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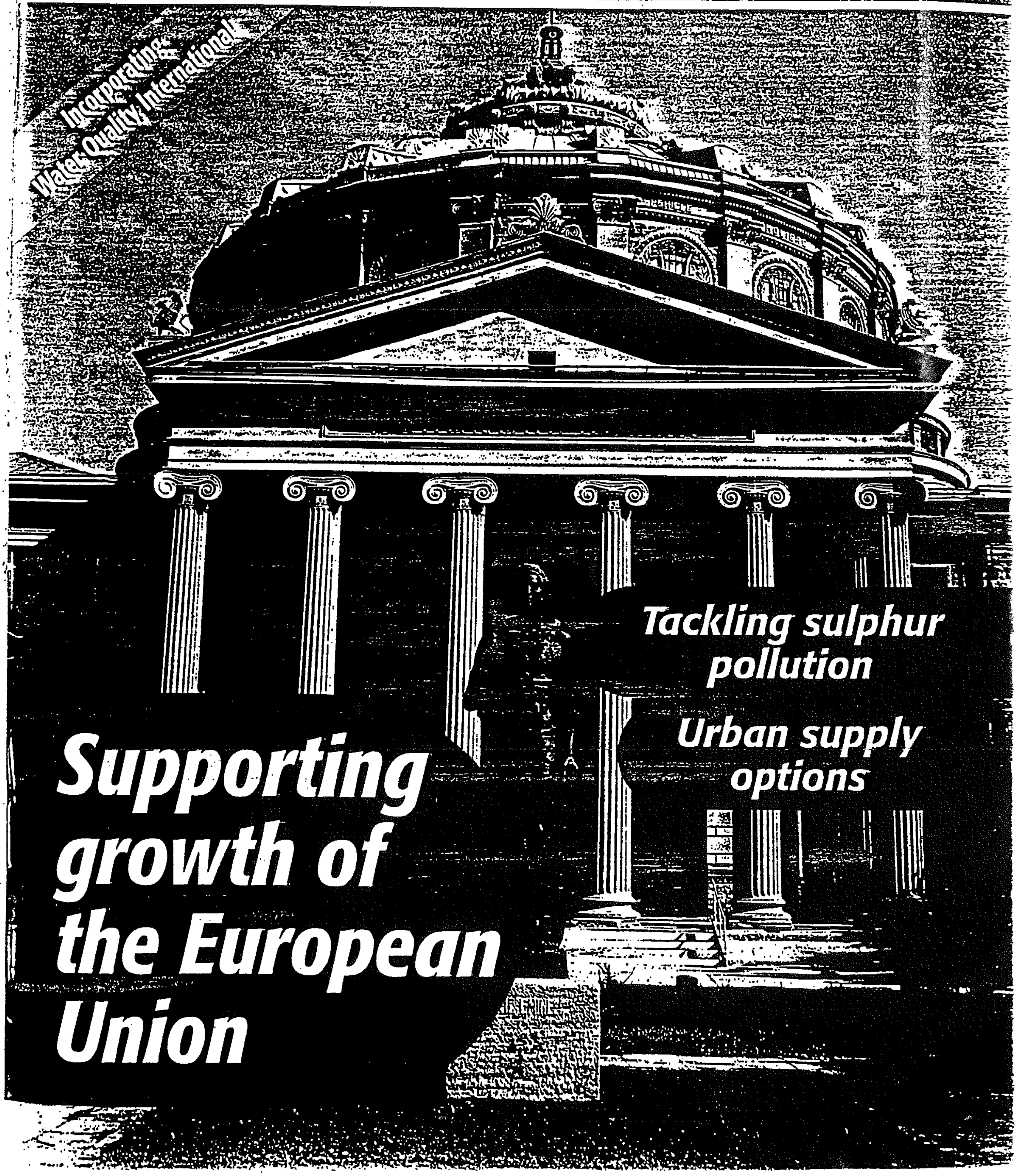

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The future of environmental engineering: technical pressures and constraints

● The first article in this series of three appeared in the last issue of the magazine and looked at some of the broad factors shaping environmental engineering. Here, in the second in the series, **REZA IRANPOUR, GIL GARNAS, VINCE VARSH, KRIS FLAIG** and **GEORGE TCHOBANOGLOUS** examine some of the technical pressures and constraints that are forcing the pace of change.

