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Using Nature's Technology: Constructed Wetlands

Karen Mundy

Everyone contributes to wastewater. Everyone prepares food, washes dishes, takes showers, flushes toilets, washes clothes. Farmers face strict regulations concerning disposal of animal waste. Industry, which has its own set of regulations, generates wastewater as it produces the products society uses. These wastes can be toxic to humans and animals. Local landfills produce wastewater in the form runoff. The highway department applies chemicals to roads to melt snow and ice. As the snow and ice melt, they carry the chemicals off the roads. Heavy rains wash the oil and grease from roadways and carry topsoil and nutrients like nitrogen and phosphorus into streams and rivers. Some of this wastewater leaches into the groundwater that is used for cleaning, cooking, and drinking. Some runs into streams, rivers, and bays where it can kill fish, shellfish, and plants, and could make recreational use hazardous.

With all this dirty water, the wastewater treatment facility is a critical part of the basic infrastructure of every community. Typically, these facilities are concrete, brick, and steel--and they are costly to construct, maintain, and operate. They frequently rely on coal, a non-renewable and air-polluting resource, to generate the electricity used to power pumps, aerators, and other treatment equipment. They can break, which leads to discharge of raw or partially treated sewage directly into rivers and streams. The sediment or sludge that settles in the wastewater treatment tanks and must periodically be removed is odorous and can contain toxic metals, making its disposal a problem. Treating wastewater might create more pollution than it cleans away. But we still have to treat wastewater.

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Wastewater, clean or dirty, ends up in rivers, lakes, and bays. Dirty wastewater can carry disease into waters which supply food and provide recreation. In addition, water is a limited resource. While over 75 percent of the earth is covered with water, only about 3 percent of it is fresh water--and of that small amount, only a fraction is not frozen in glaciers and icecaps. Water is essential to human, animal, and plant life. We cannot afford not to clean up and re-use wastewater.

Many communities, needing to expand or upgrade mechanical wastewater treatment facilities, are exploring less costly alternatives to wastewater treatment.

Wetlands filter and purify water

From the Florida Everglades to the Carolina Bays to the North Dakota prairie potholes, natural wetlands occur in many climatic zones. They come in many sizes and shapes and have diverse plant and animal species inhabiting them.

No matter their size, shape, or plant and animal species, wetlands are a transition zone between dry land and deep water. They are neither totally wet nor totally dry. A natural wetland may have a stream or several pools in it. But much of the land is "squishy" rather than having standing or running water. The United States Fish and Wildlife Service defines a wetland as an area that must exhibit one or more of the following characteristics:

1. support, at least periodically, predominately hydrophytes (plants that can live in saturated soil);

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2. have predominately undrained, hydric soils; that is soils "wet enough for long enough to produce anaerobic [without oxygen] conditions that limit the types of plants that can grow there"; and
3. have "nonsoil substrata (. . . rock or gravel) that are saturated or covered by shallow water at some time during the growing season." (Hammer (b), p.6)

Plants require oxygen to survive. They obtain oxygen not only from the air, but also from the soil. The soil has spaces or pores that are filled with water and air. In wetlands, these pore spaces are entirely filled with water for long enough periods of time that only plants such as cattails and bulrushes which are adapted to saturated conditions can survive.

Since the early 1950's scientists have studied natural wetlands as a means of purifying water. In fact, they have been described as the "kidneys of the landscape." While there is still much to be learned about wetlands, we do have a basic understanding of how they purify water. Plants, animals, and bacteria in wetlands work together to decompose the harmful substances by turning them into food and energy for themselves. "Natural filtration, sedimentation, and other processes help clear the water of many pollutants. Some [substances] are physically or chemically immobilized and remain . . . [in the wetland] unless disturbed." (Hammer (b), p. 12)

"Natural filtration" occurs as plants recycle the nutrients from the wastewater as they grow. "Sedimentation" is the settling of sediments such as topsoil, organic matter, silt, and sand particles. Other processes include the breakdown of pollutants by microbes. The microbes use the pollutants as a source of energy and release harmless elements like carbon dioxide, nitrogen, and phosphorus that are, in turn, used by the plants. (Box 1)

Why not just use natural wetland systems?

There are not enough natural wetlands to purify all the wastewater generated. Constructed wetlands mimic natural wetlands. Just as in nature many forms of wetlands exist, constructed wetlands can also take many forms. Engineers design a constructed wetland for a specific purpose. They consider the soil in the area; the kinds of plants necessary for the climatic conditions, and the size of the body of water to receive the effluent or discharge from the wetland in their design. If natural wetland systems are used to clean water, we lack control over these factors. Some of the purposes that constructed wetlands serve are treatment and reuse of wastewater, treatment and disposal of wastewater, the management of water and nutrients, and flood control.

Box 1. What Needs To Be Removed

BOD--Biological Oxygen Demand or Biochemical Oxygen Demand represents organic and other substances that require oxygen to break them down. This oxygen is also needed by fish, plants, and other wildlife. BOD is best removed by environments that have a lot of oxygen.

