The Earth Sciences and Society: the Needs for the 21st Century

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ABSTRACT

As world population moves to 10-12 billion next century, there will be, must be, vast development of Earth Resources. If there is to be truly sustainable development, we must use all knowledge about our planet with greater wisdom than in the past. We must integrate all knowledge to solve critical problems like energy supply, food security, waste management and the maintenance of quality air and water for all species who live with us and support us. Knowledge from the Earth Sciences is at the core of intelligent development of our life support systems.

Keywords: Resource management, sustainable development, geological education.

INTRODUCTION

The 20th century has been remarkable in terms of the development of Homo sapiens. Two thousand years ago the human population has been estimated at about 300 million. It then took 1700 years to double the population, social conflict, disease, famine controlled the global population. Then carne the birth of modern science and technology and the beginning of new knowledge about our planet. The giants of the period around 1900 (from Lyell to Darwin to Einstein) opened new visions including the understanding of atoms and energy and planetary systems. We now live in the age of observation on all scales. The thoughtless application of the new knowledge led to the present population explosion. For many the quality of life has greatly improved but today we are concerned and following the famous Bruntland report (World Commission on Environment and Development, 1987) the new consideration of the concept of "sustainable" development arose.

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Today, most agree that the present world human population of about 6 billion will again double in the next 30-40 years. But it will be a world with a new demography. Europe and North America will make a small part of the world population by 2050. The greatest population expansion will occur in the so-called developing (or overdeveloped) nations. Fertility rates tell the story (India, 3.8; Nigeria, 6.5; Egypt, 3.9; Pakistan, 6.2; cf Germany, 1.3; Italy, 1.3; Sweden, 2.1).

Recent world data show the rising problems of overpopulation; major areas like

M Asia and Africa with vast problems of malnutrition (Sadik, 1989) and all the problems associated with malnutrition. The expansion of classic diseases like tuberculosis, malaria, ...and with the competition for resources increasing, the often brutal conflicts in some 40 nations.

A new symptom of the present situation is the rise in so-called environmental refugees, "outcasts from Eden". As Fell (1996) recently wrote, "The ranks of refugees fleeing floods, drought, desertification and other assaults on the environment could swell to 200 million by 2050. Is there any hope of fending off global catastrophe?"

The surface of our planet will be very different by the year 2100. During the past decades we have seen the growth of environmental science. We have studied in detail changes in environment over the past 100,000 years or so and we have recognized many of the factors from the Sun - atmosphere - hydrosphere - biosphere - solid Earth system that lead to fluctuations on many time scales. Our environment never was, never will be, steady state.

But I think that as Earth Scientists we must be honest. The past will not be the key to understanding the new world. For example, imagine our planet when:

- very few rivers flow freely to the oceans (e.g about 5,300 large dams in 1950, 36,600 in 1985; Abramovitz, 1996);
- many nations have no forests;
- irrigation on the continents will lead to new patterns of global evaporation - new continental water regimes, salinzation, etc.;
- global soils become thinner and less bioproductive;
- more xenobiotic chemical, pesticides, herbicides, etc. etc. cover the planet;
- biodiversity is greatly reduced and genetically modified species cover the earth.

In all, our planet will have new outer geosphere chemistry and biology, a new albedo.

Will the average quality of life be greater by 2050? I often think that the lead question which must be addressed by all who are educated must be "can this planet support 10-12 billion humans well and leave the planet in good order for all who follow us?" I think the answer to this question is now clear. It may be possible - but not with our present technologies and social morality. I am angry when I read recent reports of the growing income disparities. In 1960, the ratio of the wealth of the top 20% of population to the bottom 20% was a factor of 30, today it has grown to over 60 times. Yes - "globalization" or, as some say, "corporate feudalism" is working.

In what follows I wish to consider some of the new developments which are urgently needed and most of which involve, in part, the Earth Sciences. R is difficulty to put such things in any order of priority for all are interrelated.

