



INTEGRATED WATER AND WASTE MANAGEMENT

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ABSTRACT

The paper discusses concepts and developments within water quantity, water quality, integrated environmental assessment and wastewater treatment. The historical and the global perspectives are used in the discussion of the role of engineers in today's society. Sustainability and ethics are taken into the analysis. There is a need for re-evaluation of the resource, society and environment scenarios with a view to the totality of the system and with proper analysis of the flow of water and matter through society. Among the tools are input-output analysis and cradle to grave analysis, in combination with compilation of identified sets of values with respect to sustainable use of resources and ultimate fate of the environment and quality of life. The role of the engineer is to make available to society as many technical options as possible - and to put these options into the proper perspective in relation to the objectives of society. © 1997 IAWQ. Published by Elsevier Science Ltd

KEYWORDS

Water; sustainability; water quality; integrated environmental assessment; wastewater treatment; global perspectives; input-output analysis.

INTRODUCTION: FROM SHADOW PROBLEMS TO SUSTAINABILITY AND ETHICS

History. During the last thirty years the basic attitude to environment has changed. In fact the term "environment" had a totally different meaning. The Department of Environmental Science and Engineering at DTU dates back to 1865, when the motivation for water engineering was the cholera epidemics in the European cities. That was successfully dealt with by centralised delivery of purified water. Since then and until the 1960s the problems of waste and pollution were considered the shadow side of society which nobody wanted to take seriously until the detrimental effects became impressive and the whole development of society came up for scrutiny. That process is still going on and we have not seen the last of it. We have to be thankful to the public and to the pressure groups, because the fact is that it has been publicly driven in opposition to the establishment. That is in particularly apparent when compared to countries with a centralised planning and policy making, where the environmental disasters are even greater than we have experience to imagine.

By today's standard environmental issues have developed into basic concepts for the performance of society in line with resources, economy, social well being and concern for the next generations. Environmental

ethics is not a fantasy, but a serious discipline for the choice of performance of scientists, engineers, politicians and the public.

Sustainability. There is a severe contradiction between the development of societies and the frequently formulated objectives for the same society. Sustainability is a striking example. There are many interpretations to sustainability. I find that the general development of the concept is on the wrong path, confusing **quality of life** issues with **sustainability**. I will use the interpretation below, which has a resource component and an environmental component.

Society should use its resources such that the society can continue its mode of operation without exhausting its resources.

Philosophically this is utter nonsense, because it violates the thermodynamic principle of entropy. When mineral resources are mined and used, the result is a conversion from a concentrated to a dispersed state. It will require energy to reconcentrate the matter, which makes energy basically the ultimate measure of sustainability. The practical solution is to approach the ideal. That makes sense in societies which have violated the principle due to lack of concern in the past. Water and a few other substances are unique in making real sustainable operation possible.

Society should protect the environment against irreversible damage, including protection of unique species and habitats.

The conflict is that the very basis for the success of man in a modern society is his ability to change the environment with the aim to sustain larger populations. The turning point is that man has pursued this track of development to the extent where the changes develop to the detriment of man himself.

There are many examples in history where the exploitation of resources and the environment has developed into environmental disasters. What is new is the scale at which this takes place in the 20th century.

WATER QUANTITY

Sustainable usage of water is technically easy. It is the control of demand which is difficult

The engineer enjoys the idea of the challenging technical issues and problems. I am sure that a dam construction engineer in e.g. India does not feel that it is a fair statement to say that water structures are technically easy. However, in the larger perspective it is seldom the technical issues that cause water projects to fail. It is the circumstance under which they operate, that cause failure.

Misuse. Through history the misuse of water has led to some of the biggest ecological and societal disasters. Mesopotamia developed a society as advanced as did Egypt on the basis of water reclamation and vast irrigation systems. When society fell apart, so did the irrigation system and the semiarid land became deserted.

The society stopped maintaining the aqueducts supplying water to Rome, when the Roman empire declined. The disrupted aqueducts caused permanent ecological devastation where they accidentally dumped the flow. It was not until the 1950s that the quantity of water supply of the ancient Rome (some 20 m³ /s) was surpassed in modern Rome.

The example today is the disappearance of the Aral Sea. Upstream irrigation has diminished the flow to the Aral Sea to the extent that one of the biggest lakes of the world is disappearing. That is misuse because the effect could have been foreseen on the basis of well known fundamental hydrological principles.

