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THE EVOLUTION OF ENVIRONMENTAL RESPONSIBILITY . . . AN ENGINEERING VIEW

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ABSTRACT: The environmental ethic in engineering has slowly evolved from viewing Nature as an adversary, to Nature as a partner, to Nature as a patient, needing remedial attention. Much of this change has proceeded as a reaction to obvious environmental abuse and damage, and an earlier response would have been more appropriate. A listing of high priority environmental issues includes: global warming, biodepletion, consumption, population, third world poverty, soil erosion, water shortages, ozone depletion, and synergisms. The concept of Sustainable Development, which recognizes that economic development must proceed with environmental sensitivity in a manner that will allow future generations to meet their own needs, is a practical unifying principle which can be used by scientists and engineers. As an engineer, the author's principal interest is in sustainable technology, to be specific, in sustainable transportation systems. An important consideration in designing sustainable transportation systems is the use of industrial by-products in construction/maintenance. By-products of obvious utility are: scrap tires, coal combustion ashes, and spent foundry sands. In addition, paving materials should be reused, as should much of the product of building demolition. The more obvious uses of these by-products are briefly described in this paper.

KEYWORDS: Environmental issues, industrial wastes, reuse/recycle, sustainable development.

PREAMBLE

Teach your children what we have taught our children, that the earth is our mother. Whatever befalls the earth, befalls the children of the earth. If we spit upon the ground we spit upon ourselves. This we know. The earth does not belong to us; we belong to the earth...One thing we know, which the white man may one day discover, our God is the same God. You may think now that you own Him as you want to own our land; but you cannot. He is the God of All people, and His compassion is equal for all. This earth is precious to God, and to harm the earth is to heap contempt on its Creator. So love it as we have loved it. Care for it as we have cared for it. And with all your mind, with all your heart, preserve it for your children and love...as God loves us all. (Chief Seattle, 1855)

INTRODUCTION

As the technology available to society developed, the ability to overcome natural obstacles increased. No river valley was too deep or wide to be dammed; no water body was too wide to be bridged above or tunneled beneath; no mineral resource was too remote to be exploited. The ruggedness or expansiveness of the natural scene might pose enormous technological challenges, but these challenges could be overcome. Nature was an adversary to be bested, and losses accruing to the loser were...well, natural.

Conscionable technologists, of course, had canons of ethics which demanded that such activity be "for the benefit of Humankind." However, short-term and localized benefits were the focus. Scant attention was given to the potential unfavorable effects on future generations or to natural effects which transcended the local scene.

The healing and restoring capacities of Nature were overestimated or ignored. Solid wastes were dumped, piled, and buried; liquid wastes were flushed into waterways; combustion products, both particulate and gaseous, were spewed into the air. Such activities could not be sustained; environmental quality deteriorated badly over large geographic regions...there were even global effects.

Of necessity, the image of Nature was slowly, even reluctantly, changed from Adversary (to be beaten) to Partner (deserving consideration and cooperation). The notion of building **with** Nature and of building to achieve total and long-standing social benefit gained acceptance. Assessment of the environmental effects (even impacts) of new building activities became routine and were often mandated. Lest the argument that the building activity should simply be avoided always prevail, the social cost of **not building** was also estimated.

Developments continued at a rate and in a manner that accrued environmental damage, until the set of environmental issues reached the current (1994) crisis level. The need for drastic rethinking of economic policy has lead to the definition and implementation of *Sustainable Development.* In this philosophy, development is adjusted to that level/kind which admits both economic growth and environmental preservation...even some restoration.

In terms of the human species, Sustainable Development is meeting the needs of the present without compromising the ability of future generations to meet their own needs. In terms of the global ecosystem, Sustainable Development is the middle ground, where humans thrive in the same landscape with healthy ecological processes, characteristic vegetation, and biological diversity.

Sustainable Development recognizes that an economy which provides new jobs must continue and rejects the irrational argument that development must be abruptly and drastically curtailed to "save the environment." Sustainable Development also rejects the position that environmental losses are imaginary or overstated and that we can proceed with "business as usual." Sustainable Development challenges all of us to reevaluate and strengthen our fundamental values and to rethink our operational procedures, including routine actions that are based primarily on short-term individual convenience.