PRIORITY ONE - UNIVERSAL QUALITY EDUCATION

When we consider the human condition, situations where environments are improving with true change toward sustainable systems, world data are clear (see World Resources Institute Report, 1996-97). In nations with excellent and improving education for all, of all ages, problems are being solved and human society is accepting its place in the biosphere and on the planet. As has been said many times, we require universal literacy, numeracy and sciency. AH who live on a planet in the solar system, still the only one we have available, must understand how it functions, the factors that control our life support systems. While the need for literacy has been long recognized, it is clear that equal priority must be given to universal sciency. And it is possible to use the planetary system to introduce the most basic concepts of science (matter-energy dynamics) to people of ali ages and stages. We must educate for global responsibility (see Fyfe, 1992a). All people must understand that conditions on this planet are never steady state. We must be prepared for surprise and that means we must have surplus.

At advanced levels, universities, the time has come to produce much more integration of the specialized fields. Yes - we must have experts of all kinds. But today we must have experts who can communicate with other experts and not hide behind their jargon. I recently re-read an old report (1963) from UNICEF stating that by 1970, malaria would cease to exist on the planet. Much foreign aid given to developing countries was in the form of DDT. But the experts were wrong; they did not understand ecology or evolution. Under the title of environmental science we need interactions from diverse areas of physics, chemistry, biology, geology, engineering, sociology and economics.

SOME PRIORITIES IN THE EARTH SCIENCES

I. Development of the Geologic Map

As never before, there is need for highly precise geological mapping on scales appropriate to the development problems being considered. Such maps must be precise in describing the timing of events and must be precise in 3 dimensions. For example, if we consider the growth of mega cities, the geological knowledge required to prevent-reduce costly engineering mistakes (e.g. Kobe, Japan) to provide and protect water, to prevent pollution etc., is of a detail and range far beyond most present mapping systems. Recent studies, as with the German deep drilling experiment (the KTB), clearly show that our techniques for deep remote sensing are far from adequate today. 1 was recently on a field trip with an excellent group of Portuguese (Lisbon University) structural geologists. They were concerned with mapping a region of some interest in terms of a site for nuclear waste disposal. The region was well known for some major fault structures. But their detailed studies, clearly revealed the complexity of the stress patterns and showed that micro-fault systems were present with a frequency distribution of tens of meters. This type of detail is essential to the planning of any major engineering project. At a recent meeting in Norway, Swedish geologists reported on the use of good maps in planning the exact location of new highways resulting in large cost reductions. As urban regions expand, consideration must be given to using the subsurface for storage facilities, factory construction, transport routes, etc. The surface of our planet is precious with its role in food and fiber production and bioproductivity in general.

Geologic maps must include the surface chemistry (related to agricultural potential) and the water storage in the top few km. Recent work sponsored by the International Union of Geological Sciences and UNESCO has shown the vast importance of surface geochemical mapping to a host of problems from agriculture, to public health, to waste disposal (see Darnley, 1995).

2. Quality Control of Materials

Today we have amazing techniques for the description of all materials, inorganic, biological in all phase states, gas, liquid, solid, and for the study of surfaces. Before any material is used and dispersed around our planet, we require exact knowledge of what it is and how it reacts with the outer geospheres. As discussed below, earth materials are used and dispersed on a vast scale and often, their chemistry etc. is only studied after problems arise. Some of our classic specializations like mineralogy and petrology should be considered as the science of natural Earth materials in the broadest sense.

3. Energy

At the present time, the bulk of world energy comes from the combustion of coal, oil and gas; all these resources are based on natural capital and are nonsustainable. The thoughtless waste of such valuable resources is a global disaster. Of the fossil carbon sources, only coal and certain types of carbon rich sediments have reserves of interest for more than a few decades. In a general way, there has been little change in burning technologies - add air - burn - and exhaust to the atmosphere.

There is no need here to discuss the potential future impacts of the climate changes related to the fact that we have rapidly changed the chemistry of the atmosphere. Discussion is normally concerned with CO2, C11, and acid compounds, but, as stressed previously (Fyfe and Powell, 1995), many coals contain significant quantities of all halogens: F, Cl, Br, I, and the steadily increasing ozone depletion catastrophe may be influenced by combustion of these fuels. Also, time after time, the detailed chemistry of coal and coal ash is not well known. Many coals have significant quantities of elements like uranium and arsenic, and an array of heavy metals immobilized in the reducing, sulfur-rich, medium of coal. It is amazing how little is known about the detailed chemistry and phase chemistry of this major world fuel.