The previous article (The future of environmental engineering: resources and economics, Water21, September/October 1999, p12-14) concluded by looking at some of the relatively general economic pressures for change affecting environmental engineering. These pressures are combined with or are implemented by the much more specific constraints imposed by technological conditions and regulatory agencies, and this article summarises several of these influence. The final article in the series, which will appear in the next issue, will look at some emerging technologies likely to have an impact.

A changing role for regulatory agencies

Regulatory agencies will be a key factor in changing the focus of environmental engineering, because such engineering is frequently undertaken so that the project's client can meet requirements imposed by these agencies.

Additionally, construction undertaken for any project of this type usually needs to meet regulators' building codes. This means that a regulatory agency that embraces new standards and technologies can speed up the development of resource recovery, but one that refuses to change will slow or prevent it.

But promoting resource recovery can be complicated by the adversarial relationship that often exists between regulators, waste processors and waste producers. The latter organisations have tended to see regulators primarily as sources of increased costs and have often mounted legal and legislative challenges to regulations, sometimes simply violating them when they have expected to get away with it.

In the past, many companies have successfully ignored regulations, for law enforcement officers usually do not have the chemical, biological or toxicological knowledge and equipment needed to identify many violations of environmental laws, while regulators' inspectors have not had law enforcement powers to make arrests or obtain search warrants. Now, closer collaboration between regulators and law enforcement is increasing the rate of prosecution and punishment of violators (Johnston, 1997).

The ability to turn wastes into profitable resources may change the economic conditions that have promoted conflict in the past, because income from recovered resources may at least offset some of the costs of compliance with previously established regulations. In some situations it could potentially become a source of profit.

These changes could also promote a stronger degree of co-operation between regulators and regulated. An example of such co-operation is the efforts to make recycling more popular in Los Angeles (Hedzik, 1990). Hedzik reported that Joan Edwards, director of integrated solid waste management at the City of Los Angeles at the time, visited schools, hospitals, associations of office building owners and many other groups to encourage them to recycle more of their waste, and to learn about the most common kinds of waste in Los Angeles. Both she and Carl Hornberger, the 1997 National Solid Waste Management Association chairman, emphasise the importance of promoting additional markets for recycled waste, so that there is more of an economic benefit for everyone involved (Aquino, 1997).

By such means resource recovery can become compatible with the previous primary concern of these agencies - protecting the public and the environment. Needless to say, they will still demand careful demonstrations of the safety of methods for reusing reclaimed wastes.

It is worth recalling that the present regulatory structure has achieved important improvements. For example, since the Clean Water Act was passed in 1972, the quality of rivers and other bodies of water in the US has greatly improved (Richman, 1997). Under the CWA, secondary treatment systems have been installed in many cities that did not have them, and there have been no recent repetitions of spectacular pollution such as the 1969 incident when oil wastes on the Cuyahoga river in Ohio caught fire. Although these improvements have been spread around the US, as late as 1988 a small percentage of the wastewater in the US did not receive even primary treatment (Bastian, 1997). Thus, a great deal of the progress that has been made is more recent than we usually believe.

As the situation in wastewater treatment has improved, the emphasis is shifting to other areas that have received less regulatory attention in the past. For example, stormwater pollution is now receiving increased attention (Wong et al., 1997). Likewise, much more attention has been paid to standards for water than for solid waste. This is understandable because discharges into bodies of water often travel long distances, but solid wastes do not travel of their own volition. However, this lack of attention is likely to end, for there are many valuable materials that could be reclaimed from the solid waste stream. This means regulatory agencies are more likely to divide their attention more evenly in future among wastewater, stormwater and solid waste issues.

Computer innovations

Computers will contribute in several ways to this new era of environmental engineering. There is likely to be heavy reliance on computational technologies that - although related to systems used in other areas of engineering or in business in general - will nevertheless need to be customised for the needs of environmental engineers.

Geographic information systems (GIS) are among the most recent of these technologies. These systems are of course partly derived from earlier types of graphic systems, but they are now being developed to provide a new level of knowledge integration by displaying the relationships to geography of information that in the past has mainly been tabulated in relational database systems (RDS). Moreover, they support queries and commands formulated in spatial terms, in addition to the temporal and abstract classificational queries and commands provided by RDS in the past.

