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THE NEW GREEN PARADIGM© – ECOCYCLET®

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ABSTRACT

The discharge of partially treated wastewater to receiving waters be they groundwater or surface waters is increasingly unacceptable due to the presence of man-made chemicals and pharmaceuticals. There are presently no technologies that both store and productively reuse wastewater by growing valuable plants while guaranteeing that no effluent can contaminate the receiving waters.

The use of wastewater to safely grow valuable plants, be they for biofuels, flooring or just landscapes for aesthetic value is the highest use for the nutrients, organics and water in what used to be called 'wastewater'. This is the new Green Paradigm that combines pollution prevention, economic savings and energy production in one innovative concept.

The patent-pending Ecocycl**ET** (ET stands for Evapo-Transpiration) is based on the premise that effluent can be accumulated, stored, recycled, aerated and transferred to a lined bed planted with valuable plant species. The plant bed size and plant species are designed so that all the wastewater will ultimately be transpired. Any excess effluent not used up is returned to an appropriately sized recirculation tank or disinfected and transferred to a holding cistern to be used for non potable purposes.

Because there is a separate cistern containing disinfected and treated effluent, it completely avoids the need for a back up disposal field. The latter application is called the Ecocycl**ET** Wisconsin Reuse System because it was first approved in the state Wisconsin, USA as a reuse product to be installed where soils are too poor to be considered for a soil absorption system.

An impervious liner forming the planting bed ensures that no effluent can enter the subsurface environment or nearby receiving waters. Zero-discharge is the ultimate protection of the environment and growing valuable plants ensures that it is the most cost-effective on a life-cycle basis.

These systems can either be in sheltered or unsheltered environments depending on the local weather conditions. Storage in subsurface tanks or constructed aquifers holds the greatest promise for on-site applications. One unique unsheltered application is to store the effluent either in the recirculation tank or a subsurface constructed aquifer beneath the planting bed during cold winter months and use it up during the plant growing season. Larger applications will more resemble farms for production of biofuels and other valuable crops such as bamboo flooring.

Key words: Biofuel production. Evapo-transpiration, EcocyclET®, Green Paradigm©, Recirculation, Reuse, Rhizospherics©, Zero discharge,

INTRODUCTION

The discharge of partially treated wastewater to receiving waters be they groundwater or surface waters is increasing unacceptable due to the presence of man-made chemicals and pharmaceuticals. There is a need to grow biofuels without using valuable food-producing farmland. An innovative concept called the Green Paradigm address both of these issues in one integrated technology—The EcocyclET.

RECYCLING IS NOT ENOUGH

Arid regions are increasingly looking to wastewater recycling as the answer to a secure water supply. While recycling wastewater is an important step in the conservation of fresh water, it is technologically complex, expensive, and unacceptable to many communities. As with desalinization, it is expensive and energy intensive to remove vast amounts of minute particles and bacteria from enormous volumes of wastewater so that it is safe for direct human contact. To identify advanced wastewater recycling and desalinization as the best answer to the world's water supply challenges is to use the same mentality that created today's many water problems. The practice of centrally collecting combined effluents—including excreta, toxics, pharmaceuticals and heavy metals—from a wide variety of sources, and then treating them with end-of-pipe solutions with advanced ultra filtration will not be feasible for many cities, especially those in developing countries. This approach has evolved to avoid the complexity of using many smaller, more local and effluent-specific strategies. Yet nature's model shows us that local complexity is the best way to manage resources. The principle objective of this technology is the utilization of water and nutrients by plants i.e. bio-mimicry. (Del Porto, 2006).

THE GREEN PARADIGM© (Del Porto, 2005)

Too valuable to waste
Wastewater's content of nutrients, organics and a large volume of water makes it an ideal resource for growing plants. If those plants are not to be eaten, then the wastewater does not have to be treated to potable quality. This points to an opportunity, as laws require cleaner discharges to lakes, rivers, oceans and for indirect potable reuse

No upgrading treatment plants
We can avoid upgrading to advanced tertiary treatment of wastewater if we instead direct wastewater treated only to advanced primary or secondary standards to nearby barren lands to grow non-edible oil plants for refinery or cellulosic grasses for ethanol.

