging the role of supervising staff, project owners and system designers and –implementers.	• Systematic listing of roles and responsibilities to support awareness on the whole range of levels and people directly or indirectly relevant in the context of system O&M and monitoring.

References

Bartram, J., Corrales, L., Davison, A., Deere, D., Drury, D., Gordon, B., Howard, G., Rinehold, A. & Stevens, M. (2009): Water safety plan manual. Step-by-step risk management for drinking-water suppliers. Geneva, Switzerland: World Health Organization. URL: http://www.who.int/water_sanitation_health/publication_9789241562638/en/ (accessed 5 January 2016)

Davison, A., Howard, G., Stevens, M., Callan, P., Fewtrell, L., Deere, D. & Bartram, J. (2005): Water Safety Plans. Managing drinking water quality from catchment to consumer. Geneva, Switzerland: WHO World Health Organization. URL: http://www.who.int/water_sanitation_health/dwq/wsp0506/en/ (accessed 5 January 2016)

Mayr, E., Lukas, A., Aichlseder, W., Perfler, R. (2012). Experiences and lessons learned from practical implementation of a software-supported Water Safety Plan approach. Water Science & Technology: Water Supply 12(1), 101-108.

Müllegger, E., Freiberger, E., McConville, J., Samwel, M., Rieck, C., Scott, P. & Langergraber, G. (2012): Operation and maintenance of sustainable sanitation systems. Factsheet of Working Group 10, Sustainable Sanitation Alliance (SuSanA). URL: http://www.susana.org/es/recursos/biblioteca/details/939 (accessed 5 January 2016)

NaWaKit (2015): http://www.sswm.info/category/step-nawatech/introduction (accessed 5 January 2016)

Nicolics, S., Edathoot, A., Patwardhan, N., Staribacher, E., Masi, F., Caballero, A., Panse, D., Labhasetwar, P.K., Meinhold, K., Langergraber, G. (2015a): Application of the NaWaTech safety and O&M planning approach for resources-oriented wastewater treatment systems in Pune, India. Oral presentation at the IWA Water and Development Congress „Water Security for Sustainable Growth", 18-22 October 2015, Dead Sea, Jordan; http://www.sswm.info/sites/default/files/reference_attachments/NICOLICS%20et%20al%202015%20Application%20of%20the%20NaWaTech%20safety%20and%20O&M%20planning%20approach%20at%20Amanora%20COEP.pdf (accessed 5 January 2016).

Nicolics, S., Hewitt, D., Pophali, G.R., Masi, F., Nagarnaik, P., Panse, D., Labhasetwar, P.K., Meinhold, K., Langergraber, G. (2015b): Application of the NaWaTech safety and O&M planning approach re-use oriented wastewater treatment lines at the Ordnance Factory Ambajhari, Nagpur, India. In: Vymazal, J. (Ed.): Proceedings of the 9th International Workshop „Nutrient Cycling and Retention in Natural and Constructed Wetlands", 26-29 March 2015, Třeboň, Czech Republic, Springer, submitted.

NIPHJ/IWA. 2015. Water Safety Plans & Operation and Maintenance. NIPHJ National Institute of Public Health Japan and IWA International Water Association. Online article at http://www.operationandmaintenance.net/templates/ld_templates/layout_33215.aspx?ObjectId=4172&lang=eng (accessed 5 January 2016)

Patil, S., Edathoot, A., Patwardhan, N., Bresciani, R., Panse, D., Masi, F. (2016): 4. Natural and Cost Effective Way of Treating Domestic Wastewater with Reuse in Non-Potable Purposes: The College of Engineering Pune (COEP) Hostel Campus Case Study. Sustainable Sanitation Practice 25 (January 2016), 21-27.

Pophali, G.R., Sahu, N., Khilnani, A., Kaur, H., Yadav, S., Labhasetwar, P.K., Bresciani, R., Masi, F., Meinhold, K. (2016): Domestic Wastewater Treatment and Reuse in Ordnance Factory Ambajhari, Nagpur. Sustainable Sanitation Practice 25 (January 2016), 12-16.

Tilley, E.; Ulrich, L.; Lüthi, C.; Reymond, P.; Zurbrügg, C. (2014): Compendium of Sanitation Systems and Technologies. 2nd Revised Edition. Duebendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (EAWAG). URL: http://www.eawag.ch/en/department/sandec/publications/compendium/ (accessed 5 January 2016)

Williams, T., Breach, B. (2012). Global challenges and opportunities: lessons learned from Water Safety Plan implementation. Water21 - Magazine of the International Water Association, 14.

WHO (2015): Sanitation Safety Planning: Manual for Safe Use and Disposal of Wastewater, Greywater and Excreta. Geneva, Switzerland: World Health Organization. URL: http://www.who.int/water_sanitation_health/publications/ssp-manual/en/ (accessed 5 January 2016)

Zapata, P., Bribián, J.L., Caballero, A., Lorenzo, A. (2016): Wastewater Treatment and Reuse in Amanora Park Town, Pune. Sustainable Sanitation Practice 25 (January 2016), 34-41.

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Nature-Based Solutions for Wastewater Treatment in Peri-Urban Areas of India: Pilot-Scale Experiments

This paper presents the experiences gained during the operation of a pilot-scale hybrid constructed wetland system for wastewater treatment in urban and peri-urban areas of India.

Authors: Cristina Ávila, Catiane Pelissari, Pablo Heleno Sezerino, Joan García, Marianna Garfí

Abstract

This paper summarises the results obtained at the pilot-scale experiments carried out during the NaWaTech project. The purpose of the research activities was to assess a three-stage constructed wetland system under two hydraulic regimes and a simulated storm event to test the potential of the implementation of this technology in urban and peri-urban areas of India. The pilot hybrid constructed wetland system, located at Universitat Politècnica de Catalunya (UPC) (Barcelona, Spain), consisted of three stages of wetlands configurations (two vertical flow beds (1.5 m² each) alternating feed-rest cycles followed by a horizontal flow (2 m²) and a free water surface (2 m²) wetlands in series). The research activities were coordinated by UPC and various European and Indian researchers were involved thanks to the twinning of students provided by the NaWaTech project, resulting in Ph.D and master's theses.

Introduction

Nowadays, nature-based solutions such as constructed wetlands constitute a great alternative to conventional wastewater treatment in rural and peri-urban areas of both developed and emerging countries given their low operational and maintenance expenses, as well as other advantages such as the promotion of biodiversity or easy integration into the landscape. Moreover, they can be less expensive to build than other treatment options.

One of the main objectives of the NaWaTech project was "to enhance the natural water treatment systems for the production of recycled water to supplement water sources considering extreme climatic conditions and highly and widely varying pollutions loads (e.g. monsoon floods)" which characterise the Indian context.

Aiming to identify the potential of constructed wetlands as a wastewater treatment technology in urban and peri-urban regions of India, various studies were carried out at pilot-scale by the Universitat Politècnica de Catalunya (UPC). These took place in a hybrid three-stage constructed wetland system located in Barcelona, where a Mediterranean climate predominates. Various UPC and Indian researchers (from NEERI and ESF) were responsible for these experiments thanks to the twinning of students programme provided by the NaWaTech project, resulting in different doctoral and master's theses.

Taking into account the specific context of India, where the presence of major storm events during the rainy season could hinder the correct performance of these systems, and where land availability is an issue, especially in urban and peri-urban areas where land pressure is higher, the following specific objectives were stated:

- To minimize the area needed for constructed wetland implementation by studying the

Key findings:

- The overall specific surface area required for long-term operation of a three-stage hybrid constructed wetland system (VF + HF + FWS in series) was 2 m²/PE
- The use of an Imhoff tank as pre-treatment prior to a CW system is recommended given its superior performance, simplicity and reliability of operation compared to an anaerobic reactor (hydrolytic up-flow sludge blanket reactor)
- Overall removal efficiencies achieved during a simulated storm event did not vary significantly from those obtained during the normal operation of the system thus demonstrating the high robustness of the CW system

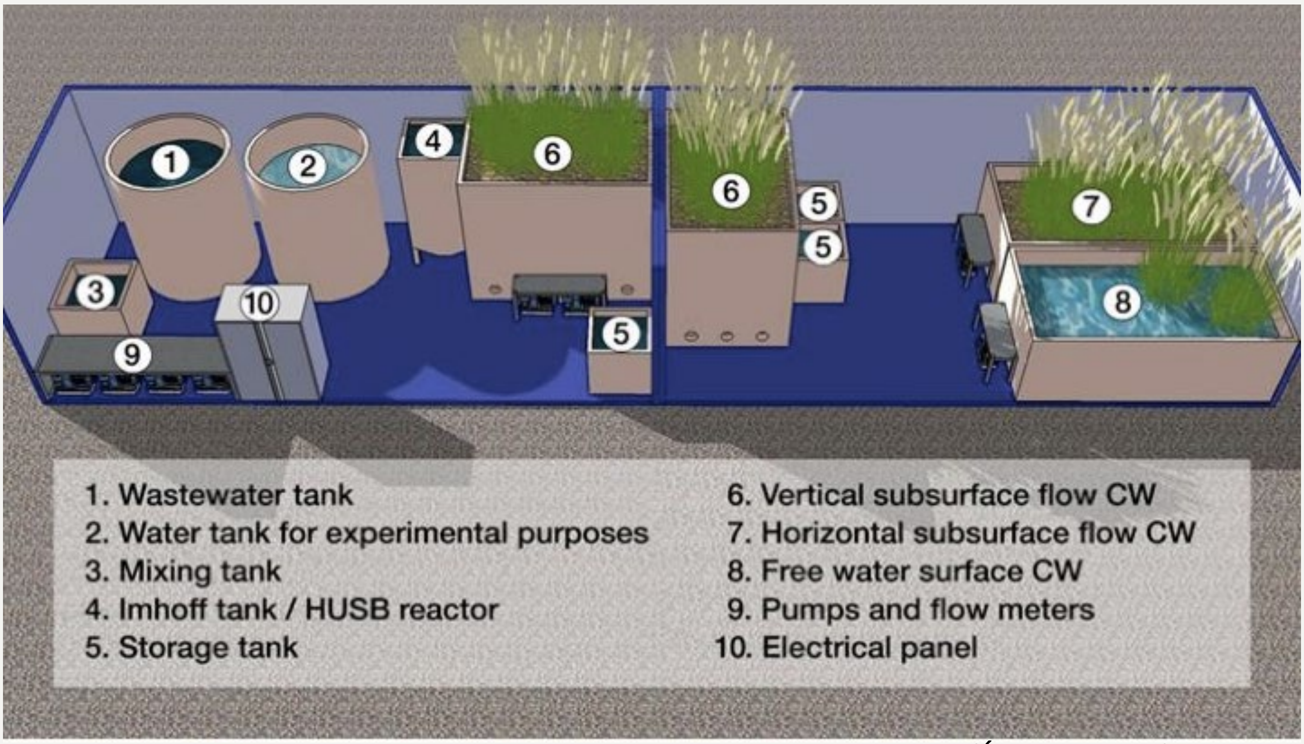

Figure 1. Layout of the pilot three-stage hybrid constructed wetland system (Ávila et al., 2013)

performance of a hybrid constructed wetland system considering different organic loading rates.

- To simulate the performance of hybrid constructed wetland system during a monsoon episode.
- To compare the efficiency of different primary treatments.

Material and methods

Description of the treatment system

The hybrid constructed wetland system was built in 2010 at the facilities of the Department of Civil and Environmental Engineering of the Universitat Politècnica de Catalunya (UPC) in Barcelona (Spain) treating urban wastewater directly pumped from a nearby municipal sewer. The entire system consists of a primary treatment (Imhoff tank or hydrolytic up-flow sludge blanket –HUSB- reactor) followed by three different wetland configurations in series (Figure 1).

These are two 1.5 m² vertical subsurface flow (VF) constructed wetlands with alternating cycles of feed and rest (3.5 days each), followed by a 2 m² horizontal subsurface flow (HF) constructed wetland and a 2 m² free water surface (FWS) wetland in series. The purpose of providing different wetland units was to treat the water up to reuse standards. Feeding of the horizontal and free water surface wetlands was done in a continuous mode through peristaltic pumps, while the vertical flow beds

Table 1. Main characteristics of the treatment system (Ávila et al., 2013, 2016)

Parameter	Value
Dimensions Imhoff tank	0.2 m^3
Dimensions HUSB	0.44 x 1.7 m (internal Ø x useful height)
Dimensions VFs	1.0 x 1.5 x 1.3 m (W x L x D)
VF filling media	Upper layer: 0.1 m of sand (1-2 mm) Bottom layer: 0.7 m of fine gravel (3-8 mm)
Dimensions HF	1.0 x 2.0 x 0.3 m (W x L x D)
HF water depth	0.25 m (W x L x D)
HF filter media	Main media: 0.3 m of gravel (4-12 mm) Inlet and outlet: stone (3-5 cm)
Dimensions FWS	1.0 x 2.0 x 0.5 m (W x L x D)
FWS free water column	0.3 m

Figure 2. View of the three-stage hybrid constructed wetland system and some of the students involved in the monitoring of the system

were intermittently fed by means of hydraulic pulses. All wetland units were constructed in polyethylene and were planted with Phragmites australis. Further specific design and operational parameters of the system can be found in Table 1 and in Ávila et al. (2013, 2016).

In Figure 2 the constructed wetland system and pictures of some of the students involved in the monitoring of the system are displayed.

Description of the hydraulic regimes

Research activities were divided into two periods based on the application of different hydraulic regimes (Table 2). These regimes were applied consecutively to this treatment plant, each lasting one year, and these differed on the organic loading rate applied, and on the primary treatment used before the wetland units: in regime 1 the plant was operated at the nominal hydraulic loading rate, whereas during regime 2 the plant was submitted to a very high load corresponding to approximately 4 times the nominal one. Moreover, during regime 1 the

Table 2. Operating characteristics of constructed wetlands in each hydraulic regime

Hydraulic Regime	Period	Flow rate (L/d)	Hydraulic loading rate (m/d)	Organic loading rate (g BOD_5 m²/d)	Primary treatment	Pulses VF beds (pulse/ day)
1	06/2012 to 05/2013	200	0.06	9.8	Imhoff tank	15
2	05/2013 to 05/2014	800	0.27	103	HUSB reactor	30

primary treatment used was an Imhoff tank, while this was substituted by a HUSB reactor at regime 2. Further details on operational parameters and analytical methods can be found in Ávila et al. (2013, 2016).

Simulation of storm event

Aiming to assess the appropriateness of the system for tropical climate regions, a heavy rain episode (monsoon), a characteristic phenomenon of Indian climate, was simulated. To this end, the inflow was increased by 10 times during 1h, through mixing the usual wastewater flow with tap water (333 L/h; 33 L of wastewater + 300 L of drinking water). The duration of the experiment was 10 hours. Samples were taken hourly at the effluent of each treatment unit. Further details on experimental set up and sampling strategies are described in Ávila et al. (2016).