The value of GIS for environmental engineers is obvious, since they deal so much with maps of wastewater and stormwater collection systems, city street maps, maps of rainfall and natural drainage basins, sources of air pollution and so forth. Some briefly described examples of such uses (Goldstein, 1997; Wong et al, 1997) provide a more extended discussion of a particularly large and complex GIS application - a model of non-point source pollution of Santa Monica bay, which required depiction of a large part of the city of Los Angeles and several other coastal cities, as well as wilderness areas and detail of the depth distribution of the bay.

This technology has matured relatively recently because it has required the development of software that does not burden the user with the details of accessing the many types of files required, and is compatible with the existing RDS, since many of them continue to have long-established uses as well as being accessed through a GIS. An important aspect of this development has been the modification of the familiar client/server structure with a new layer of software between client and server, known as 'middleware' (Goldstein, 1997). Although environmental engineers are not usually strongly interested in details of computer system design, the introduction of middleware and related innovations have some significance as steps in the evolution of management practices based on computer networks (Denning, 1997).

This development is part of the larger evolution of business and organisation management to a greater reliance on computer networks. However, it is particularly valuable for engineers, who rely much more on graphical information than most other professions, not only for geographic information systems but for design. The use of computerised drawing systems is well recognised as a source of vast improvements in efficiency (Mills, 1997), but even here innovations continue to be made. Conventional CAD systems are mainly used for two-dimensional plans and schematics, automating the drawings used by engineers before computer graphic systems were available. However, three-dimensional graphic systems can now provide virtual versions of solid models which have proved extremely time-consuming and expensive to build on the relatively rare occasions when they have been used in the construction planning process. These models allow the engineer to examine different possible sequences for assembling a large structure (Coles and Reinschmidt, 1994).

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There are two other major areas of computer applications in which contributions continue to be made to environmental engineering. One is in process control. For example, a wastewater treatment plant could be placed under computerised control similarly to a microprocessor being used to control an automobile engine, so that pumping rates, aeration rates, sludge wasting and possibly other aspects of plant operation could be controlled based on BOD measurements, dissolved oxygen, and perhaps other measures of the state of the plant and the influent. Such control systems are already used in some parts of plants, such as aeration basins (Stenstrom, 1991-1994), but automated control applied to a whole plant is less common. The timescale would be much slower than for automobile control systems, so the necessary calculations would be well within the capabilities of present control processors.

Likewise, computer control could make an important contribution to improved solid waste processing. The control problems in this case are likely to be more complicated, because there is a more diverse collection of materials to process, and separating material using automated recognition technologies could be an important improvement.

Computerised control will also improve treatment plant operations by providing improved instrumentation. Microprocessor controlled instruments that make their measurements by carrying out complex sequences of chemical steps are becoming more common. Current instruments for measuring BOD are examples of this (Iranpour, 1997; Logan, 1997), and other types of instruments may be expected in the future.

Still another major application for computers will be in extending modelling beyond its present uses. For example, in wastewater treatment there is a need to understand more about the bacteria in secondary treatment, instead of merely relying on them. Only a few species are well known, although there are thousands in any activated sludge system. A large amount of work is currently being done (Cowan et al, 1997) and as more information is gathered, interactions can be described in appropriate program modules, to be assembled as needed to model a complex situation.

Computer modelling is very helpful in determining causal relationships, because it makes it possible to compare predictions provided by a model of a hypothesised relationship to actual experimental results (Labieniec et al, 1997; Parker et al, 1996). In the past, data from experiments and observations in environmental science have often been insufficiently comprehensive to distinguish between theories, because of the expense or the difficulty of making the necessary measurements. This can also be expected to change, with increased use of computers making improved instrumentation and data processing possible.

Energy

Energy will be a major environmental engineering concern in the future, for several reasons. One is that energy production and distribution is itself a major source of certain types of waste, although many of these do not enter the municipal waste stream and hence do not typically form part of a sanitation bureau's concerns with wastewater, stormwater and municipal solid waste. For example, coal mining often produces waste rock associated with the coal, but which cannot be burned, and burning coal produces both ash and precipitate material from stack gas scrubbers. Likewise, oil production often pumps salt water along with the oil.

Secondly, waste disposal methods used in resource recovery usually require energy, so that whether a process is feasible may depend on the cost of the energy it consumes. Obviously, the trucks involved in solid waste collection require a substantial amount of fuel, and the largest single item of expense for many wastewater treatment plants is power for the aerators in the secondary treatment systems. Some forms of resource recovery which have been considered in the past use too much energy to be cost effective. Now, all longterm plans for waste disposal and resource recovery assume that energy costs will be similar to those at present, taking inflation into account.

