KALBERMATTEN ASSOCIATES, INC.
Water and Wastes Management Advisory Services

CHALLENGES IN ENVIRONMENTAL PROTECTION IN CITIES

NEW APPROACHES AND STRATEGIES FOR URBAN ENVIRONMENTAL MANAGEMENT

by

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Executive Summary

The 1990s undoubtedly is the Decade of the Environment. Not because the decade may be so designated, or because there will be another world conference on the topic. The designation applies because there exists today an awareness, even a fear that, unless we take some decisive action to protect the environment, we will suffer unacceptable consequences; that this decade indeed could be the last chance we have to create a sustainable society.

This sounds dramatic, but consider these facts:

If population increase continues unchecked, it may be impossible to create a sustainable society.

If pollution continues unabated, human health and environment, indeed life itself, may become unsustainable.

If consumption and degradation of natural resources continues unabated, sustainable economic development is unachievable.

This list can be extended at will. The conclusion would remain the same:

PRESENT PRACTICES ARE NOT SUSTAINABLE

Therefore:

Economists must begin to use environmental accounting to value not only exploited resources but also those preserved, be they unpolluted water, standing forests, or clean air.

Governments must implement measures which encourage a balance between population growth and economic development, and eliminate subsidies, grants and tax policies which encourage the misallocation and waste of resources.

Investment decisions by industry and government must be based on long-term sustainability of the proposed investment and the environment, rather than on short term financial returns alone.

Most important of all, cities must abandon **"linear"** approaches, and adopt the environmentally sustainable **"circular"** planning model.

The **linear system** imports goods (water and others) into a community, uses them once and discharges them from the community - often exporting pollution to other communities downstream. The **circular system** manages demand for maximum economic and environmental efficiency: it imports goods into the community, then reuses and recycles them to reduce the volume of waste and to optimize environmental benefits. Discharges from the community are minimized and are not environmentally damaging.

Implementation of these concepts requires agreements at global level to set overall objectives, such as the international agreement on targets to protect the ozone layer. At national level, it requires a **partnership between government and cities**. The government needs to set appropriate country-wide policies and standards. The cities need to take implementing action because pollution, whether its impact is local or global, is caused by local actions, and eliminating it requires local action. At the local level, partnerships between service agencies, the private sector, and the people are essential if the full resources of the community are to be effectively mobilized to solve the problem.

The circular system is not a theoretical concept: many of its elements have been used by progressive cities in countries around the world. They have proved the benefits of applying its key principles:

- efficiency in energy and in water use and reuse (both on and off-site);
- strict conservation measures to minimize demands on resources and to reduce downstream pollution;
- selection of technology through determining "effective demand", in order to ensure sustainability;
- recycling of solid waste to conserve resources, minimize disposal cost and generate revenues;
- involvement of the community in all aspects of municipal service provision.

Now is the time to bring these concepts together, to promote the establishment of environmentally self-sustaining service districts, and to take advantage of the synergism of combined operation of potentially inter-related services (such water supply and waste disposal), thus making the overall benefits of the entire package of municipal services greater than the sum of its components.

A strategy at municipal level to implement these approaches systematically, supported by national policies and better economic tools, will lead to global environmental improvements and a sustainable society.

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NEW APPROACHES AND STRATEGIES FOR URBAN ENVIRONMENTAL MANAGEMENT

1. The 1990s undoubtedly is the Decade of the Environment. Not because the decade may be so designated, or because there will be another world conference on the topic. The designation applies because there exists today an awareness, even a fear that, unless we take some decisive action to protect the environment, we will suffer unacceptable consequences; that this decade indeed could be the last chance we have to create a sustainable society.

2. This sounds dramatic, but consider these facts:

If population increase continues unchecked, it may be impossible to create a sustainable society.

The world's population continues to grow. In 1950 we shared earth and its resources with 2,500 million people; in 1990 we numbered 5,300 million, in the year 2000 we will be 6,250 million, and predictions are that we will be over 8,000 million in the year 2025 and 12,000 million by the end of the next century. The urban share of population will grow from 29% in 1950 to 48% in the year 2000, to 57% in 2025. In some countries, up to 75% of the population already live in urban areas.

If pollution continues unabated, human health and environment, indeed life itself, may become unsustainable.

Cities are the major contributors to a country's economy through the production of goods and provision of services. They are also the greatest polluters of the environment. Urban society, misguided by traditional economic analysis, has adopted industrial and human consumption and waste disposal practices which are extremely detrimental to the local and global environment. For example, carbon and sulfur emitted by industries and cars in urban areas contribute most significantly to global warming and acid rain, the discharge of CFCs results in ozone depletion, and excessive consumption of goods and services creates waste and local environmental degradation.

If consumption and degradation of natural resources continues unabated, sustainable economic development is unachievable.

Land put into agricultural production stopped increasing in 1981; biological productivity and diversity is decreasing. This is the result of increasing pollution and non-sustainable agricultural practices, resulting from the pressure to keep up with the increase in both the number and the rising per capita consumption of growing populations. For the same reasons, other resources, for example water and energy, are becoming increasingly scarce in many areas.

3. This list can be extended at will. The conclusion would remain the same:

PRESENT PRACTICES ARE NOT SUSTAINABLE

4. Therefore:

Economists must begin to use environmental accounting and value not only exploited resources but also those which have been preserved, be they unpolluted water, standing forests, or clean air.

The problem with present methods, basically the accounting which determines the GNP, is that it does not value preservation of natural resources or of the environment. A tree has value when cut down, but there is no allowance for the negative impact reflecting that the forest has been diminished or no longer exists. The Alaskan oil spill in 1989 added to the US national GNP, because the cost of labor and equipment for cleanup was counted as an income, and no deduction was made for the destroyed environment. Fortunately, efforts are underway to develop methods which measure not only economic factors reflected in GNP calculations but also other parameters of well-being, in order to create a better measure of a nation's wealth and standard of living, and provide a better basis for economic decision-making.

5. **Governments must implement measures which encourage a balance between population growth and economic development and eliminate subsidies, grants and tax policies which promote the misallocation and waste of resources.**

Each time that government, in order to promote some activity or investment, provides subsidies, the effect is that true costs are hidden and decisions are made which in the long term affect the economy and the environment adversely. Policies and fuel subsidies encouraging private transportation to the detriment of public systems makes cities almost

unlivable as a result of air pollution and traffic congestion. A government-city partnership is needed to ensure that government policies which cause harm to the cities will be eliminated.

6. **Investment decisions by industry and government must be based on long-term sustainability of the proposed investment and the environment, rather than on short-term financial return alone.**

Processes and methods which waste finite resources are not sustainable over the long term. Abstracting more groundwater than is recharged, in order to increase agricultural production obviously is financially rewarding in the short term, but inevitably will lead to the abandonment of the investment made. Wasting non-renewable energy resources due to a lack of adequate housing insulation, partially encouraged by housing subsidies and tax breaks, wastes natural and financial resources for short-term gain. Government policies and economic tools must properly reflect not only the cost and benefits of production, but also the cost of resource use and the benefits of conservation.

7. **Most important of all, cities must abandon the "linear" for the environmentally sustainable "circular" planning model[1].**

> The **linear system** imports goods (water and others) into a community, uses them once and discharges them from the community. The **circular system** imports goods into the community, manages demand for maximum efficiency (through using water- and energy-saving appliances, using solar and other sources of renewable energy, imposing peak load charges, etc.), reuses and recycles water and other goods to reduce the volume of waste and to optimize environmental benefits (through park and greenbelt irrigation, stormwater infiltration, wastewater-fed irrigation and aquaculture, agricultural use of sludge and compost, resource recovery from solid waste, etc.).

8. The linear planning model is based on the notion that there are unlimited resources to be exploited for the benefit of the user. This model, based on introduction and one-time use of goods, discharge after use, was adequate for the smaller populations of the past. But with increasing populations demanding more and more consumer goods, single use of resources, followed by discharge (the "throwaway society"), is no longer viable or tolerable. The model has heavy environmental costs, and these are increasingly being reflected in financial costs. It will become even more costly once environmental costs are properly valued and included in the financial calculations. The linear model must be replaced with the circular model, which is environmentally-friendly and, ultimately, more economical.

