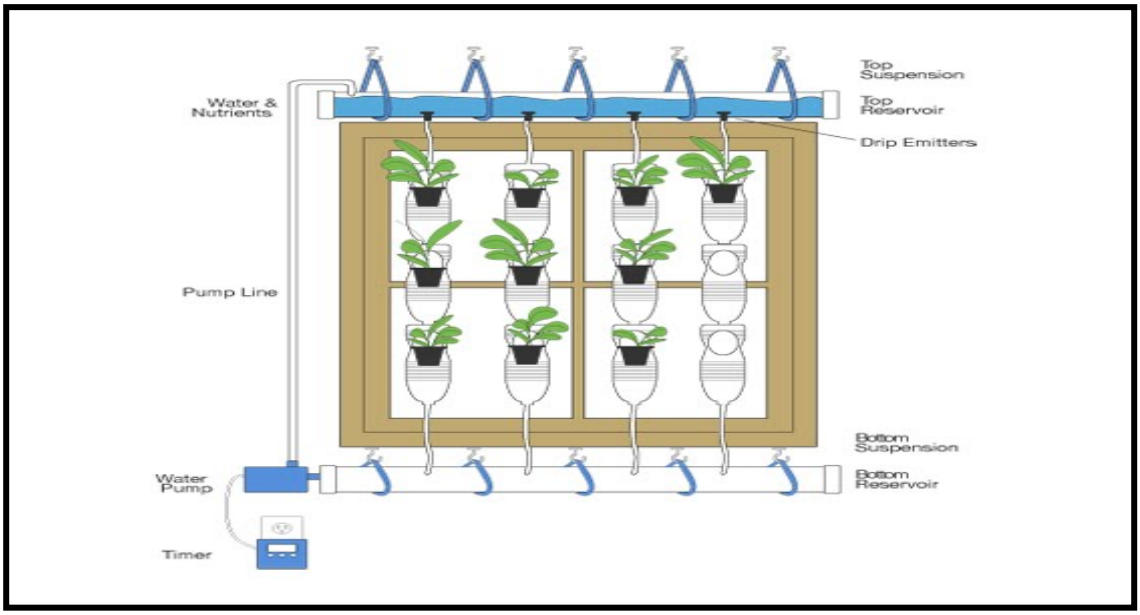
Vertical Garden for Greywater Treatment
Technical Note for Urbanised Areas in India

Technology description

The vertical garden or plant wall, green wall, bio wall is a light framed, mostly self–supporting plant community where the necessary water, light and liquid plant nutrients are provided by a highly automatized system. The system is based on the principles of hydroponics where the plants are rooted in a porous material soaked in fertilizer instead of soil. Adapting its construction to improve the filtration capacity, a vertical garden can be used for greywater treatment as well, permitting to reuse the treated water.



Key design criteria: • Required area: 2m²/p.e. of vertical surface • Allowed inflow:< 150 mg BOD/L (lightly polluted) • Capacity: (as a range) 0,5 -30 m^3/d	**This technology allows to provide:** • Secondary treatment to greywater • Tertiary treatment only to greywater **This technology needs to be combined with:** • Primary treatments: degreaser, pre-filter before drip-line irrigation system
Implementation considerations: • Land requirement: very low • Capital cost: low • Maintenance burden: low	**Application and management level in the urban context:** • Home • Neighbourhood • Peri-urban areas
Pollutant removal (%) TSS: 80-90 % Organic (BOD): 80- 90 % Ammonia: 30-50 % Pathogens (FC): 90 %	**Effluent suitable for:** • Wastewater reuse: gardening, non-potable uses at home (WC) • River discharge • Soil discharge

Design criteria for the Indian context

1.Suitability of the technology in urbanised areas in India

There are very few applications in the world with treatment purposes; even with these experiences being successful and interesting, it is currently difficult to specify precise application levels, as well as to list precise guidelines both in India and

in other parts of the world. Their application is therefore limited to experimental and demonstrative applications, with the aim of optimizing the technique, the design and the construction principles.

Surely this technique can be very interesting and promising in Indian urban areas, where available spaces are limited, i.e. on buildings in densely populated urban areas, especially because it could permit in parallel an architectural requalification of these. In this way, the application level should be for lightly polluted water (greywater from sinks and showers), for a limited number of people (up to approximately 300 p.e.) and for decentralized usage. Vertical walls are beginning to be used in Indian architecture in new towns; therefore, their application to treat greywater can be seen as an additional function of the green wall concept for slightly polluted greywater from sinks and showers. These systems don't need any control of the process parameters and don't require power consumption (except for the pumping of the greywater if needed). Ordinary maintenance is easy and permits to ensure an adequate life-span of the system.