There are many examples of this. Examples can be taken from very small to large scale projects. The engineers have to call attention to the fundamental hydrological principles at all stages and at all levels in order to avoid the small and the large scale disasters, including the stochastic properties of extreme events, whether floods or droughts. Misuse in this context is the ignorance of or the disregard for well-known, fundamental hydrological principles, such that the detrimental effects come as a surprise - including the statistics of the extremes, whether droughts or floods. The greatest perpetuating misuse is related to land use. Humans do not seem to apprehend from experience, that changing the upstream conditions may adversely affect the downstream water regime. Deforestation is the most striking example. Frequently, deforestation is the ultimate result of farming. That has a pronounced effect in the temperate climates, but it can have a devastating effect in the subtropical and the tropical areas. Soil erosion, desertification and downstream flooding are the visible detrimental effects. Cities cause increased runoff and potentially flooding downstream. The means are available for preventing such detrimental effects, but alleviation by reversal may be very difficult indeed.

Multipurpose water projects. The success of the human society is fundamentally based on the skill to grow and harvest crops by well-nourished mono-culture fields of rice, wheat, cotton, etc. Fertile soil and water are the indispensable conditions. In the development of the big cultures transport of water for irrigation has been the basis for richness. Long distance transport of water cannot take place without potential detrimental effects due to less flow where it came from and due to more flow where it goes. There is nothing unsustainable in this, though this has been claimed in cases where detrimental effects have been experienced. The key is that these effects have to be evaluated and properly balanced against the positive effects. Detrimental effects have to be foreseen, described and evaluated.

Construction of dams necessarily causes floods in upstream valleys with devastating effects to the ecology of the valley. Ground water supply decreases the ground water level with the potential decrease in the flow of the local rivers and drying of local lakes, swamps and moors. (Some rivers in the vicinity of Copenhagen run dry during the summer due to groundwater extraction. This phenomenon is a natural event for some rivers in Spain.) Society cannot stop making projects. As in the past, they are prerequisites for the development of society. None of this is unsustainable, but it does have detrimental ecological effects. The solution is to base decisions on a balanced view on "pro et con" and to make a political decision. In that balance, environment and ecology has rightfully received much greater weight in the decision making in recent years. What is unsustainable is when flooding finishes off unique ecological habitats forever; when ground water levels keep decreasing, when unique terrestrial sites dry up, etc.

Centralisation versus decentralisation. In the last part of last century the hygienic urban water problems were solved by centralised water supply and sewerage. These solutions are now being questioned with respect to environmental adequacy and sustainability. It is interesting to note that the introduction of sewers in the City of Copenhagen in the last century was the result of a fierce debate between two fractions: one in favour of sewerage and the other in favour of night soil collection, providing fertilisers for agriculture. The latter failed in the long run, because the system of centralised transportation of night soil never functioned according to basic hygienic requirements. We have to make a clear distinction between the established industrialised city with one century of investment in a sewer system and the developing cities of the world with no such established infrastructure. The centralised system worked well in providing hygienic conditions in the cities. By modern concepts it failed completely in environmental performance, but that is being rectified by introduction of proper treatment before discharge to the environment.

The basic feature is that water is used as the means for transport. Is that a sustainable solution? That is a fair question to ask in a period where the basic concepts are being re-evaluated. However, re-evaluation has to be made with proper identification of the "pro et cons" of the system and alternative options, in view of the totality of the system and all concerns: resources, society and environment.

The advantages are: Hygienic conditions (no waterborne diseases), easy transport with little visibility, adequate handling of organic matter and nutrients, little energy consumption.

Disadvantages are:	Increased water usage, costly maintenance of the system, out of sight - out of mind, problems with recycling of contaminated sludge.
Outstanding problems:	Not all wastewater treatments live up to environmental standards, source control of substances not suitable for the treatment processes, environmentally adequate handling of rain runoff.

This has to be set against a number of suggestions favouring decentralised solutions. A decentralised solution may involve local water supply, water recycle and disposal or it may involve only local water recycle and disposal locally. The reason for the latter is that it is well realised that local ground water sources under cities are not suitable for local water supply.

