

Course Name: Bioclimatic Architecture: Futureproofing with Simple and Advanced Passive Strategies

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Lecture 03

Root Zone Treatment

Hello everybody. So last class we saw a very simple principle called direct evaporative cooling. We saw its translation into architecture in order to have cool air by increasing its humidity. Today we will look at a system. It is not a technique per se, but it is a system that is an advanced system, and then this system can be used for any climate type. It is not based on a climate, but on a system that can lead to sustainable architecture, and that is the root zone treatment.

Now, what is root zone treatment? Root zone in science refers to the entire range of biological activity that occurs amongst various bacteria, plant roots, water, soil, and sunlight. It is made up of dirt, sand, and gravel-filled planted filter beds. This system is low cost, zero energy, and it is a plant-based system. This system can be a centralized or decentralized waste water system.

It works effectively as a decentralized system. The major components of root zone treatment are you need a lot of water, you need substrates, sediments are required, litter, vegetation, and microorganisms. Each one is related to the other. And here you can see how a root zone treatment area looks like merging with the landscape. Technically, this is how a root zone treatment looks, which we will see in the next few slides.

Now, let us look at the conventional centralized wastewater treatment. The primary treatment is normally done in septic tanks, where an anaerobic process separates solid particles, effluent water, and gases. This effluent water is treated in the secondary treatment plants. The secondary treatment is time- and land-consuming and expensive. It needs long pipelines and infrastructure for the treatment.

Decentralized wastewater treatment treats and disposes of or sometimes reuses wastewater from small and low-density communities, buildings, and dwellings. So, actually, if you see, the sewage treatment plant is a centralized one. So, for the entire community, there is one

sewage treatment plant, whereas a decentralized treatment plant looks like this where there are multiple plants. We will quickly see for a perspective what is centralized wastewater treatment, which is the conventional one, which is wastewater treatment process. So, in this, the primary treatment is that the sludge settles to the bottom of tanks and lighter substances rise up.

In the secondary treatment, the sludge is treated by decomposing bacteria, and this removes suspended biological matter. This can be an aerobic or an anaerobic method. Then there is activated sludge, which is mixed with sewage. And then the tertiary treatment comprises effluent polishing for more cleaning. by making it go through sand filtration, enhanced biological treatments, nitrifying bacteria methods, etc.

Let us now look at the workings of a root zone treatment. Water treatment happens through the use of plants, aqua plants in a root zone treatment. There is extraction of contaminants from soil or groundwater. Then there is degradation of contaminants by various biotic or abiotic processes. No chemicals are used.

But only plants are used, and the breakdown action happens because at the root of these plants there are microorganisms that are voracious eaters of the contaminants that are put in the root zone treatment plant. The filtration process, or biofilm, is formed at the surface of a pebble, gravel, or coarse sand bed. Processes like adsorption or absorption in soil strata or the combination happen. vertical and horizontal flow patterns, and another possible mechanism for contaminant degradation is the metabolism within the plant. In this system, the plants produce an environment that is conducive to bacteria to develop themselves by transferring oxygen into the roots through their stems.

This makes it possible for pollutants to be broken down chemically and biologically through aerobic microbial activity. In addition to promoting better plant development and the breakdown of materials into smaller pieces, biofilm also forms colonies and mats on the water's surface and on the roots. The soil aids in the buildup of litter, which raises the amount of organic matter, which is a source of carbon for subsequent reactions in the mixture. Anaerobic activity predominates some distance from the roots and breaks down the components of wastewater, while aerobic activity is focused close to the plant roots. There is aerobic and anaerobic activity happening, but aerobic activity happens closer to the root.

So in this, you can see that the entire system works by having an inlet of the contaminant or the sewage into a pond. There are specific plants. We will look at what they are in detail about in the forthcoming slides, and you can see predominantly roots are shown because these plants have roots on which the microorganisms cling. And these microorganisms and

these plants need an immense amount of nourishment, which they get from the sludge. And then there is a substrate and an outlet.

So, the soil nutrients help the plant to grow. and therefore, more roots are formed. So, oxygen is transferred to roots for the bacterial growth. Aerobic and microbial activities start working on the sludge water and in the root zone, accumulation of waste and organic matter gets stuck to the roots and creates a biofilm, which further breaks and becomes litter. So the soil receives the remains of the treated water, and litter is formed. The rest of the water is extracted through horizontal and vertical methods.