Imagine for a moment that we did not use fossil carbon, nuclear, in our energy systems. If we relied only on wind, water, biomass, how many people would live on Earth?

The USA, and nations like China and India will depend on increased use of coal for decades to come. Can the technology be changed at reasonable cost, to reduce the environmental impact of coal combustion? I think the answer is positive. We have been studying the fixation of CO2 and organics in the cracked, permeable basalts in the caves of Kauai, Hawaii, deep beneath a very heavy forest cover. Every crack is covered with white materials (silica, clays, carbonates), formed by the action of organics with the basalt, a process mediated by ubiquitous bacterial biofilms. Bacteria can live to depths of over 4 km, up to 110°C, in favorable locations (Pedersen, 1994). Can such processes be used to fix the exhaust gases of coal combustion? Certainly, some rock types will be better than others, and volcanic with Ca-feldspars and rich in Fe-Mg phases should be ideal, as in Hawaii. Also, it is interesting to note that adding H20 - CO2 to appropriate rocks can be a highly exothermic process and the gas disposal could lead to a geothermal energy bonus! For some reactions, the heat produced per carbon atom is about 30% of the original heat of combustion per carbon atom. Recently, on a field trip in China, (East of Beijing), we discussed the possibility of using their rapidly exploited oil-gas fields for disposal of wastes of many types. If a basin can isolate oil-gas for millions of years, it undoubtedly has the capacity to isolate wastes (Desseault, 1995). And, generally, oil field structures and hydrogeologic properties are well known. Interest is growing rapidly in this area (see Fyfe, et al, 1996; Hitchon, 1996).

The growing knowledge of the deep biosphere also raises the possibility, with certain types of carbonaceous sediments, of using microorganisms for in-situ methane or hydrogen production. In place of opening deep mines, with all the related water pollution problems, could it be possible to produce bio-gas in situ?

There is no shortage of energy sources on this planet. Ultimately, the world must move to solar energy of all types (photovoltaics, wind, tidal) and geothermal energy.. Wind energy use is increasing across the world, and photovoltaic devices are becoming more efficient and cheaper (New Scientist, 1995).

Geothermal sources are normally associated with regions of high heat flow (volcanic systems) but, for some purposes (city heating, greenhouses and aquaculture systems), the normal geothermal gradient can provide background heating. There are many regions of the ocean floor with impressive potential for geothermal energy. All such potential use requires exact knowledge of deep geologic structures, porosity, permeability and geochemistry. I was interested to read in a recent tissue of the Economist, that there is a world shortage of high purity silicon. Where on the planet is the most pine SiO2 on the million ton scale. This is the type of problem with which we must be concerned.

4. Water

If the world human population reaches 10 billion, and if these 10 billion are to have adequate nutrition and supplies of clean water, there will be the necessity to manage the global water supply with great care and attention. When we come to consider the water resource question, we see the potential for real limitations and potential environmental disasters (Postel, 1992, 1996).

Over the world, precipitation is about 525,100 km3 (1 km3 = 1015g = 109 tones). However much of this falls on the oceans (78%). On land, more than half evaporates. The reliable runoff available for man is about 14,000 km3 (much more occurs but only during floods). The reliable usable water is estimated to be about 9000 km3. At this time, man manipulates about 3500 km3, almost 40%. And, after man uses water, its chemistry and biology are changed (McLaren and Skinner, 1987).

For any given region, the water supply can be quantified. Perhaps it is best to think of the "island" model (for example, a river may flow from one region to another - but who can guarantee that this inflow - through flow - will be maintained?) In an island model, the water inventory involves: the rainfall, the ground water penetration, the evaporation or evapotranspiration, the runoff to the oceans. A first most important parameter is the reliability, or variations, of the rainfall. Over what time period does one average the availability of the total supply? The numbers to be used will, in part, reflect the technologies that may be available, or possible, to store water over long periods of time.

There are certain realities in preparing a plan of management for the island water supply.

- there must be sufficient runoff to prevent salinization - runoff removes salts and other wastes from the land surface.

- the evaporation processes depend on the nature of the island's surface cover. This will vary, depending on the vegetation, urban de‘elopments, transport systems, etc.