9. Implementation of these concepts requires agreements at three levels:

- At the **global** level, to set overall objectives, such as international targets for protecting the ozone layer, reducing acid rain, or limiting carbon dioxide emissions.

- At the **national** level, to establish a partnership between governments and cities. The government needs to set appropriate countrywide policies and standards, and to ensure that they are encouraged and supported through its economic and financial practices. The cities need to implement the necessary changes because pollution, whether its impact is global or local, is caused by local actions, and its elimination requires local remedies.

- At the **local** level, to establish partnerships between service agencies, the private sector, and the people. These partnerships are essential to improve the effectiveness of service delivery: at present there is often a lack of consistency in the approach of different agencies, each dealing with a particular sector and with a different geographical jurisdiction; efforts by the private sector to improve service are ignored if not actively discouraged; and involvement by the users of services, the people for whom the investments are being undertaken, is minimal.

10. Fortunately, systems, methods and technologies exist which allow the implementation of the circular system. They are based on the approaches described below.

Increasing efficiency in resource use

11. Many developing countries are already experiencing severe local water shortages, particularly near their major cities. Conflicts between competing uses (most commonly between municipal uses and irrigation abstractions) are increasing[2]. However, development of new sources may cost two or three times as much per cubic meter as the sources currently in use[3], and may not be affordable. The short-term solution is often overdraft of groundwater supplies, but this cannot be sustained for long, and may have other severe repercussions[4].

12. Cities should follow a two-step approach to solving this problem:

- Put into effect measures to improve water use efficiency within the city jurisdiction; this will involve measures such as resource management[5], water conservation programs[6,7,8], and system rehabilitation[9], especially reduction of unaccounted-for water[10]. Introduction of tariffs that cover the full economic cost of the water used, and enforcement of collections, are a key part of this process[11]. For low-income communities, development of non-conventional resources (such as rainwater harvesting[12]) may also reduce demands on piped systems.

- Insist that national water resources policies should ensure that, in competing for allocation of water resources, each user should be required to demonstrate that its efficiency of

water use has reached the economic limit[13,14]. In many countries this will have significant implications for industrial water use[15] and irrigation policies and techniques[16,17,18], especially where private abstractions are unregulated (as is the case with much industrial use[19,20]), or where irrigation water, provided virtually free of cost to the user, is used in traditional "flood" irrigation of low-value crops[21]. Equally, national environmental protection standards need to assess overall burdens and risks[22].

13. Efficiency in water use can also have significant effects on energy requirements. Not only are pumping costs (of both water and wastewater) reduced[23], but also more effective domestic appliances reduce the volume of water heated in the home[24,25], with both energy and environmental benefits.

Broadening technical options and making choices based on "effective demand"

14. Technology choice is too often determined by purely technical considerations. This results in adoption of technologies which (while perhaps quite suitable to the situations where they were developed) are inappropriate to the circumstances.

> *"The poor will remain poor if they depend on the technology of the rich"*
> *(Motto of the Appropriate Technology Information Centre (International), Saidapet, Madras).*

15. The technological solutions most commonly adopted in industrialized countries - and exported by them to the developing world, or at least that part of it dependent on formal, public sector services - evolved in response to conditions of comparative prosperity, a skilled (and therefore expensive) labor force, and ready availability of complex machinery and equipment. In contrast, many developing countries are poor, and getting poorer, have a surplus of unskilled, low-cost labor but a dearth of skilled people, and have severe problems in obtaining and maintaining complex plant.

16. There may also be radical differences in the type of problem to be addressed or the environment in which it is to be applied. For example, municipal solid waste (MSW) in developing countries tends to be very heavy, wet and organic, and so poses special collection, recycling and disposal problems. Similarly, water-borne sewage disposal ceases to be an option if there is only scarce, unreliable and intermittent water supply and if housing does not include toilet facilities[26].

17. This has resulted in the all-too-familiar sight of technologically sophisticated plant breaking down and abandoned after only a few years, because the money and skills needed to keep it running were not available. We need to find ways to provide service that are sustainable: they fall within the capacities and the budgets of the people they are intended to serve[27]. The degree of sophistication of the service is to a large degree immaterial, provided that it meets people's needs.

18. In recent years there has been considerable attention paid to the development of "appropriate technology" for urban services, and there are many very satisfactory alternatives to conventional systems. Most of these are refinements of systems already in use in developing countries, and so their acceptance is assured. Planners therefore have a much wider arsenal of technological tools to choose from when considering how to provide service. (In parentheses, it should be noted that the "appropriate" technology for high-density central business districts in developing countries may be very similar to its counterpart in the industrialized world, just as the appropriate solution to telecommunications in rural areas may be to use space-age technology - satellite links - rather than land lines. The key is matching solutions to circumstances, not to apply low technologies uncritically).

19. This has led to the concept of planning based on "effective demand" - providing only the level of service that the beneficiaries are willing to pay for, rather than deciding on a level of service *a priori* and then trying to find ways to make it viable[28]. Ghana provides two interesting and contrasting examples: in Accra, it was assumed, without detailed investigation, that all houses would connect to a new sewerage scheme, but 6 years after it was commissioned only 50 houses had connected to it, instead of the 720 predicted; overall, the connection rate was less than 20 per cent of that expected, and the system is essentially a failure[29]. Two decades later, in planning wastes disposal for Kumasi, great care was taken to ask residents what they wanted; the unexpected result was that people in some areas expressed a preference for on-site VIP latrines rather than water-borne sewage disposal, because they were uncertain about the reliability of the water supply and their ability to pay the probable increase in charges.

20. The concept of changing service standards, sometimes quite radically, to suit the community does not only apply to sanitation. Planners are used to considering different levels of water supply service (in-house connections; patio or yard connections; public hydrants) in different types of communities. However, even here the concept can be widened. Other delivery systems (for example, carefully-controlled vendors[30]) may also have a role to play. Equally, some of the design criteria may be called into question. Many criteria are not required by "good practice" but are simply a reflection of the social conditions of their application. For example, water mains must deliver adequate supplies for fire-fighting in expensive United States residential areas, but in slum and squatter settlements, where there is no mechanized fire-fighting equipment, this is a superfluous requirement. Redesigning to meet more appropriate criteria has been found to save up to 40 per cent of distribution system costs[31].

21. Ensuring that solutions are appropriate to the community concerned - establishing "effective demand" - is of course much more than determining the technological options that are acceptable. In addition, all details of the service - how facilities are to be located, constructed, paid for, operated and maintained, and in general how the service is to be managed, need to be considered. Solutions which seem "obviously" correct to outside planners may not be in the least attractive to the intended beneficiaries[32].

Recycling to reduce costs and conserve resources

22. Whether we intend it or not, **all our urban services are inherently recycling systems.** For example: water brought into the community is discharged as sewage. If handled properly, it may be reused safely for irrigation or industrial purposes, or abstracted by a downstream community and used again for water supply. Improperly handled, it pollutes surface watercourses, coastal areas and aquifers, makes crops grown using it dangerous to the consumer, and may pose serious health risks to downstream abstracters. In either case, the water is recycled; the question is whether we choose to take an active role in ensuring that this recycling process is controlled and benefits the community at large. The same considerations apply to MSW management and to storm drainage.

23. The underlying selfishness of the linear system (in contrast to the "circular system described above"), and in particular the way in which it permits people to "export pollution", is being increasingly exposed as we learn more about the environmental costs of overuse of resources and of inadequate wastes treatment. Fortunately, the increasing cost of developing new resources is forcing a more careful evaluation of the potential for reuse.

24. There are therefore two different perspectives on recycling (although the overall outcome may well be the same). The first is recycling as a way of making better use of resources already used, and, by so doing, reducing the cost to the city of providing service. The second is as a way of preserving or replenishing resources, for either local or national benefit.