ENVIRONMENTAL ISSUES

Humankind is accustomed to seeing environmental issues one at a time, and they are formidable enough on that basis. Recently, ecologist Norman Myers (1994) was asked to list the top 10 environmental problems. His list included:

1. Global Warming
2. Biodepletion
3. Consumption

4. Population
5. Third World Poverty
6. Soil Erosion
7. Water Shortages
8. Ozone Depletion
9. Synergisms (compounded impacts)
10. Unknown Unknowns (impacts as yet undiscerned).

Space does not permit a detailed discussion of each of these issues, but a few may warrant particular attention.

Changes of only a few degrees in the planet's average temperature are able to produce profound changes in its living environment. For example, a few degrees decrease in the average temperature was apparently enough to produce an ice age. The accumulation of carbon dioxide and other greenhouse gases certainly has the capacity to raise the average temperature a few degrees. These accumulations, if continued, will undoubtedly cause *global warming*. It is not a question of whether, only of **when**.

Many of the consequences of warming are well appreciated. As a specialist in the cold regions of the planet, I need to emphasize the effects of warming on the accumulations of snow and ice as well as on the perennially frozen ground (permafrost). Ocean levels will rise dramatically, and runoff will erode and drastically alter the terrain near streams. As the permafrost is thawed over enormous areas in the North, massive ground subsidences will occur, along with countless landslides. Roads, airfields, pipelines, and other human infrastructure will be rendered inoperable as the supporting frozen ground beneath them thaws and settles. Energy conservation and the development of alternate fuels seem to be required to control the greenhouse effect.

Biodepletion, or the reduction of biodiversity, is proceeding at a rate which alarms biologists. Are we about to lose one third to two thirds of the Earth's species, before we have even identified their value? The natural habitats in which these species exist must be protected from human destruction and from external factors, such as the global warming and acid rain. To replace lost species through evolution requires millions of years.

"Recycle" is a much emphasized modern activity, but it is actually the final environmental step in the 3 "R's" — Reduce, Reuse, Recycle. *Consumption* of nonrenewable resources must, of course, be limited not only for conservation but also to reduce the quantity of wastes which must be returned to the environment. To "reuse" can mean to use with care and with proper maintenance to extend life. "Reuse" also means storing infrequently used items so that they may be periodically retrieved, used, and then stored again.

How easy is it to recycle, once further reuse is not practical? A few car manufacturers are already fabricating to facilitate recycling through disassembly and separation of materials. The same concept can be applied to structures, replacing the "wrecking ball" with tools which cut, pry, and pull components apart in the demolition process.

Much attention is directed toward recycling domestic wastes, but based on quantity, domestic waste rates well below mining and industrial wastes. Areas of carelessly disposed mining wastes must now be remediated and reclaimed for a secondary use. An excellent example is the coal waste "gob pile" and the acid mine drainage which originates in it. These areas must be graded, drained, and "capped" to prevent infiltration of rainwater which would continue to generate the acid drainage. Modern regulations require that mined material which is not marketed be placed back in the mined area, and that the mined area be appropriately graded for reuse.

Population control seems to be the most necessary element in controlling environmental problems. Even the most avid proponent of Sustainable Development will readily concede that the concept will fail unless population growth rates are sharply reduced.

Some 90% of the world's population growth occurs in developing nations, where it tends to be most difficult to control. There, political power resides in numbers, and outnumbered groups (minorities) may resist efforts viewed as an attempt to simply maintain their minority status. Cultural ethics and religious beliefs may effectively mitigate against controlling birth rates. Large numbers of women are currently unable to make responsible decisions about family size.

Certainly there are signs of hope. The Peoples Republic of China has an effective birth control plan, one child per marriage. However, minorities are exempt, and the plan is not well enforced in rural areas.

The most pervasive argument in favor of birth control may be our ability to sustain a well-fed, healthy population. Were the world on a diet deriving 25% of its calories from animal protein, as is North America, a population of less than three billion could be sustained. For people on a vegetarian diet produced using current agro-technologies, the present population of 5.5 billion is sustainable (Myers, 1994). While our ability to raise and distribute food will undoubtedly continue to increase, the trend will lag behind the projected population growth.

Many of us in the basic or applied physical/chemical sciences relate better to the next three items on the critical symptoms' list: soil erosion, water shortages, and ozone depletion. *Soil erosion*..."is as bad in parts of Indiana, one of America's agricultural States, as in India" (Myers, 1994). Loss of top soil results in loss of fertility; a downstream effect is the compromising of aquatic environments and water supplies through siltation. Economic incentives to protect topsoil work well in the US, and will probably work elsewhere. Hilly terrain is best kept in vegetation, including trees, where rainfall allows.