Local recycle has the merit that it reduces the total water consumption. The hygienic conditions under which such recycle can take place are essential. We must not sacrifice our hygienic heritage without proper consideration of "pro et con". It must depend significantly on the scarcity of the water resource. In some semiarid locations improved recycle efficiency should be pursued with vigour, e.g. on Cyprus where water shortage is a way of life and where local recycle of wastewater for local irrigation of lawns is profitable. In temperate climates with no water shortage and fewer detrimental effects from using the water resources, the decentralised options require more refined evaluation. Local infiltration of rain runoff is a suitable solution where infiltration is technically feasible. Local wastewater treatment is not a viable solution in cities, because the approach is either "low tech", which does not live up to established hygienic requirements and risk assessment, or it is "high tech", which suffers from non-sustainable energy consumption.

It is a frequent belief that "low tech" approaches are simple and easy solutions, which are "naturally" better than "high tech". That may not be the case at all. The basic rule is:

Any technical method has to work reliably.

The fact is that "low tech" solutions may be technically simple, but they are "ecologically complicated" and frequently difficult to operate.

Many examples can be mentioned: The introduction of wastewater treatment by rooted vegetation in artificial wetlands is a good example. They were introduced in Denmark as simple and natural, and specifically suitable for nutrient removal because the vegetation would exploit the nutrients. As part of a new law a parliamentary resolution specifically recommended "natural methods"; artificial wetlands were mentioned as an example. Naturally, small companies emerged to make business out of artificial wetlands. Some 80 small plants were built before an investigation revealed that they did not perform according to expectations at all. After years of research it is now clear that most wetlands are in fact low efficiency biofilters in which the rooted vegetation plays a minor role (Brix, 1994). They are difficult to operate, because there are no handles to turn and the time constants for control are too long. That development is a pity because artificial wetlands do in fact have a role to play and now they are discredited due to bad experience.

Similarly, large scale pond systems are simple to construct, but they can be very tricky to operate because they are ecologically complicated. A so-called "pond crash" is an event where the whole pond turns anaerobic due to an uncontrolled ecological excursion. There is no guarantee that technically simple systems are stable. Simplified "natural" may be difficult to operate indeed. However, due to the potential of such systems, research should be upgraded. Imagine the potential in algae production from wastewater in tropical areas as a means of protein production. It takes either expensive "high tech" solutions or very complicated, space-demanding ecosystems to work. The latter are a Chinese heritage that can be learned from where circumstances are fitting.

The alternative to the usage of water for transport of pollutants out of the cities is an alternative means of transport. In only few places has night soil collection been practised in a hygienic way (Japan). Trucking night soil is not viable from the point of view of energy consumption.

However, the point is that all the alternatives to handling water in cities have to be evaluated as a systems approach with proper analysis of all aspects. There is a tendency to publish also "religious" views on the issue. Every option has to be assessed on a rational basis with all aspects considered.

WATER QUALITY

While the water flow can be made sustainable, it is frequently not sustainable the way we use other materials in society. In relation to water usage there are some basic principles that are wise to have in mind.

*Usage of water is intended to remove unwanted matter (or energy) in excess at a given location.
The problem is the substances which are added, transported and dispersed.*

It is frequently forgotten that usage of water is deliberately polluting it, with the intention to use the water as a means of transport away from the location of usage. It is equally forgotten that significant reduction in the usage of water may involve alternative options for the usage or transport of the matter which needs to be removed. The classical example is the role of water in relation to personal, domestic and urban cleanliness. In the industrial societies the cholera epidemics showed that the urban society was living in its own filth. The population density was unsustainable without adequate measures towards better hygiene. The remedy was the urban sewer and the success has been overwhelming. Waterborne diseases are virtually unheard of in the well run urban societies. The lesson must not be forgotten in the attempts to find new solutions to other problems. We have to be constantly aware of the fact, that the most essential feature of the urban water system is to create a reliable barrier against contamination from the polluted to the unpolluted supply.

The barrier against waterborne diseases is still a basic feature of the urban water system that new technology must not jeopardise.

Due to lack of foresight or insight and looking at it in hindsight the solution was environmentally disastrous. Rivers went black, smelly and dead - with the Rhine, The Thames and The Ohio River as a few well-known examples. Lakes went green like a soup served for dinner due to proliferating algae, with devastating effects to the lake ecology. It is not until very recently that adequate measures are being implemented in order to reduce these effects. The solution is wastewater treatment. Organic matter, nitrogen and phosphorus are removed from the water before discharge.

In the urban usage of water also other substances are added to the water - including some which are not suited for removal at the treatment plant; e.g. metals and special organic substances that nature has never seen before. It is about time that the solutions to these problems are looked at in total and not individually by piecemeal solutions. In that perspective some basic principles are worth having in mind:

Any substance used in society will ultimately be detectable in wastewater.