Nutrients, while essential to plant growth, when present in large quantities in bodies of water, can cause algae blooms that deplete oxygen in the water causing plants and animals to die. Nitrogen and phosphorus are the primary nutrients removed (House (a), p.2).

"Before you invest, get your permit to know what you need to comply with. Then sit down and make your decision." Tom Faya, DEQ

In 1985, the town of Monterey in Highland County had to upgrade its water treatment facility. The facility provided primary water treatment for the town, and chlorinated the water (Box 2) that was then discharged into the local creek, which feeds the Potomac River. The town council had a conventional secondary treatment facility designed. The cost would have been $500,000--far beyond the means of the community of 200.

At the instigation of the then-mayor, Monterey citizens investigated using constructed wetlands for secondary water treatment. The Department of Environmental Quality (DEQ), knowing little about the use of constructed wetlands, agreed to allow Monterey to build a test site. One 20 foot by 60 foot cell was built in 1988 and 1989. This cell worked so well that five additional and larger cells were added. These new cells were increased to 25 feet by 70 feet. The total cost of the constructed wetland, including a chlorination/dechlorination tank, was less than $200,000. Operation of the completed facility began in 1992.

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The facility can handle 120,000 gallons of effluent per day. Annual costs are budgeted at $6,000 for materials for the facility plus the operator's salary. Until new state regulations were issued in 1996 limiting nitrogen and phosphorus levels in the effluent, the facility met all the secondary treatment requirements. The town is currently working with DEQ to remedy the problems.

Box 2. Level of wastewater treatment

Primary treatment is a settling process whereby solids in wastewater are allowed to settle to the bottom for later removal or float to the top to be skimmed off.

Secondary treatment removes organic matter. This removal is accomplished by bacteria which consume oxygen in the process.

Tertiary treatment removes the nutrients--nitrogen and phosphorus being the dominant ones--that would adversely affect the water into which the effluent is released.

"Polishing" describes the process of removing small particles, metals, and remaining nutrients.

In 1989, the town of Marion in Smyth County was ordered to upgrade their wastewater treatment facility. The facility was running at capacity and was out-of-date. Besides that, an endangered species, the brown ripple-shell mussel, was found in the area and the treatment facility could damage the mussel's habitat by discharging chemically treated water into the receiving stream.

The new facility must be able to handle 4 million gallons per day. A conventional system would cost $12 million. And because of the endangered mussel, ultraviolet light must be used to treat the wastewater, raising operating costs. The town council investigated the feasibility of a constructed wetlands. The cost of construction was estimated at $6 million, including land.

While town council members visited the facility at Monterey, they still had questions--could such a facility handle the industrial waste that Smyth County needed to treat? Monterey had no such need. There was also some question about whether the constructed wetland would function adequately when the weather turned cold. No one seemed to have the answers to these questions.

The town decided to build the conventional system. Of the five engineering firms contacted, only one had any experience with, or real interest in, constructed wetlands. Even this firm was not willing to unequivocally guarantee that a constructed wetland would work. Basically, a constructed wetland would have been a $6 million gamble--if it failed, the community would have to go back and build the conventional plant, which the engineers were willing to guarantee could be made to meet DEQ and health department requirements.

Walnut Cove, North Carolina, like Monterey and Marion, investigated a mechanical water treatment facility. A conventional facility would have cost about $3,000,000 to build, and annual operating and maintenance costs would have been somewhere between $80,000 to $100,000. They researched constructed wetlands and decided to use one rather than the conventional treatment facility.

The Walnut Cove constructed wetland for wastewater treatment has been operating for the past 18 months. It can handle a maximum of 500,000 gallons per day and covers 11 acres. At this time, Walnut Cove sends about 200,000 gallons per day to be treated. The less water that flows through the facility, the longer the water is retained in the cells. This retention time is important because the longer that the water stays in the cell, the more time the microbes and plants have to remove the nutrients and the cleaner the effluent.

There is one licensed operator who is responsible for data collection and overseeing the maintenance. She is also manager of Walnut Cove's water treatment facility. Maintenance consists primarily of mowing grass and other tasks unrelated to the actual water treatment--the wetland handles all the treatment. Operating expenses for electricity to run the aerators and chemicals to chlorinate and dechlorinate the effluent must also be paid. Total operating costs are about $40,000 annually.

In May 1996, heavy rains caused the Walnut Cove facility to flood. Even with the additional water to handle, the levels of pollutants in the effluent were below the limits set by the federal, state, or local health departments and environmental agencies for secondary wastewater treatment. Had the facility not been running below capacity, these results may have

been different. The residents of Walnut Cove are pleased with the results they are getting.