Use barren land unfit for agriculture
Instead of investing billions of dollars in wastewater pollution prevention and remediation, we can invest in the distribution system necessary to transport wastewater from existing treatment plants and animal feedlots to arid farmlands, deserts, and polluted brown fields to grow biologically based petroleum alternatives on land unfit for food crops. Because the nutrients and organics will be used by plants, they do not have to be treated to tertiary standards

This is the new Green Paradigm©, a model that calls for using the resource productively instead of improving disposal. Growing away our wastewater can reduce or eliminate the purchase of imported fossil natural gas and petroleum within the next few growing seasons by growing oils, algae, grains and grasses that can be processed to replace imported petroleum (Del Porto 2005 and 2007).

This vision is not new. The automaker Henry Ford invested heavily in soybean research and in 1942 manufactured a Ford concept car with most of its components made from materials produced by American farmers. We now add to this vision by growing these materials and chemicals with what was called 'wastewater' instead of polluting receiving waters (Del Porto, 1999).

Why is it important to safely use sewage to grow biofuels? There is a growing need to protect receiving waters, mitigate effects on the economy, promote energy independence, reduce air pollution from power plants, minimize fertilizer use, create new jobs for farmers and substitute plant derived chemicals for petroleum derived chemicals. For example:

- Wastewater from Las Vegas, Nevada is currently being dumped into Lake Mead, Nevada which flows into the Colorado River and then through Phoenix, Arizona, San Diego, California and on to Mexico. Lake Mead and the Colorado River are drinking water sources for millions of people. The Mohave Daily News (2008) recently wrote "*the Clean Water Coalition proposed (and is now planning) to dump more than 180 million gallons of wastewater each day to the bottom of Lake Mead near Hoover Dam. The Clean Water Coalition consists of the Clark County Water Reclamation District and the cities of Las Vegas and Henderson. The population of Las Vegas is projected to be more than 3.1 million by 2035. By 2050, more than 400 million gallons of wastewater could be dumped each day into Lake Mead from Las Vegas. Arguments against the project claim the treated wastewater containing pharmaceutical drugs would go through Hoover Dam and contaminate the (Colorado) river downstream".*

- Pollution from human- and animal-produced wastewater will require an investment of tens of billions of dollars in the next 10 years. The USEPA states that one trillion dollars was invested by American communities in the last 20 years to protect our water resources with upgraded water infrastructure. It is now estimated that another trillion dollars will need to be invested in the next 10 years! (USEPA, 2002).

- In 2005, a preliminary estimate suggested that the wastewater from Reno and Las Vegas Nevada could produce more than 10 million barrels of palm oil per year. It would be piped to nearby barren lands instead of disposed of into sensitive surface waters. (Del Porto, 2005). Based on the Las Vegas population projections it should yield significantly more biofuel by the year 2050.

- The water and nutrients in human-derived wastewater in the United States alone may be able, without additional treatment, sustain millions of acres of corn, soybeans or rapeseed per year. This number can be doubled or tripled by adding poultry and other animal wastes. (Del Porto, 2005)

- The nitrogen-rich gases from power plants can be used to grow millions of gallons of oil derived from the single-cell plant called algae instead of polluting the air, which results in billions of dollars in American productivity losses and health-related costs. These algae-to-oil facilities can be placed directly on power plant facilities, eliminating the need for transportation costs of fuel to the power plants (Massachusetts Institute of Technology, 2004).

- Farmers are in need of new crops to replace tobacco and other crops that compete with foreign imports. Many farmers are still paid via government subsidies to not grow crops at all. Growing petroleum alternatives creates more jobs in areas where employment is needed without threatening existing farming communities (Karg, 2000).