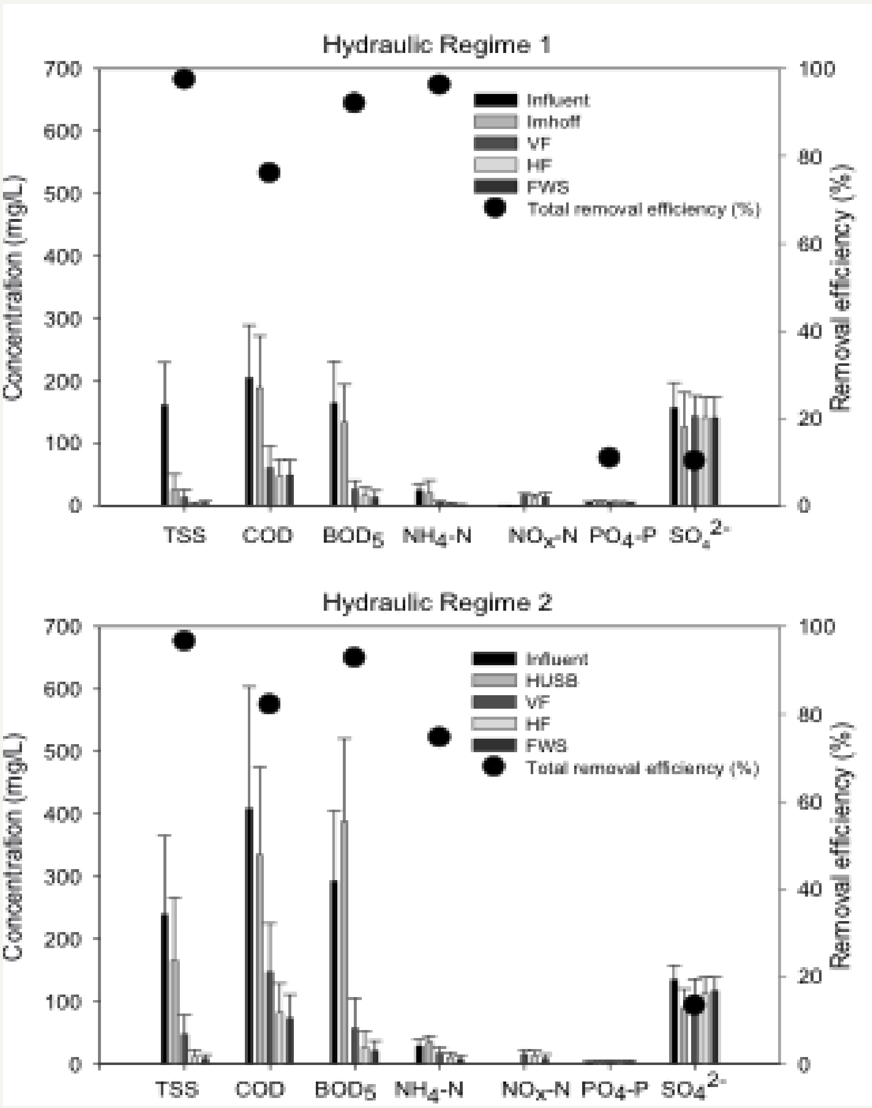

Figure 3. Average concentrations of conventional water quality parameters and total removal efficiencies obtained during the different hydraulic regimes (adapted from Ávila et al., 2013, 2016)

Results and discussion

General performance, influence of loading rates and specific area achieved

Concentrations of water quality parameters along the treatment units of the system, as well as total removal efficiencies achieved for the two tested regimes are displayed in Figure 3. In general, the performance of the treatment system during the two hydraulic regimes was very good, achieving total removal efficiencies of 76% COD, 92% BOD_5, 98% TSS and 96% NH_4-N for regime 1 and of 82% COD, 93% BOD_5, 96% TSS and 75% NH_4-N for regime 2.

During both regimes, the VF beds were the treatment step responsible of removing the major part of organic matter, given their operating characteristics and that it is the first unit receiving most of the load (Figure 3). During the hydraulic regime 1, the VF was operated at 9.8 g BOD_5 m²/d, and the removal efficiency was on average of 80% (Ávila et al., 2013). In the hydraulic regime 2, the VF was operated at 103 g BOD_5 m²/d (ten times the one applied at regime 1) and removal was still of 85%, showing its great capacity for operating at very high OLRs (Ávila et al., 2016). This is in accordance with the assertion that higher organic loading often corresponds to greater organic removal rate (Calheiros et al., 2007; Sun and Saeed, 2009). The organic loading applied in the hydraulic period 2 was much higher than those recommended in the literature: ÖNORM (2009) and DWA (2006) recommend a load of 20 g COD m²/d in cold climates, and Hoffman and Platzer (2011) of 60-70 g COD m²/d in warm climates, corresponding to approximately 30-35 g BOD_5 m²/d.

In regards to NH_4-N, again the applied loading rate in regime 2 to the VF beds was above 7 times that applied during regime 1, and removal efficiencies were of 74% and 50% in regime 1 and 2, respectively (Ávila et al., 2013; 2016). The main VF ammonia processing mechanism is associated with nitrification (Saed and Sun 2012), which was evident in both hydraulic regimes as depicted in Figure 4. Even in the hydraulic regime 2, where the VF operated with a high organic load, the nitrification was not limited, probably due to the drag of oxygen promoted by the large hydraulic rate (0.27 m/d) applied on the surface area of the VF beds. In this regard, Platzer (1999) reported that the oxygen transfer into the treatment unit is directly associated with the hydraulic rate applied, and Kayser and Kunst (2005) found that the volume of water infiltrated into the bed was replaced with an equivalent volume of air. The total removal of NH_4-N for hydraulic regimes 1 and 2 were 96% and 75%, respectively. However, although nitrification occurred in both hydraulic regimes, the denitrification was identified in low rates only in the FWS unit in the hydraulic regime 2, which indicated the presence of anaerobic/anoxic environments in the unit during this period. Denitrification was not observed in the hydraulic regime 1 which was possibly attributed to a low availability of carbon in the HF wetland.

The PO_4-P removal was low (10%) for hydraulic regime 1, and no removal existed during regime 2, which might be attributed to the saturation of the sediment of the FWS which was the unit achieving most of the removal in regime 1 (Ávila et al., 2013, 2016). In general, phosphorus removal in constructed wetlands ranges 10-20%, and no significant differences are found between HF and VF wetlands (Kadlec and Wallace, 2009). Very low removal of sulfates was observed in both regimes, being on average of 10% and 13% for hydraulic regimes 1 and 2, respectively.

Overall, the three-stage hybrid constructed wetlands systems showed a good treatment performance for both hydraulic regimes, even when the system operated with very large organic loading rates (OLRs) (Figure 4). The VF beds were the units that received the majority of the organic, inorganic and hydraulic loads applied to the system, and did not show any clogging problems during the two-year study, performing well on the removal of organic matter, solids and, especially, on nitrification. The other two wetlands units were responsible for achieving a water quality which could be reused for various applications. The specific area required for long-term operation was as low as 2 m²/PE (Ávila et al., 2016).

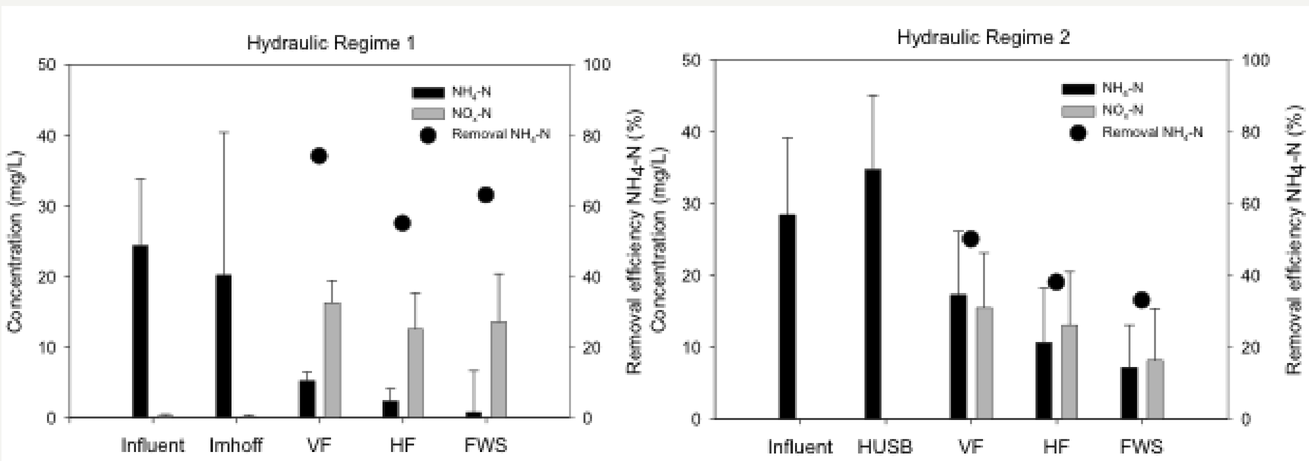

Figure 4. Mean concentrations of NH_4-N, NO_x-N, and NH_4-N removal for each constructed wetland, for the hydraulic regimes 1 and 2 (adapted from Ávila et al. (2013, 2016).

Influence of primary treatment

The Imhoff tank showed better performance when compared to the HUSB reactor. In the regime hydraulic 1 the removal of TSS was very efficient and consistent within the Imhoff tank, with a mean removal efficiency of 83%. However, during the regime 2, where the HUSB reactor was operating, the removal of TSS in this unit was only 30% (Ávila et al., 2013, 2016).

These results highlight the importance of the existence of a primary treatment unit for solids removal before the constructed wetlands, since it is crucial for avoiding any development of clogging of the bed media, in both VF and HF wetlands, which might reduce the lifespan of the system (Knowles et al., 2011; Pedescoll et al., 2011). Although the loading rate of solids applied to the VF beds during regime 2 was very large (44 g TSS m^{-2} d^{-1}), no clogging was observed within any of the two beds (Ávila et al., 2016), which may be partially owed to the fact that the two beds operated in alternation of phases of feed and rest, thus allowing for mineralization of the accumulated organic matter during resting cycles (Molle et al., 2008). In conclusion, the use of an Imhoff tank prior to the wetlands is recommended given its superior performance, simplicity and reliability of operation compared to an anaerobic reactor (Ávila et al., 2016).

Influence of simulated storm events

Overall removal efficiencies achieved during the simulated storm event did not vary significantly from those obtained during the normal operation of the system (average of 83, 99 and 80% for COD, TSS and NH_4-N removal, respectively). The system showed a very good buffer capacity, proving to be a robust technology capable of handling large fluctuations in flow, which makes it an adequate solution for treatment of wastewater in tropical countries with a rainy season such as India (Ávila et al., 2016).

Conclusions

Pilot-scale experiments carried out during the NaWaTech project aimed at evaluating a three-stage constructed wetland system to test the potential of the implementation of this technology in urban and peri-urban areas of India. These research activities took place at UPC and various European and Indian researchers were involved thanks to the students' exchange programme promoted by the project.

Results showed that the system was capable of working under high OLRs; thus, the specific area required for long-term operation can be drastically reduced making its implementation feasible in urban areas. Imhoff tank showed better performance and simpler operation and maintenance compared to a HUSB reactor, and it was recommended as a better primary treatment stage for constructed wetlands systems. Moreover, the system has proven to be robust and able to handle heavy rain episodes.

Finally, the hybrid constructed wetlands treatment system proved to be a very robust nature-based solution, suitable for the treatment of wastewater in urban and peri-urban areas, including those susceptible to major storm events, fluctuations and large organic loading rates.

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References

Ávila, C., Garfí, M., García, J. (2013): Three-stage hybrid constructed wetland system for wastewater treatment and reuse in warm climate regions. Ecol Eng 61(A), 43-49.

Ávila, C., García, J., Garfí, M. (2016): Influence of hydraulic loading rate, simulated storm events and seasonality on the treatment performance of an experimental three-stage hybrid constructed wetland system. Ecol Eng, in press, http://dx.doi.org/10.1016/j.ecoleng.2015.11.042.

Calheiros, C.A., Rangel, A., Castro, P.M.L. (2007): Constructed wetland systems vegetated with different plants applied to the treatment of tannery wastewater. Water Res 41(8), 1790-1798.

DWA (2006): Grundsätze für Bemessung, Bau und Betrieb von Pflanzenkläranlagen mit bepflanzten Bodenfiltern zur biologischen Reinigung kommunalen Abwassers (Principles for the dimensioning, construction and operation of constructed wetlands for municipal wastewater, in German). DWA, Hennef, Germany [in German].

Hoffmann, H., Platzer, C. (2011): Technology review of constructed wetlands subsurface flow constructed wetlands for greywater and domestic wastewater treatment in developing countries. Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (GTZ), Saneamento Sustentável, Programa da Ecosan, 36p.

Kadlec, R.H., Wallace, S.D. (2009): Treatment Wetlands. 2nd edition, CRC Press, Boca Raton, FL, USA.

Kayser, K., Kunst, S. (2005): Processes in vertical-flow reed beds: nitrification, oxygen transfer, and soil clogging. Water Sci Technol 51(9), 177–184.

Knowles, P., Dotro, G., Nivala, J., García, J. (2011): Clogging in subsurface-flow treatment wetlands: Occurrence and contributing factors. Ecol Eng 37(2), 99-112.

Molle, P., Prost-Boucle, S., Liénard, A. (2008): Potential for total nitrogen removal by combining vertical flow and horizontal flow constructed wetlands: a full-scale experiment study. Ecol Eng 34(1), 23–29.

ÖNORM B 2505 (2009): Bepflanzte Bodenfilter (Pflanzenkläranlagen) – Anwendung, Bemessung, Bau und Betrieb (Subsurface flow constructed wetlands – Application, design, construction and operation, in German). Vienna, Austria [in German].

Pedescoll, A., Corzo, A., Álvarez, E., Puigagut, J., García, J. (2011): The effect of primary treatment and flow regime on clogging development in horizontal subsurface flow constructed wetlands: an experimental evaluation. Water Res 45(12), 3579-3589.

Platzer, C. (1999): Design recommendation for subsurface flow constructed wetlands for nitrification and denitrification. Water Sci Technol 40(3), 257-263.

Saeed, T., Sun, G. (2012): A review on nitrogen and organics removal mechanisms in subsurface flow constructed wetlands: Dependency on environmental parameters, operating conditions and supporting media. J Environ Manage 112, 429-448.

Sun, G., Saeed, T. (2009): Kinetic modelling of organic matter removal in 80 horizontal flow reed beds for domestic sewage treatment. Process Bioch 44(7), 717-722.

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Understanding the Market Opportunities of New Indian Based SMEs in the Wastewater Sector

This article presents an overview of the wastewater management market in India and the external and internal environmental factors faced by new SMEs that affect their success in providing sustainable products and services in the sector.

Author: Leonellha Barreto Dillon

Summary

With its rapid urbanisation and explosive economic growth, India is facing now an acute wastewater management crisis. The government of India is now inviting the private sector to participate in this huge task. Hundreds of Indian and foreign companies are capitalising business opportunities in a market characterised for growth and prosperity. Therefore, there is a need of understanding the market opportunities faced by new SMEs in in this sector. This research work intends to identify the external and internal environmental factors faced by new Indian SMEs in the wastewater treatment sector. Some of the opportunities are increased government funding, increasing wastewater production as a consequence of population growth and urbanisation, increasing water scarcity and pollution of water bodies, a highly attractive wastewater sector, the popularity and price of Indian solutions as compared to imported technologies, and the low bargain power of suppliers and buyers. It was also found that new Indian SMEs in the wastewater sector are not prepared to capitalise the business opportunities, as they exhibit deficiencies in all functional areas such as financial, marketing, operations, personnel and management.

