



Technical Notes

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Notes from the President
Overview of the 2004 Meeting
2005 Meeting Announcement
Research Notes

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Editor

Marty D. Matlock, PhD, PE, CSE
Ecological Engineering Group
University of Arkansas
233 Engineering Hall
Fayetteville, AR 72701
479/575-2849 * Fax: 479/575-2846
mmatlock@uark.edu

Editorial Board

Alex Horne, President, AEES
anywaters@comcast.net
Steve McCutcheon, Vice President, AEES
mccutcheon.steven@epamail.epa.gov
Mark Brown, Past President, AEES
mtb@ufl.edu
David Gattie, Secretary/Treasurer, AEES
dgattie@engr.uga.edu
Bill Mitsch, Editor in Chief, *Ecological Engineering: The Journal of Ecotechnology*
mitsch.1@osu.edu
Dave Tilley, University of Maryland
dtilley@umd.edu
Jay Martin, The Ohio State University
martin.1130@osu.edu

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AEES Technical Notes is a forum for exchange of technical information, knowledge, experience, and ideas related to the science and practice of ecological engineering. The articles are solicited and reviewed by the editorial board. Contact the Editor or a member of the editorial board if you have an idea or article you would like to submit.

Cover Photo: Blanchard Springs recreational area in the Sylamore Unit of the Ozark National Forest, North Central Arkansas, by Robert Morgan. Photo taken Summer 2003 with an Olympus C740 3.2 MegaPixel digital camera.

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AEES TECHNICAL NOTES

Volume 1, Edition 1

www.aeesociety.org

Summer/Fall 2004

Notes from Alex Horne, AEES President 2004-2005

This is the first presidential letter in the new *AEES Technical Notes*. I feel honored. So I greet those of you who did not make the last AEES meeting and say hi to those who did make it. The summer has now past since our third successful annual meeting at Fayetteville, Arkansas.



Incoming President Alex Horne is welcomed by out-going President Mark Brown.

The June climate was perfect for a meeting and the small city was perfect for our kind of crowd. Those of you who couldn't attend missed a fine display of "white boy reggae" at one of the open air pubs on the main drag in the balmy but insect-free evenings. Back at the meeting the pre-meeting stream restoration workshop went off well with about 15 participants. A fine feature was that we waded along the stream most of the time. I have been on quite a few stream workshops but this was the first one that was essentially all in the water. Congratulations to the entire team who put this one on and even rapidly supplied spare van keys when they were mislaid at the end of the trip!

Help our committees! Our AEES business meeting was well attended and we now have a slimmed down and revised set of committees. The success of a society like ours partially depends on the member's involvement in such committees. So please, if you have any interest in guiding the path of our new society - join in. Contact our secretary-treasurer David Gattie (dgattie@engr.uga.edu) for more information. In particular, a new society like AEES needs to incorporate more members so spread the word around about us. Ensure we get

contacts to send the announcements of the upcoming meeting at The Ohio State University May 18-20, 2005.

I recently attended a meeting of a similar society to ours, NALMS (North American Lake Management Society) on Vancouver Island, Canada. Their membership has been around 1,500 for the last decade and annual meetings provide 500 to 800 attendees, including local lakeshore dwellers. The NALMS president called for doubling the numbers. At AEES we have about 200 members. We need to grow. See if any of your colleagues, professional acquaintances and students can join us.

I have a peculiar new purple car/truck, a Chevy SSR (Super Sports Roadster), and wanted to drive it to the NALMS meeting since Victoria is less than 1,000 miles from Berkeley. Long drives through the colorful fall foliage can be restful and I composed another wetlands song on the way. It might be fully developed for the next annual meeting but the first stanza goes (to the tune of "Big Rock Candy Mountain"):

"Oh there's willow trees and cypress knees, and lots and lots of cattails,

Where a duck can stay for many a day, now we've built a wetland!"

The President's Rant: How can we widen the influence of AEES and Ecological Engineering?

The concept of Ecological Engineering is now well known to us and well illustrated by my predecessor President of AEES, Bill Mitsch's famous diagram of lesser dependence on fossil or other non-renewable energy sources. However, I do not find that this wider vision is a part of even the Environmental Engineering concept in the academic or professional world, never mind the general public or the ecologists.

There are exceptions of course but even when the citizens demand "green engineering" of wastewater for example, the large firms who build \$300,000,000 waste treatment plants really have little clue how to incorporate Ecological Engineering to enhance performance and reduce costs of the conventional design. The results are a wetland stuck in but not well integrated and usually redundant since other treatment is also constructed.

The construction profits on a wetland are of course less than for a similar concrete structure since profit is usually a percentage of the total contract cost. Thus there is little incentive for the vice-president of a major engineering firm to use “green technologies”. However, I recently had a meeting, actually a very nice lunch at Alice Water’s Chez Panez restaurant in Berkeley, with some of these vice-presidents. They were interested but not fired up. I think they sense the pressure for Ecological Engineering from their new employees (our students) and perhaps the public but remain skeptical.

One would have thought that the recent doubling of crude oil prices would have spurred on concepts such as Ecological Engineering that by definition, use less oil or gas. However, no sign of movement. Are any of our readers in contact with the NSF who showed interest in “useful research” at the meeting before last? What are they thinking about Ecological Engineering and the oil cost rises?

Perhaps one just has to wait. I have been involved in negotiations with the various agencies and the public on Walker Lake in Nevada. This unusual terminal desert lake once had 30 to 50 pound cutthroat trout but is now filled only with planted small trout. The lake volume has shrunk 80% since 1890 due to consumptive use by upstream farmers.

It’s America’s unknown Aral Sea and shrank for the same reasons. The increase in salinity causes problems for the fish kidneys and the lower volume has caused the deep water to become anoxic and release toxic ammonia and hydrogen sulfide. In addition both the forage fish and the trout have no freshwater in which to lay eggs. The oxygen problem can be solved with hypolimnion oxygenation and the salinity problem with reverse osmosis (RO) membranes. However, there is a problem – cost. Walker Lake is still quite large, 2 million acre-feet for westerners and about 35,000 acres in area. Treating such a large volume costs big dollars if conventional energy sources are used.

Oxygen can be made on shore with pressure-swing differential sorption pumps and RO is just a membrane and pressure. Deserts are characterized by lots of sunshine for solar panels and even better, have lots of wind. The main problem of using wind and solar is that they cannot be guaranteed to work on hot afternoons in the cities when air conditioning peaks. There are no convenient energy storage systems since batteries are costly and water pump storage is generally confined to areas with reservoirs and some hills.

However, applying the principles of Ecological Engineering means that the lake can act as its own reservoir (of oxygen and low salinity) to tide the system over cloudy or calm days. For example, a typical eutrophic lake hypolimnion loses oxygen at 0.1 mg/L/d. If the deep water is oxygenated to 10 mg/L it can fall to the EPA guideline of 5 mg/L but it would take 50 days to do so. It’s unlikely that there would be no wind or sun over 50 days!