- Governments could disconnect from the political liabilities of its fuel dependence on other countries.

- One of the obstacles to growing petroleum alternatives is the cost of fertilizer, which requires a natural gas and petroleum to produce. The other is the lack of fertile land not already in service to growing food. By using wastewater and unusable land, these obstacles can be overcome. According to John Sawyer, associate professor of agronomy at Iowa State University, the majority of nitrogen fertilizer sold in the Midwest is either anhydrous ammonia, or products made from anhydrous ammonia (urea, ammonium nitrate, and urea-ammonium nitrate solutions) (Sawyer 2005). Natural gas is a major component of ammonia production for both energy and supply of hydrogen (H) in ammonia (NH3). Therefore, the ammonia production cost is closely tied to the price of natural gas. Natural gas supplies derived in many countries are nearly depleted; so much is imported from other countries, such as Algeria and the Middle East. Natural gas accounts for more than 85 percent of the total ammonia production cost. When the price of natural gas increased in 2004, the cost of nitrogen fertilizer also increased dramatically (Sawyer, 2005).

- There are hundreds of millions of acres of unusable land in the world that could be farmed to grow petroleum alternatives crops with the water and nutrients in wastewater.

- Vehicles can use fuels (biodiesel and ethanol) derived from vegetable oils, grasses and grains with only minor changes. This means there would be no need to penalize drivers for purchasing the vehicles they choose to drive. This averts the gasoline crises and lowers air pollution.

- Most petroleum-based chemicals, fuels, lubricants, plastics, pharmaceuticals, chemicals and other products, can be replaced by oils, grains and biomass grown on barren lands by experienced local farmers without significant changes in the refining, processing, and distribution systems now in place; all within the borders of the countries where they are grown. This eliminates the dependence on foreign oil suppliers. The existing infrastructure of the petroleum industry—be it refineries, distribution, or chemical factories—can, with minor modifications, easily convert from petroleum to oils from soybeans and alcohols from grains.

THE TECHNOLOGY

The patent-pending Ecocycl**ET** (ET stands for Evapo-Transpiration) is based on the premise that effluent can be accumulated, stored, recycled, aerated and transferred to a lined bed planted with valuable plant species. The plant bed size and plant species are designed to insure that all the wastewater will ultimately be transpired. Any excess effluent not used up is returned to an appropriately sized recirculation tank or disinfected and transferred to a holding cistern to be used for non potable purposes.

EVAPO-TRANSPIRATION

The seminal research on evapotranspiration beds using wastewater from more than 100 on-site buildings and confirmed by careful laboratory analysis, was conducted primarily by Dr. Alfred Bernhart, Professor of Engineering, University of Toronto, Canada. At several sites, the summer rate of evapotranspiration without precipitation was measured at 11.8 L/ m^2 per day. The plants were primarily grasses, flowers and small shrubs (Bernhart, 1985).

Evapo-transpiration is the plant's mechanism for evaporating excess water through openings in the leaves. Maximal transpiration is the "unimpeded intensity of evaporation from plants under the regularly occurring conditions of evaporation in their natural habitat" (Larcher, 1995). The maximal transpiration, or uptake, rate is a function of many variables that interact and co-evolve over time. They include, but are not limited to: maturation of the phytosphere (which includes the bioplex in the rhizoplane of the planting bed); surface area of the stem and leaf system; ambient temperature and moisture content of planting bed and air; species, variety and leaf area index of plants selected; light levels and phototropic issues; dissolved oxygen, influent characteristics and dosing rates; and general health and maintenance of the system (Del Porto, 2002).

