sustainable sanitation alliance

Wastewater Reuse in an Urban College Hostel Pune, Maharashtra, India

Fig. 1: Project location

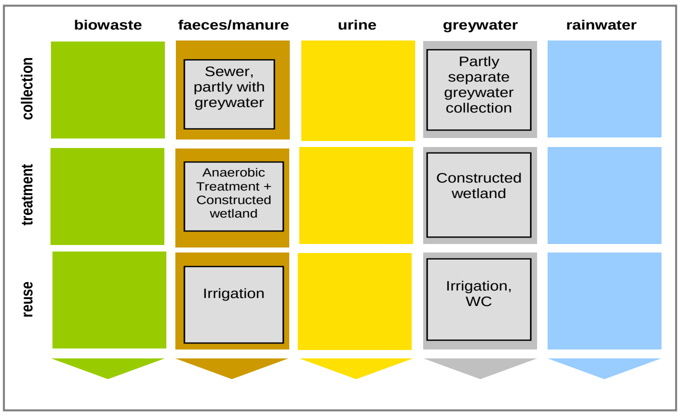

Fig. 3: Applied sanitation components in this project

1 General data

Type of project:
Greywater segregation, wastewater treatment and reuse in an urban area (College of Engineering, Pune Hostel Campus) with anaerobic treatments and constructed wetlands, full-scale demonstration project

Project period:
Start of construction: May 2014
End of construction: June 2015
Start of operation: June 2015
Ongoing monitoring period planned for: 6 months
Project end: December 2015

Project scale:
Number of people covered: max. 1500 students + personnel
Size of treatment plant:
Plant capacity: 140 m^3 of wastewater, 35 m^3 of greywater
Total investment (in EUR): 160.000,00

Address of project location:
COEP Hostel Campus, Shivajinagar, Pune – 411005 Maharashtra (India)

Planning institution:
NAWATECH consortium (www.nawatech.net)

Executing institution:
COLLEGE OF ENGINEERING PUNE (COEP)

Fig. 2: Rendering of the constructed wetland (CW) for greywater reuse at the COEP hostel (source: IRIDRA; 2013)

2 Objective and motivation of the project

The project has been developed under the EU-India research project **NaWaTech - Natural Water Systems and Treatment Technologies to cope with Water Shortages in Urbanised Areas in India**, funded by the Seventh Framework Programme of the European Commission as well as the Department of Science and Technology (DST, Government of India) for cooperation in water technology and management. One of the activities (WP3) was the design and realisation of several demonstration sites with the aim to test and disseminate sustainable sanitation approaches targeted to the reuse of treated water in an urban context.

The **College of Engineering Pune**, where one of the demonstration sites is located, is one of the most relevant technological institutions in India; the opportunity for dissemination, training and education which this intervention at the college can offer is clearly evident.

3 Location and conditions

Pune is said to be the cultural and educational capital of the state of Maharashtra, with its high number of excellent schools and colleges attracting a great number of Indian students. With almost 5 million inhabitants, Pune demonstrates 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 Maharashtra, in central India; it has a **hot semi-arid climate**, bordering tropical wet and dry conditions, with average temperatures ranging 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: almost all of the 720 mm/year of rain are concentrated in this period.

The college is located in a high density urban area of Pune and can house **up to 2000 people** in several buildings of different types (1, 2 or 3 storey buildings, towers). 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 (11-storeyed). In the college there are many green areas and small gardens as well as a concrete interest in wastewater reuse due to the long dry season and the restrictions on available water for irrigation.

Fig. 4: COEP hostel in Pune (source: IRIDRA; 2014)

4 Project history

The demonstration site at the COEP hostel has been developed under the NaWaTech project, which started in 2012 and is funded by the EC for the European partners and by the DST for the Indian partners. The management of the COEP project has been conducted by the Indian non-profit organisation Ecosan Services Foundation (ESF), Pune, which identified the possibility of the intervention, designed the anaerobic treatment systems and supervised the construction works, and IRIDRA (Italy), which designed the constructed wetland (CW) systems and supported ESF in the project.

The implementation of these activities required the availability of space at an appropriate location within a typical urban or peri-urban environment as well as:

- Relevance with the overall project objectives.
- Adequate space requirements.
- Adequate number of beneficiaries as per DST requirements (4.800 p. e. in the entire project).
- Differentiation between sites: possibility for testing different technologies and configurations.
- Support and approval by local authorities and owners.