Since the Monterey facility was constructed and Smyth County investigated the possibility of using a constructed wetland for water treatment, much more has been learned. The research has dealt not only with municipalities, but with industrial wastewater treatment, livestock wastewater treatment, landfill runoff, mining wastewater, and individual homes, churches, and schools

Constructed wetlands can potentially help solve some of the nonpoint source pollution[1] problems associated with waste from confined animal feeding operations. Currently, there are 68 sites in the United States and Canada for which there is published information. Kentucky has 21 of these sites and 15 are in Canada. Forty-six of the sites identified served dairy (average herd size 85 head) and cattle feeding operations, and 19 sites served hog operations (CH2MHILL, p. 8). These systems are beneficial if the goals to be met include "[decreasing] wastewater pollutant levels, [decreasing] odors, [reducing] the amount of land needed for wastewater application, [meeting] surface water discharge regulations, and [enhancing] the landscape." (CH2MHILL, p.10)

There is still much to be learned about wetlands. Although natural wetlands have been used for wastewater treatment since the early 1900's, available data on constructed wetlands are spotty and do not cover a long enough time period to give researchers all the answers they need. For constructed wetlands, the choice of plants, the depth of the water, the retention time, and the size of the facility all need to be considered in the design. The purposes of the system also need to be considered since these will affect the type of system constructed. Climate affects the plant selection, but not the efficacy of the system. Some wetlands are frozen part of the year, but they still remove pollutants from the water that are released into them from holding ponds, lagoons, and tanks.

Wetlands offer additional benefits that conventional wastewater treatment facilities cannot. They provide an attractive landscape. They provide educational opportunities for the study of very diverse plant and animal species. They provide open space. Many constructed wetlands have boardwalks and interpretative centers for visitors. No odor is emitted from them. Constructed wetlands can even be used for such small-scale sites as individual homes, churches, or schools. The effluent can be recycled for irrigation or for flushing toilets.

Mechanical wastewater treatment facilities are subject to mechanical breakdown and the need for costly repairs. Both conventional wastewater treatment facilities and constructed wetlands are subject to capacity limitations which can result in the need for expansion.

Not a Panacea

With all their attractive features, wetland systems are not a panacea for the water treatment problems facing municipalities, industry, agriculture, and homeowners. Wetlands are an alternative in a few cases to primary treatment and in many cases to secondary or tertiary treatment of wastewater. However, primary treatment is generally required to avoid overloading the wetlands with oxygen-demanding pollutants (BOD), which would cause the wetland plants to die. As bacteria break down pollutants, they use up oxygen, so that the more pollutants that must be broken down, the more oxygen the bacteria require and the less there is available for the plants.

The disadvantages of wetlands include the lack of long-term experience with the systems, lack of understanding of the complexities of the biological and hydrological systems that are involved, the amount of land required, and potential pest problems. One of the major disadvantages, according to DEQ, is that the effluent from the constructed wetlands cannot be controlled. If, for example, ammonia levels increase, the operator cannot, as with a conventional system, increase the retention time or the temperature. The DEQ in Virginia has adopted the standards set by the Environmental Protection Agency for nitrogen discharge. The amount allowed is a function of the size of the body of water into which the effluent is released: the bigger the body of water, the higher the level of nitrogen allowed because there is more water available to dilute it. The change in effluent requirements will affect the design of the constructed wetland. It may increase the amount of land necessary for a constructed wetland. It could add to construction and operating costs by requiring aerators

[1] Nonpoint source pollution is pollution, frequently from agricultural sources, that cannot be traced to a single source, such as an open pipe discharging into a stream.

to increase the oxygen available to microbes and plants.

Constructed wetlands have potential for providing agriculture, industry, municipalities, and even individuals with a less costly means of treating wastewater. And while the research on how to best construct them has increased exponentially over the last five years, much still needs to be learned about what works and what does not work. There is no guarantee that a constructed wetland will meet the discharge limits set by the regulatory agency because many of the operations that can be controlled in a conventional wastewater treatment facility cannot be controlled in nature. That limitation does not diminish the potential of a constructed wetland. It only means that they must be more carefully engineered by firms that are interested and understand the inherent problems and are willing to find solutions to them.

> "Once we rethink our approach to "sewage" and try to manage the flow of nutrients rather than remove them (treatment), we will find that constructed wetlands are an excellent management system. It is also important to realize that there are now at least five major wetland design types, each with design factors [that] can be manipulated toward treatment goals. Many people only think of one type. Hopefully, we'll make more!"
>
> Halford House (b)

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www.grrd.bc.ca/sewers/bro/wwprimar.html#process "Primary Treatment Process: How It Works."

www.waterrecycling.com "Water Recycling: Cleaning Water the Way Nature Does."

Notices

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****REAP welcomes **Dr. Joseph Coffey**, Vice President, Southern States, as our new Advisory Council Chairman.

****Correction:** New Life Crisis in Galax, Virginia is Sunrise Foodbank, a division of New Life Ministries affiliated with Second Harvest. Their phone number in Wytheville is (540 228-7788 and in Collinsville, (540 647-4444.

****In the planning stage** are several one-day seminars to discuss land-use issues that have arisen, at least partly, as a result of the 1996 Farm Bill. We will keep you informed of when and where these will take place.

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