RESOURCE RECYCLING
SERIES:RERES/6/2002-2003


GUIDELINES ON CONSTRUCTION, OPERATION AND APPLICATION OF ROOTZONE TREATMENT SYSTEMS FOR THE TREATMENT OF MUNICIPAL AND INDUSTRIAL WASTEWATER


CENTRAL POLLUTION CONTROL BOARD
MINISTRY OF ENVIRONMENT & FORESTS
e-mail : cpcb@alpha.nic.in Website : www.cpcb.nic.in

July, 2003

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

RESOURCE RECYCLING SERIES :
RERES/ 06 /2003 – 2004

Guidelines on Construction, Operation and Application of Rootzone Treatment Systems for the Treatment of Municipal and Industrial Wastewater

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

cpcb

CENTRAL POLLUTION CONTROL BOARD
(Ministry of Environment & Forests, Govt. of India)
Parivesh Bhawan, East Arjun Nagar
Delhi – 110 032
e-mail : cpcb@alpha.nic.in Website : www.cpcb.delhi.nic.in

CPCB 200 Copies, 2003

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

Published By : Dr. B. Sengupta, Member Secretary, Central Pollution Control Board, Delhi - 32
Project Coordination : Dr. S.K. Nigam
Printing Supervision & Layout : P.K. Mahendru and Satish Kumar
Composing & Laser Typesetting : Mohd. Javed
Printed at : NISCAIR Press, National Institute of Science Communication And Information Resources Dr K..S. Krishnan Marg, (CSIR), New Delhi-110 012

Constitution of Committee for Development of Guidelines on Construction, Operation and Application of Rootzone Treatment Systems

Chairman, CPCB vide order No. B-29021/1/97/IMP-III dated 05.05.1999 constituted a Committee for Development of Guidelines on Construction, Operation and Application of Rootzone Treatment Systems (RZTS). The committee consists of the following Members & Experts:

List of Members:

1. Dr. K.R. Ranganathan	**Chairman**
2. Dr. B. Sengupta, Member Secretary, CPCB	Member
3. Dr. S.P. Chakrabarti, Ex. Member Secretary, CPCB	Member
4. Shri P.M. Ansari, Addl. Director, CPCB	Member
5. Dr. R.C. Trivedi, Sr. Scientist, CPCB	Member
6. Mr. J. Biener, Env. Expert, GTZ (CPCB)	Member
7. Dr. S.K. Nigam, Scientist 'C'	**Member Convenor**

List of Expert Members:

1. Mr. Aurofilio Schiavina and Mr. Harald Kraft, Kraft Associates, Pondicherry/Berlin
2. Dr. Joachim Niklas, Ökotec GmbH, Consultant GTZ (CPCB)
3. Prof. (Dr.) J.P. Narain, Director Centre for Environmental Studies, Anna University, Chennai
4. Mr. F. Schindler, GTZ (Centre for Environmental Studies, Anna University, Chennai)
5. Mr. K.V. Emanuel, National Expert - Unido Project, Chennai
6. Mr. Surjeet Singh, Waste Management Division, Thermax Ltd., Pune
7. Mr. Sirajuddin Ahmed, Project Co-ordinator Civil Engineering Dept., Jamia Milia University., New Delhi
8. Prof. (Dr). Sultan Ismail, Director, Institute of Research in Soil Biology & Biotechnology, Chennai
9. Mr. Tency Baetens, Executive, CSR, Auroville
10. Mr. Tom Burkitt, (representing Prof. L. Gill), **oceansesu**, Bradford (U.K.)
11. Dr. V.K. Kapoor, Project-Incharge (Water), NSIT, New Delhi

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

"DISCLAIMER"

Application of these guidelines is open to everyone. However, an obligation for application may arise from legal or administrative regulations, in which case the responsibility for correct application lies with the user. This applies, in particular in the choice of the application rates and design parameters described in these guidelines. The guidelines should only be understood as 'guidelines' and not as a manual and are an important but not the only source of information for correct application.

DILIP BISWAS
Chairman, CPCB

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

दिलीप विश्वास
अध्यक्ष

DILIP BISWAS
Chairman

केन्द्रीय प्रदूषण नियंत्रण बोर्ड
(भारत सरकार का संगठन)
पर्यावरण और वन मंत्रालय

Central Pollution Control Board
(A Govt. of India Organisation)
Ministry of Environment & Forests
Phones : 2204948

FOREWORD

Rootzone Treatment Systems (RZTS) use natural processes to effectively treat domestic & industrial effluents. This technology was developed during the seventies in Germany and since then spread out all over the world. The process incorporates the self-regulating dynamics of a specially designed soil eco-system. RZTS are by now well known in temperate climates and are easy to operate on-site treatment facilities, which involve less installation, maintenance and operational costs than the conventional treatment methods. Also RZTS offer cost effective options for decentralization of wastewater treatment.

The term Rootzone encompasses the interactions of various species of bacteria, fungi and other microorganisms, the roots of wetland plants (helophytes), filter bed media, sun and, of course, water. The helophytes conduct oxygen through their stems into their root systems and create favourable conditions for the growth of aerobic microorganisms. Since the process occurs in a deep filter bed, aerobic and anaerobic zones exist side by side. The wastewater enters the root zone horizontally or vertically and it passes through the system where the organic pollutants are decomposed biochemically by the microorganisms present in the rhizosphere of the helophytes. The filter bed media are selected or mixed carefully to provide favourable conditions for both plants and bacterial growth and to ensure optimum hydraulic load.