The same idea applied to salinity. It does not matter to the lake if salinity is removed at midnight on Christmas Day so long as the annual salinity declines. In practice any energy generated in the afternoons in summer could be sold to the national grid or used by the local Native American communities in this area.

I proposed this idea along with my former doctoral student Marc Beutel, now a professor at Washington State University at Pullman, a few years ago. I was very excited and my Energy and Resources colleagues at Berkeley were also interested. However, it did not go down too well with the conservative farmers, Sierra Club and Audubon Societies who, to be fair, had other considerations in mind as well as simple lake restoration. Nonetheless, last week I got a call to submit a proposal for oxygenating and desalting the lake and Senator Harry Reid in Nevada has secured some funding. Possibly I did not wait long enough. So never say die to Ecological Engineering!

You need to write to us. AEES Technical Notes is our society’s newsletter. Please send comments or short articles, news and so on to the editor, Marty Matlock (mmatlock@uark.edu). Newsletters like this one must be interactive. I look forward to reading your contributions. Don’t delay, write today!

Alex J. Horne, PhD

President, American Ecological Engineering Society
Ecological Engineering Group,
Dept. Civil & Environmental Engineering
University of California, Berkeley CA

Overview of 2004 Meeting in Fayetteville, Arkansas

The fourth annual meeting of the American Ecological Engineering Society was convened in Fayetteville, Arkansas, on June 9-12, 2004. Seventy-three people attended the meeting including 25 professionals, six guests, and 42 students. The meeting was organized into a workshop followed by two days of plenary and poster sessions. The meetings were structured as seven poster sessions with a total of 56 posters and five plenary

presentations. The Stream Restoration Workshop held on Wednesday, June 9, 2004 had 15 attendees. That evening the AEES membership held a business meeting at the Fayetteville Radisson followed by a social at George's Majestic Tavern, complete with live music. Plenary and poster sessions were convened Thursday and Friday, June 10 and 11. Thursday's proceedings were followed by an evening mixer at the Radisson Hotel.



Participants in the poster session share ideas.

The five plenary speakers did a remarkable job in capturing the complexity and excitement of ecological engineering research and practice. The meeting was opened by Mark Brown, outgoing president of AEES, and concluded with comments by Alex Horne, incoming president. Plenary presenters included:

- Patrick Kangas – The Existential Pleasures of Ecological Engineering
- Stephen Luoni - Designing Recombinant Ecologies
- Kent Thornton - An Integrated, Conceptual Framework For Sustainable Water Resources Management: Engineers, Soft Sciences and the Hard Reality of Water Management.
- Jim Bays - The Business of Ecological Engineering: Progress and Prospects
- Steve McCutcheon - Self-Engineering in Phytoremediation: A relationship with Ecological Engineering



Brown and Kangas debate life, the universe, and everything.

Proceedings of the meeting, including posters and plenary session presentations, can be found on the website, under the 2004 annual meeting (www.aeesociety.org).

Ecological Engineers Receive Stockholm Water Prize

From http://www.siwi.org/press/presrel_04_SWP_Winner_Eng.htm

The 2004 Stockholm Water Prize has been awarded to Professors Sven Erik Jørgensen, Denmark, and William J. Mitsch, USA, and founding President of AEES. Through their pre-eminent contributions to the knowledge of how lakes and wetlands function, Professors Jørgensen and Mitsch have contributed substantially to understanding how to make human use of them more sustainable and how to protect them better in the future.

Professor Jørgensen, 69, is a professor of environmental chemistry at the [Danish University of Pharmaceutical Sciences](http://www.dtu.dk) in Copenhagen. Professor Mitsch, 56, is a professor of natural resources and environmental science and director of the [Olentangy River Wetland Research Park at The Ohio State University](http://www.osu.edu) in Columbus.

His Majesty King Carl XVI Gustaf of Sweden presented the Prize in the Stockholm City Hall on Thursday, August 19, 2004.

2005 AEES Annual Meeting Announcement

AEES 5th Annual Meeting Ohio State University Columbus, Ohio

May 18-20, 2005



"Restoration and Design of Ecosystems "

Please make plans to attend the [American Ecological Engineering Society's](#) 5th annual meeting to be held May 18-20, 2005, at Ohio State University. The purpose of the meeting is to explore the theory, principles, practices, and academic foundations of ecological engineering.

Symposia and workshop proposals and abstracts (500 words) should be sent to Jay Martin (martin.1130@osu.edu). Abstract submission deadline is January 31, 2005.

SCHEDULE OUTLINE AEES 2005 MEETING

Wednesday, May 18th

- 8:30-10:00 Welcome and Plenary
- 10:00-12:00 Technical Sessions
- 1:00-3:00 Technical Sessions
- 3:00-5:00 Technical Sessions (Posters)
- 5:00-6:30 Field Trips
- 7:30-9:00 Social

Thursday, May 19th

- 8:30-10:00 Technical Sessions
- 10:00-12:00 Technical Sessions
- 1:00-2:00 Closing
- 3:00-4:00 AEES Business Meeting

Friday, May 20th

- Modeling and other workshops



ECOLOGICAL ENGINEERING: Interface ecosystems and adaptive self-organization

Mark T. Brown

Associate Professor

Department of Environmental Engineering Sciences

University of Florida

Email: mtb@ufl.edu

Abstract

Restoring humanity's partnership with nature is essential if society is to transition to the coming lower energy age. In this paper, we describe general principles and fundamental concepts of ecological engineering for a lower energy future.

Self-organization is the process by which the various parts (components) of systems become connected and interact so as to work together. Interactions of components that contribute to better use of available resources succeed because they are reinforced. Self-organization results in emergent properties of systems.

Self-organization is rapidly adapting the environmental systems of the biosphere to our fuel-driven, high energy economy. The systems of atmosphere, oceans, and landscapes... including weather and global atmospheric circulation, ocean temperatures and global oceanic circulation, and the ecosystems of the landscape are self-organizing in rapid sequence to the accelerated growth of populations, fossil fuel use, and conversion of wild lands into developed lands. It is now more apparent than ever that our fuel culture will not...cannot last forever. As it shrinks, *environmental fit* is likely to become society's next concern and humanity will need knowledge to refit society to renewable resources. New kinds of ecological systems and human dominated systems will be needed to fit human society to the environment of the future. New innovative combinations of plant and animal species will be needed to interface with the diversity of human technology.

Environmental Interfaces and Management

In the past, with less energy at their command, humans controlled a small percentage of the environment. Humans relied directly on natural systems to provide clean air and water, and on relatively simple domestic ecosystems to supply food and fiber. Now, with rich supplies of energy at their command, humans control and manage enormous quantities of the world's energy, affecting the whole biosphere. The empower¹ of human operations is now greater than the natural processes that maintain the stability of the air and ocean (Brown and Ulgiati, 1999). Concentrations of carbon dioxide are rising, other wastes are increasing, and the productive buffer of our natural systems is being displaced or degraded by developed lands. Everywhere human culture is becoming more and more dominant, displacing ecosystems and ultimately changing the driving energies of the biosphere. As a result, the biosphere's ecosystems must change...which requires that human culture must change to fit in a never ending cycle of self-organization. This cycle of self-organization takes place at the interface of humanity and environment and it is the realm of Ecological Engineering.