25. Recycling at the city level should always be considered as a way to reduce the cost of service and to make it more efficient. The underlying principle should be "**Waste is just a resource in the wrong place**". Sewage, adequately treated, can be sold for industrial processes (especially cooling) as well as for agriculture, and should be considered for replenishment of water resources[33]. Municipal solid waste is a mixture of a wide variety of potentially valuable resources[34,35], which in many developing countries already support a large number of scavengers and small-scale recyclers. As cities grow (leading to increases in haul distances and more mechanized collection) it becomes more attractive to sort and recycle before materials are mixed, compacted and hauled away; local enterprises may then act as feeders to larger companies making use of the reclaimed materials[36]. Metals[37], paper[38], plastic, glass, and rubber are all very economical to recycle in this way: the companies make a profit on the exercise, haul costs are reduced, and the lives of the ultimate disposal sites (usually landfills) are extended. In addition, "remanufacturing" of mechanical equipment and appliances can recycle valuable components and eliminate bulky items from the waste stream[39].

26. An extreme case of forced recycling occurs when there are no facilities for off-site disposal. This may occur, for example, when no sewage collection and treatment facilities are available, and people wishing to develop there land have to provide closed-circuit

systems[40],[41]. This approach is also being applied in Japan, to high-density urban centers where the logistics of bringing in water and exporting sewage are unattractive[42,43].

27. Recycling to preserve natural resources and the environment may have impacts far beyond the city itself, and so may require promotion through national rather than local initiatives (even though, as noted above, it is probably in the city's self-interest to do so, in either the short or long term). Treating sewage to the point where it can safely be used for irrigation lessens or eliminates the demand by irrigators on fresh water supplies, releasing these for municipal use. Treating sewage and stormwater so that they can be safely used to recharge underground aquifers enables existing groundwater resources to be utilized at higher rates without overdraft. Co-composting of MSW and sewage sludges provides a soil conditioner that can be used to reclaim degraded land, reestablishing vegetative cover or allowing local forestry for shelter belts or fuelwood; all these measures reduce soil erosion and flood runoff, reducing the siltation of storage reservoirs and lessening the impact of heavy rains on life in the city. However, these efforts must be complemented by efforts in other sectors, especially industry; these also may be found by the sectors concerned to have unexpectedly beneficial results[44].

Broadening the institutional framework

28. Institutional weakness is frequently blamed as the root cause of many of the problems in urban service provision. Until very recently, the preferred prescription was often to devise measures to create or strengthen what was regarded as the ideal model: the "public utility" of the industrialized countries. This formed the basis of various forms of water supply boards, sewerage boards, and even stormwater management utilities. However, it is now recognized that this model may not be applicable in many situations developing countries: income levels are too low to support the type of operation usually associated with public utilities; the utilities have generally not been granted sufficient autonomy in key matters such as tariff setting; and the capital and bond markets are not well enough developed to allow utilities to raise the funds needed for expansion and operation. Attention is therefore being focussed on a variety of other options, coupled with transforming the sector agencies from being direct providers of service to being "enabling institutions", whose prime objective is to create a policy, financial and regulatory climate in which other types of institutions can flourish.

29. This movement is still in its infancy, and it is at present too early to determine which path it will eventually take. It is certainly premature to write the obituary of the public utility model: this may continue to remain appropriate for certain specific situations, especially to handle service in the core areas of the larger cities, where more complex technologies and sophisticated management techniques are needed. Even here, other forms of achieving essentially the same objectives, through a carefully regulated private sector enterprises, are being considered; the longest established is the *concession* system used in a number of developing countries, but other models of successful "privatization" also exist[45], and can be

highly efficient[46]. There seems to be a particular opportunity in reuse and recycling operations, as these need the private sector's profit-oriented approaches[47].

30. What is quite clear is that extending service to everyone in the rapidly growing urban areas will require not only a wider mixture of technology but also drawing on a wider range of institutions. Expertise, which is in short supply, especially in developing countries, is not the monopoly of the public sector; private entrepreneurs are already active in the sector in many ways. Much of this involvement is on a relatively small scale (such as vending water in areas without piped supply, constructing shelter and latrines, or recycling MSW); in other cases, such as industrial water supply and waste treatment, the scale of operations, as well as the technical complexity and the need for sustained and reliable service, requires skills comparable to those needed in the public sector.

31. This resource may hold one of the keys to extending or improving service to many people at present badly served, if these entrepreneurs can be provided with assistance that they may need to upgrade their operations. There are many support elements (such as: training and technical support; more appropriate codes and standards[48]; better access to credit; improved model designs; short-term relaxation of restrictions on imported equipment and spare parts; and long-term encouragement of local manufacturing capacity for needed components) which central agencies can provide without inhibiting the initiative or taking over the role of the private sector[49].

32. Whether public or private, sector institutions need to have the capacity to operate on a highly decentralized basis, reaching down to the community as the basic element in urban services design. "Effective demand" cannot be established except as a relatively local phenomenon, and technology options and choices need adjustment to reflect local "boundary conditions"[50]; thus, decisions have to be discussed and taken locally, within an overall strategy framework for the city[51].

33. Involving the community in determining what facilities should be provided, and how - the establishment of "effective demand" - logically leads to the concept that communities should be encouraged to take responsibility for the eventual management of the facilities. This has led to some remarkable successes[52], and is undoubtedly a trend that will grow greatly in the future. However, there are so far few, if any, examples of this approach being applied on a city-wide basis - most examples are in particular slum or squatter communities - and planners need to make due allowance for the lead time and the supporting efforts that will be required to ensure success.

34. One particular problem in some urban communities is that there may not be an easy mechanism for ensuring that all residents get a fair hearing; the better-off and more articulate may dominate the proceedings[53]. Another problem, especially in low-income communities, is that it is unreasonable to expect communities to provide entirely volunteer inputs to secure services[54], as most of their members are hard-pressed to make ends meet in any case, and often depend on long hours of erratic casual employment. In these cases

community management needs to be put on a businesslike footing (this need not necessarily involve salaries; for example, free service could be provided to those managing the system. Cash payments of course become easier if there is an incoming revenue stream from outside the community, as is the case with recycling projects).

35. Where community organizations do not already exist (which is probably the majority of cases), an attractive alternative is to work through Non-Governmental Organizations (NGOs) or similar groups with experience of developing social sector programs at the grass roots level. These have considerable advantages over public sector agencies in being able to arrange outreach activities (such as health and hygiene education, an essential accompaniment to water supply and sanitation program in low-income areas if full benefits are to be achieved). The only caution to be observed is that NGOs may only have operated on a relatively small scale, and may be overwhelmed by the magnitude of the urban problems; as with communities, they may need assistance and support if they are to meet expectations.

Ensuring synergism

36. Because our urban environmental services have traditionally been planned and managed independently, we have got out of the habit of ensuring that they are developed and maintained as a balanced system and, where possible, that opportunities for synergism are exploited, so that "the sum can be more than the sum of its parts".

37. The most conspicuous failure of urban services today, especially in developing countries, is lack of synergism: there has been over-emphasis on the provision of water supply, with basic sanitation, storm drainage and solid wastes management receiving far less attention and a much smaller share of investment and operating budgets. Even if the water supply programs had been successful (which they have not been, for the reasons discussed above), they would still not have had the expected health and environmental benefits because they were not accompanied by the necessary improvements in the other services.

38. In many cities water was brought into neighborhoods but no provision was made for the removal of the resulting wastewater, or for providing even basic sanitation improvements; slum and squatter areas remained vulnerable to flooding, making life almost intolerable for some seasons of the year; and solid wastes collection remained rudimentary, resulting in insanitary conditions in the neighborhood itself and causing blockages and stagnation in storm drainage systems. Indeed, commitment of resources to water supply investments which are not paying their way has had the effect of restricting funding available for the other essential complementary services. **If we are to achieve urban living conditions which are significantly better than those today, we need to ensure "balanced" service development.**

39. Beyond this most basic level of integration - ensuring that development in one sector does not result in an overall deterioration in living conditions - there are many opportunities for linking services so that the effects are mutually reinforcing. The most obvious are the

various applications of wastewater recycling mentioned above; suitable design and location of sewage collection and disposal systems can convert this problem material into a valuable supplementary water resource for industry, agriculture, or preservation of water resources themselves.