To investigate the efficiency of Rootzone Treatment Systems in warm climates, a pilot project in collaboration with the German Technical Co-operation (GTZ) has been set up at Mother Dairy, Delhi to treat the dairy wastewater. On the basis of data collected from the Mother Dairy project as well as from other plants in India and abroad, Guidelines for Construction, Use, Operation & Maintenance were elaborated by a Committee set up for this purpose under the Chairmanship of Dr. K.R. Ranganathan. The contributions of the members and experts of this Committee and the support by the management and the staff of Mother Dairy are gratefully acknowledged. We hope, this document will be useful for municipalities, panchayats, individual house owners and industries. However, this document presents the present state of knowledge of application of RZTS in tropical climate and it will be updated periodically with growing experience and availability of a larger database in India.

(DILIP BISWAS)

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

CONTENTS

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

1.0 OBJECTIVE

The objective of the guideline is to facilitate the utilization of the "Rootzone Treatment Systems" (RZTS) for the treatment of wastewater from various sources containing biodegradable compounds. Relevant principles for planning, design and operation of the main types of RZTS based on the experience with RZTS in India and abroad are detailed. RZTS are important elements for decentralized wastewater treatment and water recycling. Thus the guidelines intend to promote the introduction of cost-effective and integrated systems for wastewater treatment, alternative water supply and water conservation. Further development of this technology should be encouraged, not only for domestic, but also for wider industrial application.

2.0 SCOPE

These guidelines contain the principles and design parameter required for dimensioning, construction and operation of Horizontal and Vertical RZTS systems, also known as Constructed Wetlands with Subsurface Flow. Performance and the requirements for achieving it, field of application and the limitations are described. However, the guidelines do not include all the details required for the construction of RZTS, as already a large variety of partly proprietary solutions exist for meeting the given requirements.

Permanently flooded systems and special applications like sludge treatment or removal of specific nutrients as well as description or assessment of proprietary modifications and devices do not fall within the scope of these guidelines.

3.0 DEFINITION

RZTS are sealed filter beds consisting of a sand / gravel / soil system, occasionally with a cohesive element, planted with vegetation which can grow in wetlands. After removal of coarse and floating material the wastewater passes through the filter bed where biodegradation of the wastewater takes place.

The different types of Rootzone Systems can be differentiated according to the following criteria:

- Filter bed media: Origin, composition, grain size distribution, hydraulic properties
- Flow direction: Horizontal, vertical or hybrid forms
- Operation: Continuous or intermittent feeding
- Planting: Mono- or mixed cultures, single or multiple zone planting

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

Position within the treatment sequence:	As single or multilevel biological treatment stage (with or without pretreatment), as polishing stage after conventional treatment

A classification scheme for wastewater treatment systems and the basic design of horizontal and vertical RZTS are depicted in Figures 1 and 2.