The design and management of nature's self-organization is the field of *ecological engineering*, where the energies of human control are smaller than the environmental part of the interface.

Shown in Figure 1 is a diagram illustrating three ways in which our fuel subsidized society interfaces with the environment: (1) protected wild ecosystems used for watershed control, life support, and tourism; (2) extractive yield systems such as agriculture, forestry, mining, aquaculture, and fisheries that provide products to the economy; and (3) *interface ecosystems* that are self-organizing with society. All three of these are the realm of Ecological Engineering, albeit at very different scales. Taking each of these separately we will seek explore principles for their effective employment as strategies that will foster a better fit between humanity and nature.

¹ Empower is energy per unit time. Energy is defined as the energy of one type that is required to make something (Odum, 1996).

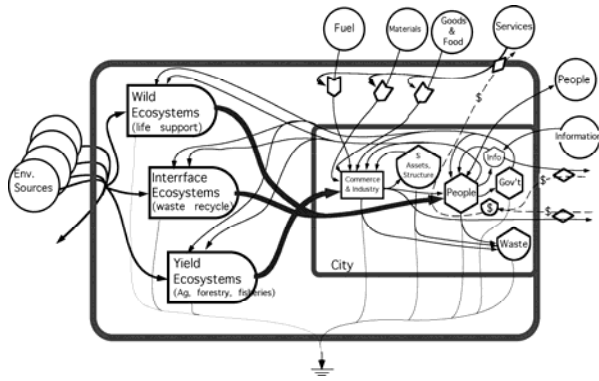


Figure 1. Diagram illustrating three realms of ecological engineering: a) wildlands and watershed protection, b) interface ecosystems for waste recycle, and c) extractive yield. Urban systems use directly the natural capital and environmental services from each realm. Often the feedbacks from the city to the environment are missing.

PROTECTED WILD ECOSYSTEMS

As a result of the changing face of the biosphere, human society, now, more than ever needs WILDLANDS PROTECTION (Brown and Vivas, 2004). There are several reasons for and ways to protect wild ecosystems...

Wildlands protection through watershed protection

Water will probably become limiting to human society before fossil fuels do. Already in many parts of the globe, there is grave concern over availability of freshwater. Inspired ecologically engineered development is necessary to minimize losses of recharge capacity and destructive runoff. Holistic approaches to planning and ecologically engineering landscapes to set aside wildlands for the protection of watersheds against incompatible uses is critical if dwindling water supplies are to be maintained and water quality is to be protected.

Wildlands protection through bio-reserves

It may be necessary and prudent to protect large areas of the biosphere as reserves, limiting human use and contact. These reserves are ecological refugia for genetic information that may be important in the future. Much needed is an understanding of the required size and spacing of bioreserves to insure viable gene
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pools for self-organizing landscape restoration. Landscape restoration can be greatly facilitated if seed sources are readily available. Our simulation models (Figure 2) of regions that incorporate bio-reserves as an integral part of the cycle of lands suggest that about 25% of land area need by protected to maximize economic yields (Odum and Brown, 1987).

Wildlands protection through Recreation and Ecotourism

Wild ecosystems are protected in parks, where impacts are minimized and often human management is greater than natural inputs of ordering energies. Figure 3 is a diagram of a tourist system that shows the relationship between people and environment during tourist activities. Park systems are driven by contributions of nature (through ecosystems), money contributed by tourists (dashed lines), and purchased inputs of fuels, electric power, goods, and services.

Preservation of ecosystems for their tourism values may not be all that it is cracked up to be, however. As more and more tourists use the environment, a larger energy budget is required to maintain ecosystems in good health... rarely are there arrangements to reinforce the environment in exchange for the load placed on it. In addition, ecotourism can be a mixed blessing to local economies. The tourists represent a demand on local resources that cannot be used by local populations, essentially draining these resources from the local economy.

Much of the money tourists spend is used to buy other inputs from outside the region and very little money makes its way into the hands of the local populations. Probably more important is the fact that tourists have negative impacts on the local economy. Their demand raises the local price of food, land, and other environmental products, which reduces local living standards.

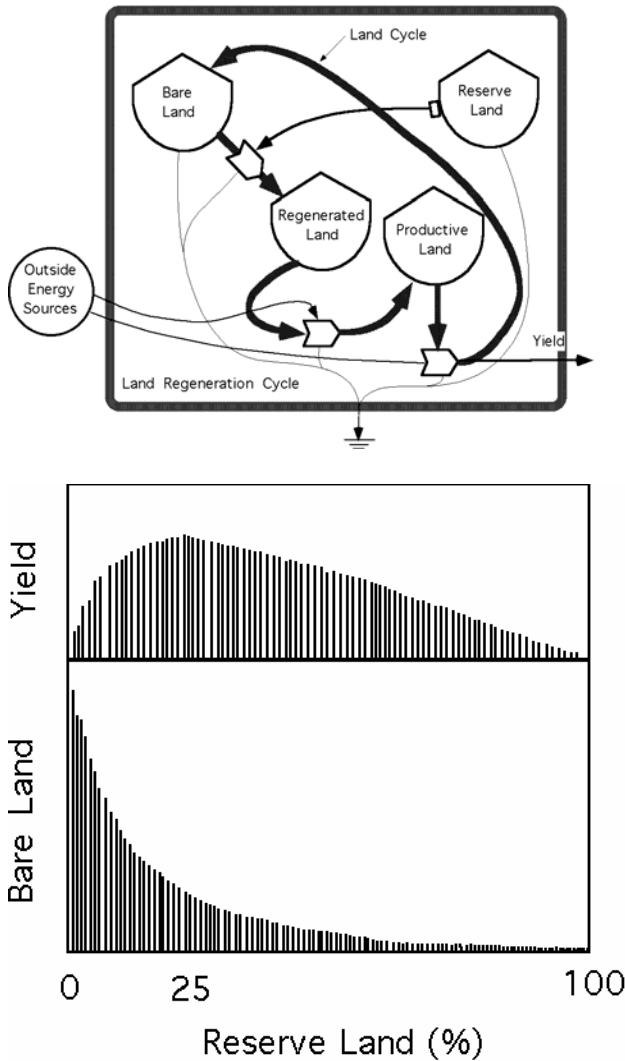


Figure 2. Model of landscapes that cycle land between economic uses to bare ground, to seeded and regenerated land to productive land indicates that approximately 25% of lands need be preserved as “bio-refugia” and seed sources for the regenerative cycle to maximize yield. Each vertical line in the graphs represents a simulation run of the model. The graphs show the yield that results from successive amounts of reserve land (top) and the amount of bare land remaining during each simulation run. Model was first published in Odum and Brown, 1986.