With the ever increasing refinement of chemical analysis we are able to or will be able to detect even the smallest traces of any substance used by society. That poses a problem because the "zero standard" or the "non detectable standard" is simply a desirable, but unattainable goal. Society must come to grips with the reality that all residues from human activities are chemically traceable, despite severe emotional blockages.

Water can be treated to any degree of purity at ever increasing cost. No matter how well treated, there will always be left a detectable residue.

In the 1970s the US Congress decided to demand a "zero discharge policy". That is not feasible. It is common practice to demand "BAT: Best Available Technology". That is not defined. We have the technology to do better. It is a question of choosing a balanced solution in view of the totality of the system.

Some substances are suitable for removal at the treatment plants (e.g. organic matter, nutrient and bacteria). Others are not suitable and should be removed at the source.

This reiterates the need for a more global view on the system.

INTEGRATED ENVIRONMENTAL ASSESSMENT

Environmental problems can no longer be evaluated in isolation. They have to be looked at in total.

We have progressed beyond the point where we are satisfied to have treated the wastewater, cleaned the flue gas and composted the solid waste. These "end of pipe" solutions have their important role, but diffuse sources and non technological approaches are indispensable to further progress.

Few options. Society has only few options from a global point of view. These options can be listed as follows: consider a chemical that is used in society—what options with respect to ultimate fate are available?

No use, Reuse, Convert, Contain and Disperse

No use: We can stop using an unwanted substance, because the advantages of its use are overshadowed by the detrimental effects to the environment.

The historical example is the hard detergents in washing powder, which were banned in Germany in the early 1960s. Many examples have been added since (DDT, PCB, etc.). The key is to find environmentally sound substitutes.

Reuse: We can decrease the amount reaching the environment by internally reusing the substances. This approach is under development and implementation is just at its beginning. Cleaner production together with mass balances and life cycle analyses will have a much greater affect on our daily life than we can imagine today.

That is a very viable solution, but it has to be realised that there will still be a residue to be considered.

Convert: When a substance has been introduced it is important to control the route of that substance such that the transport can be identified and the flow treated. Treatment mostly means converting the substance from an obnoxious form to a form, acceptable for further transport by air or water or in solid form.

Conversion by incineration converts solid matter into an inert solid form and into a gaseous form. Wastewater treatment has the function to convert into a separable solid form (mostly by sedimentation) or into a gaseous form. The essence in this context is that the solution is rarely a final one. It is just a conversion into something that can be transported acceptably on the next route.

Contain: One of the ultimate fates is to contain the residues and leave it there forever.

The deposit of radioactive waste in old salt mines is the best example. The material is deposited in the hope that it will never seep, creep, leach or migrate out to the environment. The difficulty of this notion is illustrated by the landfill, which supposedly was aimed at as an ultimate solution. Leakage from landfills has been identified as an essential problem that calls for treatment. By the modern concept the landfill is a treatment unit for many years until ultimately an inert residue has found its final resting place (until archaeologists find interest in the remains with the aim to learn about our behaviour).

Disperse: The only other ultimate fate is to disperse in the environment.

The gas from incineration has to be treated such that the residues in the flue gas are acceptable from an environmental point of view. The wastewater treatment shall create effluents with residues acceptable to the aquatic environment. The treatment of solid waste shall be such that the product can be either recycled or dispersed or contained.

There are no other options! (Except shooting into space).

The system has to be looked at in total. Water can only be considered within the context of mass balances in societies. Flow of matter in society can no longer be looked at except in the total context of resources, society and environment. Cradle to grave, input-output and mass balance considerations have become indispensable tools. The instruments are available, though still under development and refinement.

Management systems. Efforts are made to create a system by which to analyse the problems in total. The following is taken from the ongoing project within the European Environmental Agency (EEA, 1995) aimed at establishing a commonly agreed concept and methodologies by which to assess integrated systems.