40. These links may also be established across sectors. For example, for a long time sewage treatment plants have generated methane as a fuel to power their internal processes, and in some cases[55] the gas is also used in adjacent neighborhoods. Another example is the incineration of municipal solid waste (MSW) to provide both energy and heat[56], or to be co-composted with MSW[57]. In areas where the MSW is largely organic, and where there is an inadequate market for compost, energy can be recovered from properly-designed landfill sites by extracting the methane resulting from the decomposition of the material[58].

41. Another example of synergism, although it would often not be noticed, is the improvement in the quality of life in urban areas through the creation of public open spaces using land that is or has been devoted to providing environmental services. Reclaimed landfill sites[59] and wetlands used for sewage treatment[60] or stormwater detention are examples.

42. One of the most promising new developments, which illustrates these principles well, is the use of duckweed ponds to treat sewage. Properly cultivated, duckweed is a high-protein material[61] ideal for feeding fish[62] or for use as a replacement for expensive imported ingredients in poultry[63] or cattle feed. With careful nutrient management, the final effluent from the ponds is very high quality - usually better than that of the watercourses into which it is discharged. Most importantly, sales of the duckweed lead to the process earning a high nett income. Replacing a sewage treatment problem by an agribusiness opportunity therefore safeguards public health, results in environmental improvements, reclaims a valuable water resource, improves people's diets, and increases employment of unskilled and semi-skilled workers - while making a profit[64]!

Developing environmentally self-sufficient service districts

43. It is instructive to assemble some of the key concepts in the approaches discussed above:

- Water resources are becoming scarcer and much more expensive to develop, and so greater emphasis has to be placed on more efficient use of existing systems
- Technical solutions have to be matched to local conditions and preferences if they are to be sustainable over the long term
- Recycling must be encouraged as part of more efficient resource utilization

- Past exclusive reliance upon public sector institutions to provide service should be replaced by a broader partnership, involving the private sector and the communities themselves

- Opportunities for synergistic developments should be sought out, to increase overall effectiveness or reduce user costs

In sum, these arguments support the concept of breaking down the problem into more manageable elements[65]: establishing environmentally self-sufficient service districts in large metropolitan areas, where the scale of operations is such that it can be managed effectively by locally-based staff, where community inputs can be fostered, and which in themselves encourage the establishment of environmentally sound practices.

44. Such districts would not themselves provide every service needed - for example, they would in most cases be dependent on a city-wide water supply agency and, to some extent, on city-wide sanitation and storm drainage facilities, but the intention would be that they would treat these external agencies as "wholesalers" of service (which the district would then "retail" to the users). The district would have the choice of the level and extent of service it would request from centralized agencies, and could also engage in "trading" on its own account; for example, a district might accept (for a fee) solid wastes or sewage from an adjacent district and treat them on its own land.

45. While this approach has not yet been tried on anything more than a small pilot scale[66], it appears to hold great promise for the future.

CONCLUSION

46. Each of these approaches, individually, offers the opportunity to achieve greater efficiency in the use of our limited resources, extend service to more people, and reduce pollution and environmental degradation. Taken in combination, the effect would be dramatic.

47. Systematic implementation of these approaches at municipal level, if supported by national policies and appropriate economic tools, will lead to global environmental improvements, sustainable services for the world's growing urban population, and a significant step towards achieving a sustainable society.

ENDNOTES AND REFERENCES

1. A concept first described by Sheaffer, J.R. and Stevens, L.A., in their book Future Water, William Morrow and Company, Inc., 105 Madison Ave., New York, N.Y. 10016, and expanded here by the author.

2. Falkenmark, Malin, Mike Garn and Rita Cestti: Water resources: A call for new ways of thinking. Unpublished draft, INUWS, The World Bank, March 1990. See also many other publications by Falkenmark on this topic.

3. See, for example: FY90 Sector Review: Water Supply and Sanitation. INUWS, The World Bank, December 1990. Also World Development Report, 1992, World Bank, 1992, when available.

4. The most obvious effects are the land settlement which has occurred in a number of cities, as abstraction of groundwater allows the strata underlying the city to consolidate. The best known examples are Bangkok and Mexico City, but there are many others: portions of Beijing have been sinking 20-30 cm/year since 1950, and in the Houston-Galveston area of Texas land levels have sunk 2 m in the last half century (corresponding to a fall in the water table of 60 m). This settlement results in structural damage to buildings and infrastructure, as well as making effective storm drainage more complicated and expensive. Less visible are the resource and pollution effects of over-abstraction; particularly in cities near the coast, intrusion of seawater into fresh water aquifers may render them permanently useless. (Postel, Sandra: Water: Rethinking Management in an Age of Scarcity. Worldwatch Paper 62, Worldwatch Institute, December 1984.) In Jakarta groundwater abstraction is about 2 million m^3/day; this has depleted the aquifers below the city so severely that saline water has intruded almost 10 miles underneath the city (Rita Cestti: Water Resources: Problems and Issues for the Water Supply and Sanitation Sector. Unpublished manuscript, INUWS, The World Bank, August, 1989).

5. For example, an analysis of the three reservoirs serving the city of Indianapolis found that, although over 10 per cent of capacity had been lost to siltation, the total reliable yield could be increased by about 25 per cent if the reservoir operations were better coordinated. This study cost only about 1 per cent of the cost of adding additional reservoirs to provide the same result (Bakken, J. Darrell and Bruns, Thomas M.: Assessing the Reliability of Urban Reservoir Supplies. JAWWA, Vol. 83, No. 3, pp. 46-51, March 1991). An earlier study also concluded that improving the operation of existing facilities can achieve benefits at 1 per cent of the cost of constructing equivalent new facilities (Sheer, Daniel P. and Meredith, Dale D.: Improve Operations or Build New Projects?. J. Water Resources Planning and Management, Vol. 110, No. 3, July 1984). This does not mean that there is a "1 per cent rule", only that **improving efficiency to its economic limit** should always be planners' first option.

6. Pricing water at its full resource cost is a key element in any water conservation and demand management program. The following quotation applies to only one region of the world, and to all sectors, but could be applied to most municipal systems worldwide: "With prices well below marginal costs, the demand for water is expected to grow beyond the ability of governments to supply it..... Pricing distortions..add unnecessarily to environmental degradation... Low prices..encourage excessive use and provide little incentive for enterprises to invest in resource recovery and reuse. ...The pricing of water below economic cost throughout the region discourages the treatment and reuse of wastewater, leading to rapid depletion of freshwater supplies.... In ..... water prices are at most 20 per cent of marginal costs..." (Preserving a Shared Heritage and Managing a Common Resource. Environmental Program for the Mediterranean, World Bank/European Investment Bank, 1990).

7. A study of demand management as an alternative to supply augmentation in Beijing indicates that, taking the discounted cost of a new source as 100, the cost of alternative ways of saving 15 per cent of current domestic consumption were improved water conservation in public facilities: 14; leakage reduction program: 22; recycling

air conditioning water: 34; and installation of water-efficient flush toilets: 81. (Hufshmidt, M, J. Dixon, L. Fallon and Z. Zhu, 1987, cited in WDR92, November 4 draft).

8. This conservation need not be confined to municipal usage. In the United States, there are several examples of innovative approaches to finding new water resources for municipal use by encouraging conservation by other sectors: in the Imperial Valley in California: the Metropolitan Water District of Southern California is financing measures to improve the efficiency of irrigation systems (through providing new flow-regulating reservoirs, improved canal lining and more flow monitors), in exchange for the 106,000 acre-feet of annual water saving (Mathews, Jay: Urban, Rural Interests at Odds as California Thirsts for Water. Washington Post, June 26, 1990). The city of Casper, Wyoming, USA, pays farmers to line their irrigation ditches and to install water-saving irrigation devices; in turn, the city receives the salvaged water. A Utah city pays $25,000 for the option to use irrigation water (which otherwise would have a prior claim on releases) during droughts. In return, the city provides the farmers with an amount of hay equivalent to that which they would have been able to grow had they been able to irrigate normally (Nichols, Alan B.: Western Water Development in Transition. Water Environment & Technology, Vol.3 No.8. WPCF, August 1991).