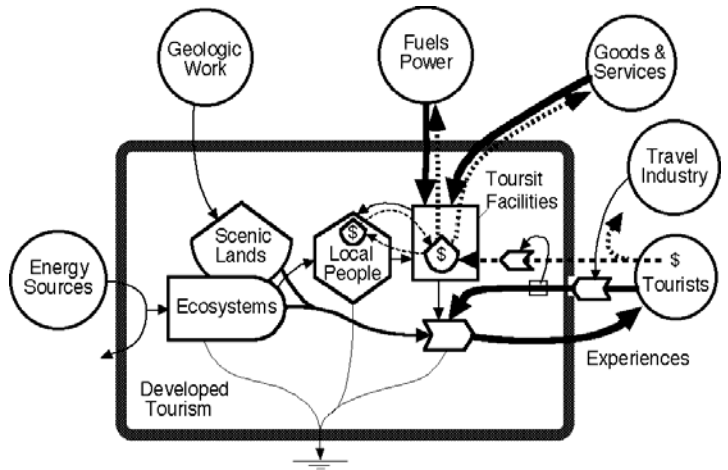


Figure 3. Diagram of a tourist system that shows the relationship between people and environment during tourist activities. Park systems are driven by contributions of nature (through ecosystems), money contributed by tourists (dashed lines), and purchased inputs of fuels, electric power, goods, and services.

Wildlands protection FOR Human Life Support

Our global metabolism is now out of balance caused by the increased use of fossil fuels and the increased destruction of earth’s vegetative cover, With consumption of oxygen and organic matter greater than production the imbalance has caused a steady rise in carbon-dioxide in the atmosphere. More carbon-dioxide and related gases are increasing the atmosphere’s greenhouse effect in storing atmospheric heat, increasing the temperature of the oceans, adding more vapor to the air, and causing stronger storms.

Simulation of global CO₂ models (Odum and Odum, 2001) suggests that if part of the earth’s bare lands are revegetated and the consumption of fuels decreases 1% per year, we could reverse the current trend of increasing atmospheric carbon dioxide in about 30 years. Figure 4 shows a simplified macroscopic mini-model of the global CO₂ cycle and simulation results.

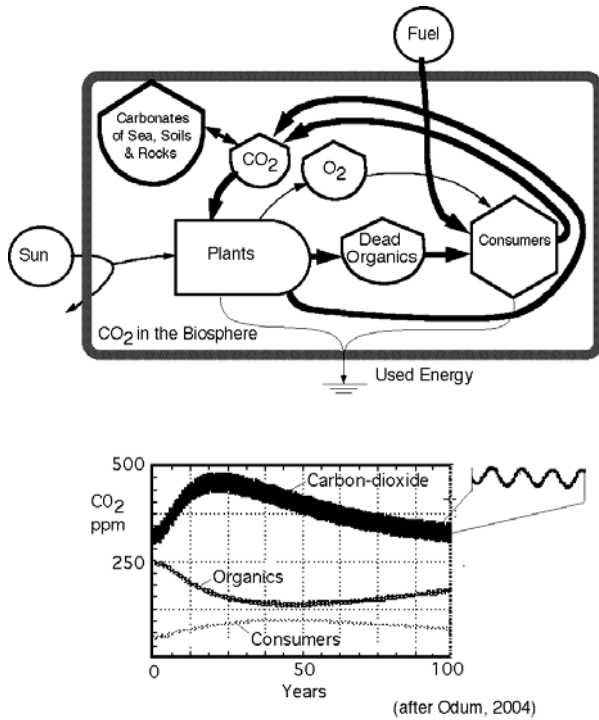


Figure 4. Macroscopic mini-model of global CO₂ showing the production of CO₂ by human society and the cycle where some CO₂ is sequestered in the bicarbonate cycle of the oceans and some in terrestrial forests. The model was simulated with increasing forested land and decreasing fossil fuel consumption by 1% per year. The current trend in increasing CO₂ concentrations is reversed in about 30 years. Model is after Odum and Odum, 2001.

MANAGEMENT OF YIELD SYSTEMS

Humans plant simple *yield systems* (agriculture, forestry, aquaculture, etc.) and then apply enough control energy to prevent nature from reorganizing. In order to maintain a high net production humans subsidize yield systems and control natural tendencies toward increased diversity. The large yields require large subsidies.... more ecologically inspired agriculture relies less on fuel subsidies and more on diversity (multicropping and permaculture) and human labor. Yield systems that do not incorporate direct feedbacks to the environment will not be competitive in the future. Recycle of nutrient rich waters, solid waste recycle to lands, and more human services are examples of needed feedbacks.

MANAGING INTERFACE ECOSYSTEMS

The management of nature's adaptive self-organization is the field of *ecological engineering*. Shown in Figure 5 is a much-simplified diagram of the interaction of the human economy with interface ecosystems. The work of ecological engineers is shown as the feedback of services and actions controlling the flows of genetic information. Through out millennia, genetic information to seed new situations has been supplied from the earth's pool of species... moved around the world primarily by earth processes... and in recent history, by people. Hand in hand, evolution controls species, the available species determine the nature of the ecosystems, and the ecosystems then control the next evolution of species. The present changing conditions associated with the pervasive activities of humans is causing adaptation of the earth's ecosystems to fit them. Ecological engineers can help in this transition by facilitating the movement of species to fill new situations.

Everywhere at the interface between our rich, fuel culture and the natural environment stand emerging eco-systems. These interface systems often look terrible, disrupted, patchy, stunted, and low in productivity. Left alone, nature, using available energy sources and whatever species are at hand, will eventually develop ecosystems adapted to the new conditions, a consequence of the maximum empower principle. On the other hand, ecological engineers can assist adaptive self-organization through their management inputs and facilitate the spread of genetic information that these new emerging environments require.

Since humans have disturbed and displaced large areas of the environment in which conditions are much different, new species may be required to form new ecosystems associated with human society. Large scale multiple transplantation is needed now to develop new designs and new ecosystems. This kind of self-design will take place anyway, but over very long time scales... ecological engineers can help by providing multiple-seeding tests in selected situations.

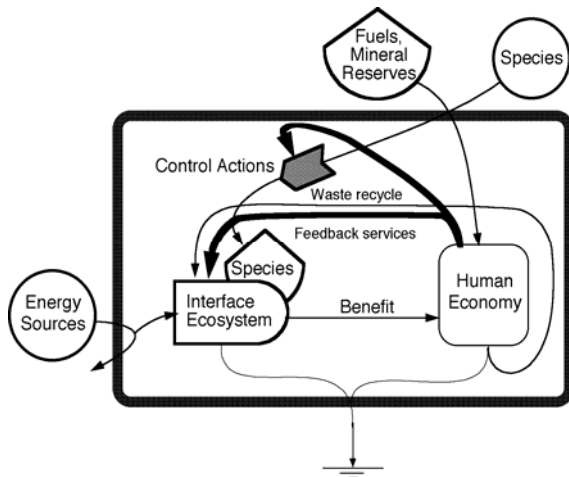


Figure 5. Diagram illustrating the place of ecological engineering in the overall system of humanity and nature. The human economy driven primarily by non-renewable inputs of fuels and mineral resources can influence interface ecosystems through controlled introductions of genetic information to foster adaptive self-organization, and through management services (dark flow lines). Interface ecosystems receive and recycle wastes to the biosphere providing a benefit to the human economy.