Wastewater treatment market in India

Wastewater management in India has become an extremely important area of focus due to increasing health awareness and population pressure. Despite the wastewater sector witnessing major growth in the last decade due to increased government support and private participation, the scale of the problem remains enormous. In India it is estimated that 22’900 MLD of domestic wastewater is generated from urban centres, while the installed treatment capacity available is only for 5‘900 MLD (EBTCb, 2011). Thus, there is a huge gap in treatment of domestic wastewater. Furthermore, considering population growth and the level of urbanisation, the projections indicate a duplication of urban domestic wastewater generated by 2021 (see Table 1).

The wastewater treatment market in India is currently worth ~ USD 1.74 billion, and it is expected to grow at a rate of 13% in the next 3-4 years (EBTC, 2011a).

Although unsaturated, the wastewater treatment market is characterised by the presence of about 15 large players, accounting for approximately 30% share, and more than

Key findings:

- The business opportunities and threats (from SWOT analysis) of SMEs in a sector are defined by the external environmental trends and characteristics represented by the PESTEL analysis (political, environmental, social, technological, economic and legal conditions) as well as the characteristics of the industry (existing rivalry, entry barriers, power of suppliers, threat of substitutes and power of buyers).
- Weakness and strengths of SMEs can be evaluated according to the organisational capability analysis, considering financial, marketing, operations, personnel and management capabilities.
- By implementing a few management systems, new Indian SMEs could take advantage of the given opportunities and capitalise the business opportunities. They should leverage on their experience with the Indian market and their influence during the tendering procedures, focusing on non-sophisticated and non-expensive technologies for wastewater treatment for reuse and find niches, such as villages and small cities, to improve their operational capabilities.

Table 1 Projected wastewater generation in urban India. (Source: OSEC, 2010)

Year	Urban population (million)	Consumption (lpcd*)	Gross wastewater generation (mld**)
2021	488	121	59,048
2031	638	121	77,198
2041	835	121	101,035
2051	1,093	121	132,253

**** Litres per capita per day***

***** Million litres per day***
Source: EA Water Pvt. Ltd., 2009

800 small and medium players (Avalon Global Research, 2011). Most companies are small, not registered and run by an entrepreneur with a small size of staff (Chemtech, 2012). The following picture shows the wastewater market distribution relative to existing players (Figure 1).

The sector features large number of companies across the value chain, from technology providers, EPC (engineering, procurement and construction) companies, consultants to other solution providers. The following picture shows how the large players concentrate on large projects, meanwhile the small players mostly perform small projects in the residential and commercial area.

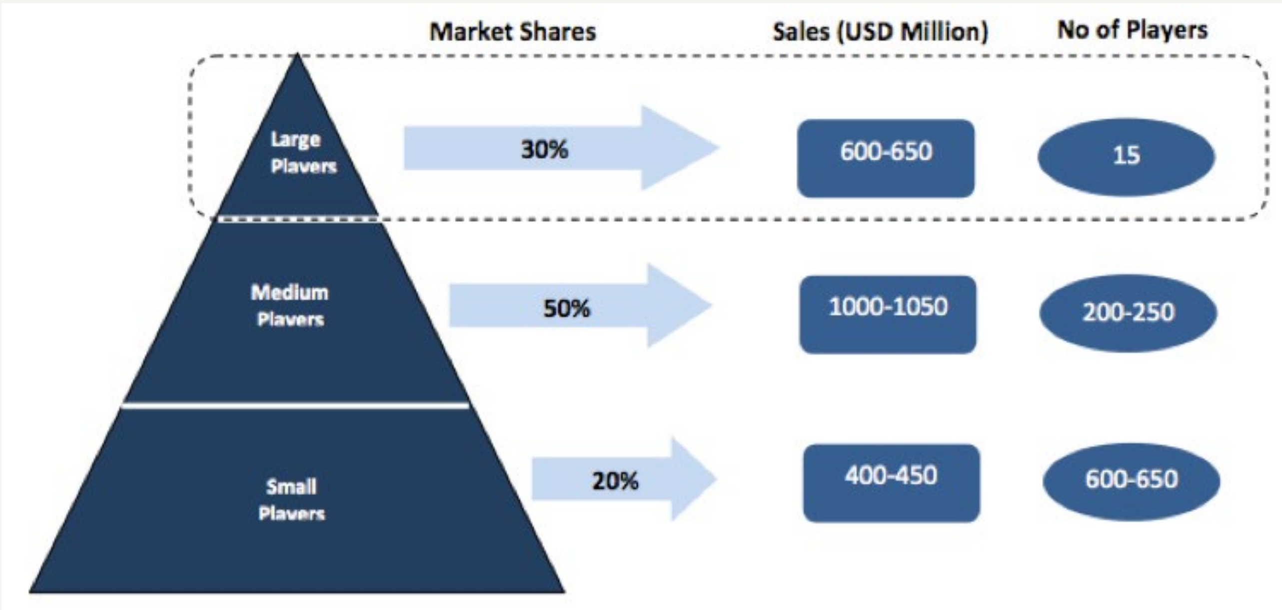

Figure 1: The wastewater market distribution relative to existing players (Source: Avalon Global Research, 2011)

Table 2: Products and services offered by different types of players according to size and sector. (Source: Avalon Global Research, 2011)

Category of player	Size of projects			Service /Product offering			Focus Sectors
	Small	Medium	Large	Designing & Consulting	Mechanical	Civil	
Large Players			✓	✓	✓	✓	Power, Municipal, Oil & Gas
Medium Players	✓	✓		✓	✓	✓	All segments
Small Players	✓			✓	✓	✓	Residential, Commercial, Engineering, Chemicals, Food

The market has undergone a tremendous change in the last few years. Today, there are a dozen medium-sized companies who have rapidly increased their operations and won a number of projects. Furthermore, hundreds of small system-integrators have come up all over the country, addressing local requirements.

Research methodology

The present methodology was developed by the author during a descriptive research (Barreto Dillon, 2013). Three different empirical models were developed based on well known theoretical models: PESTEL analysis (Johnson and Scholes, 1993), industry analysis (Porter’s 5 forces and the industry attractiveness of GE McKinsey Matrix) (Porter, 1980) and the organisational capability analysis proposed by Kazmi (2012). The different models were operationalised based on the “logic structure matrix” proposed by Barreto Colmenares (1997).

The first two models served to collect and interpret secondary data related to the external environment and industry environment. External factors included political, economic, social, technical, environmental and legal factors, while industry factors were classified as existing rivalry, entry barriers, power of suppliers, threat of substitutes and power of buyers. The external and industry environmental factors identified where classified as opportunities (with regards to the SWOT model - strengths, weaknesses, opportunities and threats) if they were positive aspects that, according to the author, can be capitalised as business for new India-based SMEs; while threats referred to unfavourable situations for entrepreneurs. To complete the SWOT analysis, strengths and weaknesses of a population of SME wastewater service providers in India were identified. SMEs in India with a lifetime of 3 years or less providing wastewater treatment products (wastewater treatment plants and equipment) were contacted. An organisational capability analysis (based on the proposed methodology of Kazmi, 2012) was carried out focusing on those strategic strengths and weaknesses existing in different functional areas within an organisation, which are of crucial importance to achieve success. The key factor rating method (Barreto Colmenares, 1997) was used to prepare a questionnaire to apply a survey within the research population (40 new SMEs) with the aim of identifying the capabilities of the young SMEs in the sector based on the collection of primary data. The following factors were analysed among the selected SMEs: financial, marketing, operational, personnel and general management capability.

Analysis of the results

The data analysis (Table 3, 4, and 5) was carried out based on the SWOT analysis, where each of the factors (external, industry and company capabilities) was classified as strength, weakness, opportunity and threats. To complement this classification, each main finding was evaluated as to:

- Their relative importance to new Indian SMEs:
  “-“ means not important
  “0” means medium important
  “+” means very important
- The time, understood as when this implication will affect the operations of new Indian SMEs:
  “N” means now
  “N/F” means now and in the future
  “F” means in the future
- The dynamics, whether this trend will grow:
  “=” means remains stable
  “>” means it is increasing
  “<” means it is decreasing

Table 3: Analysis of the data regarding external environment factors

Variable	Dimension	Main finding (MF)	Type (Opport. or Threat)	Relative Importance (-,0,+)	Time (N, F, N/F)	Dynamics (=, >, <)
Political factors	Institutional arrangements	Bureaucracy and lack of clarity about responsibilities in water and sanitation is an area of prime concern, but the scenario is steadily improving.	T	+	N	<
	Government led funding	Government of India is consciously stimulating the wastewater sector with massive financing.	O	+	N/F	>
	Private participation incentives by government	Incentives offered by government e.g. tax holidays, FDI, other subsidies. Focus of govt. and private sector.	O	+	N/F	-
Implications for new Indian SMEs		Increased funding will ease availability of capital thereby benefiting new Indian SMEs. The numerous incentives offered by the government will stimulate the participation of new entrepreneurs. New Indian SMEs can conduct business through the PPP channel and benefit from reduced cost and availability of low cost capital. This would significantly reduce their operational cost and ease business operations. To deal with the complex bureaucratic systems and lack of institutional clarity remains a challenge.				
Economic Factors	GDP growth	India is one of the fastest growing economies in the world and is one of the few countries that have been relatively less impacted by the global financial meltdown.	O	+	N/F	>
	Import tariffs	Import tariffs and corporate taxes applicable to foreign companies are higher than those for domestic.	O	0	N	<
Implications for new Indian SMEs		New Indian SMEs can capitalise the economic growth in the nation, and the fact that Indians have a growing disposable income. Furthermore, indigenous technologies do not suffer from import barriers, making foreign companies a comparatively expensive proposition.				
Social Factors	Water consumed as result of urbanisation and population growth	India's population is growing, and there are more private households in an increasingly urbanised setting. As a result, the demand for drinking water and sewage treatment is growing rapidly.	O	+	N/F	>
	Domestic wastewater production as result of population growth	There is a huge gap between domestic wastewater production and treatment.	O	+	N/F	>
	Increased awareness about any degradation and health effects of wastewater	Changes in public perception and raised awareness about proper management of wastewater. Growing health conscious population.	O	0	F	>

Table 3: Analysis of the data regarding external environment factors (continued)

Implications for new Indian SMEs		New SMEs already benefit from the rapidly rising population, which has led to increased requirements for drinking water and sewage treatment. One important issue is the fact that while this is largely in the urban areas at the moment, this could shift to smaller towns and villages in times to come, giving new niches for Indian adapted technologies.				
Technological factors	Technological innovations in the wastewater sector	Trend building to move towards 100% reuse and recycle; however, the scale is currently limited and is expected to grow in the next 2-3 years. At the same time, many existing treatment plants would need to be replaced or upgraded to meet with more stringent standards.	O	+	N/F	>
	Demand for sophisticated machinery	Demand for advanced waste management technologies such as membrane bioreactors is rising especially in highly polluted and urban regions.	T	-	F	>
Implications for new Indian SMEs		New SMEs could focus on wastewater technologies that render the water safe for reuse (with lower discharge standards), without applying sophisticated technologies for complete nutrient removal. However, they need to develop a technology strategy to increase their portfolio to compete with foreign companies with a more advanced technology proposition.				
Environmental Factors	Water scarcity	Reducing availability of water forcing users to go for reuse & recycling of wastewater.	O	+	F	>
	Pollution of surface water sources	Untreated domestic sewage, industrial effluents and runoffs from chemical intensive agricultural farms are the main contributors to widespread pollution of surface and groundwater sources.	O	+	N/F	=
	Varied climates	Different climate situation requiring different solutions in wastewater technologies. Need for customisation.	T	0	N/F	=
Implications for new Indian SMEs		Decreasing water quantity and quality in water bodies and rivers has increased the environmental pressures on wastewater discharge from government pollution control boards. This can be capitalised by new Indian SMEs; however, they need to offer a portfolio of offerings depending upon regional/climatic considerations.				
Legal Factors	Legislations driving India's wastewater treatment markets	Favourable regulatory policies. The Indian government has legislations and regulations in place to facilitate growth in this sector.	O	+	N	>
	Stringent regulations	Stringent environmental norms related to wastewater composition	T	0	N/F	=
Implications for new Indian SMEs		Despite there being a favourable legal framework, India is still lacking an effective enforcement framework. The water quality standards play an important role in determining the technology and equipment, which will be used to treat and recycle. SMEs might have problems to compete with foreign companies with highly environmentally conforming solutions.				

Table 4 Analysis of the data regarding industry environment factors

Variable	Dimension	Main finding (MF)	Type (Opport. or Threat)	Relative Importance (-,0,+)	Time (N, F, N/F)	Dynamics (=, >, <)
Existing rivalry	Industry attractiveness	Indian wastewater industry is expanding at a tremendous rate, with demand surpassing supply.	O	+	N/F	>
	Competition intensity	Fragmented market and highly competitive	T	+	N	=
	Product differentiation	Indian solutions based on sophisticated and natural processes are popular as overall costs are less as compared to EU and US average.	O	+	N/F	>
Implications for new Indian SMEs		There is an intense rivalry in the wastewater sector in India; however, given the enormous size and high growth rate, the market offers opportunities for new SMEs. As experienced Indian companies as well as competitors from overseas offer high quality sophisticated products, new SMEs should focus on decentralised small systems based on natural treatment, to gain competitive advantage.				
Entry barriers	Economies of scale	The wastewater sector in India offers the opportunity to companies to achieve economies of scale.	O	+	N/F	>
	Company incorporation procedures	Highly bureaucratic and slow procedures with multiple levels hamper speed of market entry and business operations.	T	+	N	<
Implications for new Indian SMEs		Indian companies face fewer problems when incorporating as compared to foreign companies, which might need a local partner to operate in the country. This need for joint ventures and subsidiaries gives an opportunity to new SMEs to partnership with foreign technology providers and capitalise the opportunity of economies of scale.				
Suppliers' power	Number of suppliers (concentration)	The number of suppliers is relatively high to that of buyers, thus having a low bargain power.	O	+	N/F	>
	Importance of industry to suppliers	High importance of the wastewater service and technology providers.	O	+	N/F	>
Implications for new Indian SMEs		The low bargain power of suppliers of wastewater treatment plants, makes it easy for new SMEs to enter the sector.				
Threat of substitutes		The substitute to wastewater technologies is "no implementation at all".	T	0	N	<
Implications for new Indian SMEs		Given the weakness presented by the enforcing agencies and the corruption in the government at all levels, there is a significant threat that budget lines for wastewater treatment plant implementation are deviated, decreasing the chances for SMEs to enter the sector, specially for projects in townships, small cities and villages.				

Table 4 Analysis of the data regarding industry environment factors (continued)

Buyer's power	Number of buyers relative to seller	The number of buyers is relatively high to the number of sellers, which gives a relatively low bargain power.	O	+	N	<
	Buyer's threat of backward integration	There is no threat that the urban local bodies, the main client, could design, implement and construct the water treatment systems	O	+	N/F	=
Implications for new Indian SMEs		New Indian SMEs could concentrate offering solutions to Municipal Councils and Gram Panchayats in City Class II to V, who are prevalent and are less qualified to solve their wastewater crisis.				