9. This implies a major shift in emphasis in sector support: at present it is comparatively much easier for municipalities to obtain financial assistance for the construction of new works than for preservation and rehabilitation of their existing assets, although the latter is almost invariably far more critical and more cost-effective as a means of improving and extending service. National policies therefore need to stress rehabilitation as a first step in any sector strategy, and external donors supporting the sector should be requested to comply. There are a number of important consequences, such as the restrictions imposed by tied aid and the need for a different profile in technical assistance (drawing more on operating utilities and less on consulting firms) that need to be explored.

10. In an evaluation of the performance of 134 projects in developing countries, the World Bank's preliminary findings are that unaccounted-for water averaged 35 per cent (Study of Major Issues in Bank-financed Water Supply and Sanitation. World Bank, Washington, D.C. In preparation). As an indication of the low levels of unaccounted-for water that can be achieved with efficient management, over a 16-year period, one city, faced with a relatively high and increasing water tariff, systematically reduced losses from 16 per cent to less than 5 per cent (Mills, R. E.: Leakage Control in a Universally Metered Distribution System: Pinetown Water's Experience. JIWEM, Vol. 4, No. 3, pp. 235-241, June 1990).

11. The average incremental cost of water supply projects financed by the World Bank in the period 1966-81 was about $0.49/m^3. The average tariff on water sold (sales revenue divided by water volume sold) was about $0.26/m^3. Since the average level of unaccounted-for water was about 35%, the effective price/m^3 was about $0.17 - about one-third of the cost of producing the water (data, in 1988$, from FY90 Sector Review: Water Supply and Sanitation. The World Bank, December 1990).

12. For example, in two barrios of Tegucigalpa, Honduras, over 90 per cent of residents reported collecting rainwater, and estimated that it met at least half of their needs during the rainy season (primarily for domestic tasks such as washing dishes, bathing, or laundry; less frequently for drinking or cooking). According to this study, improved rainwater catchment could provide a wet season supply of 25 lcd, which would cost the average household $110 each year if purchased from a water vendor (Brand, Anthony and Bradford, Bonnie: Rainwater Harvesting and Water Use in the Barrios of Tegucigalpa. UNICEF/Honduras, 1991).

13. The prime need is to establish water as a **national resource**, and to charge all users the real cost of using that resource (these charges should reflect the impact of their use on the economy as a whole; for example, if their use of the water means that additional resources have to be developed to meet some other user's needs, or if they return the water after use in such poor and degraded condition that it is worse than useless, and so further investment in purification is needed to avoid environmental damage). At present, water charges are usually far

below the levels that would be required for economic efficiency or optimal allocation. Since the costs of new water supplies are steadily increasing, the adjustments needed to bring costs and revenues into line are going to become progressively more painful, the longer they are postponed.

14. "Raising irrigation efficiencies just 10 per cent would save enough water to supply all global residential water uses". (Postel, Sandra: Water: Rethinking Management in an Age of Scarcity. Worldwatch Paper 62, Worldwatch Institute, December 1984.)

15. Industries have often located themselves on the periphery of major cities, and developed their own water supply systems in the absence of a municipal supply. Since the marginal cost of this water is usually very low, and water forms only a very small proportion of total manufacturing costs, there is little incentive for conservation. The volumes of water used in manufacture can vary widely, depending on the industrial processes adopted and the extent of recycling: manufacturing a ton of steel may take as much as 200,000 liters or as little as 5,000 liters, and a ton of paper may take 350,000 liters or 60,000 liters. Proper regulation of abstraction, and introduction of tariffs reflecting the opportunity cost of the water, would stimulate much more efficient use in this sector, without having a marked effect on input costs. For example, in Israel, water-use standards have been established for each unit of production in various industries, and water allocations are then determined accordingly; in consequence, the average water use per unit of industrial production has dropped by 70 per cent over the last two decades. (Postel, Sandra: Water: Rethinking Management in an Age of Scarcity. Worldwatch Paper 62, Worldwatch Institute, December 1984.)

16. World-wide, it is estimated that about 73 per cent of water withdrawals are used for irrigation, while industry and domestic usage account for 21 and 6 per cent respectively. In developing countries as a group, the relative percentages are 85, 10 and 5. (Regional Study: Wastewater Reuse in the Middle East and North Africa. Final Report. EMENA Technical Infrastructure Division, The World Bank, June 1990.)

17. Even seriously water-short countries have often been slow to adopt packages of measures (such as canal repairs, land levelling, improving release patterns, and on-farm water management) or new techniques (such as drip or trickle irrigation) more appropriate to their situation. The effect is low efficiency (probably under 40 per cent, worldwide) and excessive water use, followed by serious agricultural problems with drainage, waterlogging and salinization, and eventual loss of productivity. Untreated return flows from irrigation schemes may also damage the rivers into which they discharge (quite apart from the risk that they may carry pesticides or other harmful chemicals).

18. During the present California drought, urban residents are questioning why they should bear the brunt of restrictions: "If all the urban areas and all the businesses cut water use by 25 per cent, it would be equal to agriculture cutting use by only 3 per cent." (Mathews, Jay: Urban, Rural Interests at Odds as California Thirsts for Water. Washington Post, June 26, 1990).

19. For example, in Izmir, Turkey, groundwater accounts for 90 per cent of industrial water, but the municipality is not allowed to charge for water extracted from private wells; industries therefore have to pay only the pumping costs, which are far below the cost of supplying the city with water from distant sources. Over-pumping of the aquifer has led to saline intrusion and local subsidence (Preserving a Shared Heritage and Managing a Common Resource. Environmental Program for the Mediterranean, World Bank/European Investment Bank, 1990).

20. The study of alternative water resource strategies for Beijing, cited above, also found that, compared to developing a new source of water supply for industry (relative discounted cost: 100), the following alternatives could be considered: increased recycling of cooling water: 19; power plant cooling water recycling: 47; and wastewater recycling: 66.

21. While there are difficult policy and pricing issues to be addressed (including maintaining rural incomes and national food self-sufficiency), uneconomical or unsustainable use by one sector of the economy is not in any nation's interest. The complex issue of national food self-sufficiency lies outside the scope of this paper. It is evident that for many water-scarce countries this goal is unattainable, even if it were desirable; a more feasible alternative strategy may be to concentrate on greater production of crops for export, enabling developing countries to accumulate foreign exchange reserves so that they may purchase foodstuffs on the international market. In any event, close scrutiny of cropping strategies is essential: the same amount of water needed to grow one acre of sugarcane can irrigate thirty acres of millet (Jan Lundqvist: Right Food, Right Way & Right People, in Falkenmark, Malin, Lundqvist, Jan & Widstrand, Carl: Water Scarcity - An Ultimate Constraint in Third World Development. University of Linköping, 1990).

22. An assessment of the environmental problems of the Mediterranean caused by industrial pollution found that primary treatment, emphasizing resource recovery and the removal of the most dangerous pollutants, would cost only 10 - 20 per cent of the cost of full treatment, but remove 50 - 90 per cent of the most dangerous pollutants. Effective industrial waste discharge reduction (including this primary treatment) would probably have greater environmental impact than insisting on full secondary treatment for the much smaller volume of municipal wastes (Industrial Pollution in the Mediterranean. Environmental Program for the Mediterranean, Working Paper No. 5. World Bank/European Investment Bank). Public health engineers are only too familiar with the problems and costs of removing traces of contaminants (of the order of parts per billion) from municipal water supplies, while industrial discharges continue to release large quantities of the same materials into the environment.

23. For example, for its next new source of water the city of Quito, Ecuador, would have to catch snowmelt from a height of about 10,000 feet above sea level, pump it up 2,000 feet, bring it nearly 4 miles through tunnels through the rock of the Andes, and then pump it up a further 3,000 feet. When it was decided to extend piped water supply to the 350,000 people (about 25 per cent of the city's population) who live in informal peri-urban settlements, the most economical "source" of supply was savings in existing water use. By launching a vigorous campaign against leaks, installing 72,000 new meters, and generally inspecting and overhauling the system, the city expects to save 27 per cent of its present consumption for reallocation to these new customers (Quito, Ecuador: Water for the Poor, in World Congress of Local Governments for a Sustainable Future: Acting Locally for A Sustainable Future. UNEP, 1990).