Interface ecosystems associated with the waste streams of our fuel culture are badly needed. Technological treatment solutions only create more pollution and are costly to build, operate and maintain. Ecological systems built as waste interface systems cost little or nothing to operate and are self-maintaining. The millions of species of plants, animals, and microorganisms are the raw materials of self-design and the palette of the ecological engineer for building waste treatment ecosystems. The use of species from different systems generates new combinations of organisms that may organize new relationships around wastes and cultural by-products. Multiple seeding and the ensuing self-organization, as an ecological engineering technique, may provide new ecosystems for these new conditions.

Human society depends on this same adaptive process of transmitting and selecting information. National meetings of scientists such as annual AEES meeting are where newly generated information is, selected, extracted, shared, reinforced and eventually used. The diagram in Figure 6 shows the annual information cycle of academic science where scientists and engineers spend the bigger part of the year generating new information, then select

and extract some small portion for sharing. If in some way, it “catches on”, it finds a reinforcement loop, becomes a part of our information base and gets used, ultimately feeding back to generate new information within the research groups. New ideas are the “seeds” of our human cultural ecosystem.

Evaluating the Costs and Benefits of Ecological Engineering

The real wealth coming from environmental systems is a combination of their services and natural capital. Environmental services and natural capital (otherwise known as the storages and components of ecosystems) cannot be evaluated properly using traditional economics.

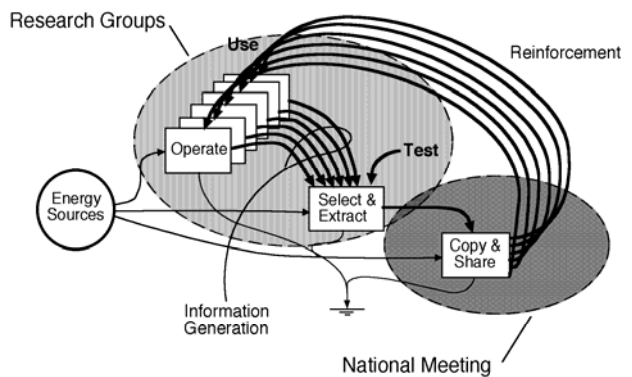


Figure 6. Diagram of the information cycle. The diagram shows the annual information cycle of academic science where scientists and engineers spend the bigger part of the year generating new information, then select and extract some small portion for sharing. If, in some way it “catches on” then it finds a reinforcement loop, and becomes a part of our information base and gets used, ultimately feeding back to generate new information. New ideas are the “seeds” of our human cultural ecosystem. In ecological systems the information cycle can be thought of as short term generation of new genetic information and the longer term evolution of different species characteristics adapted to differing conditions. The information cycle can be enhanced in natural systems by the introduction of new information (ie species).

The notion that one can determine environmental values by creating pseudo markets is a false one. Determining how much people are willing to pay does nothing more than create a false impression of value. Systems of value based on utility assume that humans are the ultimate consumers of all things and that their willingness to pay is the meter stick by

which we should measure all value. Willingness to pay is a false god of value.

What is required is a system of value that is free of human biases. A value system based on inputs rather than consumption. Figure 7 shows an emergy based system of value that assumes real wealth of environmental systems results from what is embodied into products and services and not what can be extracted. The concept of basing value on what goes into making something rather on what utility one gets out of it is somewhat foreign to our thinking, and runs counter to traditional economic valuation. However, humans are used to thinking of a “donor based value system” for many things...the more we put into something (art, information, craft, service, etc) the more “valuable” it is.

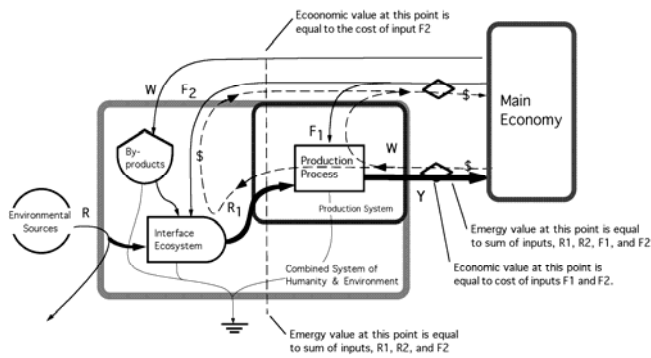


Figure 7. Inputs of emergy, when summed, provide the basis for determining the value of environmental services (R1). The Yield (Y) from this system may be some harvested product or service. Its economic value is the monetary cost of inputs F1 and F2. The Emergy value of the product is the sum of R1, F1, and F2. W is waste by-products from the main economy, F1 and F2 are economic feedbacks (goods and services) from the main economy.

Three Realms of Ecological Engineering

Ecological engineering uses small energy to have large effects by going with, rather than against, the self-organizing tendencies of nature (Odum, 2003). As energy becomes less available for the present massive, high intensity agriculture, forestry, aquaculture, and biotechnology, productivity may be sustained by using

techniques of ecological engineering...which let the ecosystems do most of the work.

There will be three main areas and scales of Ecological Engineering in the future (see Figure 8):

1. The smallest scale is design and management of interface ecosystems (ie waste processing),
2. An intermediate scale of restoration and “refitting” of ecosystems in an increasingly human dominated landscape, and
3. A regional scale...the ecological engineering of the LANDSCAPE itself...the design of landscapes that include humans and nature and that incorporate elements of self-organization.

At all scales some general initiatives are appropriate for the future of ecological engineering. The following is a list of initiatives that span these three scales:

Manage whole systems and whole cycles

At all scales of the economy, from government, to industry to commerce instill responsibility for management of the whole cycle of materials. For instance, industry should be responsible for managing materials used in products from mining through use and back through reuse, reprocessing, and environmental recycle. Wastes generated by residential developments should be managed as close to point of generation as possible.

Encourage industrial ecology

Industrial ecology deals with the relationship of industry to environment. At present industrial ecology is thought of as a method to improve the “greenness” of industry by reducing environmental impacts. Ecological engineering can help industry and society with better environmental interfaces at all scales...at the scale of individual processes to development of management schemes for whole life cycles of materials and products.