- the potentially useful ground water resources depend on the geology, the deep porosity, permeability and the chemical nature of the rocks, which will influence the chemistry of the water and its suitability for various purposes, agricultura! and industrial.

- surface storage removes land area, and can increase evaporation.

- subsurface storage is only of sustainable use if recharge exceeds withdrawal, and if the cycling does not reduce long term porosity and permeability.

It is remarkable that, in many regions today, such basic data are not considered in the use of water (see Postel, 1996). Groundwaters are being mined in many regions.

There is little doubt that, in the near future, there will be development of massive technologies for the massive recycling, re-use of water, particularly in urban and industrial systems. Given an appropriate climate, urban-industrial runoff would be redistilled by abundant solar energy - a sort of Space Ship Earth technology (imagine a colony on Mars!). By use of appropriate rocks, the distilled water could be easily remineralized to required levels of mineral content for human nutrition. For industrial uses, modern filtration systems (inorganic or biological) can allow re-use and reduction of waste discharge.

But for this writer, a great problem with the potential for major problems involves the agricultural-energy uses of major systems of runoff. A major river is dammed for such purposes. The runoff to the oceans now fluctuates over large values, depending on fluctuations in rainfall. Downstream, the aquatic biodiversity and biomass is seriously perturbed. At sites of ocean discharge, the nutritional supply to the ocean biomass is seriously perturbed, and modern satellite pictures show us clearly that the marine biomass is concentrated near continental margins.

But, perhaps most seriously of all, ocean current systems may be perturbed. .About 10,000 years ago, the great Gulf Stream current that transports energy to the Atlantic Arctic regions was perturbed. The North went into a little Ice Age, the Younger Dryas event. An explanation by Broecker et al (1989) is that, for a period, the Mississippi river system was diverted into the St. Lawrence system. This placed a vast flow of light continental water onto the surface of the N. Atlantic, which perturbed the Gulf Stream and the Northern energy transport. Very rapidly, the North Arctic froze. This model warns us that, if a large outflow is changed, the patterns of ocean currents, ocean mixing, may change effecting local and global climate. But it should be noted that the Broecker et al model has been recently questioned (Vernal et al, 1996). Such phenomena must be considered when there are plans to modify major components of continental runoff! I am sure that most water engineers have never considered such possibilities.

Finally, we require new technologies for cleaning, remediation, of polluted waters. For inorganic, heavy metal, pollutants, mineral surface reactions can be of great significance. Thus, elements like lead and mercury can often be sequestered by adsorption on sulphide mineral surfaces. Uranium and many metals can be adsorbed by appropriate microorganisms. Many techniques are being developed for simple applications of solar energy distillation for purification of polluted and saline waters. Where pollution involves toxic organic compounds, again processing via appropriate microorganisms is gaining increasing attention. And the possibility of using subsurface, thermophylic organisms, is of great interest. And in hot regions where evaporation is intense, large area reservoirs should be avoided. We need to explore better strategies for underground storage or even inert cover technology. New observational technologies like Radar satellite technology which can monitor soil moisture, may cal) on more intelligent planning of the agricultural industries with reduced need for irrigation.

5. Air

Across the world there is growing concern with air quality and public health. For example, it is estimated that in England (Hamer, 1996) that "sickness, deaths, lost working days caused by particulate pollution cost the country £17 billion a year." In England the major recognized problems come from the transport technologies. But a recent paper by Nriagu (1996) shows the incredible scale of metal emissions to the atmosphere. For example, he shows that four million metric tons of lead are emitted annually to the atmosphere today. As mining of metals has increased, so have the atmospheric emissions.

In many urban areas (see world Resource institute, 1996) where particulates are rising, the sources and nature of them is rarely well characterized. There is an urgent need to characterize all particulate and gas emissions to develop technologies for their control. The situation in general is similar to that for fossil fuel use. We know that there are possible technologies.

6. Soil

At this time, at least one billion humans do not have an adequate supply of food of well balanced nutritional values (Sadik, 1989). Across the world, wood is becoming an expensive and declining commodity. Despite the electronic revolution, the use of paper products is increasing (per capita, 3x in the last 40 years). In addition, the world's marine resources are declining at an alarming rate. Again, the rich-poor gap is dramatically increasing the nutritional difference in the world's population.