24. Beginning in 1988, San Simeon, California carried out a retrofit program to install low-volume toilets and water-saving shower heads. Starting with high-water-use facilities (schools, hotels, hospitals, gas stations) cut wastewater volume by 25 per cent. Extending the program to residential areas and restricting summertime watering reduced overall water use and wastewater volume by 50 per cent. Besides a reduction in the volume of wastewater to be treated, other benefits are:

- Recovery of the water supply aquifer, which had been suffering from over-pumping: chloride levels, which in 1987 were 960 mg/l, near the limit of potability, have declined to below 35 mg/l.

- Reduction in the cost of water heating, sufficient by itself to pay for the entire program.

(Based on Krause, Al: Low-flow fixtures pay off for San Simeon, California. Small Flows, Vol. 5 No. 3, July 1991.)

25. Public health authorities, knowing that intermittent supplies are inherently vulnerable to contamination, often warn all residents to boil their water. However, this is often impractical for low-income people, who cannot afford the fuel required. It is also a very large expenditure that would be better devoted to making the system safe in the first place: it is estimated that the people of Jakarta spend $20-30 million each year boiling their water. (Davis, Gloria: Indonesia Forest, Land and Water: Issues in Sustainable Development. The World Bank, 1988.)

26. In developing countries, materials may be dumped into the sewers that cause serious operating difficulties, even if the materials are themselves fairly innocuous. In Madras, for example, "There are approximately 40,000 cattle within the city limits and much of the dung from these cattle is disposed of through manholes into the sewer system. The high content of solids and straw in the dung leads to rapid clogging of the sewers. This problem is further complicated by the custom of washing metal bowls and pots with sand and disposing of the sand-laden wastewaters into the sewer system." (White, Robert L. and Beers. Gary D.: Four Developing Country Waste Disposal Projects, in Gunnerson, Charles G. and Kalbermatten, John M. (eds.): Environmental Impact of International Civil Engineering Projects and Practices. ASCE, 1978). This underscores the need to have a clear sociological understanding of the communities to be served, if elementary technical mistakes are to be avoided.

27. "Willingness to pay" is of course very dependent on people's priorities. One group studying public health facilities in rural areas reported with dismay that vaccines were not being kept properly because there were no working refrigerators - this complaint being voiced over cold beers from the local restaurant! Clearly there were both the money and skills needed to keep refrigerators serviceable - but public health was (as usual) a low-priority item.

28. Research is underway on developing techniques for finding out people's willingness to pay for certain levels of service, while keeping within realistic budgetary and manpower constraints for the planning agency. One promising approach is Contingent Valuation, in which people are asked directly how much they would be prepared to pay for a certain level of service if it were provided (hence "contingent"). Provided this work is carefully carried out and corrected, as far as possible, for any bias, it can probably give results which are at least as reliable as any other technique currently available. It is certainly better than assuming that there is some fixed proportion of income which people are willing to spend on water and sanitation; apart from the basic problems in defining and determining "income" in many communities, there is ample evidence that using this rule of thumb results in two sorts of problems: levels of service are set too low (so people do not value the improvements and will not pay for them), or they are set too high (so people would like to be able to afford them, but can not). (Whittington *et al.*: Willingness to pay for water in rural areas: Methodological approaches and an application in Haiti. Field report No. 213, WASH. September 1987).

29. Wright, Albert M.: Accra - Updating a Feasibility Study, in Gunnerson, Charles G. and Kalbermatten, John M. (eds.), *op. cit.*

30. As well as ensuring an increased supply of better-quality water, water vending may be an important source of income for community development activities, as the following two examples illustrate:

In one low-income area in the capital of Honduras, water during the dry season comes from the river or traditional vendor, and costs as much as 50 cents/10 liters. By establishing a water cooperative and buying water in bulk from the municipality, the cost of water from a neighborhood kiosk is only 10 cents/10 liters. The two women heads of households who manage the kiosk are paid from the revenues. Every 3 months, the kiosk operators are changed, so dividing the benefits of employment among several poor families.

In a community-managed system in South Africa, users buy plastic tokens, each valid for one 25-liter unit of water, at shops near the kiosks. This rate costs three times what the association pays for municipal supply; the surplus finances operation and maintenance, pays back the construction loan, and expands the number of kiosks. The project has created 20 full-time jobs, and reduced the cost of water by a factor of 3 to 7 compared to traditional vendors. The supply has been operational for 99.9 per cent of the time during the first 3½ years.

(Both references are given in van Wijk-Sijbesma, Christine: "What Price Water?"; User participation in paying for community-based water supply. Occasional Papers series. IRC Water and Sanitation Centre, The Hague. The original references are, respectively, Elmendorf, M and Kruiderink, A.: Promotion and Support for Women's Participation in the IDWSSD: Report on Mission to Honduras. Project INT/83/003, UNDP, New York. 1983;

and Rivett-Carnac, J.L.: Community Water Supplies for Peri-Urban Areas. MSc Thesis, Department of Civil Engineering, University of Capetown, Republic of South Africa).

31. See, for example, Hébert, Paul V.: Impact of Design Criteria and Standards on Water Supply Costs in the Philippines. Paper presented at a symposium on "Natural Resources Research in the 80s", Quezon City, Republic of the Philippines, 20-22 June, 1983, and Hébert, Paul V. and Yniguez, Cesar: Sensitivity of Water Distribution Costs to Design and Service Standards: A Philippine Case Study. Technology Advisory Group Technical Note No. 16, The World Bank, Washington D.C., 1986. A set of computer programs for this work has been made available free of charge to planners and designers in developing countries: Microcomputer Programs for Improved Planning and Design of Water Supply and Waste Disposal Systems. Technology Advisory Group, The World Bank, Washington D.C., 1985. Between 1986 and 1989, over 1,000 copies were distributed. In India, the government has mandated use of these program by all water supply agencies, and they are used extensively in the curricula of engineering institutes and universities (Maber, Steven: personal communication). Approximately 100 engineers from most states have been trained in these techniques. State agencies report capital cost savings of 10-30 per cent as a result. Sample projects reviewed by an evaluation team showed savings in the range 5-60 per cent. Actual savings would be higher than these figures indicate, since the ease of design using computers permitted staged construction, with each stage being tailored to prevailing circumstances, not usually attempted by the agencies in the absence of such facilities (Berna, James J. and Kalbermatten, John M.: Water Supply and Sanitation Sector Development Team for Asia, RAS/86/160: Report of the Joint UNDP/World Bank Evaluation Mission. Part II: Country Reports. The World Bank, Washington D.C. April 1990.) A recent case study from the Philippines, probably typical of 40 systems now being improved by the Local Water Utilities Administration with World Bank support, reports that these design modifications resulted in per capita costs falling from $45 to $25, nearly a 45 per cent saving (Kinley, David: Philippines Pioneers Low-Cost Solutions. Source, Vol. 2, No. 2, pp. 18-21, June 1990. UNDP).

32. In the Philippines, "affordable" water supply to low-income people was to be given through public standposts. It was found, however, that people would be prepared to pay the full costs of yard connections (but nothing towards standposts), and that there was far less wastage when people had their own connections. Also in the Philippines, monthly collections for service proved too burdensome for low-income people; the problem was solved by arranging for daily or weekly collections managed by the community - *barangay* - leaders (Authors' field experience).