Before the intervention, all the wastewater was discharged in the sewer leading to a central wastewater treatment facility under the Pune Municipal Corporation. From there the treated water is discharged into the Mutha River. The college area has plenty of green areas which require irrigation during the dry season; some of these areas could be utilized for the treatments as well.

Plans for the site were 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, allowing the characterization 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 systems, considering the development plans of COEP in the hostel as well. After an accurate topographical survey and several meetings with the management of the hostel facilitated by ESF, certain 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 landscape architects at KRETA to ensure adequate 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 supervisors on the realisation activities. Construction works started in May 2014, after the definition of the main aspects related to the access to the area with the beneficiary. During the monsoon season the works had to discontinued, restarting in October 2014, when a second support mission was undertaken by IRIDRA. In May 2015 all the works were completed and after the necessary tests the treatment system was put into operation in June 2015, the same time when the research plan was initiated.

The realisation of the pilot systems inside the campus constitutes a great opportunity of research and dissemination on the proposed approach, besides guarantying the availability of water for irrigation during the dry season.

5 Technologies applied

The solution initially approved by the NaWaTech consortium during a workshop in February 2013, Nagpur addressed the use of **constructed wetland** technologies, due to several advantages compared to many other technologies, such as the better functioning with oscillating loads, the simplicity in construction and maintenance, or the opportunities for landscaping. The limited spaces turned the initial approach into a more compact system for mixed water reuse, combining an **anaerobic treatment** system with constructed wetland (vertical flow type) as tertiary treatment; greywater will be treated instead completely with a constructed wetland (vertical flow type).

Overall, three different treatment lines were implemented at COEP (see figure 5): The first line (*domestic treatment system/DTS 40*) treats 40 m³/d of domestic wastewater through an anaerobic primary treatment and then discharges the effluent to the sewer line; the second line treats 40 m³/d of greywater through vertical flow constructed wetlands (VF Greywater); the third line (*domestic treatment system/DTS 100*) treats 100 m³/d of domestic wastewater through an anaerobic primary and secondary treatment as well as three vertical flow constructed wetlands (VF1-3) for tertiary treatment.

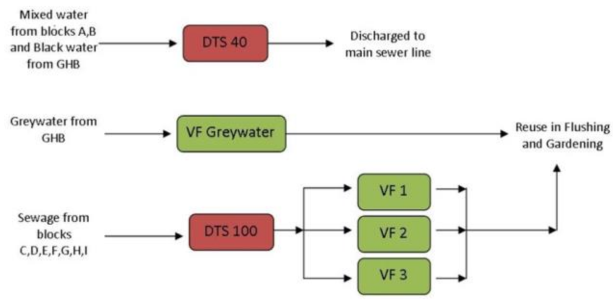

Fig. 5: Flow chart of the reuse system (source: ESF; 2014; GHB = girl's hostel building)

The underlying reason for implementing the **DTS 40 treatment line** was the fact that currently the irrigation demand is lower than the total wastewater production. Due to the limited reuse potential on site 20-25% of the total domestic wastewater is treated solely by anaerobic treatment and subsequently discharged into the sewer. The anaerobic treatment is composed by a **primary settler**, an **anaerobic baffled reactor** followed by an **anaerobic filter**; on the basis of the expected high temperatures across the year, the system should be very effective not only in suspended solid reduction but also in organic degradation (70-80% of BOD_5 is expected).

The **VF Greywater treatment line** treats for reuse purposes 40 m^3/day of greywater produced in the hostel building for girls (at the Eastern side of the Campus), where the segregation from blackwater is possible. The treatment scheme provides a preliminary treatment (degreaser, capacity 10 m^3) followed by **two VF reed beds in parallel with a surface of 133 m^2**; it is possible to alternate the loading cycle and stop temporarily one basin. The treated water will be stored in a tank and reused to flush the toilets in the Eastern side of the campus thanks to a new dual network designed within the project.