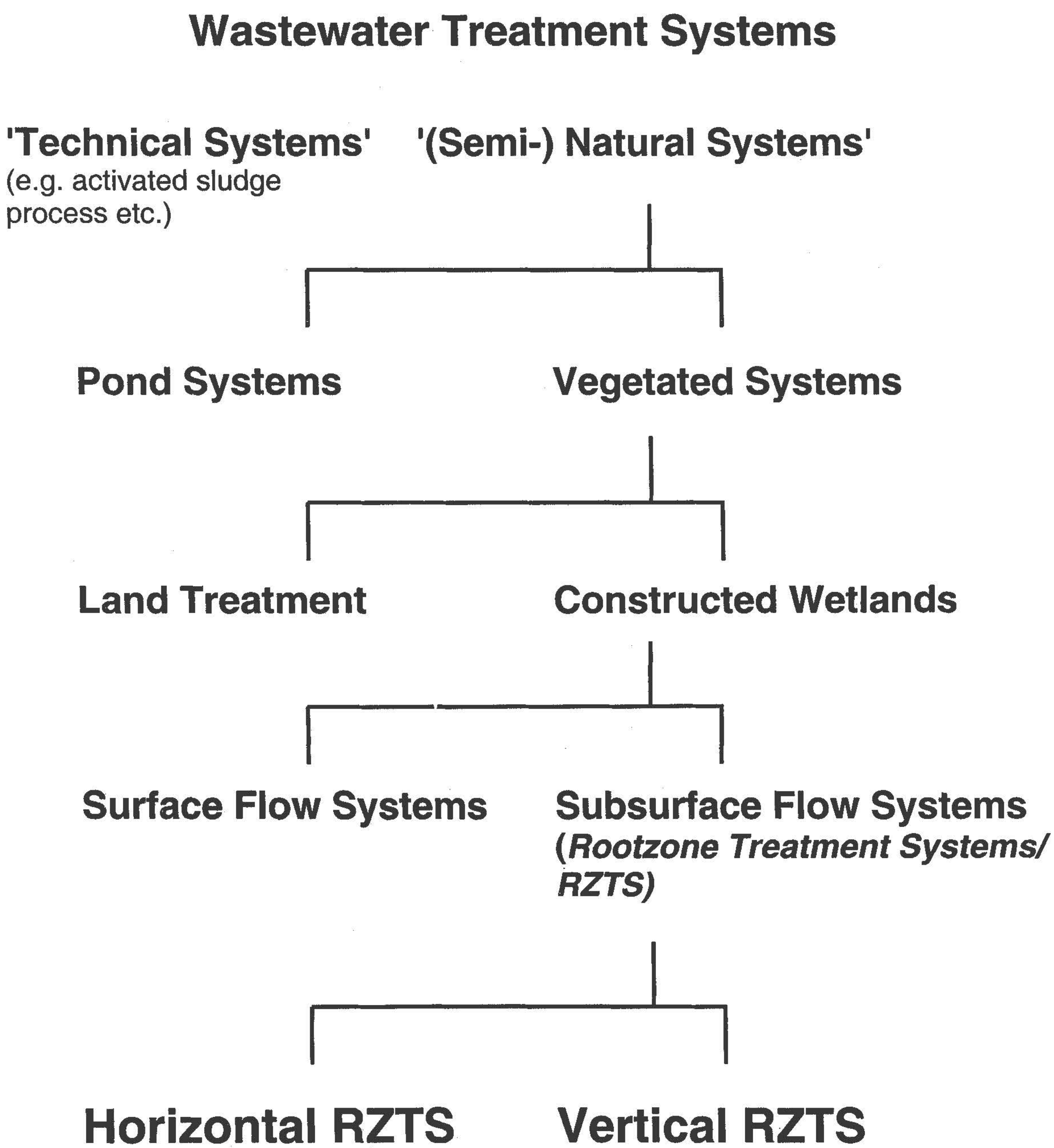
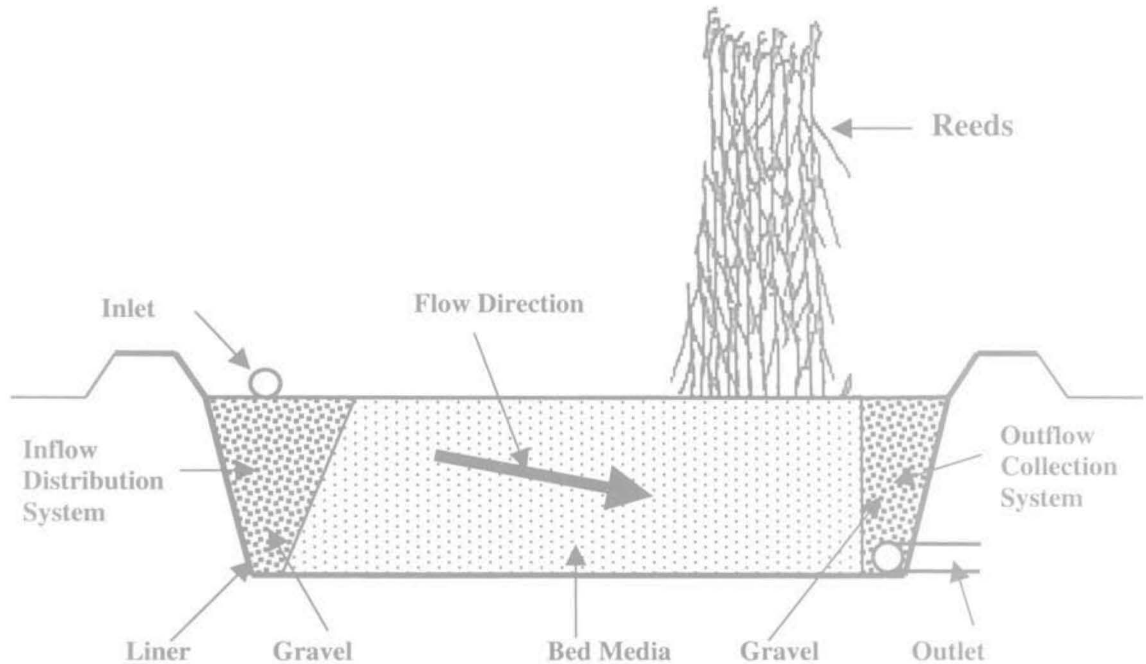