Provide incentives for environmental reinforcement

For too long feedback to the environment has been thought of as planting trees, restocking fisheries, or managing wildlife populations. It now time to rethink environmental feedback from a whole systems perspective. Emergy equal to that drawn from the environment must be returned to maintain symbiotic

interfaces. Those who extract from the environment should provide feedback services and resources equivalent to the amount harvested.

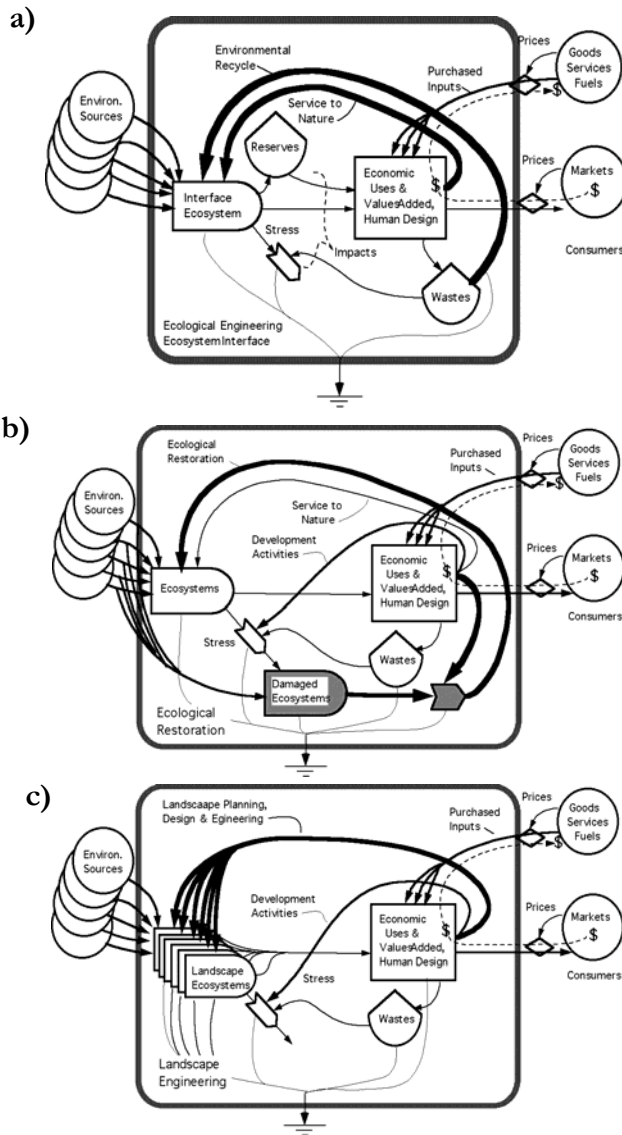


Figure 8. The main areas and scales of Ecological Engineering in the future: a). the design and management of interface ecosystems (ie waste processing), b). restoration and “refitting” of ecosystems in an increasingly human dominated landscape, and c) the design of landscapes that include humans and nature and that incorporate elements of self-organization.

Manage systems at all scales with high diversity

Low diversity interface ecosystems provide one yield or service, high diversity provides multiple services and values. Sustaining high diversity forests protects watersheds and their discharges and provides multiple other services. Manage landscapes for high diversity of land uses and land cover instead of monocultures of agricultural crops. Except where concentration of wastes dictate simple systems, development of “plantation-like” interface ecosystems are likely to fail because of the mechanisms that keep ecosystems diverse. The maintenance of single species monocultures goes against the successional tide and requires large energy subsidies.

Organize systems based on nutrient status

Whether at the scale of landscapes or individual interface ecosystems, we should strive to organize systems to maximize use of nutrients close to their sources. High nutrient runoff from developed lands should be channeled through high nutrient early successional ecosystems first followed by increasingly mature and diverse systems as nutrients decline. In interface ecosystems zone systems so that concentrated wastes are first released to many small highly managed systems and then passed to larger systems of decreasing management requirements.

Connect organic waste to decomposition

Relegating organic wastes to land fills wastes this valuable resource and squanders much land and energy in operation and maintenance of solid waste facilities. Organic wastes should be combined with nutrient flows to speed decomposition and develop useful products like compost, fungus, worms or fishes.

Use Microcosms to test properties of interface ecosystems

Often environmental conditions associated with high energy human systems produce new situations that offer new opportunities for ecosystem development. To test alternative designs set up microcosms or mesocosms that exhibit the new conditions and then seed them with available species. The systems that emerge and their self-organizing properties provide insight into the larger scale opportunities.

Control systems by controlling energy sources

Pulsing systems often have higher yields than continuous systems. As ecosystems respond to pulsing energy sources, conditions may be introduced to which ecosystems respond with pulses of net production. This process may be managed to remediate human induced pulsing such as increased hydrologic and nutrient loads associated with urban development. The fluctuations in wastewaters and stormwaters from urban centers could be turned into net ecosystem benefits.

Small amounts of limiting materials can be used to control ecosystem self-organization. For example, adding fertilizer nutrients to some organic wastes can speed decomposition.

Increase adaptation with controlled introductions

Species transplanted from one location where they were part of a stable system to another may result in higher yields. The new situations created by human dominated systems may require ecosystems composed of new species introduced from other locations for rapid adaptation and self-organization.

Evaluate systems using emergy

The costs and benefits of ecological engineering projects cannot be evaluated with money alone, because it does not include the real wealth coming from the environment. Evaluating with emergy includes both the work of environmental systems and that by humans in the economy.

Summary

Examples of adaptive self-organization are all around us as new kinds of ecosystems are developing at the interface between society and environment in response to the new conditions that have been created. In other words, the landscape of humans and nature is self-organizing. What is needed is mindful design, planning and engineering at the landscape scale to capitalize on and direct self-organization and adaptation.

Field experiments and the use of microcosms have generated much information and formed the basis for principles of adapting ecosystems as interface systems. The evidence is clear that self-organized ecosystems are capable of “treating” many types of wastes.

Soon the restoration of lands and ecosystems will be a main concern of society as our fuel culture enters a lower energy future based on good use of environmental resources. Restoration should be a main focus of ecological engineers.

Contributions of environment and economy should be evaluated quantitatively on a common basis using emergy. Economic evaluations cannot capture the true value of environmental services or natural capital.

As we approach the peak of our fuel culture we are faced with the possibility of two alternative paths to deal with the reality...the “might makes right” approach our current administration seems bent on pursuing, or one that accepts the reality of a lower energy future and uses the talents, energy and creativity of engineers and scientists to redefine our culture and its fit within its life supporting environment. I believe that defining, designing and managing that fit is the realm of ecological engineering and our challenge in the coming years will be to not only convince society of the coming low energy future, but then to lead the way toward an integrated system of humanity and nature.

