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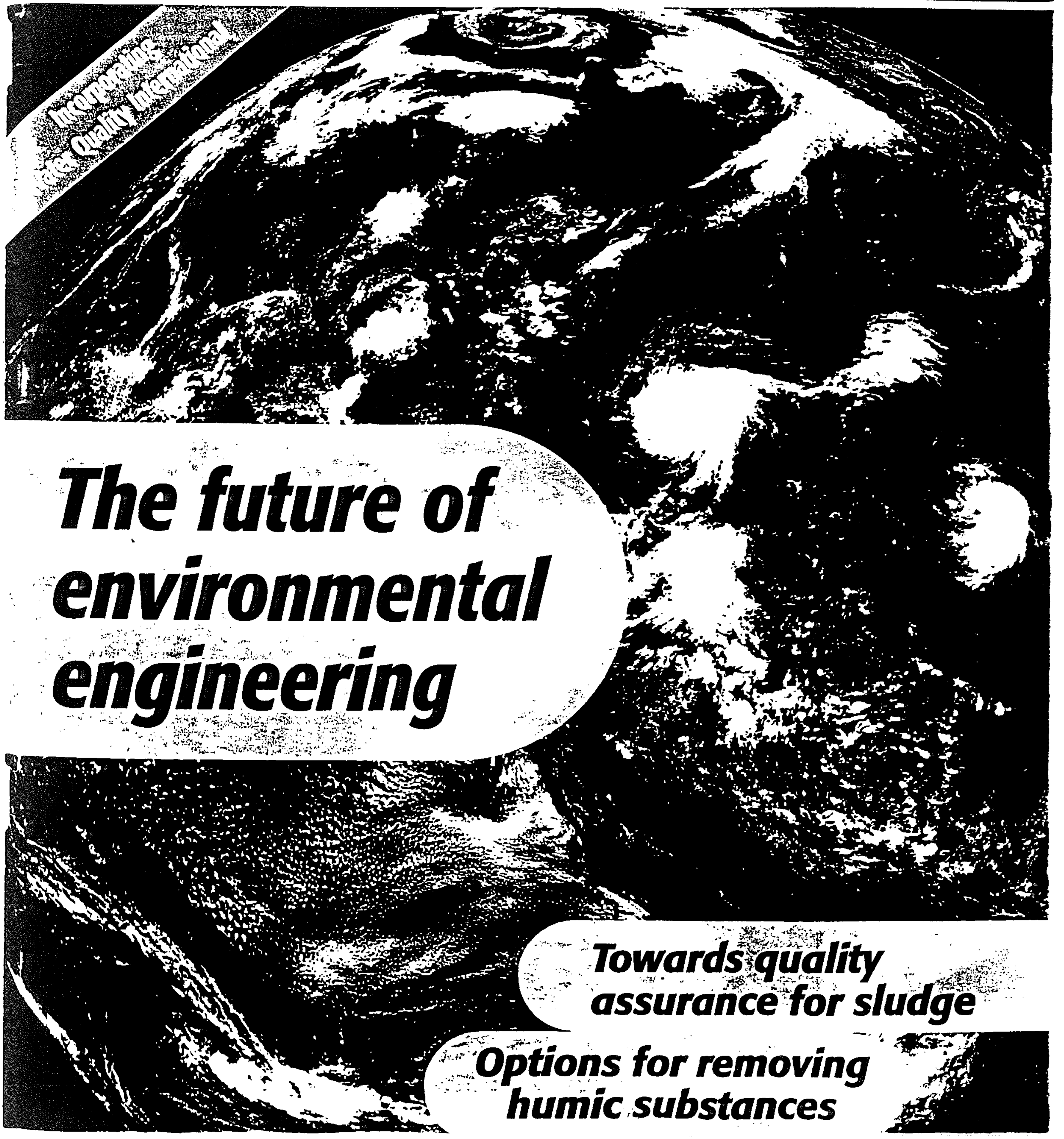

The future of environmental engineering

Towards quality assurance for sludge

Options for removing humic substances

The future of environmental engineering: **resources and economics**

Environmental engineering is a broad and growing profession. In the first in a series of three articles, **REZA IRANPOUR, OMAR MOGHADDAM, SHARAM KHARAGHANI, JIM LANGLEY, JIIN JEN LEE** and **EDWARD SCHROEDER** look at current perceptions of wastes and the rise of privatisation, setting the scene for articles on the constraints and emerging technologies set to shape the careers of those working in this sector.