Fig.1: Classification scheme for wastewater treatment systems

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

A) Horizontal Flow System



B) Vertical Flow System

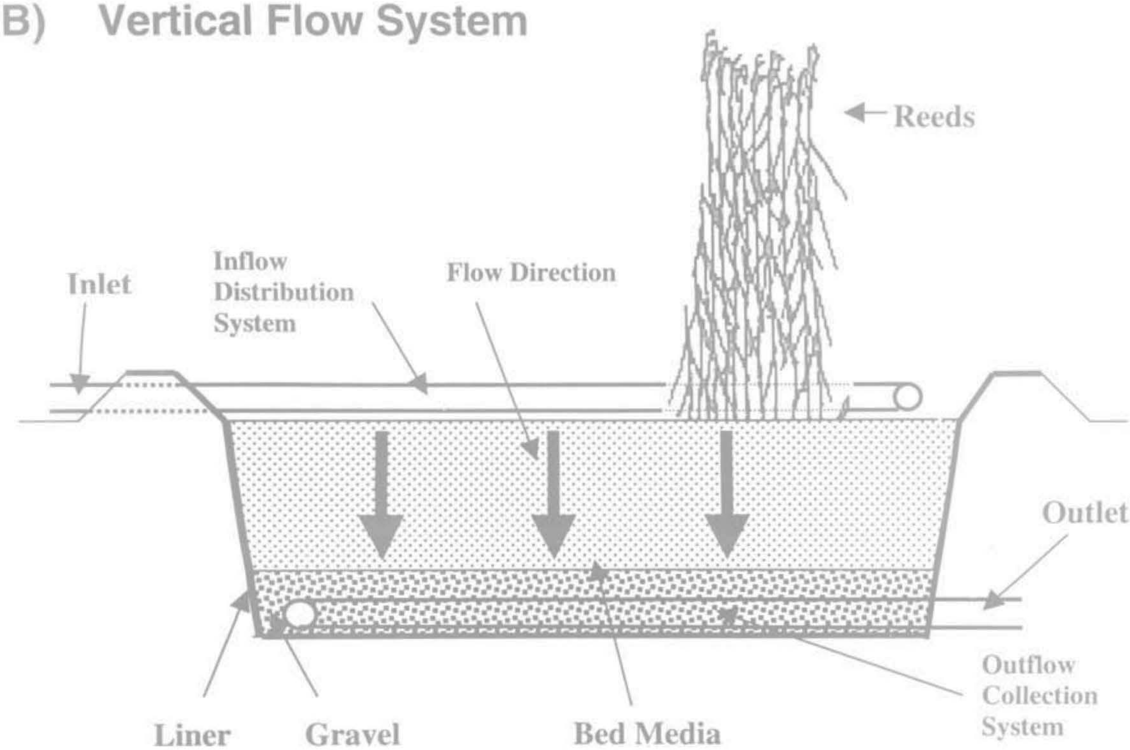


Fig.2: Conceptual diagrams of Rootzone Treatment Systems

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

4.0 TREATMENT MECHANISM

4.1 The functional mechanisms in the soil matrix that are responsible for the mineralisation of biodegradable matter are characterized by complex physical, chemical and biological processes, which result from the combined effects of the filter bed material, wetland plants, micro-organisms and wastewater.

4.2 The treatment processes are based essentially on the activity of microorganisms present in the soil. Smaller the grain size of the filter material and consequently larger the internal surface of the filter bed higher would be the content of microorganisms. Therefore the efficiency should be higher with finer bed material. This process, however is limited by the hydraulic properties of the filter bed; finer the bed material, lower the hydraulic load and higher the clogging tendency. The optimization of the filter material in terms of hydraulic load and biodegradation intensity is therefore the most important factor in designing RZTS.

4.3 The oxygen for microbial mineralisation of organic substances is supplied through the roots of the plants, atmospheric diffusion and in case of intermittent wastewater feeding through suction into the soil by the outflowing wastewater. The roots of the plants intensify the process of biodegradation also by creating an environment in the rhizosphere, which enhances the efficiency of microorganisms and reduces the tendency of clogging of the pores of the bed material caused by an increase of biomass.

4.4 RZTS contain aerobic, anoxic and anaerobic zones. This, together with the effects of the rhizosphere causes the presence of a large number of different strains of microorganisms and consequently a large variety of biochemical pathways are formed. This explains the high efficacy of biodegradation of substances that are difficult to treat.

4.5 The filtration by percolation through the bed material is the reason for the very efficient reduction of pathogens, depending on the size of grain of the bed material and thickness of filter, thus making the treated effluent suitable for reuse.

4.6 Conversion of nitrogen compounds (Nitrification / Denitrification) occurs due to planned flow of wastewater through anaerobic and aerobic zones.

4.7 Reduction of phosphorous depends on the availability of acceptors like iron compounds and the redox potential in the soil.

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

5.0 POTENTIAL AREAS OF APPLICATION

5.1 Types of wastewater

5.1.1 Domestic and industrial wastewater containing biodegradable matter is treatable with RZTS after sedimentation of particulate matter.

5.1.2 Wastewater containing not easily biodegradable substances can be treated in RZTS by appropriate operation of the plant (e.g. prolonging the residence time of the wastewater or changing the conditions in the filter bed between aerobic and anaerobic environment). Stormwater can also be treated as well with RZTS after removal of settleable substances.

5.1.3 RZTS have to be planned and designed in such a way that they comply with the environmental stipulations, standards and criteria, laid down by the concerned regulatory agencies.

5.2 Unit size range of RZTS

RZT Systems are very suitable for treatment of small quantities of wastewater (minimum 250 g BOD per day), since a homogeneous flow of wastewater through small RZTS can easily be maintained and complicated inflow distribution systems are not needed. For sewage treatment, up to 50 kg BOD per day is considered as a maximum quantity of effluent to be treated in one plant. In case of larger RZTS more complex wastewater inflow distribution systems have to be applied.

5.3 Decentralization of wastewater treatment

The fact that the construction of small RZTS is easy makes it suitable for on-site treatment of domestic sewage avoiding long sewerage lines. Even treatment of the wastewater of a single house is possible. Thus small plots become usable for wastewater treatment, especially in situations where it is not possible to have a connection to a central wastewater plant such as hotels and tourist complexes, which are sited away from cities. In case of dispersed settlements, RZTS offer a feasible solution for decentralized sewage treatment after adequate pretreatment.

5.4 Position within the treatment sequence

The potential design variations of RZTS offer the possibility to use them in the main treatment and in the polishing stage of the wastewater treatment sequence. Therefore RZTS can also be combined with high-tech and low-tech treatment systems. The filter media has to be designed accordingly.

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

5.5 Removal of pathogenic organisms

The high degree of removal of pathogens, including coliforms, protozoans and helminthes (see 4.5) makes RZTS a feasible option for recycling of wastewater, especially in decentralized treatment systems. The treated effluent from properly designed RZTS can be used safely for gardening within domestic premises, toilet flushing, aquaculture, recharging groundwater etc. The use of treated industrial wastewater depends on the type of industry and the specific type of wastewater.

5.6 Industrial wastewater

For industrial wastewater the location and wastewater specific consideration have to be taken into account.