Table 5 Analysis of the data regarding organisational capabilities

Variable	Dimension	Main finding (MF)	Type (Strength or Weakness)	Relative importance (-, 0, +)
Financial capability	Sources of funds	Given the complex capital raising criteria prevailing in India, most new SMEs count only with the entrepreneur's own assets and money lent by family and friends.	W	+
	Usage of funds (liquidity)	Availability of cash is a problem for new SMEs in the wastewater sector in India.	W	+
	Management of funds	About half of new SMEs in the wastewater sector in India count with a financial and budgetary system.	W	+
Implications for new Indian SMEs		Financial capability of new Indian SMEs in the wastewater sector is rather poor, which explains the difficulty to write winning business plans and raise capital.		
Marketing capability	Product-related	Relatively few number of products for the diverse technical standards. The quality of products is low, foreign companies and already established Indian companies offer commercially viable advanced technology and environmentally conforming solutions.	W	+
	Price-related	Government usually follows the following mechanism before making purchase decisions (in no specific order): minimum requirement criteria, financial stability, reputation, experience, cost and price. Since most of the new SMEs are following the economy strategy (low price-low quality), they have a competitive advantage.	S	+
	Place-related	New Indian SMEs are familiar with the Indian procurement systems. Considering that foreign companies have lack of Indian experience to meet tender requirements, the Indian companies have more chances and also have alternate routes to get the work done.	S	+
	Promotion-related	Most of new SMEs do not have the budget to run advertising campaigns. However they try to participate in networking events.	W	0
	Integrative and systematic	Most of the new Indian SMEs in the wastewater sector do not have a marketing department in place.	W	+

Table 5 Analysis of the data regarding organisational capabilities (continued)

Implications for new Indian SMEs		New SMEs in the sector count with a competitive advantage, which is that they are familiar with the tendering processes at municipal level, and offer solutions, which are less expensive compared to the competitors. However, a marking department (or orientation) would help them to overcome the weaknesses in product and promotion.		
Operations capability	Production system	The size of the projects acquired by new Indian SMEs is mainly small. They exhibit low extent of vertical integration. About half of the SMEs depend on imported equipment.	W	+
	Operational and control system	Most of the interviewed new SMEs do not have standard operation and quality procedures.	W	+
	R&D system	Technology is not a value proposition for most SMEs. Most of them do not have any patent in place, which means that their products are based on state-of-the-art technologies. SMEs show low technological expertise with weak R&D capabilities. However, some SMEs are spin-offs of universities and research centres.	W	+
Implications for new Indian SMEs		New SMEs in the water sector in India present a rather weak technology value proposition, characterised by imports of core components, no research or patents. They also need to integrate parts of value-chain to derive cost benefit and thereby effectively compete with established companies.		
Personnel capability	Personnel system	Most of the new SMEs do not count with a system for manpower planning, selection, compensation, communication and appraisal.	W	+
	Organisational and employee characteristics	Given the dynamics of the sector, employees are offered growth opportunities.	S	+
Implications for new Indian SMEs		New Indian SMEs do not have with a human resource system, which indicates that they might loose qualified personnel to their established competitors. However, being flexible, they might offer opportunities for entrepreneurial employees.		
General mgmt. capability	General management system	In some cases, SMEs count with a system for strategic formulation, implementation and evaluation.	W	+
	General managers	General managers are experienced in the water sector.	S	+
	External relations	Most of the general managers are considered influential among governmental and regulatory agencies.	S	+
Implications for new Indian SMEs		The management capability among the SMEs is considered high, with well-experienced and influential managers. Most of them have created the SMEs as spin-offs from government departments and universities.		

Conclusions

New Indian SMEs in the wastewater sector face a number of external and internal factors that impact their business opportunities in India. Each factor can be classified as an opportunity, threat, strength or weakness.

External environmental factors that currently affect business operations of new SMEs in the wastewater treatment sector are classified as political, economic, social, technological, environmental and legal. External factors that are considered “opportunities” in the current scenario are: (political) increased government funding and various incentives of the government to encourage private participation; (economic) GDP growth and import tariff/corporate taxes for foreign technologies and companies; (social) increasing wastewater production as a consequence of population growth and increasing urbanisation, as well as increased awareness among the people; (technological) a technology shift to decentralised wastewater treatment for reuse; (environment) increasing water scarcity and pollution of water bodies; (legal) favourable regulatory policies. External factors that are "threats" to new SMEs in the sector are: (political) bureaucracy and lack of clarity in the wastewater management institutional framework; (technological) demand for advanced wastewater management technologies; (environmental) different climatic situations requiring different solutions in wastewater technologies; (legal) stringent environmental norms related to wastewater composition.

Internal environmental factors can be divided as industry environment and organisational capabilities. According to Porter (1980), an industry analysis can be done by understanding the existing rivalry, entry barriers, bargain power of suppliers, threat of substitutes and bargain power of buyers. Industry factors that are considered "opportunities" for new SMEs are: (existing rivalry) the wastewater sector is highly attractive expanding at a tremendous rate and a demand surpassing supply, Indian solutions are popular and cheaper than imported technologies; (entry barriers) the wastewater sector in India offers the opportunity to achieve economies of scale; (bargain power of suppliers) as the number of suppliers is relatively low and wastewater treatment providers have high importance to them, the bargain power of suppliers is low; (bargain power of buyers) as the number of buyers is relatively high and there is not a threat of backward integration, there is low bargain power of buyers. Industry factors that are considered "threats" for new Indian SMEs in the wastewater sector are: (existing rivalry) fragmented market with more than 800 companies operating at all levels and scale throughout the country; (entry barriers) highly bureaucratic and slow procedures for incorporation; (threat of substitutes) the "no implementation at all".

New Indian SMEs in the wastewater sector are not prepared to capitalise the business opportunities offered by the external and industry environments. The empirical research has shown deficiencies in the functional capabilities of the new SMEs. Organisational factors that are considered "weaknesses" are: (financial) limited sources of fund, cash shortfalls and a lack of financial systems; (marketing) limited number of products offered with low quality, limited promotion activities and lack of a marketing department; (operations) low extent of vertical integration, dependency on imported equipment, lack of standard operation and quality procedures, low technological expertise with weak R&D capabilities; (personnel) lack of a human resource system; (managerial) lack of a system for strategic formulation, implementation and evaluation. Organisational factors that are considered "strengths" are: (marketing) competitive prices and familiarity with Indian procurement systems; (personnel) growth opportunities for employees; (general management) experienced and influential general managers.

By implementing a few management systems, new Indian SMEs could take the advantage of the given opportunities and capitalise the business opportunities. They should leverage on their experience with the Indian market and their influence during the tendering procedures, focusing on non-sophisticated and non-expensive technologies for wastewater treatment for reuse and find niches, such as villages and small cities, to improve their operational capabilities.

References

Avalon Global Research (2011): Water and Waste Water Treatment Opportunities in India. An Overview. Mumbai, India. URL: www.avalonglobalresearch.com (accessed 5 January 2016)

Barreto Colmenares (1997): La encuesta estadística en la investigación de mercados turísticos. Barquisimeto: Ediciones de la Fundación del Instituto Universitario Experimental de Tecnología Andrés Eloy Blanco [in Spanish].

Barreto Dillon, L. (2013): Understanding the Market Opportunities of new Indian based SMEs in the Water and Sanitation Sector. Unpublished MBA Master Thesis. Manashagotri, Mysore: Karnataka State Open University, India.

Chemtech (2012): Trends in Water and Wastewater Treatment. URL: www.chemtech-online.com (accessed 5 January 2016)

EBTC (2011a): India-EU Creating Market Alliances, Building Access for "Waste-Water Management" Companies. New Delhi, India: EBTC. URL: www.ebtc.eu (accessed 5 January 2016)

EBTC (2011b): Water and wastewater in India, snapshot. New Delhi, India: ETC. URL: www.ebtc.eu (accessed 5 January 2016)

Kazmi, A. (2012): Strategic Management and Business Policy. 3rd Edition. New Delhi, India: Tata McGraw Hill Education Private Limited.

Johnson, G., Scholes, K. (1993): Exploring corporate strategy –text and cases. Cambridge, UK: Prentice Hall International.

OSEC (2010): Water and water treatment in India. Market Opportunities for Swiss companies. Zürich; Switzerland: OSEC. URL: www.osec.ch (accessed 5 January 2016)

Porter, M. (1980): Competitive Strategy. New York, USA: The Free Press.

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Supporting NaWaTech Entrepreneurs and SMEs Tapping the Indian Wastewater Market

This article presents the opportunities offered by the growing wastewater market in India, as well as the current weaknesses of SMEs in the sector, together with a description of the activities and tools developed by the NaWaTech consortium to help overcome the current challenges.

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Summary

India is facing a water and sanitation crisis that might hinder the economic development of the nation, with water scarcity and pollution being one of the most severe national-wide environmental problems. Traditionally, the water and sanitation sector in the country had been owned and operated by the government, however not being able to solve all the problems on its own, the government is encouraging the private sector to participate in this complex process through partnership programs and regulatory reforms. This opens a wide range of opportunities for business in the different areas of water management and sanitation that could be capitalised by existing SMEs and entrepreneurs in the sector. However, most new Indian SMEs in the wastewater sector are featuring a chronic deficiency in all functional areas (financial, marketing, operations, personnel and general management). The NaWaTech consortium, recognising the key role played by entrepreneurs, developed the online platform NaWaKit and carried out a training programme to support these key players in providing appropriate wastewater technologies while building successful businesses.

Wastewater management: a niche for entrepreneurs

India is facing an acute wastewater management crisis characterised by an increasing unregulated and illegal discharge of contaminated water. This presents an enormous threat to human health and wellbeing, with both immediate and long-term consequences. To sustain the integrity of some of India's most productive ecosystems and to avoid the spread of water borne diseases, it is imperative to tackle the problem today and prepare the nation to meet the future demands for wastewater treatment.

Key messages:

- The private sector is instrumental to improve the wastewater crisis in India that might even jeopardize the economic growth and overall development of the country.
- With an Indian population of 1.22 billion growing at 1.3% annually, the urban wastewater production will grow from 29 MLD to 59 MLD by 2021 and to 132 MLD by 2051.
- This is the time for entrepreneurs in the wastewater treatment sector to start business in India.
- Most of new Indian SMEs in the wastewater sector are presenting a chronic deficiency in all functional areas: financial, marketing, operations, personnel and general management capability factors.
- The NaWaTech consortium recognised the role played by entrepreneurs in the sector to promote and multiply the adapted wastewater technologies developed for the growing urban India.
- The NaWaKit, a Knowledge Platform for Water Practitioners in India, was created and is available at: http://www.sswm.info/category/step-nawatech/introduction
- The NaWaTech Training Program of SMEs and Entrepreneurs trained a total of 55 wastewater professionals, including SMEs and entrepreneurs, in appropriate wastewater technologies, business development and sanitation safety and O&M planning.

Despite the fact that the government of India at its different levels (national, state and local government) has initiated programs in the past decades to ensure the correct management of the millions of cubic meters of wastewater produced in India, there is a still a huge gap, which might not be filled without the participation of non-traditional actors. The Indian authorities need the assistance of latest technologies and processes, manpower, financial resources and technical know-how. The private sector is, without a doubt, instrumental and needed to improve the wastewater crisis in India, that might even jeopardize the economic growth and overall development of the country.

This is the time for entrepreneurs in the wastewater treatment sector to start business in India. In marketing terms, if an “unfulfilled need” creates a “want”, with the 17’000 millions of litres of wastewater per day (MLD) that are untreated today, “the want for wastewater treatment plants” offers multiple business opportunities to new actors in the sector. This alarming need together with an increasing health consciousness among the Indian society has fuelled the growth in the Indian wastewater sector. And the trend is growing. With a population of 1.22 billion growing at 1.3% annually, the urban wastewater production will grow from 29 MLD to 59 MLD by 2021 and to 132 MLD by 2051 (Avalon Global Research, 2011). This indicates that the sector is currently experiencing the growth stage and there will be decades before it reaches the maturity stage. Rapid urbanisation and population growth also translates into water scarcity and pollution of water bodies. It is estimated that by 2025 India will be a water-stressed country with less than 1’000 cubic meters of water available per person (OSEC, 2010). This calls not only for wastewater treatment solutions, but wastewater treatment and reuse.

The Indian authorities are now recognising the importance of a monitored and controlled reuse of wastewater, with new legislations, such as the NUSP 2008 calling urban local bodies (ULBs) to plan and implement water and wastewater systems considering adapted decentralised technologies to render the water safe for reuse (MOUD, 2008). As the responsibility of wastewater management has been decentralised, even establishments and residential areas with more than 50 people will be responsible for treating their own wastewater on-site, with new technical options now coming into place. This represents a technological revolution of how wastewater is dealt with in India.

Now more than ever, adapted technologies and technologies developed in India based on anaerobic treatments and filtration with indigenous materials, are gaining a place in the wastewater sector. Universities and research centres around the country are embarking on this new mission of developing solutions serving India’s purposes, including the NaWaTech project.

Understanding current wastewater SMEs in India

A SME in India is defined as Small Scale Industries (SSI) that either manufactures products (with an investment in plant and machinery up to Rs. 10 Crores - approx. 1.3 million EUR) or provides services (with an investment in equipment up to Rs. 5 Crores - approx. 675 thousand EUR). New Indian Small Scale Industries (similar to Small and Medium Enterprises SMEs in the rest of the world) could capitalise the several opportunities offered by the external environment in the wastewater sector in India. SMEs in India in the wastewater sector are manifold, it is estimated that there are more than 800 SMEs operating across the country (Avalon Global Research, 2011).

A descriptive research carried out by the author (Barreto Dillon, 2013), showed that some of the companies are created by retired professionals who have worked in the government for many years, which offers the competitive advantage of knowing the system and the decision makers. Other companies are the result of a joint effort of young graduates who, with an immense entrepreneurial spirit, decide to enter the sector with a particular technology. Other SMEs are spin offs of universities and research centres led by professors and assistant professors that intend to commercialise a particular technology developed within the universities laboratories and research departments. Other types of new SMEs are those created as a joint venture with a foreign company, looking forward to market their products. Other types of SMEs, and maybe the most common, are formed by individuals, with or without formal education in wastewater treatment, that have gradually entered the market by offering a range of products and equipment such as pumps and filters, and have decided to vertically integrate to offer other services in the value chain.