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This article is the first in a series that attempts to bring together many of the diverse considerations and constraints with which present and aspiring environmental engineers must deal.

Even though the environment interacts with everything else, environmental engineering has largely been carried out in a relatively isolated manner. There has been little interaction between the agencies that dispose of wastes and the organisations that produce them, with the principal concern being to dispose of waste in the most convenient and least expensive way, without attempting to convert them into useful raw materials.

Now, with a growing recognition of the potential value of substances that had been considered wastes, the field is changing. This shift in outlook is expressed by calling the field environmental engineering instead of earlier terms such as sanitary engineering. There are many new challenges, both in subject matter and on the human side of the field. More people are entering the field and more diverse forms of expertise must be combined to obtain useful methods of resource reclamation.

Moreover, the value of reclaimed resources depends not only on waste processing technology but on technology for using reclaimed materials, and on social, economic and political factors that are influenced but not fully determined by technology. Thus, many environmental engineers must have sufficient familiarity with other fields to understand and be understood by the people with whom they must work.

As an example of challenges that are more human than technological, consider recycling. Convincing the public to recycle is more a challenge of persuasion and education than of technology, and the present situation can be described as a combination of good and bad news. The good news is that far more material is being recycled than in the past. The bad news is that large additional increases in recycling are needed to make a significant reduction in the solid waste streams, while some markets for recycled materials are glutted.

Under these conditions, technology and social factors interact in complicated ways. For example, people are careless about separating the colours of glass when they recycle them, and contamination with other colours means reclaimed 'clear' glass comes out of the furnace a sickly greenish yellow. Will the public accept containers made from such 'ecology glass?' Is it necessary or even appropriate to exert pressure for such acceptance if there are alternative uses for such glass, such as in glass-fibre composite materials, or replacing some fraction of the rocks and sand used in concrete? What would be the economic merit of looking for new uses, such as melting it together with other rocks and sand into an imitation stone that could be used ornamentally in building and landscaping? Is this preferable to inventing a device that could separate glass fragments with a thoroughness not achieved by the public?

Moreover, each specific form of waste has its own particular problems, and there have been limited opportunities for transfer of expertise. For example, there is no problem in recycling aluminium beverage cans comparable to the colour problem for glass, and wastewater treatment usually is considered to have little in common with processing solid wastes. This may change, since anaerobic bacteria form methane that is extracted from landfills for power plants, and a combination of bacterial action and the activities of various multicelled organisms, such as worms and arthropods, break down garden waste and other organic solid waste into compost that enriches the soil. Perhaps there will eventually be closer ties between the controlled biodegradation processes used in wastewater treatment and in processing organic solid waste. If so, this would be an example of the principle that the more knowledge that can be applied in designing comprehensive waste disposal and resource recovery systems, the better. However, such advancements would require increased understanding of the chemistry, biology, toxicology, and other aspects of waste.

All of this change brings difficulties because recognition of the need for more understanding, both of the environment and of industrial or commercial processes that might be applied for resource recovery, has led to an increased emphasis on research, especially in university engineering faculties. With this rise of engineering science research, the boundaries between science and engineering and between various subfields that are applied to these problems, such as biology, chemistry and toxicology, have become more blurred than used to be the case. However, this has not been fully compatible with the older focus on designing systems based on relatively simple considerations. There is still a strong sense that the chief activity of a professional engineer should be practical designs instead of research. The only resolution of such disagreements is to demonstrate new designs that are based on new knowledge and are clearly shown to perform better than the old ones. In this context, one of the chief aids is increasing use of computers, for modelling processes of decomposition and contamination, as aids to design when software incorporates new knowledge, and as control systems for plants that convert wastes into resources and render risky substances safe.