The **DTS 100 treatment line** treats 100 m^3/day of wastewater produced in the Western part of the campus, where the segregation of greywater from blackwater was not possible. The treatment scheme provides an **anaerobic primary and secondary treatment**. In order to achieve the quality for reuse, a tertiary treatment, constituted by **three vertical flow (VF) reed beds with a total surface of 405 m^2**, has been provided. The treated water will be pumped towards several tanks on the roofs of the buildings and reused for garden irrigation. The VFs are loaded with 3 independent pumps, ensuring an alternate loading and permitting 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.

The reuse and discharge limits are given by the Environment (Protection) Act, No. 29 of 1986, SCHEDULE VI (Rule 3-A) - General Standards for discharge of environmental pollutants Part-A effluents, as reported in the following table.

Table 1: Reuse limits in India

Main parameter given by national legislation	Public sewer	Land irrigation
	mg/l	mg/l
Oil and grease	20	10
Ammoniacal nitrogen (as N)	50	
BOD5	350	100
Suspended solids	600	200

In case of reuse in toilets (as per greywater), no rules are currently in force in Maharashtra and in India; in any case, it was considered to reach more stringent values for BOD_5 (<10 mg/l). Regarding bacteria and pathogens, a final emergency disinfection system is provided and the real necessity of it will be defined during the monitoring period.

The system will be monitored for 1 year within the NaWaTech project, for which a proper research and monitoring plan has been developed.

Table 2: Research plan

Test	Frequency[#]
Flow rate	Daily
Organic load (BOD and COD)	Once in a week
Ammonia	
TKN	
TSS	
Nitrates	
TDS (only for ATs)	
Coliforms - E.coli, Total coliforms and fecal coliforms	Monthly

In general, the spread of CWs in India is still limited and there is a need to standardise the practices and design methodologies to rough design methods and maintain adequate surface/population equivalent (p.e.) ratios. This would prevent problems such as clogging and poor removal of pollutants. Despite this, the interest in the technology is growing significantly and one of the NaWaTech targets is to educate and train local experts and companies on CW application in urban areas in India.

Surely, the limited space and the high urban density are constraints to the application of CWs in Indian urban areas; however, the segregation of greywater (for which the ratio wetland surface / p.e. is lower), the combination of CWs with anaerobic treatments (quite largely diffused and well known to Indian sanitation experts) and the recourse to **vertical flow systems** (more efficient in terms of required space than horizontal flow systems) could be interesting options.

6 Design information

Preceding the design, a preliminary survey on water consumption (with direct measures) and wastewater quality (by sample analysis) was conducted by ESF. Concerning water consumption a survey on existing facilities (number of toilets, urinals, washing units, laundries, kitchens, etc.) was carried out as well. This permitted to determine the basic design parameters, summarized in the following table.

Table 3: Basic design assumptions for the water quality

	m^3/day	BOD_5 (mg/l)	BOD_5 (gr/d)
Total WW	**175**	**279**	**48815**
Left side WW	99	287	28263
Right side GW	42	150	4763
Right side WW	35	457	15790

The design methodology for anaerobic treatments and CWs considered international literature indications and accepted guidelines of several countries.

Table 4: Basic design assumptions for the anaerobic treatments

Anaerobic Settler	100 cum	40 cum
Width (m)	6	4
Lenght (m)	4.25	3.25
Water level (m)	2.20	2.20
Volume (m3)	56	28.6
Anaerobic baffled reactor	100 cum	40 cum
Width (m)	5	4
Lenght (m)	9	5.48
Water level (m)	2.1	2.1
Volume (m3)	94.5	46
Anaerobic filter	100 cum	40 cum
Width (m)	5	4
Lenght (m)	4	3.9
Water level (m)	2.05	2.05
Volume (m3)	41	31.98
Total treatment volume (m3)	191.5	106.58
HRT (days)	1,915	2.66

For the dimensioning of the VFs German guidelines (ATV) were considered, as well as using oxygen balance as verification method, assuming oxygen transfer rates from literature. The main design parameters for CWs are reported in the following table:

Table 5: Basic design assumptions for the CW treatment

VFs	WW	GW
P.E.	1054	1315
Daily flow (m^3/day)	100	42
AT and pre-treatment removal	0.75	0.25
Total surface VF (m^2)	405	133
COD loading rate (grCOD/m^2 per day)	29	39
Hydraulic loading rate (l/m^2 per day)	252	325
Expected outlet BOD_5 concentration (mg/l)	14	9
Expected outlet SST concentration (mg/l)	15	15