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Clear the air! Thoughts on ecological engineering for air quality improvement

David R. Tilley

*Department of Biological Resources Engineering,
Natural Resources Management Program,
University of Maryland, College Park, MD
Email: dtilley@umd.edu*

Can ecological engineers revolutionize air pollution control the way they did waste water treatment? Ecological engineering has a long and distinguished history rooted in the application of constructed wetlands for treating liquid wastes of many varieties, but expanding in many new directions (Kangas 2003, Mitsch and Jorgensen 2003, Tilley 2003). The main characteristics that have made treatment wetlands a technological success—a high reliance on solar power, microbiological activity of soil, plant uptake and other natural processes, and a minimum use of fossil fuels and electric power—can also be embraced by the ecological engineer to clean the air we breathe. Let us look at how the metabolism of natural systems works to destroy a poisonous and environmentally detrimental compound such as carbon monoxide (CO), to what extent natural processes have been integrated into air purification technologies such as biofilters and soil bed reactors, and finally explore ideas and opportunities for the ecological engineer to advance the development and integration of these techniques.

Globally, the biologically active soils of grasslands, forests, wetlands, and cropland are estimated to oxidize between 9 and 36% of total CO emissions (King 1999). A multitude of soil microbes, including methanotrophs, ammonia oxidizers, carboxidotrophs, oligotrophic bacteria, fungi and algae, have been demonstrated to aerobically oxidize CO (Chappelle 1962, Inman and Ingersoll 1971, Bartholomew and Alexander 1982, Conrad and Seiler 1982, Duggin and Cataldo 1985, Bedard

and Knowles 1989, Conrad 1996). Experiments with C^{14} revealed that 95% of C from CO was oxidized to CO_2 , with only a minor amount remaining in the soil (Bartholomew and Alexander 1979, Whalen and Reeburgh 2001). Plants and plant-associated ecological communities contribute to CO oxidation. Wolverton et al. (1985) observed CO decrease from 128 ppm to less than 5 ppm (96% removal) in 24 hours in enclosed chambers containing common indoor houseplants (e.g., spider plant, *Chlorophytum elatum*), while soil-filled pots with no plants only removed 14%. Wood et al. (2002) and Darlington et al. (2000, 2001) generated evidence that leaves and stems remove air contaminants (e.g., toluene, o-xylene, and ethylbenzene) from indoor environments. Even the ecological engineer's good friend the wetland was shown to harbor microbial CO oxidizers on plant roots (Rich and King 1998). Important soil factors that affect CO oxidation rates include total organic carbon, moisture, and temperature (Moxley and Smith 1998), which exhibit optimum effects. In our own studies (Tilley and Mentzer in review), we have witnessed the ability of vegetated soil ecosystems to reduce CO emitted at 800 ppm in the exhaust of a gasoline powered engine to 710 ppm in one hour, demonstrating that microbial metabolism is robust and can withstand mixtures of complex gases.

Air biofilters work by creating a nutritional environment amenable to microbial transformation of waste elements and compounds. Bach (1923) and Pomeroy (1963) were the earliest researchers to investigate the principles of air biofiltration when they discovered that odorous gases emanating from sewer pipes could be removed by passing the foul air through natural soil beds. Continuing upon Pomeroy's early findings, Carlson and Leiser (1966) used soil beds to control the odors of wastewater treatment plants. Smith et al. (1973) showed that natural soils had the capacity to adsorb substantial amounts of sulfur dioxide, hydrogen sulfide, methyl mercaptan, and small amounts of CO, ethylene and acetylene. Newer biofilter designs, which isolate soil microbes in an enclosed chamber, offer the advantage of higher flow rates, faster reaction times and greater loading, over a smaller footprint than soil bed reactors (DeVinney et al. 1999). During the last decade biofiltration began to find significant commercial success in the U.S. (DeVinney 1999, Boswell et al. 2002). A brief list of the contaminants removed by

biofilters includes both organic (e.g., diethyl ether: Yang et al. 2002; BTEX: Martinez and Tamara 2002) and inorganic compounds (e.g., ammonia: Liang et al. 2000; nitric oxide: Davidova et al. 1997, Woertz et al. 2001; hydrogen sulfide: Jones et al. 2002; CO: Ganeshan 2004).

An important question in biofilter performance concerns the role of microbial diversity in controlling removal rates and long-term operability. Historically, the goal for microbial diversity in biofilter applications has been meager. However, the number of microbial species in the world is estimated at 10^5 to 10^6 , with only a few thousand characterized (Tiedje quoted in Kaerberlein et al. 2002, Torsvik et al. 2002). Indeed there is now great emphasis on identifying, cultivating, counting and generally understanding the ecology of microbial diversity (Kaerberlein et al. 2002, Hughes et al. 2001, Finlay 2002). Maybe the gastrointestinal tract of the earthworm, which hosts a diverse culture of 100 bacterial species that aid in assimilation and waste processing (Furlong et al. 2002), is an appropriate ecological model for the ecological engineer. The advantages of integrating diversity into environmental pollution control may be more effective and environmentally sustainable than genetically modifying strains for specific tasks. For example, von Canstein et al. (2002) determined that under variable loading of mercury-laden wastewater, a mixed microbial culture biofilm outperformed all monoculture reactors tested, including one inoculated with a genetically modified strain. If diversity adds stability, increases resistance and improves resilience of ecosystems (Tilman 2000), then more of it in living air pollution control technologies seems to be desirable, especially for an episodically forced system where improved control is a goal.

Brown (this volume) described a major goal of the ecological engineer as creating 'interface ecosystems,' meaning new ecosystems designed and built to treat and recycle humanity's wastes before they enter less well adapted environments. Ecological engineers can work to improve air quality by combining their skills in mechanical design with their intimate knowledge

of ecosystem functionality to research, develop and commercialize new eco-technologies that are energetically passive and financially inexpensive. One idea given here is the Urban Passive Solar Inhaler (UPSI) (Figure 1).