It is important that environmental engineers recognise these changes and take advantage of new opportunities for partnerships with business and government. Contributions from environmental engineers will become valuable in process design and in regulations covering many topics, from stormwater disposal to many types of commercial products. Professional societies in environmental engineering have an important role to play in establishing new principles for doing these things so that they can be taught in universities to increasing numbers of bright students who are studying environmental engineering in hopes of making the world better.

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Resources, wastes and risks

As long as environmental engineering is understood as the field that develops technologies for disposal of wastes and builds and operates facilities implementing these technologies, it will always be merely reacting to governmental and public ideas about wanted and unwanted materials. However, a resource is merely a substance that is wanted under certain conditions and a waste is something that is unwanted. Hence, neither wastes nor resources are rigidly defined concepts, but depend on customs or values and on available knowledge and technology.

Thus, the question can always be asked, what is it about a waste that makes it unwanted, or are there any components that could be extracted or transformed into resources? Obviously, there are substances or organisms that are dangerous to humans, so that their presence in a substance is contamination that makes the substance unacceptable. Obvious examples here are many types of toxins, and disease organisms. Thus, the new approach to environmental engineering must be to understand what makes a waste unacceptable and to seek ways of separating the harmful components from those that might be useful or made useful.

From this viewpoint, environmental engineering becomes more proactive, because there is a broad range of opportunities to find ways to develop methods of separation and reclamation. The approach that has been the most successful in the past has been controlled biodegradation, so one obvious strategy is to seek new ways to do this.

The chief examples of controlled biodegradation are secondary wastewater treatment and sludge digestion, in which the combination of nutrients, toxins and disease organisms in wastewater is removed from the water. Bacterial action consumes the nutrients under conditions that prevent them from leaking into the environment. Toxins and disease organisms are too thoroughly mixed with the nutrients for separation, so the only solution has been to replace the uncontrolled biodegradation that formerly occurred in natural waters with this controlled biodegradation.

As there are many forms of organic material in solid wastes, there may be unexplored opportunities for controlled biodegradation of solid wastes. Moreover, with further research it may be possible to increase the yield of useful fuels or chemical feedstocks, such as methane or alcohols, from controlled biodegradation. This could give the degradation process a positive result, in addition to the present purpose of preventing harm.

Controlled biodegradation may be applicable not only to unwanted materials that are largely harmless, but also to some organic toxins. Although many toxins are highly resistant to degradation, under some circumstances bacterial degradation is known to occur; enhanced exploitation of these effects may be possible, and would be desirable.

Ingenuity and opportunism will be needed to take advantage of particular characteristics of wastes and degrading organisms and their interactions with chemical and physical processes. Some specific suggestions will be made in the last article in this series.

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Economics

In the future environmental engineering will be conducted in an economic framework that differs in two ways from the conditions of the past. First, as will be noted in the discussion of regulatory agencies in the second article, the sale of recovered resources will offset at least some of the costs of waste processing, and may even provide a profit in some cases. Second, current efforts to privatise activities that previously were carried out by government will continue.

In considering the potential return from recovered resources, it is important to look beyond the fact that recycling has generally not been very profitable in the past, and that markets for reclaimed materials are not very well developed, certainly in the United States (Aquino, 1997). The availability of materials at low cost will eventually promote the development of more businesses that use them, and it is possible for governmental action to promote such use. The more common approaches are mandates for recycled contents in certain types of materials, and subsidies or tax abatements for using recycled materials. It is possible that a better approach would be to support research into methods of substituting recycled materials for new ones, or into new uses for recycled materials. This is because, as noted near the beginning of this article, wastes are often materials for which beneficial uses are not known, or are not economical, so that some sort of innovation is needed to find ways of using them. From this viewpoint, subsidies and tax abatements seem less desirable than the other alternatives, because they may simply promote dependence on these government measures instead of any innovation in technology. The relative merits of pressuring private companies to innovate to meet a mandate versus sponsoring research to find innovations depends on the particular economic and technological conditions in various industries.