Water sources are either surface or underground, with flow connections, of course. Where water is scarce, it is expensive, and conservation measures are strict. Overuse of surficial supplies is obvious and tends to be controlled. Excessive groundwater use is hidden, and depletion of major aquifers is common. Irrigation is needed for a substantial part of global food production. And, as more food production is required, water supplies will be further stretched.

Careless and unregulated underground disposal of toxic materials has contaminated large quantities of groundwater. Industrial and domestic sewage has polluted surface waters. Environmental laws and regulations have sharply reduced such pollution in the US, but in the former Soviet bloc, abatement has scarcely begun.

Contaminated waters produce enormous health problems. Today, more than a billion people suffer shortages of clean water. Myers (1994) estimates that this number will triple in the next two decades.

The *ozone layer* shields the earth from lethal solar radiation. Thus, ozone loss is a grave threat to most living creatures. Ozone losses occur due to release of chemical compounds containing chlorine, including coolants used in refrigerators and air conditioners, into the atmosphere. These chlorine molecules combine with ozone to form acid compounds. Substitution for these harmful chemicals is taking place; unfortunately, the replacement materials are more expensive. Will reduction in ozone-depleting refrigerants in North America and Europe be countered by increases in Asia and Africa?

THE NEW ETHIC

In the face of these environmental ills, governments, institutions, agencies, families, and individuals require a philosophy, which is realistic, positive, and adequate for the challenge. The Sustainable Development approach will work, if population growth rates can be sharply reduced.

Our philosophy, and our activities in behalf of it, are undergirded by a set of behavioral principles and guidelines. As a Civil Engineer with 50 years of experience, the author is a member of and subscribes to the Canon of Ethics of the American Society of Civil Engineers. The seven canons in this list will, after a healthy debate, be joined by an eighth, which will likely read: "Engineers shall perform services in a manner as to sustain the world's resources, and protect the natural and cultural environment."

The implications of this pledge are far-reaching and already have significant beginnings. More and more structures are being planned and designed with a predetermined life cycle of construction, maintenance, and deconstruction (Abraham, Lovell, and Kim, 1994).

The "built environment" is made compatible with the "natural environment." The modern structure also conserves natural building material resources while maximizing recycled content and the recyclability of the materials in the structure. The structure is not only "healthy" for those using it, but it also avoids being an environmental liability when destructed.

Certain institutional and commercial structures (e.g., churches, public buildings, financial institutions) are properly built for a very long life, with periodic remodeling/renovation. Other structures with a limited service life (e.g., motels, strip malls, fast food restaurants) should be built so that upon decommissioning, the materials can be easily separated for recycling.

WASTE TYPES AND VOLUMES

The effort to reuse/recycle begins with an assessment of waste types and rates of generation. Our data are, of course, better for the US, and we will use them for purposes of comparison. The annual rate of waste production by type is (in order from greatest to least): agricultural, mining, industrial, and domestic (including scrap tires).

Agricultural waste tends to stay close to the point of generation, and it is not a high-profile waste in the US. However, in small, livestock-oriented countries like The Netherlands, manure production must be legally controlled, and even plans to export the waste are under consideration (Dahlburg, 1994). In developing countries, dried manure is often used as fuel.

Second on the list is *mining waste*. This waste is comprised of the earthen material which must be removed to access the commercial mineral, the host rock, if any, and the waste from extraction/refinement of the mineral. Improper disposal in the past has often seriously compromised the quality of the surface and groundwater in the vicinity of the mine. Current disposal is highly regulated. Of course, coal mining is the principal source of such wastes in Indiana.

The third category is *industrial waste*. In Indiana, the primary example is coal ash or coal combustion by-products (CCBPs). This grouping includes the cementitious fly ashes (Class C) and others (termed Class F) as well as the boiler slags and bottom ashes. Improvements in combustion processes and the desire to burn higher sulfur coals are leading to increasing amounts of fluidized bed residuals and flue gas desulfurization products. Interestingly enough, as combustion and clean air technologies are improved, more and more solid wastes are generated.