These are also called constructed wetlands. Root zone treatment plants are also called constructed wetlands. Depending on the level of water and substrate, there are three types of wetlands. First is the surface flow wetland. The water surface here is above the substrate.

So, if you see, the top of the water is above the substrate. The advantage of this system is that it promotes ecosystems and can be used where evaporation is not a major concern. The disadvantage is that it creates odour and needs more land space. The second is a subsurface flow wetland, which is this. So, what happens in subsurface flow wetland is that these wetlands again get classified into horizontal flow and vertical flow constructed wetlands.

They consist of a sealed basin with a porous substrate of rocks and gravel. So, you can see the rocks and gravel on top. The advantage is that there is minimization of pest and odour problems, and there is less area requirement compared to surface flow wetland because there is a layer of gravel that prevents the frothing from coming up. The disadvantage is you have to actually construct them.

So it costs money. So economically, it is more expensive compared to surface flow wetlands. Also, clogging and unintended surface flows are a problem. But this is more applicable in arid regions because in arid regions the water could get evaporated. And having the gravel on top can prevent it. The third is floating wetlands.

Floating wetlands are small artificial platforms that allow these aquatic emergent plants to grow in water that is typically too deep for them. Their roots spread out through the floating island and down into the water, creating dense columns of roots that have a lot of surface area. And it is on these surfaces of the roots that the microorganisms cling to. The advantage is that the roots and floating islands provide extensive surface area for microbes to grow. Here you can see Raja Ramanna Center for Advanced Technology in Indoors has a floating wetland.

Let us now look at the advantages and disadvantages of subsurface flow wetland. The

advantage of subsurface flow wetland is that it has higher rates of contaminant removal per unit of land than surface flow wetland. Thus, they require less land to achieve a particular level of treatment than the surface flow wetlands. The second advantage is that they have lower lifetime costs and capital costs as compared to conventional treatment systems. They are less expensive to operate than surface flow systems.

They have minimal ecological risk due to the absence of an exposure pathway. They are more accessible for maintenance because there is no stagnant water. The odors and insects are not a problem because the water level is below the media surface. These are great for providing a habitat and an ecosystem for plants and wildlife. However, they have disadvantages because it requires more land than conventional treatment methods.

So, the subsurface flow wetland requires more land than the conventional treatment methods. They may be slower to provide treatment than the conventional treatment. They are more expensive to construct than the surface flow wetlands on a cost per acre basis. Water containing high suspended solids may cause plugging. Next, we will look at surface flow wetland.

The advantages of surface flow wetland are that they are less expensive to construct on a cost per acre basis, and they operate and are simpler to design than subsurface flow wetlands and conventional treatment methods. They can be used for higher suspended solids and waste waters. They have more operating data in the United States. So there is extensive data in some parts of the world for any research to take ahead. They offer greater flow control, and they offer more diverse wildlife habitat because they need more space.

They provide habitat for plants and wildlife. The disadvantage is that they have lower rates of contaminant removal per unit of land. Thus, they require more land to achieve a particular level of treatment than subsurface flow wetland. Because they look more natural as a large water body. They require more land than conventional treatment methods.

There is a risk of ecological or human exposure to surface flowing waste water, which is very dangerous. They may be slower to provide treatment than conventional treatment. The odors and insects may be a problem due to the free water surface. Let us now look at the types of root zone treatment.

So, there are two types. One is the horizontal root zone treatment, and the second is the vertical root zone treatment. the horizontal root zone treatment in this process, the flow of water to the root zone of the plants is in a horizontal manner. The plants can be selected that are deep-rooted and oxygenate the rhizosphere of the roots. Whereas, in the vertical root zone treatment, the process requires the oxygen input to be enhanced by the

intermittent surface application, and hence plant selection is less critical. The flow of water to the root zone is in a vertical manner.

Let us quickly look at a few cases where root zone treatment has been used. The wetland project at IIT Madras started in 2013. In Chennai, there is conservation of the Sembakam lake after restoring it and therefore for a natural treatment system for wastewater entering the lake. The unabated sewage from neighboring areas has been used. The floating treatment wetland has been experimented with at the University of Oklahoma.

It is also used in Puducherry village. A number of root zone treatment plants are seen in the Auroville community. Hyderabad also has floating wetlands set to give the city lakes a new lease of life. Let us look at the challenges of root zone treatment wetlands. First is the site condition. The topography of the site is an important criterion.

So, wetland systems work on the flow of water slope. The flow can be maintained naturally if the site has a proper slope. Second is the water table. The depth of wetlands is not more than 2 meters or 2.