Management involves the following steps:

1. Describe and quantify the causal chain from human activities to environmental impacts
2. Set targets
3. Identify policies
4. Assess the impact of policies
5. Prioritise policies
6. Implement policies

The process of integrated environmental management is partly scientific-engineering and partly political. "Scientists/engineers deduce consequences - politicians decide policies" is a good description of the roles played, quoted from the EEA-report draft (EEA, 1995). It is far too frequent that the players do not identify their role properly, like the political scientist or the politician pretending to convey "objective" scientific information. Over the past two decades it has been politically opportune to state that there is no "objective" truth. Philosophically, that may be true, but based on identified axioms and experimentation consequences can be deduced and verified. If that is not attempted by the scientist/engineer there will be nothing to hold on to in the political debate and even the wildest claims may be presented as "facts". That scenario is common in the debate on environment. That is an issue for academics to deal with.

In regard to items 2. Set targets and 3. Identify policies, the approaches applied in Auckland, New Zealand, involves participation of non-governmental groups and the public. This is novel in comparison to the approaches applied in other projects and highly recommendable in a situation where the values change rapidly and even the politicians have a hard time keeping up with the public concern.

WASTEWATER TREATMENT

The basic motivation and demands. It is interesting to note the historical development of demands on wastewater treatment. When the water pollution issues were on the shadow side of society with little public attention and little political priority, the requirements were simple: removal of organic matter and suspended solids. With the development of environmental concerns the requirements have increased in spectrum and stringency, chronologically like this:

Organic matter, settleable suspended solids, inhibitors to carbonaceous removal, odour, disinfection, phosphorus, ammonia, nitrogen, aerosols, metals, filterable suspended solids, ecotoxic chemicals, volatile organic chemicals

With this bewildering spectrum of demands there is a need to consult the philosophers and stick to the basic concepts of integrated management. Otherwise, we end up in utter confusion in our role as engineers. We do

not set the standards. Society does. We provide the spectrum of technologies that can solve the issues raised. In this regard it is mandatory to identify which processes are suitable for treatment of domestic wastewater, and which are not. There are substances that can be removed from the water - just to end up in the sludge. That is not an end solution - unless we are prepared to contain that sludge for eternity at a landfill with no leakage! The sustainable solution is to reduce the contribution of metals and non-degradable organics at the source.

The choice of technology. A whole spectrum of technologies for cleaning wastewater is available (Henze *et al.*, 1997). I repeat, we have the technology to treat wastewater to whatever degree of purity we want - at a price. In this regard the traditional sanitary engineer is very conservative, like the statement: "That is not value for money". Sure, the engineer can calculate the cost, but can he also set the value? NO!. The willingness of the public and subsequently the willingness of politicians to prioritise the cost of environmental protection is constantly on the increase. In Denmark the cost of water has been increased by a factor of FIVE over the last few years. That has been the most effective way of making industries save water, switch to cleaner production or purify in house before discharge. The attitude of industry has changed from hostile opposition to investment in pollution abatement during the 70s, over reluctant allocation of funds in the 80s to making environmental issues a question of public image in the 90s.

We have the technology to remove organic matter, solids, bacteria and nutrients. Here, I am not concerned with the detailed technical approaches, because basically they all play around with the same basic processes - and essentially they can all work. However, they cannot be designed without proper information as a basis for design and for operation.

Wastewater characterisation. It is still the basic concept of sanitary engineering that treatment plants can be designed on the basis of some scarce data on flow, BOD and SS, today supplemented with ammonia, total P and total N. That is combined with simple design rules that can be written on one page. The fact is that the combination of processes includes oxidation of organic matter by heterotrophs, nitrification, denitrification, biological removal of phosphorus (backed up by chemical precipitation as a safety measure), suspended solids removal and disinfection, all combined in one plant. This spectrum of processes can neither be designed properly nor be operated successfully without proper information about inflow and on-line performance. In order to make a proper design much more information is required with respect to the wastewater, its flow and fractionated components and the statistics of daily and extreme performance. Organic matter cannot be characterised just by BOD. Much more specific characterisation is required, for which purpose COD is much better suited, because of the mass and energy balances that can be established on this basis (Henze *et al.*, 1995). There is no way in which biological phosphorus removal can be kept track of without monitoring "easily biodegradable COD". There is no way nitrogen removal can be understood without accounting for "inert soluble organic nitrogen", etc. Proprietors of treatment plant, designers and operators must get accustomed to much higher cost of monitoring and data analysis.

The role of pilot plant studies. Many pilot plant studies have been performed just to show that the chosen processes work and to verify preconceived ideas with respect to design. That is a waste of time and money. Pilot studies have to be designed in combination with wastewater characterisation to determine crucial performance parameters - sometimes by deliberately provoking a breakdown. Otherwise, the limits of the performance cannot be determined. That is not something to be done in a few months or half a year. Therefore it is just as well stick to preconceived design. Pilot studies in this respect are an ongoing exercise at considerable cost that will pay in the end by better design and better performance.