All of the new SMEs present the characteristics of the entrepreneurial process, particularly during the first stages of the “successful venture life cycle” (from Leach and Melicher, 2006). The first 2 years of any entrepreneurial venture, composed by the development, start-up and survival stages, are characterised for uncertainty and financial instability, especially because the entrepreneur needs to invest his/her resources (time, efforts and money) into a business idea that might sound promising, but still has not being developed into a business model that generates revenues. The chances of surviving increases when the entrepreneurial venture follows a business strategy, in which the entrepreneur establishes a road map to success. However, most entrepreneurs in the wastewater sector in India are technicians and engineers, many of them lacking managerial (formal) education, resulting in a set of weaknesses that can limit their success in the challenging and competitive wastewater treatment sector. It has been shown (Barreto Dillon, 2013), that most of new

Indian SMEs in the wastewater sector are presenting a chronic deficiency in all functional areas (as described by Kazmi, 2012): financial, marketing, operations, personnel and general management capability factors. New Indian SMEs in the wastewater sector exhibit the following characteristics:

- Lack of strategic formulation.
- Lack of marketing knowledge, as the term "marketing" is highly misunderstood by the new Indian SMEs, as it is related only to advertising and promotion. There is no conception of the 4 Ps (price, product, place and promotion) among the technicians participating in the wastewater sector.
- Most of the SMEs have no real understanding of the customer needs, and concentrate on selling one (or maybe 2) products across all segments of the market.
- Low technology expertise with weak R&D capabilities, basing their products on state-of-the-art technologies without a proper technology value proposition.
- Lack of knowledge about decentralised and natural wastewater technologies.
- Most of the projects implemented do not consider actions to ensure sustainability of the infrastructure (such as operation and maintenance).
- Lack of a personnel system for manpower planning, selection, compensation, communication and appraisal.
- Lack of a financial management system to plan for sources of funds throughout the first years of the venture life cycle.

These weaknesses exhibited by new Indian SMEs in the wastewater sector in all functional areas are limiting the chances of entrepreneurs to tap the wastewater treatment market. However, the opportunities in the sector are so large, that only a few strategic components in place would enhance the capacities of new SMEs to capitalise business opportunities.

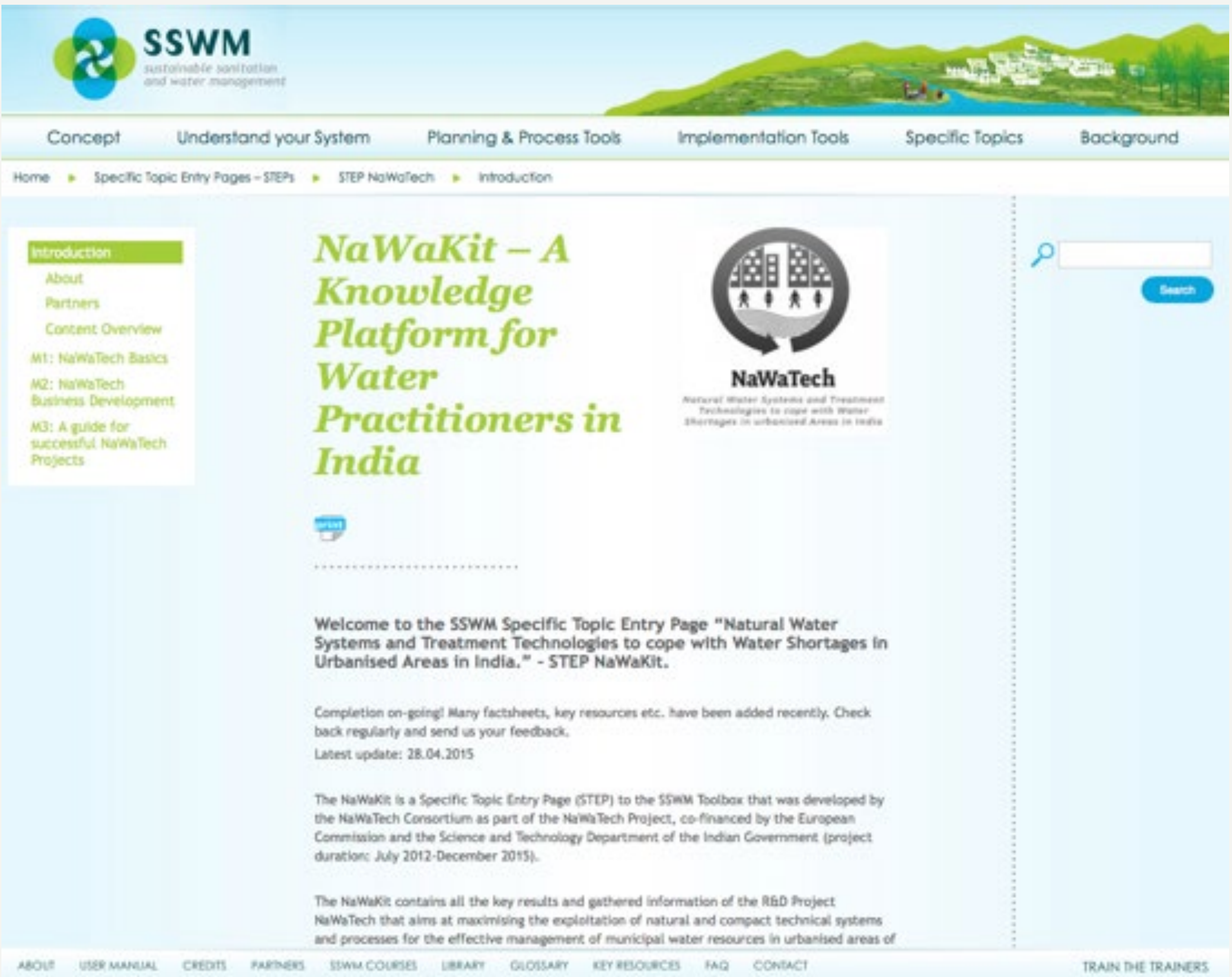

Figure 1: Entry page to the NaWaKit in the SSWM toolbox

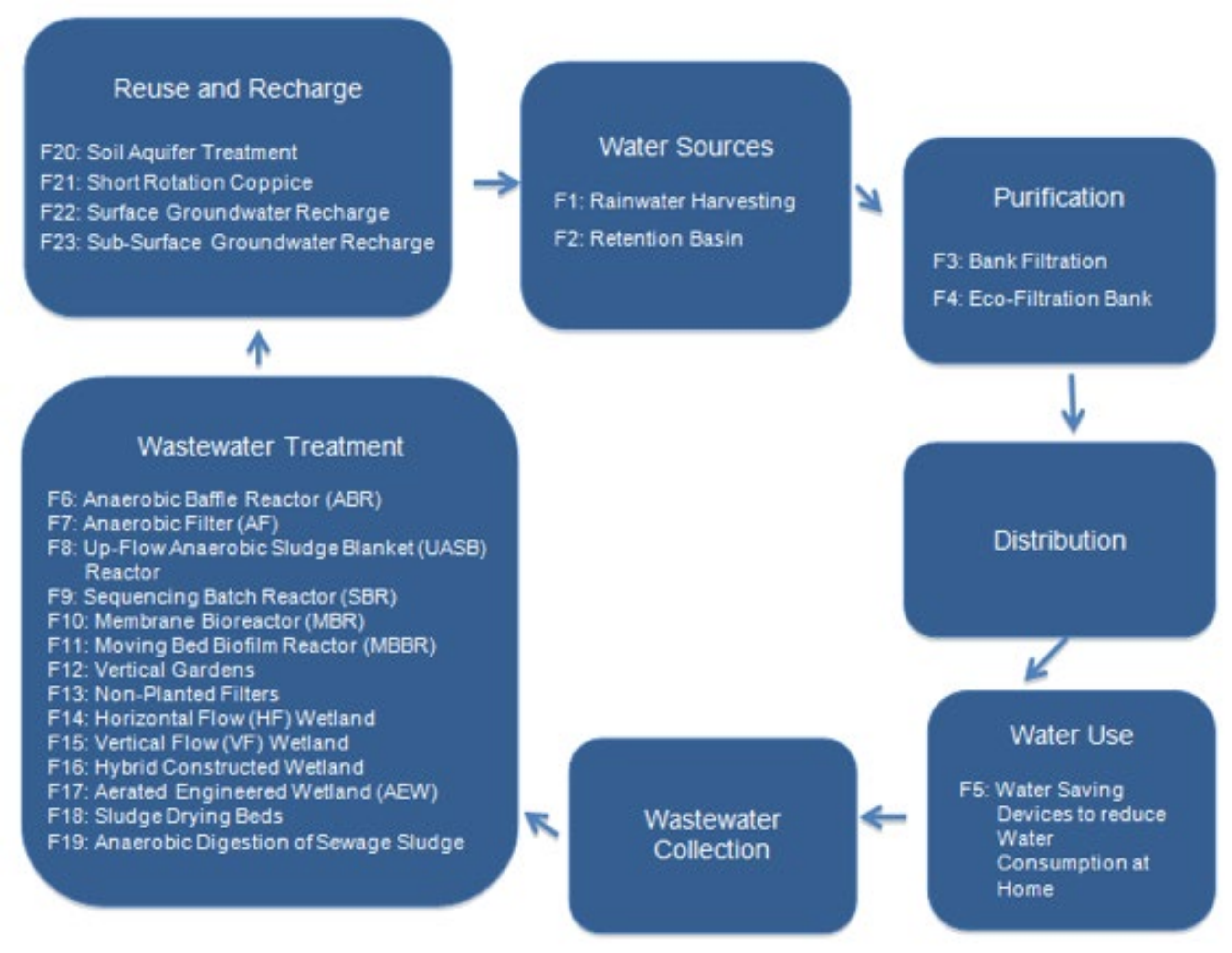

Figure 2: Selected technologies for NaWaTech systems.

NaWaTech actions to support SMEs and entrepreneurs

The NaWaTech consortium recognised the role played by entrepreneurs in the sector to promote and multiply the adapted wastewater technologies developed for the growing urban India. Taking into consideration the market research carried out and the profile of current actors in the sector, the NaWaTech consortium defined a strategy to ensure the transfer of the knowledge, as well as the strengthening of key managerial capabilities of Indian wastewater professionals. The two main activities carried out were the development of the NaWaKit – A Knowledge Platform for Water Practitioners in India, and the NaWaTech Training of SMEs and Entrepreneurs.

NaWaKit- A knowledge platform for water practitioners in India

The NaWaKit is an online platform (http://www.sswm.info/category/step-nawatech/introduction) containing all the key results of NaWaTech project. It has been developed as a Specific Topic Entry Page (STEP) within the Sustainable Sanitation and Water Management (SSWM) Toolbox (http://www.sswm.info).

The NaWaKit has been designed as a one-shop information tool for practitioners, such as local SMEs, service providers, entrepreneurs and consultants working in the water and sanitation sector in India, in order to guide them during the design, implementation, operation and maintenance of decentralised water and wastewater treatment system in urban India, as well as the funding of a new business. Figure 1 shows the entry page of the NaWaKit.

The key results of NaWaTech have been organised in 3 sections.

Module 1: NaWaTech basics

This module contains an introduction to NaWaTech, including the current situation of water management in India as well as the presentation of the NaWaTech approach. Furthermore, a list of 23 appropriate technologies for water supply and use, wastewater treatment, sludge treatment and water reuse/recharge for the Indian urban context are presented, including a set of examples in India and other parts of the world. Above picture shows the technologies selected appropriate for implementation in Indian urban areas.

Finally, this module presents the case studies describing the project sites in Pune and Nagpur, Maharashtra, India.

Module 2: NaWaTech business development

This module presents a number of tools for the development of business models in the water and sanitation sector, such as the business model canvas, the blue ocean strategy and tools to scan the business environment. Furthermore, a second section contains a group of factsheets to support entrepreneurs while writing their business plan, considering issue such as understanding competitors, developing value propositions, marketing components, action plans, risk analysis and financial issues. A third component of this module helps entrepreneurs while establishing their organisations, as it provides information about possible legal bodies, financing, strategic management and how to present business ideas and ventures to potential investors.

Module 3: A guide for successful NaWaTech project

This NaWaKit module provides practice-oriented tips and tricks guiding entrepreneurs through the different project phases to ensure that the NaWaTech systems are planned, designed and constructed keeping in mind the operation and maintenance needs to sustain them. This module is composed of three factsheets: Technology selection and design, implementation of NaWaTech projects and safety and O&M management, according to the NaWaTech safety and operation and maintenance planning methodology.

The NaWaTech training of entrepreneurs and SMEs

With the aim of supporting existing SMEs and entrepreneurs to capitalise business opportunities in the water and sanitation sector, the NaWaTech consortium offered a training programme in Maharashtra, India during 2015. This training program was designed to provide participants with the needed knowledge, skills and attitudes to start or grow their businesses in the wastewater treatment sector in India, being able to plan, design and commission adapted technologies and systems ensuring their sustainability. It was expected that at the end of the training, participants would be able to:

- Design, plan and implement natural wastewater treatment systems, such as anaerobic technologies (anaerobic baffle reactors and anaerobic filters) and wetlands systems (horizontal, vertical, hybrid and French systems), as well as compact systems, such as MBR (membrane bioreactors) and SBR (sequence batch reactors).
- Plan sustainable wastewater treatment systems, considering the tendering and statutory requirements in India, and specifically in Maharashtra.
- Design successful business models to commercialise natural and compact wastewater treatment systems and services, considering the trends of the business environment, the competitors and the customer needs.
- Prepare NaWaTech safety and O&M sanitation plans to ensure the sustainability of the projects commissioned to their clients.

The addressed participants were existing SMEs in the water and sanitation sector that wanted to expand their portfolio to widen or include natural and compact wastewater treatment systems and related services, as well as young entrepreneurs with an idea in the sanitation sector.

Figure 3: Participants of the 10-day training in Pune, April 2015

Figure 4: Participants of the 4-day training in Nagpur, August 2015

The training programme counted with the participation and support of NaWaTech wastewater and business specialists, who offered two very dynamic, pedagogic and innovative workshops, helping to activate a change in how Indian wastewater professionals participate in the competitive Indian wastewater market.

The first training took place in Pune from April 9th to 19th with the participation of 24 individuals representing 7 SMEs and entrepreneurs, 2 private organisations and 2 public institutions (see Figure 3). During a total of 7 days, practitioners had the opportunity to learn in detail about key appropriate technologies such as constructed wetland systems, anaerobic wastewater treatment systems and SBRs and MBRs systems. Not only did the lecturers provide theoretical information, but participants had the opportunity to design and dimension different systems as well, while also learning about operation, maintenance and troubleshooting. Furthermore, participants had the opportunity to have first-hand experience with the different technologies, while visiting the NaWaTech project sites at the College of Engineering Pune (COEP) Hostel Campus, Maharashtra Jeevan Pradhikaran (MJP), and Amanora Park Town.

A second training took place in Nagpur, Maharashtra from August 17th to 20th 2015 (see Figure 4). This shorter version of the training was taken by a total of 31 participants, most of them representatives of public institutions, such as state pollution control boards, municipalities, etc. A total of 7 existing SMEs took part in the training, which offered a 3-day intense training in constructed wetlands and anaerobic wastewater treatment technologies. Furthermore, participants had the opportunity to visit the Ordnance Factory Ambajhari (OFAJ) in Nagpur, where a system composed of anaerobic units and vertical up-flow constructed wetlands was being implemented.

Following the technical part of both trainings, participants had the opportunity to think different about wastewater as a business, thanks to the business model canvas development atelier offered by seecon international gmbh. Every entrepreneur and intrapreneur (i.e. staff member of an existing company) developed a business model canvas for a particular idea, considering the external and structural factors influencing customer behaviour. With the help of several presentations and continuous coaching and pitching, participants developed and improved their business models, while understanding marketing, organisational and financial concepts.