The main strengths are: no energy consumption, no chemicals usage, easy and cheap operation and maintenance, the possibility to reuse greywater, the landscaping opportunities, the positive thermal protection on the building, and extremely low footprint/usage of land. The main weakness seem to be the relatively high cost (however, the adoption of a green wall for greywater treatment is very cheap if compared to other treatment methods), the still low level of experience, the absence of large scale interventions in India, and the worldwide very limited diffusion; research and demonstrative pilot systems could help to overcome this phase.

The main advantage related to this scheme is the recovery of unused space (all the walls of buildings that are not containing windows for instance) with a simultaneous on-site treatment and reuse of about 60-70% of the domestic wastewater, specifically the greywater, and thus a reduction of the wastewater amount discharged into the sewers and treated elsewhere. The green walls can also provide positive effects for the micro-climate of the houses by their insulation capacity (i.e. some savings for cooling the houses by air conditioning) and can clearly increase the urban biodiversity and esthetical aspects. Large vegetated surfaces could also increase the CO_2 sequestration and the release of oxygen in the urban air. All these aspects are making this idea really appealing for Indian cities with a high density of population and lots of concrete buildings with available surfaces for the purpose.

2. Treatment performance expected under Indian conditions

A pilot system was recently developed in Belgium (Rousseau & Baumer, 2013), with a hydraulic loading rate of 35 L/ m^2 of vertical wall (2 m^2/p.e.); the unit shows removals of 96% for COD, 91% for N, 67% of P, 97% of foam, whereas the disinfection is limited to 2 logs. The loading often happens on two panels in series.

The performance measured in the first pilot systems seems to indicate a good efficiency in COD and SS removal, comparable to vertical filtration systems. These removal efficiencies should guarantee the respect of the limits for the reuse of treated greywater; therefore, feeding the vertical garden with greywater allows both to avoid the irrigation adopted in typical architectural solutions and to reuse the treated greywater exceeding the plant evapotraspiration requirements.

Monsoons don't constitute an issue; considering the vertical installation the surplus received water is very low even with the extreme rainfalls due to the very limited horizontal surface; of course the structure that contains the pots and the anchorage to the walls have to be strong enough to resist to extreme climatic events.

3. Pre-treatment and post-treatment required considering typical Indian domestic influents and effluents

Greywater has to be pre-treated (degreaser and a pre-filter are suggested to avoid obstruction of the drip irrigation system and of the vertical filters). The technology can very well be adapted to slightly polluted greywater coming from showers, sinks, etc.; in case of greywater from kitchen, higher attention should be given to pre-treatment, providing the possibility to separate fat and oils that could clog the little pots, equipping the degreaser with coalescing filters or lamella clarifiers. Greywater from kitchen could increase significantly the organic and solids concentration, and in this case the real effectiveness of the green wall greywater treatment technology should be tested better before large application.

Post-treatments are not required. In some applications, instead, green walls can be used as tertiary treatment (i.e. after a degreaser and another kind of filtration system).

4. Construction materials and equipment availability in Indian urban areas

The design of vertical gardens depends on the available material, space and local preferences; from very simple designs like tray models similar to nursery flats, where rectangular, plastic trays are divided into planting cells — all slanted at a 30-

degree angle, with bottom holes that promote drainage and aeration. Each tray comes with a bracket for mounting. A more complex way to realise green walls is the usage of stainless metal frames covered with a 10 mm-thick humidity-proof plastic panel filled by a special, rot-free, absorbent synthetic felt mounted in layers. This felt serves as the pockets for planting. The entire width of the structure is 4-20 cm, with the larger measure adopted for greywater treatments. A green wall used to treat greywater should avoid the leakage of the water from the pots whatever structure is used, therefore plastic waterproofed pots should be preferred or otherwise the structure must have a waterproofing plastic layer in contact with the existing wall. The selection of the plants is a technical criterion of utmost importance because it determines the texture, the colour-combination, shape variety and life span of the wall and in case of treatment the removal efficiency as well.

The inlet system includes a water-tank from where the water is pumped and an automatized drip irrigation system, or a similar pressure loading structure, in order to distribute the water into the several pots; the loading can take place by gravity as well in case the source of greywater source is located at 1-2 m above the vertical wall (in this case a valve or a siphon that permits to regulate flushing and resting periods could be used instead of a pump). Treated water is usually collected by gravity at the bottom of the green wall by small open channels.