Who would risk investing his private money in a factory without meticulous analysis of the suitability of the raw material, the performance of the processes with which to make the product and the adequacy of that product? The wastewater profession has a lot to learn from neighbouring disciplines.

New technologies: sensors and real time control. While we today master the processes for wastewater treatment in the traditional way, new approaches are changing all that. The combination of reliable sensors, knowledge and understanding of the processes plus computer facilities to handle the flow of data has made it

possible to improve performance on the basis of on-line measurements and continuous optimisation of operation. New sensors are being developed, new mathematical tools are introduced and a whole new philosophy of design is just in front of us. That is a whole new lecture by itself.

THE GLOBAL PERSPECTIVE

Water demand is basically a local population issue. Urban water demand is a public health issue and rural demand is a food production issue.

Water is by nature a sustainable resource. It is recycled by nature. It is not a question of exhausting a limited resource, but a question of redirecting an available flow. The problem is that societies tend to permit populations to grow at locations without adequate available local flow. The technical question becomes one of transport of water and/or food, which is relatively simple compared to limiting/relocating people. The developing cities cannot afford to invest in a centralised system that does not perform reasonably until the whole system functions. Decentralised solutions have been investigated for a long time. The experience is that only "high tech" solutions work (Japan). But they are costly and use too much energy. There are no new "low tech" solutions being invented. There is no miracle "low tech" solution in sight. The reason is a question of attitude, culture and education. It is a social problem more than a technical problem. In this regard the situation in the large developing cities is quite depressing. They expand at a rate, which cannot possibly be sustained with proper technology and investment. Local solutions do not work. The internal filth becomes limiting to growth. The solution is social.

Do all to prevent the big cities from expanding in size and number of inhabitants.

In the established, still developing cities the sanitary conditions will be a limiting factor and the effects will be unpleasant, e.g. increase in number and severeness of communicable diseases.

The engineers are called upon to make solutions. It is time that the engineers shout to the world that there is no technical solution - rather than being used as the scapegoat for an unrestrained and unsustainable growth which it is politically unacceptable to stop. Many of the sustainable solutions are viable in a less dense population, in the rural areas where the ground water can be utilised locally without risk of waterborne diseases (if handled properly, which requires education). There are more options to disposal of wastewater such as infiltration, treatment and discharge locally, even for local recycling if done properly. Organic matter can be recycled locally, as has been done for centuries. The system can be made both pleasant and sustainable if supplemented with adequate knowledge about hygiene and environment. In this regard China has experienced an interesting development. First, China has made greater effort with respect to keeping down population growth than other nations. They have realised that uncontrolled growth will not only be to the detriment of economic growth, but also contribute to degradation of the environment to the detriment of health, living standards and social well-being. In spite of many cities larger than 10 million they have in fact attempted to control urban growth. The result was not foreseen. Instead, so-called "township and village enterprises" have developed in the countryside, which have caused uncontrolled diffuse pollution at a scale not seen anywhere else, in regions which presently exhibit the largest economic growth rate in the world. In China they have a long tradition for ecologically sustainable agriculture and village culture. Now it is rapidly exchanged with the highly efficient, but less sustainable agricultural development using fertilisers and pesticides at a rate similar to that used in the western countries.

CONCLUSION

There is a need for re-evaluation of the resource, society and environment scenarios with a view to the totality of the system and with proper analysis of the flow of water and matter through society. The tools are input-output analysis and cradle to grave analysis, in combination with compilation of identified sets of values with respect to sustainable use of resources and ultimate fate of the environment and quality of life. Implementation will require a set of tools with respect to technology, behaviour and economics. The social aspects will be the most difficult issues, also politically.

The debate has to be more relaxed so that "pro et con" can be listed without prejudice in an attempt to make a total assessment. The premises for evaluation should be open to debate and should be the results of such an analysis. It is wise to have the analysis and the reasoning performed by the experts and leave the setting of values, the premises for the analysis and the final decision to the politicians, representing the people.

The role of the engineer is to make available to society as many technical options as possible - and to put these options into the proper perspective in relation to the objectives of society. This includes making clear when technology alone does not provide solutions to the problems created by the development of society.

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