Interesting business models developed by participants were:

- Design and construction of constructed wetland systems integrated into the landscape producing treated wastewater for irrigation. Customer segment: new and existing townships in Pune with more than 100 acres.
- O&M services that include customised O&M plans, design of O&M plan and manuals, training of own/ external operators to assure the quality of treated effluent and ensure the longevity of the WWTP. Customer segment: Treatment plant designers in Pune; Treatment plants owners in and around Pune.
- Design and implementation of water pollution abatement measures, by means of advanced treatments such as MBR and SBR. Customer segment: Large and medium size builders and IT companies in Pune.
- Design, construction, commissioning and training for operation and maintenance of wastewater treatment systems composed by constructed wetlands or anaerobic systems integrated into the landscape. Customer segments: High profile resorts in environmental sensitive areas in West

India. Campuses and institutions with land, where landscaping services are required.

- Customised services, including design, monitoring of construction, commissioning and period maintenance of water, wastewater, solid waste, hazardous solid waste and rainwater harvesting solutions. “One stop solution”. Customer segment: industries in India (medium, small and large size); Education institutions and hospitals in India.

At the last day of the training, participants developed a draft of a sanitation safety and O&M planning, which included the identification of hazards and hazardous events in different components of a sanitation system, as well as possible control measures, monitoring measures and trouble shooting.

Conclusions and recommendations

The wastewater treatment market in India is currently worth an approximate of USD 1.74 billion, and it is expected to grow at a rate of 13% in the next 3-4 years (EBTC, 2011). Existing SMEs and entrepreneurs have the opportunity to capitalise the business opportunities in the wastewater sector characterised by growth and dynamism. Unfortunately, the existing companies present major deficiencies in their different functional areas, hindering their success in the sector.

NaWaTech, recognising the opportunity of the private sector, developed a programme to support SMEs and entrepreneurs, considering the following challenges: lack of knowledge about appropriate technologies, lack of marketing and business development knowledge and lack of planning for sustainability. The programme counted with two components: an online platform with key information and gathered knowledge and a training programme that took place in Maharashtra in 2015.

After the close work with the entrepreneurs, and evaluating the real market opportunities for small players, the author lists the following recommendations for future NaWaTech entrepreneurs:

- Despite the fact that most of the literature describes the sector as “highly competitive”, the opportunities for small-scale projects are infinite. New SMEs should never try to compete with the strong players in large project tenders. The process of preparing an offer alone will exhaust their personal capacity and the chances of winning the bid are very low.
- The government of India has expanded its budget to increase the wastewater treatment coverage, and multiple projects are currently being sanctioned. With numerous public private partnerships and tax incentives and subsidies, there is a clear commitment of the government of India to stimulate the participation of private technology and service providers in the wastewater sector. But the stimulus is not exclusively coming from government agencies. Builders and developers of townships and residential areas are now required to install wastewater treatment systems at the point of source, and given the lack of space, decentralised small systems are the need of the hour.
- Concentrating in small projects for the municipal councils, Gram Panchayats and developers is a good strategic option. The new Indian SMEs should opt for non-sophisticated technologies to fulfil the needs of the clients. SMEs that specialise in any of the following technologies, services and infrastructure solutions will be well placed to serve the Indian market:
    - Integrated solutions such as performing feasibility studies, designing, technical consulting and providing operation and maintenance services.
    - Wastewater treatment plants based on close-to-nature technologies (anaerobic treatment systems, constructed wetlands systems).
    - Ready-made, small-scale and transportable wastewater treatment systems.
    - Irrigation and low-flow faucets and other water use systems.
    - Equipment for monitoring and analysis of wastewater management systems.
    - Equipment for water saving and water recycling.
    - Services for rehabilitation of sewer systems (including septic system rehabilitation).
- Domestic SMEs show low technology expertise with weak R&D capabilities, basing their products on state-of-the-art technologies without a proper technology value proposition. Small projects at very local level, for instance with Gram Panchayats or the tertiary sector of class A cities and class B cities lacking adequate treatment infrastructures, represent an opportunity for SMEs to test new approaches, integrate vertically and diminish their dependency on imported equipment.
- Cooperation agreements with universities and research centres should be encouraged, to help commercialise those indigenous technologies and patents that do not reach the market.
- Due to India’s future water scarcity and pollution of water bodies, there is a need to develop integrated solutions considering not only wastewater treatment but also treated water reuse.
- The era of conventional activated sludge treatment systems is history. India requires adapted and natural treatment systems, such as those studied within NaWaTech.
- The marketing challenge that every NaWaTech entrepreneur needs to focus on is to shift the mind-set among decision makers, allowing the introduction of new sustainable technical options

different from lagoons and activated sludge treatments.

- Every SME and entrepreneur in the wastewater sector in India needs to strengthen their capacity in all organisational functional areas: financial, marketing, operations, personal and managerial. Of particular interest is the financial planning, which is critical during the starting-up and survival stages, because operations are not yet producing profits and the cash burn often leads to inability to pay the expenses. Terms such as liquidity planning, projected balance sheet and projected income statements need to be used by the entrepreneurs or the employees of the SMEs.
- SMEs and entrepreneurs in the sector need to build their marketing capacities, allowing them to conceive successful marketing mixes (price, product, place and promotion) based on the customer needs.

There is a systematic error among entrepreneurs – most likely not only in the wastewater sector or India, but overall - of not planning sufficiently for the future. In history, only a few fortunate entrepreneurs have managed to launch successful businesses without a plan. But in a complex sector such as the wastewater treatment sector in India, if the venture is expected to capitalise the business opportunities, there has to be a road map for the business.

References

Ávila, C., Garfí, M., García, J. (2013): Three-stage hybrid constructed wetland system for wastewater treatment and reuse in warm climate regions. Ecol Eng 61(A), 43-49.

Ávila, C., García, J., Garfí, M. (2016): Influence of hydraulic loading rate, simulated storm events and seasonality on the treatment performance of an experimental three-stage hybrid constructed wetland system. Ecol Eng, in press, http://dx.doi.org/10.1016/j.ecoleng.2015.11.042.

Calheiros, C.A., Rangel, A., Castro, P.M.L. (2007): Constructed wetland systems vegetated with different plants applied to the treatment of tannery wastewater. Water Res 41(8), 1790-1798.

DWA (2006): Grundsätze für Bemessung, Bau und Betrieb von Pflanzenkläranlagen mit bepflanzten Bodenfiltern zur biologischen Reinigung kommunalen Abwassers (Principles for the dimensioning, construction and operation of constructed wetlands for municipal wastewater, in German). DWA, Hennef, Germany [in German].

Hoffmann, H., Platzer, C. (2011): Technology review of constructed wetlands subsurface flow constructed wetlands for greywater and domestic wastewater treatment in developing countries. Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (GTZ), Saneamento Sustentável, Programa da Ecosan, 36p.

Kadlec, R.H., Wallace, S.D. (2009): Treatment Wetlands. 2nd edition, CRC Press, Boca Raton, FL, USA.

Kayser, K., Kunst, S. (2005): Processes in vertical-flow reed beds: nitrification, oxygen transfer, and soil clogging. Water Sci Technol 51(9), 177–184.

Knowles, P., Dotro, G., Nivala, J., García, J. (2011): Clogging in subsurface-flow treatment wetlands: Occurrence and contributing factors. Ecol Eng 37(2), 99-112.

Molle, P., Prost-Boucle, S., Liénard, A. (2008): Potential for total nitrogen removal by combining vertical flow and horizontal flow constructed wetlands: a full-scale experiment study. Ecol Eng 34(1), 23–29.

ÖNORM B 2505 (2009): Bepflanzte Bodenfilter (Pflanzenkläranlagen) – Anwendung, Bemessung, Bau und Betrieb (Subsurface flow constructed wetlands – Application, design, construction and operation, in German). Vienna, Austria [in German].

Pedescoll, A., Corzo, A., Álvarez, E., Puigagut, J., García, J. (2011): The effect of primary treatment and flow regime on clogging development in horizontal subsurface flow constructed wetlands: an experimental evaluation. Water Res 45(12), 3579-3589.

Platzer, C. (1999): Design recommendation for subsurface flow constructed wetlands for nitrification and denitrification. Water Sci Technol 40(3), 257-263.

Saeed, T., Sun, G. (2012): A review on nitrogen and organics removal mechanisms in subsurface flow constructed wetlands: Dependency on environmental parameters, operating conditions and supporting media. J Environ Manage 112, 429-448.

Sun, G., Saeed, T. (2009): Kinetic modelling of organic matter removal in 80 horizontal flow reed beds for domestic sewage treatment. Process Bioch 44(7), 717-722.

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NaWaTech Community of Practice (CoP)

This paper describes the role of the NaWaTech Community of Practice (CoP) in the promotion of natural water systems and treatment technologies in India.

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A Community of Practice (CoP) builds on natural parts of human behaviour, to socialize and work with other individuals. CoPs are generally accepted as locales of engagement, learning and development. A characteristic approach of CoPs provides vital opportunities in the development of research based projects. This paper describes the brief idea about the CoP concept and reflects on the case study of the evolution of a CoP within the NaWaTech project for the promotion of natural water systems and treatment technologies to cope with water shortages in urbanised areas in India. The case study reveals the role of CoPs in research based projects and the adopted approach for this particular application. Within the case study, there is evidence of significant outcomes and the requirement of a vision and a sustainable approach for the continuation of the activities.

Introduction

What is a CoP?

The concept of "Community of Practices", first introduced by Etienne Wenger and Jean Lave in the early 1990s, describes groups which share a common concern about certain problems or a passion regarding a specific topic, and which expands its knowledge and tones its expertise through interactions on a continual basis (Wenger et al., 2002). The concept provides a useful perspective on knowing and learning. The basic characteristics of CoPs involves the combination of the elements "The Domain", "The Community", "The Practice" and "The Support". The domain is the topic in which members have a shared interest. It should be well-defined, relevant, and fill a need for professional development among community mem¬bers. The community consists of the members and should encourage the sharing of thoughts and ideas while setting a tone of mutual respect and trust. Learning together is integral to community building; it is essential that mem¬bers develop a sense of belonging and mutual commit¬ment. The practice is based in the particular knowledge of the issue that community members share. This knowledge may be research-based or involve promising practices gath¬ered from the field. It may include tools, strategies, stories, or personal experiences that members find useful and wish to share with others (Wenger, 1998). CoPs provide platforms for sustained cross-disciplinary dialogue to achieve a common goal in the given domain.

Essentials of CoPs

The concept of CoPs originates from a sense of belonging and an urge to socialize which are parts of basic human behaviour. Although community has always been a part of the human race, organisation of community for a specified practice has only gained significance and attention over the past decades. As territorial boundaries are fading with increased interactions, it is a challenge to acquire explicit and tacit knowledge flowing around the globe and convert into sustainable activities. Although explicit knowledge is uniformly acceptable across the

Key messages:

- A Community of Practice (CoP) is a group of people who interact, learn together, build relationships, and in the process develop a sense of belonging and mutual commitment.
- By linking various stakeholders (e.g. entrepreneurs, decision makers, colleges, researchers), the NaWaTech CoP aims to promote the use of natural water systems and treatment technologies in India.
- Two chapters of the NaWaTech CoP have been started in Pune and Nagpur, respectively.
- The continuation of the CoP shall mainly be facilitated within the Indian Water Works Association (IWWA). The NaWaTech CoP shall be embedded in the 34 IWWA centres all around India (two of them in Pune and Nagpur).

communities through established facts and findings, the tacit knowledge of practice needs to be shared among people. Application of knowledge in practice requires concrete information from practitioners in the context which it is used.

The application of CoPs has gained momentum in large corporations seeking to find new ways to identify expertise dispersed across global operations for enhanced customer satisfaction and to remain updated with changing technologies (Van Winkelen and Ramsell, 2002). CoP is based on mutual learning, shared experiences and collective brain storming of ideas. The focus of CoPs is to share tacit knowledge and promote continual learning for effective implementation of a common goal (Hearn and White, 2009). As CoPs are voluntary and self-incentivizing, they create trusted relationships for the exchange of ideas and enhance the feeling of ownership. Community members remain involved in CoPs because of intrinsic benefits of collective learning and collaboration (Johnson and Bremer, 2005). As part of the CoP, transfer of knowledge can be through discussions with colleagues and mentors. The strength of CoPs is self-perpetuating. Members in CoPs share own experiences and knowledge in free flowing and creative ways which foster new approaches to problems. The inherent flexibility of a CoP makes it an individual entity and uniquely distinct. CoPs can develop and define measures to assess its effectiveness. Although this could look loosely guided, the success and sustainability of a CoP depends on contribution and sense of curiosity within the individual members of a CoP. Each CoP must develop its own approach, organisational structure, culture and communication channels. CoPs are built on efficient ways of learning through observing other people's behaviour rather than by trial and error. CoPs can exist over time irrespective of changes in membership. Traditionally, CoPs were bound by geographical locations; however, nowadays communities are linked less by location and more by common interests and goals.

CoPs can have different approaches in different kinds of applications which impacts its benefits on the community and the activity for which the CoP is carried out for. Thus, a CoP is essentially a social endeavour. CoPs provide platforms for networking, access to information, and discussion for problem solving. CoPs, a type of informal learning organisation, have been used in business, organisational design, government, professional associations, civic life and developmental / research projects. Although CoPs have been used in the educational and business sector for over 20 years, its experience in the water and wastewater sector is limited. The water and wastewater sector in developing countries has predominantly remained unorganised and localised for many decades. A paradigm shift has been recently observed towards its organisation. CoPs in such a sector with dispersed learning shall help to realign and enhance efficiency in achieving common goals.

In this paper, we will understand the role of a CoP in the perspective of a technical research projects - NaWaTech - and its contribution to the sustainability of the project. Our goal was to identify promising directions to advance the use of the CoP concept in the water and wastewater setting in developing countries.

The NaWaTech Community of Practice

The NaWaTech CoP was established to produce and exchange knowledge, technologies, guidelines and tools for the implementation and operation of natural water systems and treatment technologies between skilled service providers and SMEs, academia and public authorities; enabling research partnerships and creating favourable institutional environments for the application of natural water treatment systems and compact systems to cope with water shortages in urban areas of India. The NaWaTech CoP was setup to foster take-up in practice and mainstream NaWaTech activities as well as output by key stakeholders and enable an exchange of knowledge, information and practice between stakeholders, beneficiaries and practitioners. The NaWaTech CoP brings together the key stakeholders from academia and research, industry, end-users and decision makers, investors, non-governmental and non-profit organisations working in relevant fields and all supporters of the development of integrated water management and technologies.

Due to the involvement of many stakeholders in the consortium as part of the NaWaTech Project, a CoP structure was likely to evolve naturally. However, in order to fully explore the potential of having so many different experts and practitioners jointly working together and in order to ensure the establishment of the foundations for a long-term cooperation between EU and India in water technologies, the NaWaTech CoP was set up, promoted and established a working strategy.

1. Basic strategy of the NaWaTech CoP

A strategic approach of CoP activities is obligatory to achieve the aims/objectives of practical applications in the different fields. The NaWaTech CoP brings together the key stakeholders to learn from each other face-to-face in order to establish a long-term partnership.
The NaWaTech CoP was established having the following strategic purpose:

Vision:
NaWaTech CoP will ensure the take-up in practice and mainstreaming of NaWaTech activities and output by key stakeholders and enable an exchange of knowledge, information and practice between stakeholders, beneficiaries and practitioners.