5.7 Limitations

5.7.1 RZTS are based on filtration mechanism, therefore, they are sensitive against clogging. Higher concentrations of settleable matter, oil and grease, especially mineral oil in the wastewater higher the tendency to surface clogging as well as internal clogging. Overloading of RZTS with organic matter can also cause clogging due to increased growth of bacteria within the filter matrix. These problems can be avoided by appropriate pretreatment of wastewater, design of the filter bed and proper operation of the system.

5.7.2 RZTS are limited regarding the hydraulic loading, which depends on the design and quality of the filter material. This limitation has to be considered especially in case of irregular flow and in case of treatment of stormwater or polishing of already treated effluents.

5.7.3 Heavy Metals from wastewater can accumulate in the RZTS depending on type of wastewater, bed material and species of plants. Heavy Metal containing wastewater should therefore be pretreated according to effluent limits given by the regulatory agencies.

5.7.4 In very hot and dry climate the evaporation in RZTS can be so high that the wastewater is concentrated substantially. RZTS with smaller specific surface, for example vertical systems have to be used in cases where increase of TDS is undesirable.

5.7.5 In case of wastewater containing toxic substances the same precautions are required as in other biological treatment systems (specific pretreatment).

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

6.0 PLANNING AND CONSTRUCTION OF RZTS

6.1 Site selection

6.1.1 A distance of 5 to 20 m from the next residential building in case of domestic sewage is recommended, depending on the type of pretreatment, the size of the RZTS and the type of feeding of the plant beds. However in case of industrial effluents site-specific separation from residential areas is required. If properly designed and built, RZTS do not create any odour or nuisance in the vicinity. The location is to be selected in such a manner that drinking water sources are not impaired. The site must be safe from flooding.

6.1.2 The RZTS should be protected from unauthorized access. It must be possible to dispose of the treated effluent at the selected site as per standards set by the concerned regulatory agency. The following precautions shall be taken:

(a) RZTS have to be marked clearly as wastewater treatment systems.

(b) The site should be accessible for maintenance.

(c) Natural slope should be used, to avoid the need for pumps.

6.1.4 The application of RZTS and the design depends also on the availability of suitable filling material for the filter beds. It is recommended to use locally available filter material to reduce the construction cost.

6.2 Pretreatment

6.2.1 RZTS require wastewater with low concentration of settleable and floating solids. Insufficient pretreatment can cause surface clogging in vertical systems and clogging in the infiltration area in horizontal systems. Sand settling devices, grease traps, gratings and sieves have to be used according to the characteristics of the raw wastewater. Industrial effluents have to be characterized fully before deciding upon adequacy and type of pretreatment.

6.2.2. In principle all proven pretreatment systems can be combined with RZTS. The following anaerobic pretreatment systems are especially suitable for small RZTS dealing with domestic sewage:

- Multi-Compartment Septic Tank
- Imhoff Tank
- Baffle Reactor
- Biofilm Up-flow Reactor

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

6.2.3 In special cases the use of composting devices can be considered.

6.2.4 If space is limited the use of trickling filters or other aerobic installations may become necessary in order to reduce the organic load of the wastewater.

6.2.5 Industrial wastewater has to be assessed for the specific requirements of physico-chemical pretreatment.

6.2.6 Specially designed Vertical RZTS can be used for pretreatment.

6.2.7 Suitable measures should be taken for the disposal of primary sludge.

6.3 Filter media

6.3.1 The filter media effective for the biological treatment must consist of sand / gravel, a carefully mixed soil or a comparable media. The design of the correct filter media according to the available material is the most important step in the design process. If the material is too coarse the wastewater will flow too fast; if it is too fine clogging and overflow will occur. Both cases cause poor treatment efficiency.

6.3.2 A remarkable reduction in permeability by deposition, sedimentation and bacterial growth has to be considered. High temperature as in tropical regions will influence this effect significantly.

6.3.3 Sand and gravel with rounded grains are ideal. Large and sharp edged particles can lead to damage of the liner. Media of relatively similar grain size, like river sand or sieved materials are best. The following filter bed parameter should be met:

- Permeability (k_f) : $\approx 10^{-4}$ - 10^{-3} m/s for of domestic effluents, $\approx 10^{-6}$ - 10^{-3} m/s for industrial effluents.
- Uniformity coefficient (U) : $d_{60} / d_{10} = \leq 5$; (ratio of grain sizes which contain 60% and 10% of the total weight)
- Effective grain size (d_{10}) : should be ≥ 0.2 mm
- Content of silt or bonded admixtures : should be $\leq 5\%$ (if at all)

The grain size distribution is to be verified using soil analysis and a percolation test has to be performed before incorporation of the material in the beds.

The permeability of the media can be calculated by the following formula (after Hazen):

- $k_{f\,[m/s]} = (d_{10})^2 :/ 100$; [$d_{10}$ in mm]

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

This gives a rough estimate; a safety factor of at least 5 should be chosen. In case of suitable locally available material of lower permeability the hydraulic and organic loading has to be adjusted accordingly.

Rounded gravel / pebbles should be chosen, if available, for the infiltration area in horizontal RZTS and for the drainage area in both systems.

6.3.4 Depth of filter bed:

The recommended depth of the filter media is:

- For horizontal filters : 50 - 100 cm
- For vertical filters : 60 - 120 cm

If a horizontal system is used, increasing the depth upto more than one meter is not useful, because of the limited root growth of the plants which is the only oxygenating factor. In vertical systems an increase in depth of more than 120 cm will enhance the treatment efficiency further, but this is normally limited due to increased cost of filter material.

6.4 Slope of filter bed

6.4.1 Both horizontal and vertical beds should have an even and flat surface to avoid the development of channels and pools and allow for evenly flooding in vertical systems. It also helps in horizontal systems to flood the surface at certain times to suppress weed growth.