5 meters. With high water tables, wetland channels should be constructed and sealed with proper materials to avoid mixing groundwater in wetland channels. Third is the soil type. This depends on the soil's capacity to remove and retain contaminants. Sandy or gravel-based soils have high porosity, so it is not recommended. Medium-textured or loamy soils have high retention of pollutants, and they provide the organic matter to fuel plant growth and microbial activity.

Then another important criteria is the effect of seasons. So separate channels must be there for rainwater; otherwise, this can flow into the tank or into the system and cause an overflow. In the summer period, the evapotranspiration rate is higher, which increases the chances of drying of wetlands, and this can increase the concentration of pollutants and the dying of plants. Extreme winters need a special system to help with aerobic and anaerobic reactions. So, the soil type ranging from clay, silt, sand, and loamy is shown here.

Sand and loamy independently are not good for this kind of system. Neither is only clay good. So, it must be a combination soil. Let us look at the challenges of root zone treatment.

The first is everyday peak loads. Now daily loads of waste water are needed, and in some circumstances the load could increase, which will lead to the failure of the system. So one must not overload the system. Second is plant selection. Plants with emergent vegetation, non-woody plants that grow with their roots in substrate or in water and the stems and leaves emerging from the water surface, are needed. So, there are certain reeds like

Phragmites australis (reed), *Phragmites karka* (reed), *Arundo donax*, which is a Mediterranean Reed. These are all good. Then next is the detention period. Treatment performance of this depends on the detention time. A time period of 6 to 7 days has been reported to be optimal for the treatment of primary and secondary wastewater.

Longer stagnant water can lead to an anaerobic condition and can give out a smell. Here we will see the details of the plant used for root zone treatment. The *triflida* folia planted for root zone treatment is known as the broadleaf cattail. It's a perennial herbaceous plant of the genus *Typha*.

It is an obligate wetland species. So, this is the growth of the root after treatment, and this is the growth of the root before treatment. So, after treatment, a number of fibrous roots emerge from each of these roots. So, this species of plant is highly efficient in treating the polluted water. Then the tests that are conducted include pH value, chemical oxygen demand, biochemical oxygen demand, nitrogen, phosphorus, and potassium. To summarize, a nature-based system is what this entire thing is.

So, root zone treatment is a nature-based system. It does not give out any odor. It meets or it meets the government and WHO demands. Treatment of sewage, wastewater, sludge, mud, and oil can be carried out. Sludge is reduced by 95% through mineralization.

There is no energy consumption and no need for any chemicals. Positive carbon credit without emission of carbon dioxide is possible. It consumes very minimal electricity. It is aesthetically enhanced than conventional methods. It has low maintenance. It is cost-efficient in terms of construction, operation, and maintenance.

It uses technology that is simple to understand and manage. Low energy consumption is required for its operation, assisted by maintaining groundwater and subsurface water levels. This contributes to environmental protection by providing an ecosystem and habitat for microbes, plants, and sometimes even small animals. If we look at the current status of this concept in India, the Central Pollution Control Board has taken initiatives to publish guidelines for root zone treatment systems. Let us quickly look at a few case studies. The first case study is the Arvind Eye Hospital, Abhishekapakam, Pondicherry, India.

So, this project was first executed by the Bremen Overseas Research and Development Association. The DEWAT system was used in Auroville using root zone treatment. Again, this process included sedimentation, bacterial action, filtration, adsorption, precipitation, decomposition, nutrient uptake, and the vegetation system. So, phytoid, which is a subsurface flow-type treatment system, is used to treat the wastewater with the help of porous media like crushed bricks, gravels, and wetland plants. This system is broadly

divided into three zones, which are the inlet zone, treatment zone, and outlet zone.

The water that comes out of the outlet is used for irrigation purposes. From this picture, you can see that there is no trace of a sewage treatment plant when you look at this root zone treatment. The second case study is again in Bangalore. Avinash Krishnamurthy, Biome Environmental Trust has done this with a phytoid technology-based treatment plant.

So, this has a capacity to purify waste water, which is very large. The anaerobic process tank size is about 8 meters by 8 meters with a depth of 4 meters. And if you actually see the pictures, there is no trace of this picture showing a sewage treatment plant. So, today we saw a system that is a sustainable wastewater treatment system and can come under passive technique because passive technique is not related only to energy; it is also related to sustainability. And today we saw the root zone treatment along with the case studies. So, we will stop today's class here and we will continue with yet another strategy in the next class. Thank you.