Baseline considerations focus on the necessity of an integrated water management approach, including (i) interventions over the entire urban water cycle;

Objectives of the NaWaTech CoP

- To promote innovation
- To increase the competitiveness in the field of integrated water management and technologies
- To create conditions for increasing expertise in the area of integrated water management and technologies
- To increase cooperation with national and foreign organisations
- To promote entrepreneurship
- To organise professional, scientific, educational and awareness actions
- To conduct editorial and publishing activities
- To defend vigorously and lobby for the best interests of the membership
- To enable members to understand and to promote the NaWaTech systems
- To encourage the highest standards in creative, technical and commercial practices at all times
- To create general awareness of the urban water cycle and its problems, including aspects such as effectiveness of the different solutions and economics, amongst others
- To transport NaWaTech project experiences to stakeholders and share the outcomes
- To influence decision-makers

(ii) optimization of water use by reusing wastewater and preventing pollution of freshwater source; (iii) prioritization of small-scale natural and technical systems, which are flexible, cost-effective and require low operation and maintenance. Such an integrated approach has advantages compared to conventional end-of-pipe water management in order to cope with water shortages in urban areas – particularly when considering that population growth, urbanisation, industrialisation, climate change and a steep increase in water consumption are putting increasing pressures on urban water resources in India.

Mission:
To produce and exchange knowledge, technologies, guidelines and tools for implementation and operation between skilled service providers and SMEs, academia and public authorities, enabling research partnerships and creating favourable institutional environments for the application of natural water treatment systems and compact systems to cope with water shortages in urban areas of India.

2. Developmental stages of NaWaTech CoP activities

The CoP approach is a well-known practice in different practical fields in the last few decades. A generalised structure of the stages involved in the strategic development of CoP activities in a practical field is required. Basic stages of CoP development were modified to establish common lifecycle steps for the NaWaTech CoP. Communities have lifecycles – they emerge, they grow, and they have life spans. For each lifecycle phase, specific design, facilitation, and support strategies exist that help achieve the goals of the community and lead it into its next stage of development. If the community is successful, over time the energy, commitment to, and visibility of the community will grow until the community becomes institutionalised (Figure 1).

It is critical to understand these lifecycle phases and monitor the CoP evolution to not lose momentum. The expectations, plans, communication, collaborative activities, technologies, and measures of success are defined at the different phases to successfully facilitate the CoP.

The implementation of the NaWaTech project is based at two locations with an intent to build close relationships with relevant local stakeholders. Therefore, two independent NaWaTech CoP chapters were established

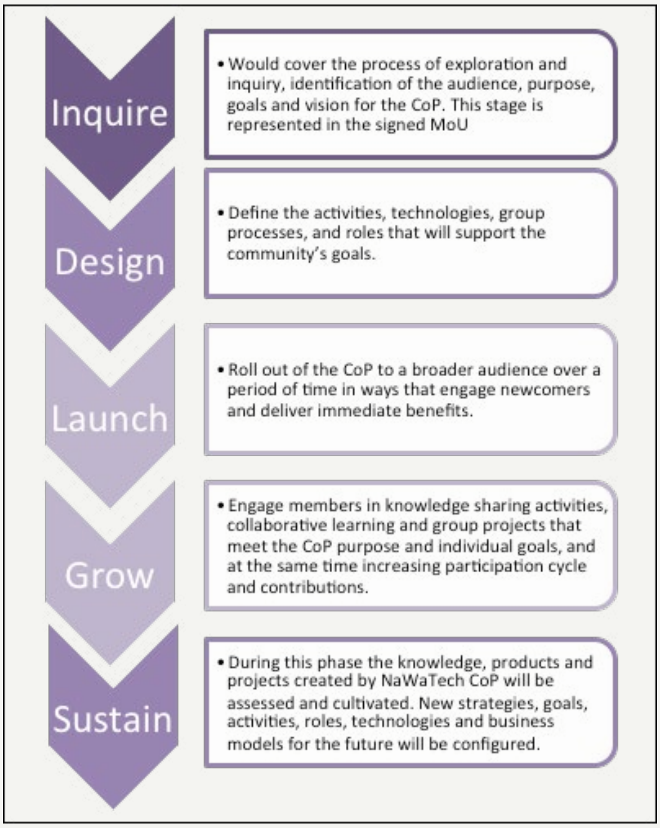

Figure 1: Evolution of a CoP

Table 1: Level of participation in NaWaTech CoP activities

Members	Role
Core group members	• Participating intensely in the CoP through discussions and projects • Taking leadership roles in guiding the group
Active member	• Attending and participating regularly, but not to the level of the leaders
Peripheral group member	• Passive participant, but still learning from their level of involvement

at each location (i.e. Nagpur and Pune) under a common APEX board. As deliberated within the development stage, the NaWaTech CoP established three different levels of participation as described in Table 1.

3. Reflections on the CoP activities within the NaWaTech Project

The NaWaTech CoP was developed as part of the research based NaWaTech project. In the timeline of the project activities, NaWaTech CoP activities, tasks and responsibilities were framed and worked out, considering the main objectives of the NaWaTech project. The tasks involved in the CoP activities are given in Table 2.

Research activities

The NaWaTech CoP was useful for certain research activities within NaWaTech. For instance, the implementation of any wastewater treatment plant requires social acceptability especially if it is being constructed in a public place. Experience from Europe suggested to conduct a baseline socioeconomic survey to assess social awareness and cultural acceptability of wastewater treatment and reuse before undertaking the project. Such an activity was undertaken e.g. at Dayanand Park, a public area where people from the nearby areas practise different leisure activities. Users of the park are important stakeholders to be considered and they have to be involved in the implementation, operation and maintenance of the constructed wetland system at the park. A social survey helped to map the socio-economic profile, activities in

Table 2: Activities and tasks of NaWaTech CoP

Activities	Tasks
Research	• Invitation as a research contributor in the NaWaTech Project • Updated with research outputs and participate through CoP forums, e –scientific exchange • Comment on articles, newsletters, blogs and publications • Share publications with the known professional circle and CoP Members
Awareness	• Share articles, information about workshops, conferences, etc. socially through blogs and the NaWaTech CoP Facebook page • Arrange sessions with different organisations, platforms and talk with individuals, students, professionals, etc. • Help through organising conferences, group events • Participate in awareness activities, viz. lectures, presentations, etc
Membership	• Visit different forums, colleges, organisations, townships • Introduce them to the NaWaTech project and ask them to be part of it • Meet decision makers and aim for policy interventions
SME development	• Identify SMEs in the water and sanitation sector, introduce them to NaWaTech and encourage them to participate in the CoP • Share output and results of the NaWaTech research and use their experience for feedback into the research process • Encourage and inspire them to adopt their business models so as to include natural water treatment systems
Sponsorships	• Introduce NaWaTech to possible funding agencies and corporate sectors • Identify sponsors for sustaining CoP activities after project timeline • Share NaWaTech technologies and outcomes within the circle

the park, water, sanitation access and environmental awareness. Conducting such activities increased the curiosity and ownership of the natural treatment plant in all the park users. Designing of awareness protocols was refined based on the education background and employment status. Interaction with park users also highlighted water scarcity issues during dry seasons, degradation of plants and grass due to bad quality water. Generation of knowledge through baseline surveys and suggestions from the park users is helpful for the success of the project. Requirement for activities such as workshops, campaigns and other participatory activities was identified based on the survey conducted in order to increase users' environmental awareness and their knowledge about wastewater treatment and reuse.

Awareness activities

Implementation of water and wastewater sector projects requires involvement of urban local bodies, enforcement agencies (pollution control boards), implementers (construction companies) and users; however, they seldom work in cohesion. Initial barriers and challenges for the NaWaTech CoP was to assemble all stakeholders for the exchange of ideas and problems faced during project implementation. The primary challenge in organising such meetings remains in creating an environment of trust and believe within each stakeholder. Interactive discussions addressing stakeholder's queries on sewage management and enforcement of environmental laws helped members to resolve implementation difficulties. Such groundwork is essential before floating new topics and new ideas for learning enrichment.

Extensive NaWaTech CoP awareness activities were carried out at both the Nagpur and Pune chapter and tried to reach maximum stakeholders, organisations, institutes and individuals. Various CoP interactions enlightened the participants / members of various business models for sustainable development, capacity building of SMEs, cost-effective treatment technology and feasible operation and maintenance plans.

Membership

The NaWaTech CoP specifically targeted academic institutions as well as professional organisations so as to encourage more participation. Higher participation in the CoP is directly related to higher exchange of ideas. The Pune chapter registered more than 150 individuals as CoP peripheral members and attached 5 educational institutions as long term CoP activity collaborators. Due to the interdisciplinary nature of the water and wastewater sector, representation from different types of stakeholders is necessary. The NaWaTech CoP emphasised on the inclusion of colleges (e.g. SCMHRD, MITCOE, VITCOE, Bharati Vidyapeeth Civil Engineering Department and Sustainable Architecture Department), decision makers and government officials in its outreach program.

SME handling

Outreach to professionals and practitioners took place at different national and international exhibitions, conferences and arranged technical trainings on NaWaTech technologies in Pune and Nagpur. Figures 2 through 5 give some impressions of different NaWaTech CoP activities conducted within the project.

It is crucial in a research based project to frame a sustainable approach for future circumstances. For the achievement of the objectives in the project, it is essential to carry out the CoP activities considering the sustainability of the communities beyond the project timelines. We have envisioned the following:

- The continuation of the NaWaTech CoP shall mainly be facilitated via the Indian Water Works Association (IWWA; integration of the NaWaTech CoP into the Nagpur and Pune chapters of IWWA).
- Further engage the collaborative institutes and organisations to carry forward the CoP activities; Involve college students/professionals in various CoP initiatives creating internship/research opportunities for them
- Continue the CoP activities through NaWaTech web forums, social sites (NaWaTech CoP Facebook page) by engaging peripheral members

Figure 2: Stakeholders outreach at NaWaTech case study sites (COEP, Amanora)

Figure 3: Outreach to academic institutions

Figure 4: Outreach to professionals and practitioners at organisations and institutions

Figure 5: Outreach to professionals and practitioners at exhibitions and conferences

Some of the challenges for CoPs (Wenger et al., 2002)

- Communities can develop a sense of ownership over knowledge; this can lead to arrogance where communities feel their perspective on the domain should prevail and that their domain is more important than others.
- Communities who are marginalised, where members have a shared discontent become places to share frustrations and gripes rather than enacting change.
- Some communities can suffer internal wars, where disagreements between members can consume the group.
- Too much dependence on the coordinator or on a central leader makes the group vulnerable if this person leaves. This also decreases the diversity of perspectives in the group.
- When leadership is not shared and distinct classes of the group develop, it is difficult for the group to have a shared identity.
- A community can be too large or dispersed to actively engage members, people may sign up but not contribute or honour their commitments.
- Barriers to outsiders can develop when communities develop specialised methods, environments and use technical jargon.
- Some communities can focus too heavily on documenting, where the group begins to see its purpose as producing documents.
- Other communities do not document enough. Where ideas are continually re-worked and discussed leading to an unproductive group.
- A reluctance to change hinders groups, where they became set in their ways and are hesitant to accept outside perspectives.

- Organise site visits for interested institutes or organisations (government or private) for knowledge sharing and convincing them to adopt it

Important issues/challenges in CoP activities

CoPs can encounter many challenges and it is unlikely that they can all be avoided. It is therefore important to be mindful and watch for their development, taking a proactive approach when problems arise (Wenger et al., 2002). Formulating a CoP chapter does not guarantee smooth and sustainable functioning. One of the major challenges arises from the existing bond between members resulting in limited integration of newcomers into the community. Thus, without a proper approach the integration of new people and new ideas is a challenging task. The essence of a CoP is to create an environment which encourages flow of ideas and knowledge from individuals instead of group thinking. In the initial phase, a coordination or steering committee is required to establish the domain and create institutional guidelines; however, constant effort is required to create a system independent of the coordinators. Rotation of leadership and development of an open culture within a CoP is required. Another challenge for being a productive CoP is to ensure that the discussions / meetings do not digress from the core theme, especially in a community with members from different faculties. Challenges also persist in a situation where members may remain dormant without any contribution. It is the responsibility of the secretariat to ensure members do not remain dormant, and contribute and honour their commitments. All the above situations may hinder exchanges of information and the development of innovative ideas within the community.

Finally, in the case of a virtual learning community, issues regarding privacy, user-friendliness of online technologies, and the ability to access a computer can become fatal barriers to an individual's ability to participate.

References

Hearn, S., White, N. (2009): Communities of Practice: linking knowledge, policy and practice. Background Note, Overseas Development Institute,. http://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/1732.pdf (accessed 5 January 2016)

Johnson, D., Bremer, C.D. (2005): Communities of Practice: A Strategy for Program Improvement. Information Brief, Volume 4, Issue 3, National Center on Secondary Education and Transition, University of Minnesota, USA, http://files.eric.ed.gov/fulltext/ED495859.pdf (accessed 5 January 2016).

Van Winkelen C., Ramsell, P. (2002): Building Effective Communities. Henley Knowledge Management Forum 2nd Annual Conference, Henley Management College, Oxfordshire, UK.

Wenger, E. (1998). Communities of practice: Learning, meaning, and identity. Cambridge, UK: Cambridge University Press.

Wenger, E., McDermott, R., Snyder, W.M. (2002). Cultivating communities of practice. Boston, USA: Harvard Business School Press.

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NaWaTech: Summary and Outlook

The paper summarises the main findings and main achievements of NaWaTech and gives an outlook on future activities.

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During the last 3.5 years (1st of July 2012 to 31st of December 2015) the NaWaTech project promoted integrated water management approaches to combat water shortages in urban India, while focusing on natural and compact technical water treatment systems. Five NaWaTech case study sites could successfully be implemented while the accompanying extensive stakeholder involvement facilitated the interest and, subsequently, concrete plans for four more replication sites. By means of the NaWaKit, the project results will contribute to help water practitioners and entrepreneurs implement further systems as well as to grow their venture in the water and wastewater sector. In this paper the main findings and main achievements of NaWaTech are summarised and an outlook on future activities is given.

Summary of main findings

Key lessons learnt from case study implementation

At the end of 2015 five case study sites had been successfully implemented. Only one case study site (Dayanand Park, Nagpur) could not be finalised yet, due to various obstacles (however it will be finalised early 2016 due to an extension of the Indian part of the NaWaTech project). The major results and lessons learnt from the case study implementation include:

- A detailed feasibility study in the beginning is very helpful, where local site conditions such as geotechnical characteristics, underground networks, prevailing wastewater properties, volume of wastewater to be treated, reuse activities expected, availability of power supply, groundwater level, etc. should be described. This reduces the risk of having to change the design at implementation stage. Landscape planning should also be considered from the start, in order to fit the system better into the surrounding environment (especially important for public sites).
- Intervention sites are located in different settings e.g. the College of Engineering Pune (COEP) hostel campus belongs to an academic institution and the wastewater treatment plant will help students to learn from the plant; wastewater treatment plant and reuse in watering the lawn in Dayanand Park, Nagpur provides opportunities for assistance in maintaining the treatment plan through park users. In addition, different settings provide higher probability of replication of these treatment plants.
- The selection of the contractor is a critical factor, capacity building of the contractor (e.g. regarding technical features, advantages of the new system, supply chain management, etc.) is highly recommended as implemented systems are not well-known yet in India. It is important to ensure that the contracting firm appointed has considerable experience in civil works and not just plug and play type water and sanitation projects.
- In the scheduling of the work activities the monsoon season has to be taken in account: from

Main achievements of NaWaTech:

- 5 case study sites featuring natural and compact technical water treatment systems based on the NaWaTech approach have successfully been put into operation
- Concrete plans for site replication in other locations in India have been established
- A knowledge platform for water practitioners in India, the NaWaKit, has been launched containing all the key results and information of the project (available at http://www.sswm.info/category/step-nawatech/introduction)
- Continuous stakeholder involvement was achieved via the creation of the NaWaTech Community of Practice (CoP), which will continue to operate after the official end of the project

July to end of September it may be very difficult to perform certain activities, especially excavation, water-proofing and concrete works.