6.4.2 Horizontal filter beds should have a defined infiltration area. This can be achieved by a reverse slope on the first part of the bed or a small earth wall transverse to the main flow direction at the end of the infiltration area. This helps also to keep sudden inflow peaks in the infiltration area.

6.4.3 A slope on the base of the filter bed is normally not required. In special cases the bottom can have a slope up to 3%.

6.5 Sealing of filter bed

6.5 1 RZTS have to be sealed with an impermeable layer at the bottom and the sides so that untreated or partly treated wastewater cannot infiltrate to the groundwater. Sealing is also required to recover the treated water for reuse and for compliance monitoring as per requirements of the regulatory agency. If the existing soil has a permeability coefficient $<10^{-8}$ m/s, no artificial sealing layer is necessary for sewage treatment applications. In this case a density test (after Procter) has to be performed. For industrial application, it is important to consider lining the system in all cases in order to prevent infiltration into the groundwater.

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

6.5.2 RZTS in soil with higher permeability require sealing of the bottom and sides. This can be achieved by:

- Using concrete or plastic tank
- Providing plastic liner, UV resistant, if exposed to the sun, thickness ≥ 1 mm, root resistant, preferably from polyethylene or equivalent material. The liner has to be protected against damages caused by rocks of the existing soil and by sharp edged gravel of the drainage layer. Geotextiles may be used for prevention of such damages.
- Providing clay sealing with a verified thickness of ≥ 30 cm. It has to be compacted properly.
- Improvement of existing soil by admixture of bentonite or very fine clay (two layers of 20 cm each, mixed and compacted separately).

After finishing the sealing a leakage test should be carried out by filling the bed with water. If the loss is less than 2mm overnight, the sealing is to be considered as satisfactory.

6.6 Dimensioning of the filter beds

6.6.1 For dimensioning RZTS for domestic wastewater the following inflow characteristics have to be considered:

- BOD, settled, 27 ^{0}C, 3 days, in grams /day
- Quantity of wastewater, in litres /day

The BOD criteria (organic loading) ranges for dimensioning are:

- For horizontal flow 10 - 30 g/BOD/m^2/day
- For vertical flow 20 - 40 g/BOD/m^2/day

For industrial effluents specific recommendation according to type of industry are required. Future revisions of these guidelines will incorporate such recommendations.

Parts near the lateral sides and the infiltration and drainage areas may not be included in the surface calculations.

6.6.2 The hydraulic load criteria range for dimensioning are:

- For horizontal flow 40 - 100 L / m^2 / day
- For vertical flow 50 - 130 L / m^2 / day

If the percolation is tested for the determination of the percolation cross-section and the bed geometry in case of Horizontal RZTS, a k_f - value reduced by a power of 10 should be applied. Hydraulic verification is indispensable.

Hydraulic calculations are carried out according to the law of DARCY:

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

$$Q = k_f \times i \times F$$

Q	$[m^3 / s]$	Flow
k_f	$[m / s]$	Permeability
i	$[m / m]$	Hydraulic gradient
F	$[m^2]$	Effective cross section

The effective hydraulic load is highly dependent upon the characteristics of the bed media as well as the characteristics of the effluent. Therefore, these figures should be treated as indicative only.

6.6.3 In case of combined systems or application of multi layer filter media, a verification of the applicability is to be provided.

6.6.4 The climatic conditions of the location have to be taken into consideration for dimensioning RZTS. Considering the kinetics of enzymatic reactions, in tropical climate a higher efficiency of RZTS can be expected.

6.7 Construction details

6.7.1 A freeboard of at least 20 cm (distance from bed surface to the upper edge of the lateral sealing) is to be provided.

6.7.2 There should be free access to all operational points, like manholes, pumping stations, maintenance locations and sampling points. The access has to be constructed in a way, that crossing of the filter bed is avoided.

6.7.3 RZTS should be designed in such a way that they are integrated into landscape as much as possible.

6.7.4 Protective measures against the undesired water inflow are indispensable such as bunding all around.

6.8 Inlet - and outlet constructions

6.8.1 Inlet structures must be so constructed that they distribute the incoming wastewater uniformly over the surface of the bed in case of Vertical RZTS, or across the infiltration cross-section in case of Horizontal RZTS, without leading to the formation of erosion furrows on the bed surface or to siltation or clogging of the filter media. Verification is to be carried out to prove the correct function of the inflow structures. The infiltration area has to be so calculated that overflow at normal operation is excluded. Hydraulic calculation of the infiltration section / area have to be done with a safety of one order of magnitude.

6.8.2 In horizontal filter beds the structures for distribution and collection of wastewater have to be designed and constructed in such a way that an even percolation of the whole bed matrix is achieved without short-circuiting.

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

Typical inlet structures are based on gravity flow (weir constructions, leveled pipe outlets, dispersion systems through gravel layers) or on fluid dynamics (location and size of pipe orifices).

6.8.3 In vertical filter beds the distribution devices have to be designed and constructed for intermittent wastewater application and even feeding of the total bed surface. After each application the pipes of the inflow construction should run empty. This prevents bacterial growth and resulting clogging problems. Typical inlet structures see 6.8.2

6.8.4 The outflow construction should have provision for adjusting the water level between the bottom of the bed and 10 cm above the surface of the bed.

6.8.5 The construction of in- and outflow devices must allow for cleaning with mechanical or high pressure flushing tools.

6.8.6 Outlet construction must allow for water sampling and examining as per the requirements of the concerned regulatory agencies.