The flush volume of each loading cycle is 270-330 litres, corresponding to a loading rate of 2-2.5 cm and enough to ensure a rest period of 1.5-1.9 h during the dry season. During the wet season, the system can be stopped or, in case of greywater treatment, slightly loaded regulating the pumping time and discharging the overflow in the sewer, due to the fact that irrigation demand is zero; this can help the systems to maintain a good hydraulic conductivity for a long period and to avoid complications during heavy rainfall (however the system can drain them without any problem and a freeboard of 30 cm avoids flooding issues).

Anaerobic treatments were realised on site by reinforced concrete and brick masonry for internal baffles, coating the walls with epoxy paint to improve the resistance of the concrete with regards 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. The VFs were obtained excavating the soil and waterproofing the basins with EPDM liner, which is available on the Indian market and easy to weld on site. The basins are filled up to a total height of 0.85 m with gravel and sand: 15 cm coarse gravel, 10 cm medium gravel 12 mm, 50 cm sand 0.2-5mm, 10 cm medium gravel 12 mm (from bottom to top).

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

- to limit odours and mosquitoes, the distribution pipes are laid under a thin gravel layer avoiding any exposure of water;
- for improved landscaping and to reduce the excavation volumes, the basins are partially over ground, surrounded by a brick wall that can also constitute a sitting arrangement 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.

Particular attention was given to the substrate material selection, particularly the sand layer, both in the design phase in order to guarantee the high hydraulic loading rates, and in the realisation phase in order to verify the quality of the material: the supervisor was trained in on-site verification tests as well as 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 are easily available in the local market.

Fig. 6: Renderings of the CW for wastewater reuse in COEP hostel (source: IRIDRA; 2013)

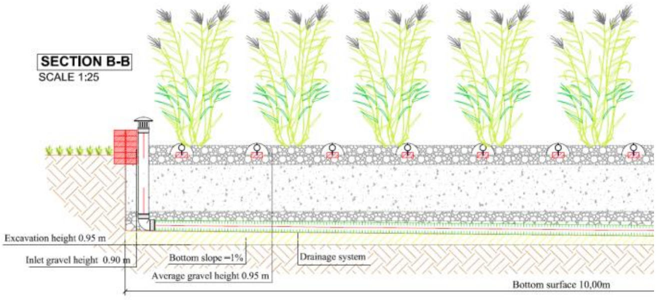

Fig. 7: Typical section of VFs in COEP hostel (source: IRIDRA; 2013)

Fig. 8: VF basins for greywater treatment during start-up in COEP hostel (source: ESF; 2015)

Fig. 9: Anaerobic treatment in COEP hostel (source: ESF; 2015)

7 Type and level of reuse

The system will permit to reuse approximately $65 m^3$/day for toilet flushing and 70 m^3/day for garden irrigation, taking into account the evapotranspiration rate of the wetlands.

Reuse for toilets will take place across the whole year, whereas the reuse for irrigation is concentred in the dry season, approximately between November and May.

8 Further project components

The system will be monitored during the NaWaTech project, as well as operational and maintenance activities and training of the personnel for future management. Several activities taking place in “Community or Practice” events will be focused on this treatment system. Furthermore, the social impact on the hostel inhabitants of the treatment and the water reuse practice will be investigated.

Depending on the results of the project and the irrigation demand, in the future a tertiary treatment of the smaller anaerobic treatment system could be considered.

It has to be noted that in another site in Pune, i.e. the MJP head office (Water Supply and Sanitation Department of Maharashtra), ESF and IRIDRA implemented a pilot demonstrative project, constituted by a **green wall adapted to treat and reuse greywater**. Initially, its installation was discussed for inside the hostel, however, the new site was selected in order to increase the dissemination and the impact of the project across different actors. Green walls are relatively diffused in newly established, modern Pune settlements, construction materials are easily available and they can constitute an opportunity to treat polluted water, saving space and combining water quality with the improvement of aesthetic and bio-climatic features of the buildings.