This is the most reasonable assumption, because energy costs have been declining or stable for more than 15 years, and predicted new energy sources, such as solar and geothermal energy, have not won significant market shares. The price of nuclear power has also not decreased in the way its proponents hoped in the years immediately after World War II, and controlled nuclear fusion has never yet produced useful amounts of power despite several decades of extremely expensive research by many outstanding physicists.

In this relatively static energy situation, if one wishes to improve recovery of an energy resource, the most obvious opportunity at present is in enhancing methane production from biomass fermentation. Methane is currently recovered from sludge digesters and closed landfills, but it may be possible to operate these in ways that would increase methane production. This would require increased understanding of the conditions which are favourable for methanogenic bacteria.

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A related opportunity would come from efforts to match heat sources better with the temperature requirements of the processes to which they are applied. In the field of methane production, an example would be if a low temperature heat source were applied to such tasks as heating sludge for digestion by thermophilic bacteria (Metcalf and Eddy, 1995) and drying digested sludge. This would make the methane available for burning in higher temperature applications, such as in power plants, in which low temperature heat sources are useless. Obvious examples of low temperature heat sources include waste heat from other industrial processes, the heat from many commonly available types of solar energy collectors, and geothermal heat from sources that are at or below the boiling point of water.

The feasibility of using such sources obviously depends respectively on the proximity of suitable industrial plants, on the land area available for solar collectors, and on local geological conditions. Nevertheless, preliminary investigation of these possibilities would be relatively inexpensive, although it has not, apparently, been considered in most places.

Global issues

A brief consideration of the relationship between these expected changes in environmental engineering and global environmental issues shows that improved resource recovery can contribute to ameliorating many forms of environment deterioration, but cannot be the entire solution for any of them.

First, the increasing CO_2 content of the atmosphere - the main source of the greenhouse effect that is believed to be changing the world's climate - is the result of burning carbon in fossil fuels. Improved recovery of fuel, such as methane from biomass, recycles the carbon already in the biosphere and thus reduces the amount of fossil fuel burned. This is an indirect form of solar energy use, since the energy in biomass ultimately comes from the sunlight that made the plants grow. The efficiency of energy use relative to the amount of light that falls on the plants is much lower than that of more familiar types of solar collectors, but there are many other advantages in terms of convenience and simplicity from reliance on plant growth, notably that plants provide food and other useful substances which mechanical solar collectors cannot.

Another benefit of improved use of biomass energy is a reduction in acid rain and the other types of air pollution which are side effects of fossil fuel use. Methane generated from fermentation does not have the sulphur impurities often found in coal and oil, and when burned it also produces less carbon monoxide and fewer of the larger hydrocarbon fragments that produce soot and the raw material for the toxins in photochemical smog.

Improved resource recovery also reduces the amount of environmental damage from mining and deforestation, the principal sources of the materials used in the vast majority of non-food products, from newspapers to automobiles. Moreover, there are also obvious reductions in pollution from waste seeping out of landfills and other methods of waste disposal.

All of these improvements reduce the per capita resource consumption and waste production of the areas to which they are applied. Since waste collection systems and the environmental engineering activities that build and maintain them are highly localised, the effect of any improvement in resource recovery is usually limited to a small area. For example, improving resource recovery in Los Angeles does very little to improve the environment in China, or even in most of the state of California.

Two conclusions can be drawn from these observations. One is that there are vast future opportunities for environmental engineering projects in many parts of the world where economic development is currently occurring at a rapid rate, or where there have been recent major political changes. In many countries even basic wastewater treatment is not available - for example, there are cities in what used to be the Soviet Union that still discharge raw sewage into the Baltic sea. The previous communist governments of the Soviet Union and the eastern European countries had very little concern for the environment, and their dictatorial nature made it impossible for private citizens to carry out the kind of protests and written criticism that were important in attracting attention to environmental problems in the US and European countries. This means the environmental legacy of communism has been a complex combination of soil and water pollution, forest removal and inefficient technology, which continues to produce much more pollution than is now common in the US and western Europe' (Somlyody and editors, 1993).

The other conclusion is that reductions in per capita resource use and waste production can be counteracted by an increase in population. Since, as noted, the effect of environmental engineering projects is local, the relevant concern is usually the local population served by particular projects or waste systems. However, since the world's population continues to grow, some forms of waste, such as CO_2 from fossil fuels, eventually have a world-wide effect. Thus, the world population has an effect that ultimately would outweigh any minor improvements in resource recovery (Ausubel, et al., 1995). These are the reasons why additional research into environmental engineering technology is needed, to reduce pollution and increase resource recovery to slow environmental damage while the world struggles to stabilise its population.