Sustainable food-fiber production depends on climate, climate fluctuations, soil quality and water resources, and knowledge from the geosciences is involved in all these parameters. Given that we are not adequately providing nutrition for the present human population, what are the prospects for the next 5 billion?

All organisms require a large array and balance of the chemical elements (about 50) for efficient production of the organics needed for life (Mertz, 1981). The geochemistry and the mineralogy of soils are critical in estimating the capacity of a soil for sustainable organic productivity. According to the Worldwatch Institute, topsoil loss globally is approaching 1% per year, while natural remediation can take hundreds of years. The technologies exist now for erosion and salinization control, but such technologies are not adequately used, and there is great need for new soil maps which clearly show good soils, soils for forests only, and ones we should leave alone! (Fyfe, 1989)

Given the chemical and physical properties of a soil, additives may greatly enhance bio-productivity. Often, such additives require the addition of simple mineral materials containing species like K, Mg, Ca, P...., and appropriate trace metals like Co, Mo, etc., which may be critical in biofunctions like nitrogen fixation. The types of additives may be closely linked to soil type and climate. For many situations as with the laterite soils of the humid tropics, slow release, mineral fertilizers (K in feldspars, rock phosphates....) may be more effective and less wasteful than soluble chemical fertilizers (see Konhauser et al., 1995).

Soil contains a complex array of ultra-fine inorganic and bio-mineral materials, with vast surface areas which control key soil-bio functions. Today, with the modern techniques of surface chemistry (Auger, ESCR....), and the power of modern high resolution transmission electron microscopy (Tazaki et al., 1987; Tazaki and Fyfe, 1986), we can precisely examine the inorganic-bio-gas-liquid interactions, which was not possible a decade ago. In soils, many of the mineralforming processes involve reactions with living cells. There is a new world in the science of biomineralization which, as H. Lowenstam showed decades ago, are of vast importance in all aquatic environments to at least 100°C (Lowenstam, 1981).

Today we can greatly reduce soil erosion of all types. Often the massive use of highly soluble chemical fertilizers is not necessary and often our waste products such as sewage, compost, rock dusts, coal ash, etc. can be useful soil remediation agents. But, in all such cases of use, there must be strict quality control on the total chemistry and microbiology. And there is increasing evidence that biodiversity does promote bioproductivity (see Tilman et al., 1996). Biodiversity can also reduce the impact of climatic fluctuations like drought.

Table 1. Nutrients in major rivers (from Berner and Berner, 1987. L. Lower).

Units are given in parts per million

River	Calcium Dissolved	Magnesium Dissolved	Potassium Dissolved	Total Dissolved Solids
Mississippi	39	10.7	2.8	265
L. Amazon	5.2	1.0	0.8	38
L. Negro	0.2	0.1	0.3	6
Ganges	24.5	5.0	3.1	167

How do we estimate the local and regional health of soil? I would like to suggest that there are simple ways to obtain a useful estimate of the health of soils on a local and regional basis. All organisms, from bacteria to trees, require a wide range of macronutrients and micronutrients. Table 1 shows the level of three key macronutrients in four great rivers of the world. Most of the water in these rivers passes through surface soil and rock. The levels of macronutrients and the total dissolved inorganic material (TDS) speak eloquently about the state of the soils which the rivers drain. The Mississippi and Ganges river systems pass through younger soils that are loaded with rock-forming minerals; the Amazon and Negro systems flow through old laterite terrains. The Amazon water indicates a low capacity to support intense bioproductivity, probably the reason this region has not been heavily populated by the human species, historically.

7. Materials - Mineral Resources

If we look around us, we notice that we are surrounded by modified materials, mostly derived from the top kilometer or so of the Earth's crust. We live with concrete, glass, bitumen, ceramics, steel, copper, aluminum, stone, zinc.... Our transport machines, our computers, contain a component from half the elements in the periodic table. Advanced societies use about 20 tones of rock-derived materials per person, per year. For a population of 10 billion living at an advanced quality of life, this means 2 X 10^{14} kg of rock per year, or almost $100km^3$ per year. This quantity exceeds the volume of all the volcanism on the planet, on land and submarine, by an order of magnitude. Human actions are now a major component of the processes that modify the planet's surface (Fyfe, 1995).