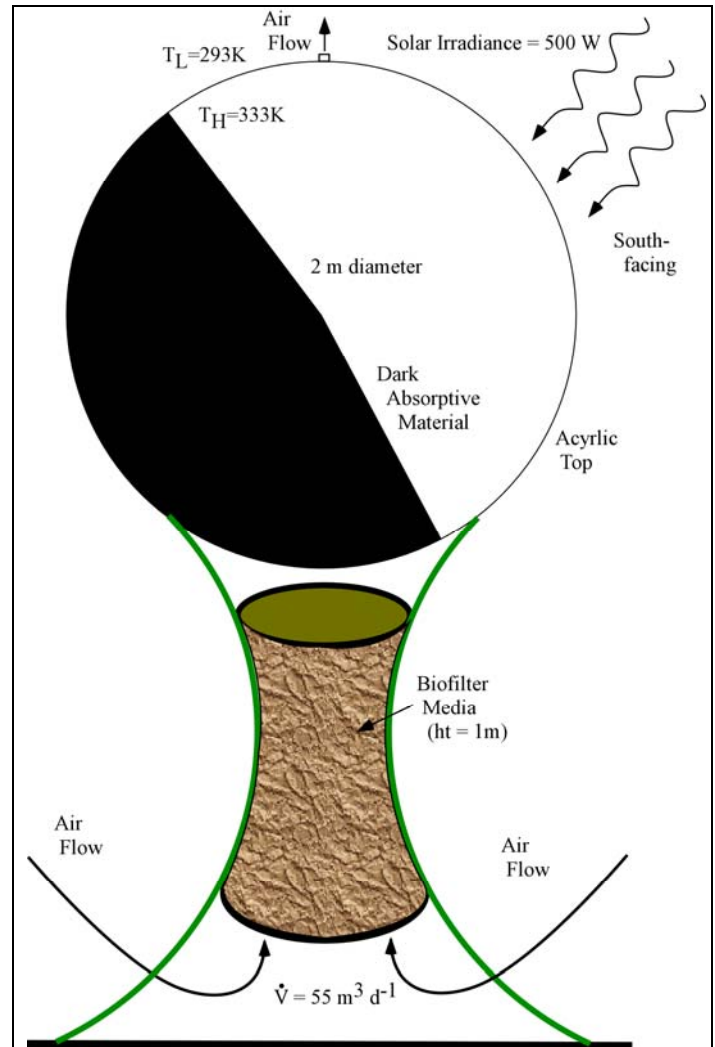


Figure 1. Urban Passive Solar Inhaler (UPSI) uses a clear canopy to capture solar irradiance to create a heat engine that pulls polluted ambient air through a microbial active bioreactor where compounds are transformed to benign by-products and air is cleaned.

This approach was inspired by tree geometry, wetland macrophyte gas transport, traditional air biofilter designs, and solar tower chimneys. The thought is to locate them in downtown areas wanting of natural systems and in need of air purification. The canopy air-bulb on top of UPSI is heated during the day by solar power creating a difference in enthalpy which induces air to flow out the top valve and pull in make-up air from street-level contaminated with a variety of

hydrocarbons and inorganic compounds. Preliminary estimates indicate that an UPSI could process 55,000 liters of air per day.

Soils of urban ecosystems purify air now without any design consideration from engineers or city planners. Is it technically, economically and environmentally feasible to improve upon the haphazardly arranged network of recreational parks, remnant forests, landscaped lawns and other 'green' space to improve nature's ability to reduce toxic and poisonous air pollutants in our cities? Are there latent, dual roles for raingardens and other urban stormwater management ecosystems? As ecological engineers let's see what we can do to answer these questions and clear the air.

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Ecological Engineering Song



Fixing the Planet on a Budget

by Alex Horne,

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- played to the tune of "Big Rock Candy Mountain"

If you're fixing the planet and don't have much cash
You'll need to be ingenious and even to be rash
Then learn some solutions as I sing this song
And you'll soon save the planet and never go wrong

Now the first thing we need is to protect our lakes
Our rivers and oceans and make no mistakes
They're full of pollutants, nutrients and oils
And we have to fix them, before the world spoils

From farms all around us, nutrients flow
Down the Mississippi to the Gulf of Mexico
The big muddy river drains half the USA
And pours out pollutants every single day

Now out in the Gulf there is the dead zone
It's origin's farm runoff, that it is known
Nitrates grow algae, that die and then sink
They use up oxygen making quite a stink

From the shores of the Great Lakes to San Francisco Bay
You see posted warnings, eat no fish today
PCBs, PAHs, and good old DDT
Its quite a sharp warning for you and for me

You can't eat the fish in Lake Onondaga
Mercury pollution, New York's saga
For over 100 years from the factories around
Mercury and salt to the lake they were bound

Out West in the Golden State we mined streams for gold
The Hearsts made super profits from all the gold they sold
Extracting shiny gold requires mercury
And they left it to poison good old you and me

Two-thirds of the planet is covered by sea
But it's mostly unknown to you or to me
If we're going to survive for another million years

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It's protect our oceans or end up in tears.

Even in Antarctica, pesticides are found
In penguins and fishes, even whales as they sound
DDT it is volatile, mercury too
So they cover the globe with a mild toxic stew

So how do we fix all of this mess?
It is not very easy, that I'll confess
Especially on a budget, where money is tight
But if we just think about it we'll do alright

I'll tell about wetlands and how they can work
To clean up pollution, a job they don't shirk
They are living factories, systems we can use
But we must get on with it and no longer snooze

In the mud of a wetland, bacteria live
They destroy pollutants, a service they give
They fix heavy metals, nitrates they destroy
And all we have to do is encourage their joy

Now to do all this good stuff and clean up the world
We must build new wetlands where pollution's been hurled
Designed to clean up water and look mighty fine
Wetlands give wildlife a pretty good time

Now how do new wetlands clean up the world so cheap?
They need no fossil fuels for benefits to reap
Sustainable power, it comes from the sun
And via photosynthesis the project we run

Let's build more new wetlands all over the planet
To clean up pollution, maybe even ban it.
Natural Treatment Systems is where they are from
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Ecological Engineering Jobs

Aquatic Ecosystems Engineer (Assistant Professor), Virginia Tech, Blacksburg, VA

This is a 12-month, tenure-track position with research (50%) and teaching (50%) responsibilities in Biological Systems Engineering (BSE) at Virginia Tech. The incumbent is expected to develop a nationally and internationally recognized research program focused on in-stream processes and interrelationships with aquatic and terrestrial ecosystems. The program is expected to complement current faculty expertise in nonpoint source (NPS) pollution modeling and monitoring, watershed management, and ecological engineering. The research program, including field, laboratory, and modeling studies, should emphasize one or more of the following areas: nutrient dynamics; biomonitoring; microorganism fate and transport; and impacts of NPS pollutants from rural and urban land uses on aquatic ecosystems.

The faculty member will normally teach three courses per academic year, including both undergraduate and graduate courses. Courses taught by the successful candidate should reflect his/her areas of expertise and meet departmental needs. Additional responsibilities include mentoring undergraduate and graduate students and participating in departmental, college, and university committees. The faculty member will actively participate in graduate education by recruiting and advising graduate students.

The incumbent is expected to secure competitive grants, establish a strong publication record, and support scholarly programs in both research and teaching. The faculty member will be a member of the land and water resources engineering group in the BSE department. The incumbent is expected to be an effective team member and to play a major role in developing interdisciplinary groups to address teaching and research needs. The Center for TMDL and Watershed Studies at Virginia Tech will provide one means for working collaboratively with faculty from BSE and other disciplines to pursue basic and applied research to address issues related to watershed and water quality management.

Qualifications: Ph.D. degree with at least one degree in engineering is required. Evidence of strong communication and teamwork skills that will enable interaction with student, academic, industry and public audiences across disciplines is required. Preference will be given to candidates with a strong background related to in-stream water quality processes or to contaminants in aquatic ecosystems. Preference will be given to candidates with field research experience, teaching experience, and with a strong record of peer-reviewed journal publications and extramural funding.

Salary: Competitive, commensurate with background and experience. Virginia Tech offers an attractive benefits package.

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