Salt Accumulation and Removal

There has been concern that when wastewater is evapo-transpired, salts especially sodium chloride will remain in the bed and become toxic (Oleary, 1984). To resolve this problem we specify the inclusion of excretive halophytes in the planting plan. Excretive halophytes transport the sodium and chloride ions to special glands in the leaves and there excrete the salt as a solid. Removing the leaves has the effect of mining the salt from the bed. Ion excretors include:

> Saltwater cord grass (*Spartina*), Amshot grass (*Echinochloa stagnina*), Salt bush (*Atriplex*), Salt cedar (*Tamarix L.*), Suaeda vera Forsk (*Suaeda fruticosa*), Goosefoot (Chenopodium *spp*), Summer Cyprus (*Kochia spp*), Saltwort (*Salicornia spp*), Russian Thistle (*Salsola spp*), Sea Blite (*Suaeda spp*).

Leaf area matters

While certain plants such as Salix spp have a reputation for high ET rates; typically it is the leaf area index plus heat and humidity that are the primary variables in evapotranspiration. When large plants such as willows, poplars and bamboo are used, the aim is to move as much water through them as possible so that they take up as much of the contaminants as possible. In 1991 the Miami Conservancy District Aquifer Update, No. 1.1 reported that a single willow (*Salix babylonica*) tree can, on a hot summer day, transpire over 19 cubic meters of water. One hectare of an herbaceous plant like *Spartina alterniflora* (saltwater cord grass) evapo-transpires up to 80 cubic meters of water per day (Henchman et al, 1998).

We have not yet utilized large trees in our systems but rather shrubs and vines as most of our systems to date have been residential. We are presently designing a system to productively utilize the filtrate from a biogas facility in Canada. We will use the shrub *Salix viminalis L.* as it has been very successful used in Denmark in removing (evapo-transpiring) all the sewage from many residences (Gregersen, 2001).

Performance

Data from 4 three bedroom residences and 1 fire fighting station monitored by the Massachusetts Environmental Protection Agency (MADEP) indicate that an annual average of 10 L/m^2 per day of evapo-transpiration can be achieved in sheltered and unsheltered systems. This was derived by metering the incoming water, minus metered water used for outdoor purposes, divided by the area of the plant growing bed (MADEP Reports). Initial approval for these systems in Massachusetts was based on the data from the work of Dr. Alfred Bernhart (Bernhart, 1985).

Security

Because there is a separate cistern containing disinfected and treated effluent, it completely avoids the need for a back up disposal field. We call the latter application the Ecocycl**ET** Wisconsin Reuse System because it was first approved in the state Wisconsin, USA as a reuse product to be installed where soils are too poor to be considered for a soil absorption system. Approval of this system was based on data from similar systems in Massachusetts and Ontario Canada.

Protecting the soil

An impervious liner forming the planting bed insures that no effluent can enter the subsurface environment or nearby receiving waters. Zero-discharge is the ultimate protection of the environment and growing valuable plants ensures that it is the most cost-effective on a life-cycle basis.

The direct use of wastewater to grow valuable plants be they for biofuels, flooring or just landscapes for aesthetic value is the highest use for the nutrients, organics and water in what used to be called 'wastewater'. These systems can either be in sheltered or unsheltered environments depending on the local weather conditions. Storage in subsurface tanks or constructed aquifers holds the greatest promise for on-site applications. One unique unsheltered application is to store the effluent either in the recirculation tank or a subsurface constructed aquifer beneath the planting bed during cold winter months and use it up during the plant growing season. Larger applications will more resemble farms for production of biofuels and other valuable crops such as bamboo for engineered lumber and flooring.

Greenhouse-based systems

In cold climates these natural systems are often, but not necessarily, housed in contained environments that provide more environmental stability and protection for operators and the public. They must allow daylight to ensure photosynthesis by the resident flora, so they are often covered with glass or high-transmissivity plastic. Solar energy, normally vented, can be collected and reclaimed, off-setting purchased energy costs.

Where are the pollutants transformed into safe forms?