33. The insistence by some US experts that any remaining sources of fresh water should always be exploited before wastewater is considered as a potential drinking water resource would strike many scientists for other countries as an uneconomical luxury, chosen because it is politically easier than controlling polluters. Other industrialized nations, which have had to come to terms with more restricted resources, have had no difficulties in accommodating reuse in their overall water resources planning. For example, in the United Kingdom the flow in the Thames, during a "1 in 20 year" drought, is 97% sewage effluent (of which about 40% is industrial effluent). (Taylor, M.R.G and Denner, J.M.: Sewage Effluent - A Water Resource. JIWES, Vol. 41 No. 1, February 1987)

34. In 1989, it was estimated that the amount of municipal solid waste generated annually in the United States was about 160 million tons (about 70 per cent of which was organic). Some analysts considered that the amount could be reduced by 20 per cent by combining packaging design and process modifications so as to favor reusable and durable containers, and that 70-80 per cent of the waste could be recycled. However, at that time only 8 states had comprehensive recycling programs, and nationally recycling only amounted to 10 per cent (Ridley, Scott and Hobson, Tina: State of the States, 1989. Renew America, Washington D.C., 1989).

35. Even apparent nuisances can be of value: old tires, of which the United States has between 2 and 3 billion in dumps, can be shredded and added to soil - up to 10 per cent in the top 6 inches - as a soil conditioner, enhancing drought-resistance, or provide up to 10 per cent of the energy needed in cement kilns. There are also

example, Teal, John M. and Peterson, Susan B.: Groundwater Threat Abated by Greenhouse. Water Environment and Technology, Vol. 3, No. 4, pp. 11-13. Water Pollution Control Federation, Alexandria, VA. April 1991.)

42. Tokyo places great emphasis on water conservation and recycling to meet the needs of its densely-packed population. Strict regulations require recycling, especially in tower blocks: structures bigger than a specified minimum area must install self-contained treatment facilities, and the water is recycled within the building. In Shin-juku, the "city in the sky" that will be the home of the new metropolitan government complex, 11 tower blocks are linked to a sewage treatment plant which provides chlorinated effluent for toilet flushing (World Water, July 1987).

43. The water supply and wastes disposal system for a city of 10 million people is a logistical marvel (or nightmare, in many countries). Assuming a per capita water consumption of 200 liters/day (including not only domestic usage but also all commercial and other uses), and a leakage rate of 30 per cent, **nearly 3 million tonnes of water have to be delivered each day**. Such a city may extend over several hundred square miles. If 90 per cent of the water used returns to the sewer system, then **1.8 million tonnes of sewage per day has to be taken back out of the city**. The use of water as a conveyance medium for human wastes is also extraordinarily inefficient; assuming that 30 per cent of the water consumed is used for toilet flushing (the percentage reflecting non-domestic uses included in the total), then **over 500,000 tonnes of water will be used to remove only 2,500 tonnes of faeces and 12,000 tonnes of urine.**

44. For example, in 1975 the 3M Corporation has initiated a company-wide effort to reduce pollution by introducing cost-effective process changes or recycling. The company estimates that in the period 1975-90 these changes have resulted in the following amounts of pollution reduction in their US operations, considering only the first year of each change: 120,000 tons of air pollutants, 15,600 tons of water pollutants, 1 billion gallons of wastewater, and 410,000 tons of sludge and solid wastes. The savings to the company (again, considering only the first years of operation) is estimated at $450 million. (3M's Pollution Prevention Pays. 3M Environmental Engineering and Pollution Control, St. Paul, Minnesota, 1991.)

45. See, for example, Coyaud, Daniel: Public and Private Alternatives for Providing Water Supply and Sewerage Services. Infrastructure and Urban Development Department Report No. 31, Policy Planning and Research Staff, The World Bank, October 1988, and Triche, Thelma: Private Participation in the Delivery of Guinea's Water Supply Services. Water and Sanitation Working Paper No. WPS477, Infrastructure and Urban Development Department, Policy Research and External Affairs Complex, The World Bank, August 1990. In the United States, the Environmental Protection A.gency has been encouraging the creation of "Public-Private Partnerships" for providing environmental services (water supply, wastewater treatment and MSW management); see, for example, Public-Private Partnership Case Studies: Profiles of Success in Providing Environmental Services. US EPA Administration and Resources Management Report PM-225, September 1989 (one of several reports on the subject prepared by this agency).

46. Since 1977, EMOS, the semi-autonomous public water company serving Santiago, Chile, has been encouraging its employees to leave the company in order to form private firms that would bid for service contracts. As a result, it has one of the highest staff productivity rates in Latin America: 2.1 staff per 1,000 connections, or 3.5/1,000 if contracts are taken into account. The average for other companies in the region is 10 - 20/1,000 (Triche, Thelma: Private Participation in Water Supply. Infrastructure Notes, Water and Sanitation, No. WS-5. The World Bank, September 1990).

47. A remarkable enterprise in New York is R2B2 - Recoverable Resources/Boro Bronx. It is a multi-material recycling company that pays cash to the public for the trash they bring in. Founded in 1982 with start-up costs of only $40,000, it has since recycled over 33,000 tons of materials, paid out over $300,000 to recyclers, and created 23 jobs. In one 9-month period, it was estimated that this one project saved the following natural resources: 7,200 tons of materials for making glass and aluminum; 15,500 barrels of crude oil; 24 million cubic feet of natural gas; and 58,000 trees (Perlman, Janice: Innovations for Sustainable Cities of the 21st Century. Mega-cities

Project, New York University. 1990).

48. Codes, bye-laws, etc., governing provision of service generally proved little more than pious hopes: "No person shall provide, construct, fix, retain or use any latrine other than a water-closet inside or under the same roof as any dwelling house, and any person who (does so) ..shall be guilty of an offence" (Public Health (Drainage and Latrine) Rules, Section 92, The Public Health Act, Kenya). Quite apart from the lack of sanitation in the slum and squatter areas in the country, the Kenyan town of Lamu has existed for at least 600 years, and throughout that time, and to this day, its citizens depend on an excellent system of in-house pit latrines (cited in England, R., de Kruijff, G.J., and Soni, P: The Pit Latrines of Lamu - 600 Years of "Illegal" Sanitation. Housing Research and Development Unit, Nairobi. 1980). It is time to establish **codes that ensure good practice in applying the technologies that will actually be used**, rather than requiring compliance with unrealistic standards.

49. Equally, donor agencies supporting the sector need to be prepared to include such elements in their loans and credits.

50. To take the most simple example: "effective demand" studies may establish that a community should be served using on-site sanitation such as pour-flush toilets. However, if an adjacent community wants, and can afford, a simplified sewer system, then it may be cost-effective to link the first community as well to the new sewers. This can only be decided on a case-by-case basis.

51. This forms the subject of "Strategic Sanitation Planning" (World Bank handbook, under preparation), an approach which could equally well be applied to other urban environmental services.

52. For example, in the squatter colonies of Sao Paulo, Brazil, there are 1,300 such associations. In Rio de Janeiro, Brazil, the Santa Marta shantytown (population: 11,500) managed to develop water lines, footpaths, electricity, health care clinics, a day care center, and storm drainage facilities. (Durning, Alan B.: Action at the Grassroots: Fighting Poverty and Environmental Decline. Worldwatch Paper 88, World Watch Institute, Washington, D.C., January 1989.) For a direct account of a visit to such a program, see Lauria, Donald T. and Whittington, Dale: Planning in Squatter Settlements: An Interview with a Community Leader. Report INU 52, Infrastructure and Urban Development Department, The World Bank, October 1989.

53. This restriction on "community participation", by sex, income or social standing, may not be readily apparent to the outside observer or admitted by the community representatives. For example, a trained "participant observer" working in an urban upgrading project in La Paz, Bolivia, found that community leadership consisted almost entirely of middle-income householders. As a result, the interests of poorer renters and of lower-income households on the periphery of the community had not been adequately taken into account. The approach was revised, to make sure that these groups were brought fully into the process (Salmen, Lawrence: Participant Observer Evaluation of Urban Projects in La Paz, Bolivia and Guayaquil, Ecuador. Discussion Paper No. 36, Water Supply and Urban Development Department, The World Bank, 1983).

54. There is in addition an equity issue: why should low-income communities contribute large amounts of time and labor to secure services which better-off people usually get at highly-subsidized rates?