- In general, all construction materials needed for implementation of the natural and compact technical treatment technologies applied within NaWaTech were locally available. However, as some systems are relatively novel to India, the search for selected parts may be time-consuming.
- In comparison with the European context the time to be considered for design, land preparation, construction and commissioning, may have to be increased. Potential issues with providers, permissions needed from authorities, etc. may prolong the time needed. Taking this into account can help avoid delay when calculating the project delivery date.
- Regarding operation and maintenance, a high focus needs to be put on hands-on training and learning, as operators on site usually work on a memory basis. Nevertheless, manuals for the site, check-lists, logbooks, etc. are of importance as well.
- So far only limited research could be performed on the sites. However, one can already say that treatment performance is generally good, with the higher temperatures in India having a potentially beneficial impact. Influence of load variability (e.g. during monsoon period) need to be carefully monitored in the future.
- Stakeholder selection and participation is essential across the entire project timeframe to create an overall supportive environment.
- Association with statutory agencies such as state pollution control board and municipal corporations was advantageous in seeking approval for setting up of wastewater treatment plants.

Dissemination of knowledge

A strong focus within the NaWaTech project was on disseminating the results and experiences gained in the project. The main activities and results in this respect are summarised below.

The NaWaTech website

The NaWaTech website (www.nawatech.net) was established with the beginning of the project. It contains a public library from which a number of resource material produced within the project can be downloaded, e.g. posters and flyers, newsletters, publications, project reports, or the different MSc thesis produced by the students involved in the twinning programme.

The NaWaKit

The NaWaKit is a knowledge platform for water practitioners in India available at http://www.sswm.info/category/step-nawatech/introduction. It is a Specific Topic Entry Page (STEP) to the Sustainable Sanitation and Water Management (SSWM) Toolbox, containing all the key results and information of the project. The NaWaKit has been designed to provide the needed technical and business strategy tools to support water practitioners (such as local SMEs, service providers, entrepreneurs and consultants working in the water and sanitation sector in India) when conceiving, launching and growing a new venture in the water and wastewater sector as well as to guide them during the design, implementation, operation and maintenance of decentralised water and wastewater treatment systems in urban India. It presents key information about technological options for the implementation of appropriate technologies, as well as the results of the case studies implemented in Nagpur and Pune in Maharashtra, India. The information is organised in 3 modules:

1) NaWaTech Basics, including information on the project, the current situation of water management in India, the different case studies, as well as the different technologies considered.
2) NaWaTech Business Development: This module presents a number of tools for the development of Business Models in the water and sanitation sector as well as a group of factsheets to support entrepreneurs while writing their business plan, considering marketing components, action plans, risk analysis and financial issues
3) A guide for successful NaWaTech Project: This module presents the steps to follow to develop a NaWaTech Safety and Operation and Maintenance Plan, which allows sustaining infrastructure projects under the Indian urban conditions.

The NaWaTech video

The NaWaTech partners produced a video about the project, focusing on the case study sites and the different technologies implemented, including shots of the sites. The video is available at https://www.youtube.com/watch?v=yfiiUT-WGws&feature=youtu.be.

NaWaTech workshops and training activities

In order to ensure the sustainable uptake in practice and a positive beneficial effect on the water and sanitation sector, three NaWaTech workshops and two training programmes (one in Pune and one in Nagpur, respectively) were carried out.

Three specialized international workshops were conducted in the frame of the NaWaTech project, in Barcelona at the facilities of Universitat Politècnica de Catalunya·BarcelonaTech, Spain, at Amanora Park

Town, Pune, India, as well as at the University of Natural Resources and Life Sciences Vienna (BOKU University), Austria. Participants mainly included young scientists, researchers, and practitioners (entrepreneurs and SMEs), both from European countries and from India. The workshop in Barcelona focused on natural technologies and sustainable water management in developing countries, the one in Pune focused on SME breeding and entrepreneurship development, and the workshop in Vienna on business matchmaking in the water sector.

In Pune, a 10 day training programme on "business development in sustainable planning and implementation of wastewater technologies" was carried out in April 2015, aimed at existing SMEs (24 participants in total). The programme was designed to provide participants with the needed knowledge, skills and attitudes to start or widen their businesses in the wastewater treatment sector in India, being able to plan, design and commission adapted technologies and systems ensuring their sustainability. At the end of the training, the participants were able to design, plan and implement natural wastewater treatment systems, such as anaerobic technologies, wetlands systems as well as compact systems, such as MBR and SBR; design successful business models to commercialise natural and compact wastewater treatment systems and services, considering the trends of the business environment, the competitors and the customer needs; and prepare NaWaTech Safety Sanitation Plans to ensure the sustainability of the projects commissioned to their clients.

The 2nd NaWaTech training programme on "appropriate wastewater treatment for housing complexes, townships and small communities" took place in August 2015 in Nagpur, India. The aim was that participants at the end of the training could understand the working and design principles of natural wastewater treatment systems, plan sustainable wastewater treatment systems, considering the tendering and statutory requirements in India, and specifically in Nagpur, and prepare NaWaTech Safety Sanitation Plans considering the different stakeholders involved to ensure the sustainability of the projects. Participants included mainly SMEs as well as public organisations (31 participants in total).

Presentation of NaWaTech results at conferences and publications

NaWaTech research results have been presented at various conferences. Main events included:

- Keynote presentation „The role of constructed treatment wetlands in resources-oriented sanitation systems" by Günter Langergraber, BOKU, at the 11th IWA Conference on „Small Water & Wastewater Systems and Sludge Management", 27-30 October, 2013 Harbin, China.
- "Decentralized sewage management practices and natural water systems", oral presentation by Dr. Girish Pohpali at the Tamil Nadu Water Supply and Drainage Board Meeting. 26-27 August 2014, Nagpur, India
- "Natural water systems and treatment technologies to cope with water shortages in urbanized areas in India", oral presentation by Dr. Pranav Nagarnaik at Saph Pani Conference: Natural treatment systems for safe and sustainable water supply in India. 18-19 September 2014, New Delhi, India.
- "Leading innovative and outstanding natural water treatment technologies implemented at various test sites at Nagpur & Pune under NaWaTech Project", poster presentation by Sandeep Yadav, Neha Patwardhan and Varad Shende at International Knowledge Exposition. 18-21 November 2014, Greater Noida, Delhi NCR, India.
- „Different urban scenarios for wastewater treatment and recycling: NaWaTech Project", oral presentation by Neha Patwardhan, ESF, at the 47th IWWA Annual Convention, February 2015, Kolkata, India.
- „Application of the NaWaTech safety and O&M planning approach for resources-oriented wastewater treatment systems in Pune, India", oral presentation by Sandra Nicolics, BOKU; „Vertical Gardens for greywater treatment and recycling in dense urban areas: a case-study in Pune", oral presentation by Fabio Masi, IRIDRA; as well as „The NaWaTech safety and O&M planning approach", oral presentation by Günter Langergraber, BOKU, at the workshop on „Sanitation Safety Planning - From concept to practice"; all at the IWA Water and Development Congress „Water Security for Sustainable Growth", 18-22 October 2015, Dead Sea, Jordan.
- "The NaWaTech project: Natural water systems and treatment technologies to cope with water shortages in urbanised areas in India", oral presentation by Kathrin Meinhold, ttz Bremerhaven at the 19th Forum on Eco-innovation "Business opportunities in Eco-innovation. Materials and products for a sustainable future", 27 October 2015, Seoul, South Korea.

Furthermore, several publications were produced:

- Compendium of Natural Water Systems & Treatment Technologies to Cope with Water Shortages in Urbanised Areas in India (2013): Barreto Dillon, L., Doyle, L., Langergraber, G., Satish, S. & Pophali, G. (Editors). Berlin: epubli GmbH
- Ávila, C., Garfí, M., García, J. (2013): Three-stage hybrid constructed wetland system for wastewater treatment and reuse in warm climate regions. Ecol Eng 61, 43-49.

- Samsó, R., García, J. (2013): Bacteria distribution and dynamics in constructed wetlands based on modelling results. Sci Total Environ 461-462, 430-440.
- Ávila, C., Garfí, M., García, J. (2016): Influence of hydraulic loading rate, simulated storm events and seasonality on the treatment performance of an experimental three-stage hybrid constructed wetland system. Ecological Engineering, accepted.
- Masi F., Bresciani R., Rizzo A., Edathoot A., Patwardhan N., Panse D., Langergraber G.: Green walls for greywater treatment and recycling in dense urban areas: a case-study in Pune. Journal of Water, Sanitation and Hygiene for Development, submitted November 2015.
- Nicolics, S., Hewitt, D., Pophali, G.R., Masi, F., Nagarnaik, P., Panse, D., Labhasetwar, P.K., Meinhold, K., Langergraber, G.: Application of the NaWaTech safety and O&M planning approach re-use oriented wastewater treatment lines at the Ordnance Factory Ambajhari, Nagpur, India. In: Vymazal, J. (Ed.): Proceedings of the 9th International Workshop „Nutrient Cycling and Retention in Natural and Constructed Wetlands“, 26-29 March 2015, Třeboň, Czech Republic, Springer, submitted.

Scientific papers related to NaWaTech published in conference proceedings include:

- Nicolics, S., Masi, F., Pophali, G.R., Patwardhan, N., Satish, S., Labhasetwar, P.K., Doyle, L., Langergraber, G. (2014): Safety planning approach for ensuring long-term operation of resources-oriented systems. In: Zhou, Q., Zhai, J., (Eds.): Conference Proceedings 14th IWA Specialized Group Conference on „Wetland systems for Water Pollution Control“, 12-16 October 2014, Shanghai, China, pp.43-53.
- Knauer, C. Doyle, L. (2014): Short Rotation Plantations Irrigated with Wastewater: Evaluation of Suitable Species for India.In: Hoffmann, C., Baxter, D., Maniatis, K., Grassi, A., Helm, P (Eds): Papers of the 22nd European Biomass Conference. Extracted from the Proceedings of the International Conference held in Hamburg, Germany, on the 23-26 June 2014, pp.332-338.
- Nicolics, S., Edathoot, A., Patwardhan, N., Staribacher, E., Masi, F., Caballero, A., Panse, D., Labhasetwar, P.K., Meinhold, K., Langergraber, G. (2015): Application of the NaWaTech safety and O&M planning approach for resources-oriented wastewater treatment systems in Pune, India. Full paper at the IWA Water and Development Congress „Water Security for Sustainable Growth“, 18-22 October 2015, Dead Sea, Jordan.
- Masi, F., Bresciani, R., Rizzo, A., Edathoot, A., Patwardhan, N., Panse, D., Langergraber, G. (2015): Vertical Gardens for greywater treatment and recycling in dense urban areas: a case-study in Pune. Full paper at the IWA Water and Development Congress „Water Security for Sustainable Growth“, 18-22 October 2015, Dead Sea, Jordan.

Twinning of Students

Scientific cooperation, as any other cooperation activity lives much from the motivation and personal engagement of the stakeholders involved and their intercultural understanding. The experiences of the consortium members have shown that students from research groups of different geographical and cultural background can be efficient vectors for promoting a close collaboration with the laboratories. Therefore, within NaWaTech a twinning of students programme was initiated, whereas European students had the chance to work in India and Indian students in Europe, within the NaWaTech project. Besides contributing to the student's thesis (to date, 11 MSc theses and 1 PhD thesis were finalised and 3 MSc theses and PhD theses, respectively, are still on-going), the twinning programme contributed considerably to the improvement of the research partnership and the establishment of the foundations for a long-term EU-India collaboration for water technologies.

Outlook

A main aim of NaWaTech was to have an impact beyond the project's set timeframe. In this regard, the following achievements can be highlighted:

NaWaTech replications

Already within the project timeframe the opportunity to replicate water treatment systems considering the NaWaTech approach has arisen, facilitated amongst others by the extensive stakeholder engagement within the project. NaWaTech replications include the following:

1) Manganese Ore India Limited (MOIL), Gumgaon, Nagpur (100 m^3/day): A treatment plant is proposed to be setup to treat sewage from staff quarters of MOIL, Gumgaon near Nagpur.
2) Navegaon Sadhu village (50 m^3/day): A model village in Nagpur District, where sewage is discharged through open drains is also going to adopt natural treatment system. The treated effluent is proposed for recycle and reuse for gardening and irrigation purposes.
3) Patansavangi Village (treatment capacity is yet to be decided) through Zilla Parishad (District Agency), Nagpur.
4) Vyankatesh city (Housing Complex near Nagpur) to treat 30 m^3/day.

The treatment system will also be included in the Schedule of Rates of Maharashtra Jeevan Pradhikaran (MJP).

Integration of results into the cewas start-up programme

NaWaTech results will feed into the cewas start-up programme, targeting specifically Indian entrepreneurs via its South Asia branch. Cewas is a Swiss non-profit association specialised in improving business practices in water and sanitation through training and awareness-raising so as to increase the sector's integrity and sustainability. Its start-up programme provides aspiring entrepreneurs with the necessary skills, knowledge and networks to transform an idea into a working start-up in the water and sanitation sector. Key business knowledge and practical skill development is combined with support from a diverse community of entrepreneurs and water sector experts.

The NaWaTech conference

The International Conference on Innovations in Sustainable Water and wastewater Treatment Systems (ISWATS) will take place on the 21st – 23rd of April 2016 in Pune, India. The conference will include presentations of findings from all four projects supported under the framework of the India – EU Science & Technology Cooperation in water technology and management (besides NaWaTech, also SARASWATI, SWINGS, and Eco India). The strategic objectives of the conference are to exchange knowledge, technologies, guidelines and tools for implementation and operation among academia and public authorities, skilled service providers and SMEs, enabling research partnerships and creating favourable environments for the application of treatment systems and technologies for sustainable water / wastewater treatment, reuse and recycle. More information about the conference can be found at http://www.neeri.res.in/iswats.

Consolidation of the CoP

The NaWaTech Community of Practice (CoP) brings together key stakeholders from academia and research, industry, end users and decision makers in the water and sanitation sector (overall approx. 200 members). Both the Pune as well as the Nagpur chapter of the CoP aim to continue after the official end of NaWaTech, in order to facilitate the further replication of NaWaTech sites, offer internships/research opportunities for students/young researchers or site visits for interested institutes or organisations. The continuation of the CoP will mainly be facilitated via the Indian Water Works Association (IWWA). IWWA has 34 centres all around India, and two of them are concretely in Pune and Nagpur, offering the opportunity to embed the NaWaTech CoP herein. The exact future governing structures and procedures will be discussed at a CoP event in February 2016 and officially launched at the NaWaTech conference.

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