The rhizosphere is that area that surrounds and includes the roots of plants, the soil and significantly the microcosm of bacteria, algae, fungi, actinomycetes, worms and other organisms. This area appears to be simply soil and roots; however, it is more than meets the eye (Kent and Triplett, 2002). Under a microscope, the area is teaming with life that includes plant cell detritus that is food for bacteria and nematodes, and exuded sugars and proteins from the roots that nourish the bacteria and other organisms. Protozoa and other organisms feed on the bacteria. The fungi and actinomycetes produce antibiotics such as penicillin and streptomycin that contribute to the health of the plant by suppressing disease. The rhizosphere is so dynamic and complex that only with the aid of electron microscopy and organic and inorganic chemistry can these interdependent systems be investigated and understood.

The rhizosphere is a living and non-living factory where water, nutrients and minerals in the soil are prepared for absorption by the roots to support the plant. However, it is at least a two-way street. In order to support the microorganisms that support the plant; the plant sends down oxygen and nutrients via the roots which supports the microbes. In ecology, this synergy is call commensalism. Balance is assured by predation and antagonism of the competing living members of this community.

This complexity informs ecological wastewater engineers to use the root zone to treat polluted water and to harvest toxic metals from contaminated soils. Wastewater passes through constructed and sequenced ecologies containing plants. The constituents in the wastewater are transformed by complex enzymes produced by organisms, from pollutants to more benign compounds and gases such as carbon dioxide, nitrogen and water vapor. The roots, in order to support the growth of the plant, absorb the water and transform nutrients and minerals. This is known as phytoremediation. (Henchman et al, 1998). In short, the magic is in the root zone.. I recommend that all who are interested in ecological design familiarize themselves with the system ecology of the root zone, which I have called “Rhizospherics”, as it will be the treatment “plant” of the future (Del Porto, 1999).

Lower Life-Cycle Costs

We estimate that the life-cycle cost of the EcocyclET is low compared to mechanical sewerage technology. The primary reason is that they have few parts that need to be replaced unlike more complex systems such as membrane filtration technology. In addition other issues that lower the life-cycle costs (Steinfeld and Del Porto, 2008) include:

- Factoring in the avoided costs of pollution prevention, such as pumping holding tanks where the land cannot be used for soil absorption systems, is the most significant savings factor (Hopkinson, 2007).
- Easy acceptance by neighbours because they are plant based (Hopkinson 2007).
- People like them and therefore want to maintain them as opposed to conventional technologies. (Hopkinson, 2007).
- The harvesting of solar energy from greenhouses through the sale of marketable plants for uses such as energy production may off-set some or all of the operation and maintenance costs (Hopkinson, 2007).

Why are they good neighbours?

a. Attractive

We all like to be in the presence of living, green and often colorful, perfume-sented plants. Humans have evolved in these surroundings and we all have a natural affinity for them. Unlike conventional systems natural systems tend to avoid the Not in My Back Yard (NIMBY) problem because they are an amenity for the community instead of an eyesore.

b. No odour

Green plants purify the air and remove the odours associated with conventional systems Smells of the woods and the perfume of flowering plants replaces the foul odour of conventional wastewater treatment facilities.

c. Educational opportunities

Teachers from 8^{th} grade through to graduate school bring their classes to these treatment facilities to teach the application of systems ecology for solving pollution problems. Further, these systems demonstrate that human excreta should not be considered a pollutant; the nutrients and water in treated effluent can be a resource. The noted environmental educator, David W. Orr, calls these natural treatment systems “crystallized pedagogy” (Orr, 2002).

CONCLUSION

Using the EcocyclET and Green Paradigm to manage wastewater eliminates pollution of receiving waters, avoids the need to upgrade plants to advanced secondary or tertiary, and reduces dependence on imported fossil fuel. What's more, in the big picture, growing away wastewater with plants and using energy from plants sequesters carbon. Biofuels made from *current* photosynthesis-derived carbon instead of *ancient* fossil carbon will slowly reduce the impact of global warming as biofuels replace fossil fuels.

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