The selection of the filtration material is very important to obtain good performance; the percolation time should be tested in order to not have a too rapid flushing inside the pots with the risk of biofilm washing and to increase the start-up of the system. Leca 0-2 mm seems an affordable choice in order to use a low weight material suitable for the vertical structure; in some cases, especially when the pots are very small, short-circuits could happen inside and the use of an additional thin layer of finer material (such as sand 1-2 mm) can improve the hydraulic behaviour and consequently the efficiency. The size of the pots still needs to be investigated, in order to find the best solution to optimize the water distribution and the greywater treatment efficiencies.

The pilot system realised in Pune is constituted only by material provided locally in the Maharashtra state, and all the needed construction material was available with affordable costs. Green walls are provided generally with very common electromechanical and hydraulic equipment that are easily available on the local market, therefore spare parts don't seem to constitute an issue.

5. Sizing, site constrain and landscaping considerations

The main site constrains are related to sunlight exposure, and this aspect is mainly linked to the choice of plants species. The realisation of green walls for greywater treatment is in fact a recovery of unused surfaces (i.e. parts of walls without windows), with a minimal footprint, and it can be an occasion for providing esthetical benefits and increasing the urban green, in addition to some positive insulation and microclimatic effects (the water evaporation in hot seasons will slightly decrease the temperature of the wall where the system is put up).

6. Self-help compatibility for design and construction in Indian cities

There are already several construction companies and vendors of green walls; the use of green walls for greywater treatment, however, is an innovation that has to be tested and optimized also on the basis of local material availability and the local technologies used for classic green walls. The pilot system realised in Pune is constituted only by materials provided locally in Maharashtra; the only limitation seems to be the very limited horizontal surface of each pot, which requires a precise functioning of the distribution system to avoid clogging when the organic and solid content is higher.

Currently the design phase has to take into account the available material, adapting the design and the construction strategies to them; with the progressive experience collected on this application and the diffusion of this practices, it cannot be excluded that some companies specialized in green walls could offer a specific product for greywater treatment in their catalogue as well, especially adapting the pots and the grids to minimize clogging issues.

In general, the design has to include not only drawings, bill of quantities and technical specification, but also an operational program (adapted to the real case and not a standard one), a trouble-shooting section and the ordinary and extraordinary maintenance activities. The design also needs to consider the safety of the entire construction, for instance leakage/spillage occurring during the set-up of the green wall could have an impact on the walls of the building. The construction materials should have as little as possible weight but guarantee to resist extreme climatic events (such as

during the monsoon seasons). In case the main goal of the system is the treated greywater reuse, proper solutions should be adopted to limit as much as possible the evapotranspiration rate (e.g. white instead of black pots to limit the evapotranspiration during the start-up phase).

Moreover, the construction timeline needs to account the monsoon season, in which construction works often are not feasible.

Stringent contracts are suggested, to cover for delays and performance issues. The selection and the training of the contractor is another possibly critical issue in India, due to the lack of competence on the construction of nature-based systems; in this case a company expert in green wall realisation, together with a training before the start of the construction is highly suggested.

Costs and maintenance

Range of Population Equivalent (p.e.)	Up to 100-300 p.e.
Expected life span (years)	20 – 30 years
Range of implementation costs (Rs./p.e.) in India (investment and construction costs)	Difficult to assess, no experiences worldwide; probably about 30.000-40.000 RS/p.e including the green wall
Maintenance and operation costs from Maharashtra experiences (Rs./p.e.year)	Difficult to assess, no experience; probably about 160-240 RS/p.e per year
Total treated water costs (Rs./p.e.year) related to Indian context (including operation costs)	1600-2400 RS/p.e. including the green wall It has to be considered that the green wall provides multiple service besides greywater treatment, i.e. aesthetical improvement of concrete surfaces, increase of urban biodiversity, thermal insulation of the building, improvement of urban air through CO_2 sequestration; if a green wall is already provided, the conversion of it into a greywater treatment could be very cheap
Required construction staffs and skills	The technology is still at an experimental stage; green walls are however already diffused in some of the most important Indian cities, even if not aimed to treat wastewater.
Required operation and maintenance staffs and skills	Low level of skilling for O&M
Energy requirements (kW/PE)	Minimum input of energy required; eventually only to pump the greywater for the loading of the several pots.

Authors: Riccardo Bresciani and Fabio Masi

Organisation: Iridra S.r.l.

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