6.9 Plantation

6.9.1 Selection of species

With the available experience the following list of species can be given:

Phragmites australis (reed)
Phragmites karka (reed)
Arundo donax (mediteranean reed)
Typha latifolia (cattail)
Typha angustifolia (cattail)
Juncus (bulrush)
Iris pseudacorus
Schoenoplectus lacustris (bulrush)

For horizontal RZTS in principle all helophytes can be used, which are deep-rooted and oxygenate the rhizosphere through the roots. For vertical systems the plant selection is less critical, because the oxygen input is enhanced by the intermittent surface application.

6.9.2 Planting Techniques

Planting of reeds can be done in the following way:

- Reeds can be planted as rhizomes, seedlings or planted clumps.
- Clumps can be planted during all seasons. (2 / m^2)
- Rhizomes grow best when planted in Pre-Monsoon. (4 - 6 / m^2)
- Seedlings should be planted in Pre-Monsoon (3 - 5 / m^2)

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

Planting should be done from supporting boards to avoid compaction of the filter media. Initially the plants should be kept well watered, but not flooded. With well-developed shoots, the growth of weeds can be suppressed by periodical flooding. During the first growth period a sufficient supply of nutrients is required. If wastewater is used for initial watering precautions like avoidance of stagnation have to be taken to inhibit the formation of H_2S within the filter bed.

7.0 OPERATION AND MAINTENANCE

7.1 Basic considerations

7.1.1 Duration and degree of reduced treatment efficiency during the start-up period have to be stated in the technical report, which is part of the approval process (No Objection Certificate). The operation of RZTS is expected to stabilize after 4 - 6 months after the plants are fully grown. A warranty for the planned function during the different seasons has to be provided by the supplier of the RZTS.

7.1.2 RZTS require, servicing and maintenance. It is recommended to have a maintenance contract for functional control, system maintenance and care of the plants.

7.1.3 Like other wastewater treatment plants RZTS need a comprehensive operation and maintenance manual for the operator, which covers all operational situations.

7.2 Operation Manual

The operation manual has to cover - among other things - the following subjects:

- The type of wastewater application (continuous or intermittent flow) and the continuous or parallel operation of different filter beds.
- Limits of organic and hydraulic loading
- Advice for the start-up phase
- Common problems & remedies
- Measures against unplanned overflow of the filter bed.
- Measures against growth of weeds (see 5.9.2)
- Measures to keep RZTS in stand-by condition for seasonal operation (e.g. hotels with seasonal operation).
- Necessary measures for harvesting of plants, biomass removal, if required *

* Harvesting or pruning requirements varies from species to species. Indian experiences show that in certain cases no pruning was necessary, however, phragmites species requires pruning after 2-3 days.

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

- Operation during the different seasons of the year (monsoon, winter, summer)
- Maintenance and removal of sludge or compost from pre-treatment devices.
- Measures for renewal of clogged filter media.
- Trouble shooting, correction of potential faults and nuisances.
- Function control and maintenance of all technical parts of the plant, esp. check of correct feeding and flow-through of wastewater, cleaning of feeding and drainage pipes, control of embankments and safety installations, check of surface and internal clogging, and control of vitality of the plants.
- Instructions for self-control of the quality of final effluent according to the NOC.

8.0 COST ASPECTS

8.1 Capital cost

It includes:

- Purchase of plot
- Infrastructure development, incl. sewerage system
- Transport
- Excavation and construction of beds.
- Sealing
- Filter media
- Feeding and discharge system
- Plants
- Construction of pretreatment facility
- Machines and cables, if needed
- Security installations
- Planning

8.2 Operation and maintenance cost

It includes:

- Sludge removal, treatment and disposal from pretreatment facility
- Removal and disposal of plant material
- Electric power
- Maintenance
- Monitoring

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

9.0 APPLICATION OF RZTS IN INDIA

List of Agencies, Consultants and Locations

Name	Address	Place	Tel/Fax	Mail
Billore, Prof. Dr. S.K.	Professor Vikram University, Institute of Environment Management and Plant Sciences	Ujjain 456010	0734-2511226	billore@bom4.vsnl.net .in
Central Leather Research Institute (CLRI)	Adyar	Chennai 600020	044-491-6351, Fax 24911589	root@niclai.ernet,in
Central Pollution Control Board (CPCB)	Parivesh Bhavan, East Arjun Nagar	Delhi 110032	011-2221955, 22305792, Ext. 247	cpcb@alpha.nic.in scskn@cpcb.delhi. nic.in
Centre for Environmental Studies (CES)	Anna University	Chennai 600025	044 2354717, Fax 2354717	nvasu30@yahoo.com
Centre for Scientific Research (CSR)	Auroshilpam	Auroville, 605101	0413-622168, 622277, Fax 622057	CSR@auroville.org.in
Emanuel, K.V.	Unido, 1st.Floor, TNPCB, 100, Anna Salai, Guindy	Chennai 600032	044-2353158 Fax -2353156	unido@giasmdo1.vsn l.net.in
Joshi, Dr. Himanshu	IIT Roorkee, Dept. of Hydrology, 32/4, Niti Nagar, IIT Roorkee	Rourkee 247667	01332-70625, 285403(R) 285390(O), Fax -275360	joshifhy@iitr.ernet.in
Inspiration	Mankoottathil, Diwan's Road, Ernakulam	Cochin 692016	0484-353402, Fax 370502	inspire@md2.vsnl.net .in
Ion Exchange India Ltd	Tiecicon House, Dr. E. Moses Road, Mahalaxmi	Mumbai - 400001	022-4939520 (-28) Fax 493 8737	ionxchng@giasbm01. vsnl.net.in
Kraft & Associates, 7	Rangapillai Street, Flat E	Pondicherry 605001	0413-339429, 335883, Fax 337348, 335883	kraftaas@satyam.net.in
Lucent Technologies Finolex Ltd. (*Location*)	Plot No 344, Village Urce, Taluk Maval	Pune 410506	02114-24347, 25139, 25142, Fax 25140	
V.K. Kapoor Netaji Subhash Institute of Technology (*Location*)	Azad Hind Fauz Marg, Sector 3, Dwarka	New Delhi - 100 045	25099056	vkkapoor@nsit.ac.in
Tata Energy Research Institute (TERI) (*Location*)	Habitat Centre, Lodhi Road	New Delhi 110003	Fax 24682145	