The move toward privatisation involves related concerns, for it rests on an assumption that the pressure of needing to make a profit will force a private company to find innovations and more efficient ways of working that would not be found by a tax-supported bureaucracy that is isolated by its taxing authority from many economic pressures, and may further be a part of a civil service system that makes it very difficult either to promote good employees or to demote or fire bad ones.

The contrary argument, made recently by Judy Wilson, the new director of the Bureau of Sanitation, City of Los Angeles (Smith, 1997), is that a municipal entity that is not taxed and is not attempting to earn a profit can charge lower rates than a private company, because only the direct cost of the service must be recovered from user service and facility charges and municipal taxes. However, as she notes, determining the actual costs of a waste disposal service may be difficult, for in the case of Los Angeles, the Bureau of Sanitation pays fees to the Department of General Services for maintenance on the trash trucks, and to the Department of Water and Power which includes waste disposal charges on the bills that it sends to water and power customers. Thus, a thorough examination of the costs to a city of its waste disposal service may require examination of the actual costs of other departments. Wilson has been a pioneer in efforts to perform such analyses, for she believes that the cost estimates of private organisations for the advantages of their own services are erroneous. She also believes that job security, at least when combined with suitable motivation, incentives, and measures to improve workforce management cooperation, can encourage better efforts from employees than if they are concerned about losing their jobs.

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Notwithstanding such arguments, there has been a steady trend toward privatisation of solid waste collection in the United States since the 1920s (Maldonado, 1997). This trend is expected to continue at a decreasing rate for the next 20 years or more. Privatisation of water and wastewater treatment has been following a similar trend, but starting more recently. On the other hand, other economic arrangements are also being tried to cut costs and raise needed capital. One possibility is that the employees of municipal utilities will organise their own corporations to take over utilities. The hope here is that such corporations will be able to provide better service because they are only working to provide salaries for their employees, who are also the owners, and not to generate large dividends or a rising share price for outside stockholders (Maldonado, 1997). This arrangement has not been widely tried so far, but it may be used more in the future, because the record of present efforts to privatise water and wastewater systems is somewhat mixed, with both successful and unsuccessful projects found in a recent study (Dreese and Beecher, 1997).

Another approach to raising needed capital has been used in New Bedford, Massachusetts. The city did not have a large enough tax base to support a large secondary wastewater treatment plant required to meet water quality standards if the plant were financed by a conventional bond issue. However, the city was able to obtain a loan at a lower interest rate from the state revolving fund (SRF) of Massachusetts. These funds were established by the 1987 amendments to the Clean Water Act (Richman, 1997). The existence of such a low-cost fund made it possible for New Bedford to avoid having any kind of private entity take over its wastewater treatment activities.

Thus, the economic picture is changing rapidly, and it is possible that Madonado's extrapolations of past trends will not be followed. These efforts at privatisation have so far been affected by resource recovery efforts mainly in a negative way, because past efforts to make a profit from recycled materials have been unsuccessful in many cases (Aquino, 1997). If this situation changes, it is likely to influence the trends toward privatisation, both by increasing the income of present municipal waste systems and also by improving the profitability of private ones. There may come a time when public and private organisations compete with each other for some types of recyclable materials. In such a case, environmental engineers will have opportunities to design new types of resource recovery facilities.

The second and final articles in this series focus on more specific and technical matters that will be important in the future changes in environmental engineering. ●

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Future articles:

Look out for 'The future of environmental engineering: technical pressures and constraints' and 'The future of environmental engineering: research concepts and conclusions', due to appear in the following two issues of Water21.