sustainable sanitation alliance

Case study of sustainable sanitation projects

Wastewater Treatment and Reuse at the Ordnance Factory Ambajhari, Nagpur, Maharashtra, India

Fig. 1: Project location

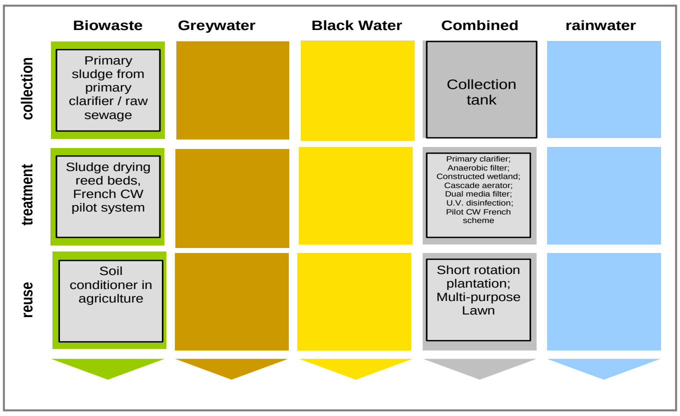


Fig. 2: Applied sanitation components in this project

1 General data

Type of project:
The NaWaTech project aims to optimise the use of different urban water flows by treating each of these flows via modular natural systems appropriated to urban and peri-urban areas of India.
The system considered in this case study is located in the Ordnance Factory Ambajhari (OFAJ), Gov. of India, Nagpur, and Maharashtra, India. It provides sewage management for at least 1,000 population equivalent (p.e.). It consists of a main treatment line (anaerobic pre-treatment and horizontal flow constructed wetland (HF-CW) as well as a sludge drying reed bed for sludge mineralisation generated from the primary clarifier) and a pilot line with a French type constructed wetland system and a short rotation plantation (SRP). It provides water for a multipurpose lawn to prevent the use of fresh water in gardening.

Project period:
Start of construction: September 2014
End of construction: November 2015 (estimated)
Start of operation: December 2015 (estimated)
Ongoing monitoring period planned for: Seven months
Project end: June 2016

Project scale:
Number of people covered: 1,000 p.e.
Water flow: 100 m^3/d
Total investment (in EUR): 94,900 € for capital and O&M for one year

Address of project location:
Ordnance Factory Ambajhari (OFAJ), Gov. of India, Ministry of Defence, Nagpur, Maharashtra 440014, India

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

Executing institution:
National Environmental Engineering Research Institute (NEERI, Nagpur)

Supporting agenciesy:
Department of Science and Technology (DST), Government of India; Ordnance Factory Ambajhari (OFAJ), Nagpur Govt. of India; European Commission (7th Framework Programme).

2 Objective and motivation of the project

The Ordinance Factory Ambajhari (OFAJ) estate holds residential quarters for the staff and employees of the factory. Currently, the untreated sewage is directed towards the wastewater treatment plant, which was commissioned in the 1960's, and the treated water is then discharged into the nearby stream. However, treated wastewater generated in such government staff colonies could also be reused in order to reduce the fresh water consumption on site. Currently fresh water is being used at OFAJ for maintaining the multiple gardens, orchards and sport complexes within the estate.

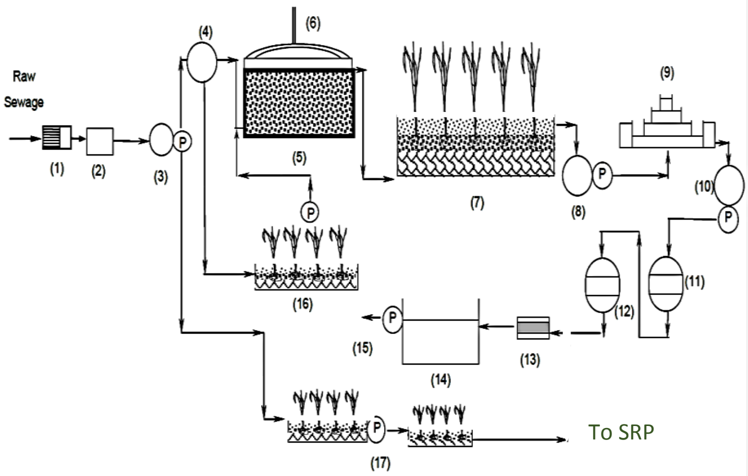
The aim of the project is to reuse treated wastewater that will result in the reduction of freshwater consumption. The solution proposed was to establish an engineered natural treatment system. Ordnance factories are located in different parts of the country. The successful implementation of reuse of treated wastewater may result in further replication of such systems at other ordnance factories across the country.