Two parallel pilot green walls with different filling media were developed and monitored: (i) LECA plus sand, (ii) LECA plus coconut fibres. The first monitoring results are satisfactorily (52% and 58% of COD and N-NH4+ average removal efficiencies) and allow to guarantee the standard for restricted water reuse (complete disinfection cannot be guaranteed for unrestricted reuse). The technology could be a further interesting application to be applied additionally in the COEP hostel in order to increase the capacity of the system using vertical surfaces.

Fig. 10: Green wall pilot at the entrance of MJP office in Pune (source: ESF; 2014)

9 Costs and economics

The **total investment** for the work is **160.000,00 EUR**, completely funded by the DST.

The **power consumption** for VF loading is max 12 KWh/d, i.e. about 4000 KWh/y considering that during the monsoon period the system will be less used. Assuming an average power cost of 0.08 EUR/KWh in the state of Maharashtra, the yearly electricity costs add up to approx. **300 EUR/year**. Almost the same price can be estimated for the dual system network. Other operational costs are mainly related to the periodical sludge extraction and disposal from the anaerobic treatments; other maintenance activities can be conducted by unskilled labour, i.e. the personnel of the campus.

The **estimated cost of reused water** is about **0.2-0.25 EUR/m^3**, in line with the current potable water network rate of 0.23 EUR/m^3. It has to be noted that during the dry season the use of potable water for irrigation is frequently restricted.

10 Operation and maintenance

Among other things, the selection of the technology was based on the need of implementing systems which are easy to operate and maintain: anaerobic treatments and constructed wetlands can be operated by unskilled labour if properly trained on the functioning of the plant. The whole system can function by gravity, except the small pumps for VF loading that are automatically controlled by a simple electrical panel. There is no need of any chemicals for the process and no parameters have to be controlled during operation, except the periodical analysis on the inlet and outlet to evaluate the performance of the system and the quality of the outlet water.

Despite the overall simplicity, some maintenance activities have to be carried out periodically, such as the maintenance of the pumps, the extraction of sludge and scums from the anaerobic baffled reactor and from the degreaser, the cut of the plants once per year or the periodical check of inlet distribution and outlet drainage systems.

During the NaWaTech project IRIDRA ensured the training and the knowledge transfer to ESF staff, who will follow the start-up and the research plan as well as the operation and maintenance of the plant, for the 1st year. An O&M manual and a safety plan were prepared, with the necessary instructions for the management of the plant and for trouble shooting. During the first year ESF will train the personnel of COEP who will later on be responsible for the management of the system.

The system will be used to meet the irrigation demand – therefore, during the monsoon period only the anaerobic treatments will be in operation, leaving the 3 VF basins rested or alternatively operated in order to recover best possibly the hydraulic conductivity of the filters. The same strategy can be applied to the greywater VF treatment as well, divided into 2 sectors, considering that the demand during the wet season is about 50% less for toilet reuse. This is possible with CWs due to the brief time of reactivation of the process, which occurs naturally without any additional operation in 1-2 weeks.

11 Practical experience and lessons learnt

The design and the bidding phase were not associated with relevant complications; the client accepted the proposal given the necessary support to develop it. The acceptance was further facilitated by the presence of the NaWaTech project and thanks to several educational activities performed in collaboration with the college. Nevertheless, some important lessons were learnt. Generally, it is useful to spend enough time to specify in advance the exact location of the works, in order to avoid any possible delay in the construction processes due to permissions (e.g. for cutting trees).

An international expert on CWs is still recommended considering the low level of knowledge about this new technology for India; however, the presence of a local partner is fundamental in order to adapt the technical project to the local standards, to enquire offers from suppliers, to obtain the several approval documents from the authorities and to prepare the bid under Indian regulations.

With regards to scheduling work activities and in the definition of deadlines, the monsoon season has to be taken in account: from July to the end of September it can be very difficult to perform several activities, especially excavation works, basin waterproofing and concrete works. At the COEP campus, the works had to pause completely during the monsoon days without the envisioned completion of the basin waterproofing and the main concrete works in the time allocated.