Further research

As indicated in this and the previous article, there are many opportunities for research on new technologies for waste disposal and resource recovery. The final article in this series will present several of them, and draw some conclusions about the future of environmental engineering. ●

References

Aquino, JT (1997). Coming to terms with change: an interview with Carl Hornberger, NSWMA Chairman. Waste Age, May, 167-176.

Ausubel JH, Victor, DG and Wernik, IK (1995). The environment since 1970. Consequences (online magazine - http://www.gcrio.org/CONSEQUENCES/fall 1995). II, 3, 1-14.

Bastian, RK (1997). Biosolids management in the United States. Water Environment & Technology, May, 45-50.

Bauer, E, Gall, V, Sauer, G (1994). Computer calculations speed, tunnel-lining design. ASCE Civil Engineering June, 46-49.

Coles, BC, Reinschmidt, KF (1994). Computer-integrated construction. ASCE Civil Engineering, June, 50-53.

Cowan, RM, Alagappan, G, Ellis, TG, Higgins, MJ and Uberoi, V (1997). Activated sludge and other aerobic suspended culture processes. Water Environment Research, Vol. 69, No. 4, June, 462-487.

Denning, J (1997). Who's surfing? we're working! ASCE Civil Engineering. June, 40-43.

Goldstein, H (1997). Mapping convergence: GIS joins the enterprise. ASCE Civil Engineering June, 36-39.

Hedzik, KJ (1990). Networking, education, and common sense: An interview with Joan Edwards, Director of ISWM/City of LA. Waste Age, August, 66-68.

Iranpour, R et al (1997). Real time BOD monitoring for wastewater field application. Journal of Environmental Engineering, 123 (2).

Iranpour, R et al (1997). A gas chromatographic-based headspace biochemical oxygen demand test, Water Environment Research, 69, 1178-1180.

Johnston, J (1997). Enforcement task forces: the co-ordinated approach. WEF Water Environment & Technology March, 43-45.

Labieniec, PA, Dzombak, DA, Siegrist, RL (1997). Evaluation of uncertainty in a site-specific risk assessment. ASCE Journal of Environmental Engineering, 123, 3, 234-243.

LaFrance, S, Balla, J (1996). Community builds future supply and regulation compliance into water system. Public Works, 127, 11.

Logan, BE, Patnaik, R (1997). A gas chromatographic-based headspace biochemical oxygen demand test. WEF Water Environment Research 69, 2, 206-214.

Metcalf and Eddy (1995). Wastewater engineering: treatment, disposal, and reuse. Third edition., McGraw-Hill Inc, New York.

Mills, C (1997). Automation makes culvert design easy. ASCE Civil Engineering, May, 61.

O'Regan, PR (1996). The use of contemporary information technologies for coastal research and management - a review. Journal of Coastal Research, 12, 1, 192.

Parker, WJ, Monteith, HD, Melcer, H (1996). VOCs in fixed film processes. I Pilot studies. ASCE Journal of Environmental Engineering.

Parker, WJ, Monteith, HD, Melcer, H (1996). VOCs in fixed film processes. II Model studies. ASCE Journal of Environmental Engineering, 122, 7.

Richman, M (1997). Clearing the way for clean water. Water Environment & Technology, March, 14-20.

Somlyody, L, and /or editors (1993). Recognising the realities of environmental regeneration. WQI. 4, 15-17.

Somlyody, L, and /or editors (1993). Looking over the environmental legacy. WQI 4, 17-20.

Stenstrom, MK (1991-1994). Offgas test report for the Terminal island treatment plant. Reports prepared for the Bureau of Sanitation, City of Los Angeles, California.

Sweeney, MW (1997). Geographic information systems. WEF Water Environment Research Literature Review. 69, 4, 419-421.

Vanegas, GA, Baker, NC (1994). Multimedia in civil engineering. ASCE Civil Engineering, May, 71-73.

Wong, KM, Strecker, E, Stenstrom, MK (1997). A picture worth more than 1,000 words. Water Environment & Technology, January, 41-46.

Woods, WR and Krasno DS (1994). A thousand points of data. ASCE Civil Engineering, June, 54-56.

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