3 Location and conditions

The system has been implemented in the estate of OFAJ located in Nagpur, Maharashtra. The local conditions include the following:

- Tropical wet and dry climate with dry conditions prevailing for most of the year. The annual rainfall of 1,205 mm stems mainly from the monsoon rains during June to September. The average annual high and low temperatures lie at 34 °C and 20 °C, respectively.
- Entire system can serve 250 households (i.e.1,000 p.e.).
- Users of the system are people living in the residential colony of the factory as well as users of the sports complexes.
- Currently drinking water supply is used for gardening, with the average water requirement being 100 m^3/d.
- OFAJ is the responsible authority for the system, collaborating closely with the executing institution NEERI. Furthermore, the NEERI team involves additional, relevant stakeholders during the development of the site in order to increase awareness and acceptance.

Wastewater Treatment and Reuse at the Ordnance Factory Ambajhari, Nagpur, Maharashtra, India



1)	Screen chamber	10)	Effluent collection tank
2)	Oil & grease trap	11)	Dual media (pressure) filters
3)	Raw sewage sump	12)	Activated carbon columns
4)	Primary clarifier	13)	UV disinfection
5)	Upflow attached growth anaerobic filter	14)	Treated effluent collection tank
6)	Bio-gas vent and collection	15)	Pumping & piping for treated effluent reuse
7)	Subsurface flow constructed wetland	16)	Sludge drying reed beds
8)	Holding tank	17)	French reed beds – 1st & 2nd stage; P – Pumps
9)	Cascade aeration		

Fig. 3: Scheme of the overall treatment system *(source: NEERI, 2014)*

4 Project history

The NaWaTech project is 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. The consortium is composed by European and Indian entities (universities, research centres, non-profit organisations and small and medium-sized enterprises). Up to now the consortium developed the following activities with respect to the different case study sites, of which the Ordnance Factory site is one:

- Site selection and characterization
- Design, drawing and landscaping
- Cost estimation
- Involvement of stakeholders
- Sustainability assessment (including social aspects)
- Safety planning (including mechanisms against thefts)
- Construction and commissioning
- Onsite research and operation and maintenance (O&M)

5 Technologies applied

The entire system is designed for 1000 p.e. in order to supply 100 m^3 of water to be reused for the multi-purpose lawn and orchards.

The **main treatment system** as shown in figure 3 consists of a bar screen chamber, oil and grease trap, inlet sump, primary clarifier, improved up-flow anaerobic filter followed by subsurface horizontal flow constructed wetland, cascade aerator, dual media and activated carbon columns and finally UV disinfection. The settled sludge from the primary clarifier (4) will be treated in sludge drying reed beds (16), permitting the final reuse of the sludge as soil conditioner and avoiding any external disposal. The improved anaerobic filter (5) ensures substantial removal of organic matter, wherein a specially designed filter media, so-called “pall rings” are used for microbial growth.

The filter media consists of poly propylene (PP) or high density poly ethylene (HDPE) material and offers 125 - 150 m^2/m^3 specific surface area. The anaerobic reactor is filled with a filter media of 80% of the total volume. Provision is made for a biogas collection system, which is proposed to be utilised as fuel. Treated effluents from the anaerobic filter (5) are fed by gravity into two parallel sub-surface horizontal flow (HF) constructed wetlands planted with *Typha latifolia* and *Canna indica* with a density of 4 plants/m^2 (7). Horizontal flow constructed wetlands ensure the removal of remaining organics and nutrient reduction. Thereafter, treated wastewater is pumped to the cascade aerator (9) to infuse dissolved oxygen and enhance the quality of effluent.
The aerated wastewater is subsequently conveyed for tertiary treatment comprised of a dual media filter (11) followed by granular activated carbon column (12) for removal of colloidal solids and non-biodegradable organics & pharmaceutical and personal care products (PPCPs), respectively. Disinfection through UV (13) 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 HF constructed wetland is 24 hours. The anaerobic filter consists of two tanks with the size of each tank being 4.5 x 4.5 x 2.5 m. Filter media of cylindrical shape with size of 37.5 – 50 mm and specific surface area of 150 m^2/m^3 are provided. The size of the two wetland beds is 12.5 x 5 x 0.8 m each, each equipped with filter media ranging from 2 mm – 60 mm. The expected performance of the improved treatment system indicates that treated effluent with less than 5 mg/L BOD and TSS as well as < 10 mg/L COD will be obtained.