Moreover, sufficient time should be spent on initial investigations regarding the presence of underground networks and exact geological conditions. The college furnished some maps during the design phase and a survey of the existing manholes was carried out in order to determine the location of pipelines and other existing networks. Being an old property, the site maps with regards to utilities did not have a very high accuracy. For instance, a main water pipeline was discovered during the excavation works of one of the anaerobic treatment units. Therefore, the design of the unit was modified to adapt to the situation, causing some delay in the work progress. The realisation of proper geotechnical tests needs to be taken into account as well: the geological report evidenced the presence of soft rocks in the first soil horizons and the realisation of wetland basins, with an excavation height of no more than 1 m, didn't create any problems. At deeper levels, however, hard rocks were found encountered during the 5 m excavations works for the anaerobic treatment; this created some disturbance to the residents during the crushing works, as well as a slower advancement of the work than initially predicted.

The training of both the work supervisor as well as the contractor responsible on the main topics of the project and on the work site organization is of key importance. For such projects, it is vital to ensure that the contracting firm appointed has considerable experience in civil works and not just plug and play type sanitation projects. It should also be noted that manual labour is common in India for civil constructions in most cases. This can have a negative impact on the speed of execution. For these reasons, stringent contracts are suggested, to cover for delays and performance issues.

12 Sustainability assessment and long-term impacts

A basic assessment (table 6) was carried out to indicate in which of the five sustainability criteria for sanitation (according to the SuSanA Vision Document 1) this project has its strengths and which aspects were not emphasised (weaknesses).

Table 6: Qualitative indication of sustainability of system. A cross in the respective column shows assessment of the relative sustainability of project (+ means: strong point of project; o means: average strength for this aspect and – means: no emphasis on this aspect for this project).

	collection and transport			Treatment			transport and reuse		
Sustainability criteria:	+	o	-	+	o	-	+	o	-
• health and hygiene		X			X			X	
• environmental and natural resources	X			X			X		
• technology and operation		X		X			X		
• finance and economics		X			X			X	
• socio-cultural and institutional	X			X			X		

Sustainability criteria for sanitation:

Health and hygiene include the risk of exposure to pathogens and hazardous substances and improvement of livelihood achieved by the application of a certain sanitation system.

Environment and natural resources involve the resources needed in the project as well as the degree of recycling and reuse practiced and the effects of these.

Technology and operation relate to the functionality and ease of constructing, operating and monitoring the entire system as well as its robustness and adaptability to existing systems.

Financial and economic issues include the capacity of households and communities to cover the costs for sanitation as well as the benefit, such as from fertiliser and the external impact on the economy.

Socio-cultural and institutional aspects refer to the socio-cultural acceptance and appropriateness of the system, perceptions, gender issues and compliance with legal and institutional frameworks.

For details on these criteria, please see www.susana.org: the SuSanA Vision document "Towards more sustainable solutions" (www.susana.org).

With regards to the long-term impacts of the project, the main expected impacts of the project are:

- **improve sanitation in Indian urban area**; even in case a sewer is present, vast amounts of sewage are still often collected by open channels (which poor people still utilise for irrigation and washing purposes) and reach the river body without any treatment; the local reuse of treated water further has the effect of decreasing the organic load in the final disposal system;
- **improve wastewater reuse, greywater segregation and dual networks**; due to the high urban density and the increasing water consumption a sustainable use of the superficial and underground water resources is currently limited and often in an advanced grade of pollution;

- **monitoring** of the overall efficiency of the system for one year, with particular regards on operation and maintenance activities;
- adaptation and "**indianization**" of sustainable sanitation technologies (as CWs) to different Indian conditions;
- **educational activities and dissemination of natural and low-tech treatment systems**;
- improve **decentralized sanitation approaches**

The assessment of the real impacts of the project will be included in the final documents at the end of the NaWaTech project, expected at the end of 2015 for the EU consortium and at the end of 2016 for the Indian consortium.

13 Available documents and references

www.nawatech.net

NaWaKit, a Knowledge Platform for Water Practitioners in India,
http://www.sswm.info/category/step-nawatech/introduction

- *Barreto Dillon, L., Doyle, L., Langergraber, G., Satish, S. & Pophali, G. 2013. Compendium of Natural Water Systems & Treatment Technologies to cope with Water Shortages in Urbanised Areas in India (2013): (Editors). Berlin : epubli GmbH – available on www.nawatech.net*
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- *Masi F., Rizzo A., Bresciani R. 2015. Green architecture and water reuse: examples from different countries. Sustainable Sanitation Practice 23: 4–10*

14 Institutions, organisations and contact persons

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