Class C fly ash results from the combustion of lower grades of coal, and the product is in demand as a cement replacement in concrete. The more abundant Class F fly ash (from the better grades of coal) has no established market. The same is true of the coarser residues, i.e., all bottom ash and some boiler slag.

A key to the use of these by-products, as soil or mineral aggregate replacements, is their method of disposal. The finer fly ash and the coarser bottom products are collected separately but may be commingled in disposal. When this happens, a complex depositional mixture of sizes of material occurs, which complicates retrieval and use.

The noncementitious fly ashes and the bottom ashes may be used as a soil replacement, when building fills for structures, including highways (Huang, 1990). They may also be used as fillers in asphaltic mixes. While the use of these wastes to replace soil in fills may seem to be of little importance, remember that in flat areas, soil from adjacent areas must be excavated for the fill, reducing the amount of tillable land. Use of CCBPs for the fill not only conserves the adjacent land for agriculture but also reduces the disposal costs for the generators.

Another important industrial waste by-product in Indiana is spent foundry sand (Javed and Lovell, 1993). Indiana foundries cast a variety of metals, of which iron is the most common. As the greensand process is used to cast ferrous metals, the spent sands are often environmentally suitable for a number of engineering applications.

One use of spent foundry sands is as a soil substitute in fills. Another is as a constituent in a low-strength, cementitious, flowable material called "flowable fill" (Bhat, *et al.*, 1995). This material is superior to compacted soil in and around pipes and other "tight" places. Flowable fill is purposely designed to have low strength for utility cuts in streets, so that it may be easily excavated and replaced. (We are all familiar with the scenario of periodic trenching operations in nearly all streets.)

The materials in buildings and pavements should be largely reused. Reuse is perhaps easiest for an asphaltic pavement, where, with the addition of a rejuvenator, the materials may be reapplied for the new paving. The same is true of old concrete paving, except that it is more expensive to break up the concrete pieces and remove the reinforcing steel prior to constituting a new concrete mix. Reuse of products from demolished buildings is complicated by two factors: the technology of construction and the technology of destruction. We have all observed the "wrecking ball" process and the impossible jumble being loaded into trucks for disposal. A number of the materials can be reused, if separated. Among these are concrete, steel, brick, wood, and rubber/asphalt roofing. Disposal should not be in a municipal solid waste landfill but in a construction debris facility. Separation can occur before the disposal of the ultimate residuals in a processing yard adjacent to the landfill.

Certain domestic wastes are commonly recycled, *viz.,* aluminum cans, bimetal cans, glass, paper, cardboard, and some plastics. A waste which needs increased attention is the scrap tire. This discard is generated in the US at the rate of about 0.8 tire/person/year. Since scrap tires have been presumed by "speculators" to have ultimate value, they have been stored, often in a most unsightly and unsanitary manner, producing disease and fire hazards.

Scrap tires must now be stored inside, which means they are usually cut or shredded to save space. Because whole tires cannot be compacted with the other wastes and actually tend to "float" upward in the mass, tires must be cut into pieces for disposal in solid waste landfills.

Tire rubber is a strong and durable material that lends itself to a variety of reuse potentials (Ahmed, 1993). For example, whole tires can be used to build an earth-retaining structure, a floating breakwater, or an underwater reef. Sidewalls and beads can be cut out and linked in a mat to stabilize low cost roads or earthen masses. Tire shreds, a few inches wide on a side, form an excellent lightweight substitute for soil in a fill. Reducing the tire rubber to small crumbs allows it to be reused to mold new rubber products or to produce a new variety of asphalt.

All of the reuse/recycle examples listed in this paper are simplistic ones and represent very low technology. These procedures can be expected to advance and develop enormously in the near future.

SUMMARY

Environmental responsibility has evolved slowly and only after abundant evidence of damage to the earth. The global issues constitute a formidable list, all of which require immediate attention and remediation. A basic principle which can stimulate scientists and engineers to cooperate and synergize is that of Sustainable Development. By this strategy, development takes place with appropriate environmental sensitivity. However, unless population growth rates are sharply decreased, humankind will undoubtedly exhaust food supplies, even given great technological developments.

Sustainable technology will involve many ideas and approaches, but an important one is the reuse/recycling of current wastes, such as scrap rubber tires, coal combustion ash, and spent foundry sands. Paving should also be recycled, and the products of building demolition should also be separated and reused.

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