Another pilot line for the treatment of 3 – 8 m^3 wastewater is implemented. This includes a two-stage constructed wetland constituted by French reed bed (FRB) with a 21 m^2 net area divided into 3 sectors + subsurface vertical flow (VF) 15 m^2 in combination with a short rotation plantation.

This pilot aims to demonstrate the applicability of the so called “French scheme” in the Indian context. This treatment scheme can offer several advantages such as the minimum possible area footprint for passive natural treatments (1-2 m^2/person) or the absence of primary sedimentation, i.e. no production of primary sludge by septic tanks or similar tools (as generally the case in “classic” CW configurations); the raw wastewater upstream of the primary clarifier is fed directly into the 1st stage bed, only following a screen chamber (1) and an oil and grease trap (2). 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 each 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. Sludge volumes are typically much smaller than in the case of activated sludge, or classic CWs. Moreover, the sludge looks like a compost or a stable humus and does not emit any

odour. Their operation is therefore relatively accessible for trained but non-specialized local staff, resulting in low costs.
The sludge is suitable as soil conditioner on agricultural land because it improves the soil structure and can also provide nutrients. Due to dewatering, decomposition and compaction processes, the volume of the final sludge is reduced by nearly 90% if compared to an Imhoff's fresh extracted sludge (cf. http://ecompendium.sswm.info/sanitation-technologies/imhoff-tank?group_code=t). Furthermore, the quality of the treated water, by the fact that the process is based on filtration, is remarkably reliable as not subject to sporadic loss of sludge. The French CW system also appears to be well adapted to the sociological context of the communities: the agricultural background, present in the majority of the leaders of rural communities, corresponds to the know-how necessary to properly operate the system. For the same reasons, their operation is generally easy understood. This treatment system corresponds, furthermore, to "neo rural" decision makers with an aspiration to "return to nature", to establish an "ecological way of life" compatible with sustainable development, as well as in terms of energy consumption and materials used (LIENARD 2010).

The SRP was installed first, in order to allow the plants to accommodate before the irrigation with wastewater starts. The size of the SRP was adapted considering the potential evapotranspiration (PET). 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*. Domestic wastewater pre-treated in the French type CW 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.

6 Design information

The design was carried out taking into account water flow/requirements; influent quality (especially BOD) and necessary effluent quality (see table 1), as well as available surface area, arriving at the described treatment scheme.

The preliminary treatment consists of oil & grease and fats removal to prevent damage to the system. The secondary treatment is comprised of up-flow attached growth anaerobic filters, which are ideal for low organic loading and are associated with the following advantages: less area footprint, low hydraulic retention time compared to suspended growth process, no odour and fly nuisance, less prone to process failures and provision of better removal efficiencies as compared to suspended growth processes (CPHEEO 2013). The subsurface HF constructed wetlands are best suited for removal of remaining organics and nutrients. The tertiary treatment is constituted of pressure sand filter, activated carbon column and UV treatment, which ensure the removal of colloidal particles, residual non-biodegradable organic matter and pathogens to generate reusable water.

The technical characteristics are as follows:

- Proposed quantity of wastewater to be treated: 100 m^3/d.
- Type of treatment system (main treatment system): anaerobic treatment system, CW system and UV disinfection.
- Quality of treated water: comply with State and Central Regulatory Discharge Norms for reuse in land applications.

Among the major advantages of the treatment system are the low operation & maintenance costs, low energy needs, possible management with unskilled manpower and the high efficiency in removing primary, secondary and tertiary pollutants. Out of the total water supply of 135 litres per capita per day 47% of water is required for gardening and flushing, hence it is envisaged to bring down fresh water supply from 135 to 90 litres per capita per day, which would save nearly 33% of fresh water supply.

Table 1: Influent quality parameters and discharge standards of the Central Pollution Control Board (CPCB)

Sr. No.	Major parameters	Raw sewage	Proposed treated effluent quality	Discharge standards for inland surface water
1.	pH	6.5 – 7.2	6.8 – 7.2	5.5 – 9.0
2.	BOD	100 –150	<30	30
3.	COD	170 -260	50 – 60	250
4.	Suspended solids	150- 250	20 – 30	100
5.	Oil & grease	26 – 30	<10	10

7 Type and level of reuse

Currently, freshwater is being used for irrigating the gardens. However, due to depletion of groundwater level, water is not available for irrigation during February to June.
Thanks to the system implementation, the multipurpose lawn, orchards and gardens will be irrigated daily with 100 m^3/d of treated and safe water.