55. One example being the Dadar WWTP in Bombay (authors' experience).

56. This is a valuable process for both disposing of wastes and earning revenues, but one that should be adopted only after careful evaluations: in many cities in developing countries the composition of MSW is such that it has very low nett thermal value, and the combustible components in it (such as paper) might have a higher value if recycled: "Recycling paper saves up to five times as much energy as can be recovered through incineration" (Young, John E., quoting Jeffrey Morris of Sound Resource Management Group, Seattle, in Burn Out, WorldWatch Vol. 4, No. 4, July/August 1991).

Project, New York University. 1990).

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51. This forms the subject of "Strategic Sanitation Planning" (World Bank handbook, under preparation), an approach which could equally well be applied to other urban environmental services.

52. For example, in the squatter colonies of Sao Paulo, Brazil, there are 1,300 such associations. In Rio de Janeiro, Brazil, the Santa Marta shantytown (population: 11,500) managed to develop water lines, footpaths, electricity, health care clinics, a day care center, and storm drainage facilities. (Durning, Alan B.: Action at the Grassroots: Fighting Poverty and Environmental Decline. Worldwatch Paper 88, World Watch Institute, Washington, D.C., January 1989.) For a direct account of a visit to such a program, see Lauria, Donald T. and Whittington, Dale: Planning in Squatter Settlements: An Interview with a Community Leader. Report INU 52, Infrastructure and Urban Development Department, The World Bank, October 1989.

53. This restriction on "community participation", by sex, income or social standing, may not be readily apparent to the outside observer or admitted by the community representatives. For example, a trained "participant observer" working in an urban upgrading project in La Paz, Bolivia, found that community leadership consisted almost entirely of middle-income householders. As a result, the interests of poorer renters and of lower-income households on the periphery of the community had not been adequately taken into account. The approach was revised, to make sure that these groups were brought fully into the process (Salmen, Lawrence: Participant Observer Evaluation of Urban Projects in La Paz, Bolivia and Guayaquil, Ecuador. Discussion Paper No. 36, Water Supply and Urban Development Department, The World Bank, 1983).

54. There is in addition an equity issue: why should low-income communities contribute large amounts of time and labor to secure services which better-off people usually get at highly-subsidized rates?

55. One example being the Dadar WWTP in Bombay (authors' experience).

56. This is a valuable process for both disposing of wastes and earning revenues, but one that should be adopted only after careful evaluations: in many cities in developing countries the composition of MSW is such that it has very low nett thermal value, and the combustible components in it (such as paper) might have a higher value if recycled: "Recycling paper saves up to five times as much energy as can be recovered through incineration" (Young, John E., quoting Jeffrey Morris of Sound Resource Management Group, Seattle, in Burn Out, WorldWatch Vol. 4, No. 4, July/August 1991).

57. An example both of synergism and privatization: in St. Cloud, Minnesota, USA, a private company bought an existing solid waste composting facility and upgraded it to accept both MSW and sewage sludge from a 3-county area. The combination of tipping fees and revenues from sale of compost to tree farms makes the venture financially viable. At the same time, the volume of waste going to landfill has been reduced by 15 to 20 per cent. (Public-Private Partnership Case Studies: Profiles of Success In Providing Environmental Services. US EPA, September 1989.)

58. In landfill sites, arrangements may in any case be required to vent methane safely; however, exploitation of the energy potential has only been done occasionally (for example, in Rio de Janeiro and Sao Paulo in Brazil), and with mixed success.

59. Although lack of land is becoming a serious constraint to landfill operations in many industrialized countries, a properly managed landfill may eventually provide a valuable civic amenity. For example, a closed landfill in Cambridge, Massachusetts has been reclaimed to form a 50-acre recreational area, providing playing fields, open space, trails, and natural meadows and woods, and adding 20 per cent to the city's open space (Kissida, John and Beaton, Nancy K.: Landfill Park: From Eyesore to Asset. Civil Engineering, Vol. 61 No. 8. ASCE, August 1991).

60. For example, the town of Benton, KY, upgraded a 0.3 mgd lagoon system into a 1.0 mgd-capacity wetland, producing a park visited by wildlife and appreciated by the community (Klockenbrink, Myra: Small Towns Build Artificial Wetlands to Treat Sewage. The New York Times, November 29, 1988, p. 26).

61. For example, duckweed eaten in some parts of Burma has a protein content of 20 per cent, double that of locally available rice, and yields 2,000 kg protein/ha each year, compared to 300 kg for soybeans and 70 kg for rice (Hillman, William S. and Culley, Dudley D, Jr.: The Uses of Duckweed. The American Scientist, July-August 1978, pp. 442-451.). Reports on other field trials indicate that protein contents of 40 per cent can be achieved by careful management of nutrients and harvesting.

62. Yields may be spectacular - up to 20 tons of fish/acre/year (Chesnin, Leon: Aquaculture for Waste Management. Biocycle, May/June 1982, pp. 52-55). However, at production levels above about 10 - 12 tons/acre/year there may be serious problems with oxygen deficiency in the ponds and with cannibalism (Gunnerson, Charles G.: personal communication), so prudent planners should base their forecasting on moderate production rates until operating and management experience has shown that higher ones can be sustained - but even moderate outputs (in the 3-4 tons/acre/year range) can provide an important source of protein and income to local communities.

63. Haustein, A.T. *et al.*: Duckweed, A Useful Strategy for Feeding Chickens in Third World Countries: Performance of Layers Fed with Sewage Grown *Lemnaceae*. Poultry Science, 1990.

64. A duckweed system in Bangladesh, treating sewage from 3,000 people, is costing less than 200 taka/day to run. The harvested duckweed (0.5 wet tons/day) has a value of about 500 taka/day as meal; used for growing fish, its value is about 3,500 taka/day. This is perhaps the only flow-through wastewater treatment plant in the world that is making a profit from its operations (Bangladesh Shobuj Shona Project, Progress Reports Nos. 3 and 4. PRISM Bangladesh, Dhaka, May 1990, April 1991; discussions with project staff).

65. "No one thus far knows how to cope with a city with a population of more than 20 million". Shanghai's pollution discharge problems are so intractable that the only short-term option is to move the water intake upstream, at an estimated cost of $450 million. The long-term solution remains an enigma. Industrial wastes are a problem: poor plant management (wasting industrial raw materials) causes 30 to 40 per cent of pollution. Industrial recycling of water is less than 20 per cent on average (compared to industrialized countries' 70 per cent), and many industries are too small to upgrade their processes. Nevertheless, policies are changing: "Managing water so as to form a

water cycle within an area results in the **water balanced society**". (Zhang Chonghua: "Environmental Issues in Water Supply and Wastes Disposal". Paper presented at an IDWSSD meeting at CEFIGRE, November 1989.)

66. The **SIRDO (Integrated System for Recycling Organic Wastes)** in the squatter settlement of Il Molino, Mexico is an example of a labor-intensive, community-managed system. "Grey" water (sullage from sinks, bathing, laundry, etc.)is kept separate from "black" water (sanitary sewage from toilets). Grey water is filtered, and 80 per cent is then used for irrigation. Black water is passed to a sedimentation tank; the resulting sludge is removed, put in an anaerobic decomposition chamber with household garbage (after glass, cans, and other recyclables have been recovered). Solar drying evaporates the water, and in a year's time, the result is fertilizer (alternating compartments enable 6-monthly withdrawals). The black water effluent is used for gardening (vegetables or flowers), or aquaculture. The system was introduced in 1979 for a low-income community (it is not economic or manageable at the household level). The local Cooperative (women hold 14 out of 18 board positions) is now selling fertilizer commercially at 70 or 80 cents/kilo (compared to a production cost of 5 cents). However, there have been severe political difficulties in introducing this concept in another community, since it interfered with traditional client/sponsor relationships in low-income settlement projects (Perlman, Janice: Innovations for Sustainable Cities of the 21st Century. Paper prepared for the International Summit on the Environment, Los Angeles, April 18-20, 1990).
Interesting lessons should emerge from a 30-month evaluation of this project, begun in January 1990, undertaken by the Grupo de Tecnologia Alternativa S.C., the Mexican NGO promoting the concept, with support from IDRC (Canada) (Water Supply and Sanitation Technologies and Management Systems for Peri-urban Areas in the Tropics: Applied Research Supported by IDRC. IDRC, March 1990.)