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

10.0 REFERENCES

Bahlo, K.; Wach, G., (1992), Naturnahe Abwasserreinigung, 137 p., Freiburg, Germany

Brix, H., (1993), Wastewater Treatment in Constructed Wetlands, System Design, Removal Processes and Treatment Performance, in Constructed Wetlands for Water Quality Improvement (Ed. Moshiri, G.A.) Lewis Publishers

Cooper, P.F. et al., WRc/Severn Trent Water (1996): Reed Beds & Constructed Wetlands, 18 p., Swindon, United Kingdom

Davis, S.H.; Ulmer, R.; Strong, L.; Cathcart, T.; Pote, J. and Brock, W., (1992), Constructed wetlands for dairy wastewater treatment, American Society of Agricultural Engineers, Paper No. 92-4525, USA

European Community/EWPCA Expert Contact Group, (1990), EUROPEAN DESIGN AND OPERATIONS GUIDELINES FOR REED BED TREATMENT SYSTEMS, 27 p., Swindon, United Kingdom

German Association For The Water Environment (ATV), (1998): Standard ATV-A262E, Principles for the Dimensioning, Construction and Operation of Plant Beds for Communal Wastewater, 12 p., St. Augustin, Germany

German Federal Environmental Agency (UBA), (1994): Untersuchungen zur umwelt- und seuchenhygienischen Bewertung naturnaher Abwasserbehandlungssysteme, 91 p. Berlin, Germany

Hammer, D.A., (1991), Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural, 831 p., Lewis Publishers, Boca raton, Fl., USA

Hosketh, P.S., (1990), The economic and environmental feasibility of municipal wastewater in small communities in Maine, University of Maine, Orono, Me, USA

Howard, H.S., (1991), Constructed Wetlands for Assimilation of Dairy Effluent: Monitoring Studies, in Proceedings of the 1991 Georgia Water Resources Conference, University of Georgia, Athens, Georgia, USA

International Association on Water Quality, (1996), Preprints of the 5th International Conference on Wetland Systems for Water Pollution Control, Vol. I/II, Vienna, Austria

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)

International Water Association, (2000), 7th International Conference on Wetland Systems for Water Pollution Control, Vol. I/II/II, University of Florida, Institute of Food and Agricultural Sciences, USA

Institut für Siedlungswasserwirtschaft und Abfalltechnik, Universität Hannover, (1995),: Untersuchungen zur Betriebssicherheit und Reinigungsleistung von Kleinkläranlagen mit besonderer Berücksichtigung der bewachsenen Bodenfilter, Hannover, Germany

Landesanstalt für Umweltschutz Baden-Württemberg, (1998): Bodenfilter zur Regenwasserbehandlung im Misch- und Trennsystem, 114 p., Karlsruhe, Germany

Landesamt für Wasser und Abfall Nordrhein-Westfalen, (1989), Pflanzenkläranlagen und Abwasserteiche für Anschlußwerte bis 50 Einwohner, 16 p., Düsseldorf, Germany

Lange, J.; Otterpohl, R., (1997), ABWASSER-Handbuch zu einer zukunftsfähigen Wasserwirtschaft, 225 p., Donaueschingen-Pfohren, Germany

Sasse, Ludwig, Bremen Overseas Research and Development Association (Borda), (1998): DEWATS, Decentralized Wastewater Treatment in Developing Countries, 160 p., Bremen, Germany

United States Environmental Protection Agency (EPA), (1993): Subsurface Flow Constructed Wetlands For Wastewater Treatment, EPA 632-R-93-006, Washington, DC, USA

United States Environmental Protection Agency (EPA), (1992): Performance of Gravel Bed Wetlands in the United States, EPA/600/A-94/167, Washington, DC, USA

Vymazal, J; Brix, H.; Cooper, P.F.; Green, M.B.; Haberl, R. (eds), (1998); CONSTRUCTED WETLANDS FOR WASTEWATER TREATMENT IN EUROPE, 366 p., Leiden, The Netherlands

Water Science and Technology, Vol. 32, No. 3 (1995), Wetland Systems for Water Pollution Control 1994, Elsevier Sciene Ltd., Oxford, U.K.

Water Science and Technology, Vol. 40, No. 3 (1999), Wetland Systems for Water Pollution Control 1998, Elsevier Sciene Ltd., Oxford, U.K.

Water Science and Technology, Vol. 35, No. 9 (1997), Sustainable Sanitation, Elsevier Sciene Ltd., Oxford, U.K.

Wissing, F., (1995), Wasserreinigung mit Pflanzen, 95 p., Stuttgart, Germany

ENVIS Centre, CPCB (www.cpcbenvis.nic.in)