8 Further project components

The aim of the project is to treat the wastewater before reusing it, in order to improve environmental conditions (saving of resources) as well as workers' safety and health. The solution proposed was a natural treatment technology, integrated into the existing landscape. Such solution can then be replicated at other similar sites, which would be in the interest of the stakeholders (four site replications are currently being discussed).

Moreover, the monitoring and subsequent data analysis on the French pilot system may facilitate further implementations and the spread of this interesting CW configuration, never applied in India, suitable for peri-urban and rural areas, thanks to its high simplicity of realisation and operation, the low investment and maintenance cost, as well as the possibility to recover nutrients from the sludge reuse.

9 Costs and economics

The project is co-funded by the DST, Gov. of India as well as the European Commission. After taking over of the treatment plant, OFAJ will be responsible for operation and maintenance costs.

Table 2: Capital and maintenance costs (as of Sep 2014)

**1 € =75 Rupees*	**Cost in Euros €***
Capital costs	88,500.00
Maintenance works for one year	6,400.00
Total	94,900.00

Regarding potential savings due to saving of freshwater resources the cost economics under existing conditions indicate that the present cost of fresh water is approx. €33/d per 100 m^3 and costs incurred for generating non-potable recyclable water for 100 m^3 is €14/d. Therefore, the net saving in respect to using recycled water would be €33/d – €14/d = €19/d. This would ensure savings of €19/d x 365 = €6,935 per annum from a 100 m^3/d capacity decentralised wastewater treatment plant.

10 Operation and maintenance

The NaWaTech consortium developed frameworks for appropriate operation and maintenance (O&M). O&M guidelines were developed by identifying and assessing potential hazards per unit that could lead to poor functioning of wastewater treatment systems. The risk for these hazards was estimated and respective corrective and preventive measures as well as maintenance protocols were developed for various unit operations.

According to these, the treatment system shall initially be maintained by NaWaTech partner NEERI, through third party outsourcing and later on it will be handed over to OFAJ management. OFAJ is planning to maintain mango and orange orchards and develop green belts with the *Melia dubia* and *Bambusa* plants using the recycled water.

11 Practical experience and lessons learnt

Following the implementation of this case study, the following lessons can be derived:

- A detailed feasibility study in the beginning (e.g. considering geotechnical aspects or prevailing wastewater properties) can be very helpful, especially in case different alternatives are considered (less risk of having to change the design at implementation stage).
- Information about soil properties (geological strata) is important, e.g. via ground-penetrating radar (GPR) studies (at the site unexpected layers of hard rock were encountered during construction, which delayed the process).
- Landscape planning should also be considered from the start, in order to fit the system better into the surrounding environment.
- For site selection the invitation to a “expression of interests” from potential institutions where a site could be implemented can be a useful tool (easier subsequent implementation process as only institutions with high interest in these treatment systems are selected).The selection of the contractor is a critical factor, training/capacity building of the contractor (e.g. regarding technical features, advantages of the new system, supply chain management, etc.) is necessary as implemented systems are not well known.
- Yet, stringent contracts with selected contractors reduce the risk of delays in the construction process.
- In this regard, one needs to be aware of the Indian tendering system: process of bidding, the contractor with the lowest costs wins, whereas ranking on technical capacity just gets the contractor into the final round → not necessarily the contractor with the best technical experiences wins the bid.
- Availability of construction materials needs to be considered (should ideally all be available locally, search can be time-consuming)
- The timing of the planting of the trees for the SRP needs to be carefully planned: if it is done too early (i.e. long before other components are finalized), freshwater needs to be used for their irrigation.

Following this case study, the dissemination/replication of similar wastewater treatment and reuse facilities should be easier, learning from these experiences.

12 Sustainability assessment and long-term impacts

A basic assessment (table 3) 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 3: 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).

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

- Manual on Sewerage & Sewage Treatment Systems 2013. 3rd edn – Revised and Updated, Central Public Health and Environmental Engineering Organisation, Ministry of Urban Development, Government of India.
- Pophali, G. R. 2013. Emerging Trends of Sewage Management in India. National Seminar on Emerging Trends in Sewerage & Sewage Treatment. October 25-26 2013, Indian Water Works Association (IWWA), Mumbai, 1-5.

14 Institutions, organisations and contact persons

Case study of NaWaTech project

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