Can we supply the necessary materials for all humankind? If we have the energy to drive the machines and transport the materials, the answer is probably yes. But, it is also clear that, for the less common materials, copper, zinc..., with rigorous attention to recycling, the modifications of the environment can be reduced from the scale of today. The new trend to design a product for recycling must become the rule for the future. The savings in total use of materials, use of energy, production of wastes, makes recycling an economic necessity of the future.

A major component of the materials we use today is derived from wood. It is quite clear that the present styles of the use of wood in products for housing, paper, packaging, and the like cannot continue. The environmental impact of removal of forests is too serious to allow present and past careless harvesting to continue. Wood will not be a major material for the 10 billion humans of next century. It is not needed, given the potential of modem systems of building and communication.

Again, I must stress that in the future development of mineral resources quality control must be improved. Before any mine is opened, we must know the total mineralogy of all phases and the total chemistry and chemical siting of all elements. And given the new observations on the deep biosphere there are exciting new possibilities for in situ mining using microorganisms (see Fyfe, 1996a).

8. Holistic Mining Technologies

As mentioned above, to provide resources advanced societies use about 20 tons of rock per person per year. Vast mine openings operate over a large range of depths, surface to several kilometers. But only recently has any consideration been given to the end use of mining cavities.

First, if the minerals removed in mining are carefully separated and characterized, many may have important use. For example in terrains with laterite soils, common minerals may be useful as soil additives in the local region. And certain types of mines may be useful for waste disposal. Could some very deep mines be useful for the isolation of high and low level nuclear wastes? Could some open cast, near-surface mines be useful for urban waste disposal? And in some cases, given organic wastes, could they be engineered with appropriate clay sealing materials, for useful bio-gas production?

All such potential uses of exhausted mines require holistic planning, beginning to end. And often the key to success is with simple separation of the gangue materials, clays, silicate minerals, carbonates and the like. With care, the consideration of end use, could significantly improve the economics of mining.

9. Wastes

The wastes from the production of energy from fossil fuels are enormous. There is no need here to emphasize carbon dioxide, and the greenhouse, or acid rain from bad coal technology. We use terms like "clean" coal technology. But, unless the carbon dioxide is controlled, a not impossible consideration as many geochemists know, coal combustion is either very dirty, or dirty. The economic and social consequences of even a small climate change or rise in sea level are simply mind boggling. We need holistic economics.

However while gaseous emissions from fuel burning CO2, CO, SOx, NOz...) are known, another huge problem is ash disposal. We have been working in India, where high ash coal (10-50%) is used, leading to a vast problem with ash disposal. Coal is a material of highly variable chemistry, and can contain significant concentrations of elements like chromium, arsenic, lead, uranium.... But coal can contain useful elements like potassium and phosphorus. The ash being in a reactive, often glassy state, can be environmentally toxic. At present, .river dumping is often the disposal method, creating severe problems, such as flooding. Globally, ash disposal is an increasing problem, as at least 1 km^3 is produced annually. Large scale coal mining, often associated with oxidation of sulphides in coal and trace-metal leaching, can perturb surface and groundwater resources.

Decades ago, it appeared possible that nuclear energy could solve the world's energy problems. But today, we are worried. While possibilities exist (see Krauskopf, 1988) the nuclear waste disposal problem is still not clearly solved (Fyfe, 1996b). Hydropower potential still exists on a large scale in some continents, like Africa and South America. We tend to consider hydropower electricity generation as environmentally benign. But recent experience in, for example, the Amazon of Brazil show that this is not always so. River valleys are often great food-forest producers. Unless topography is steep, vast areas may be flooded, forest and farmlands drowned, and a paradise created for tropical waterborne disease. There is increasing interest in bio-fuels (methane, ethanol, methanol), and Brazil leads the world in this potentially renewable resource (sugar -> ethanol) derived from solar energy. But, again, caution, biofuels use soil. The world has a major problem of inadequate nutrition for all (Sadik, 1989). Unless there is precise control of soil nutrient balance, this technology may not be sustainable. If the most agriculturally, productive regions of the world were used for bio-fuels, who would have the food reserve for "the year without summer" (Grove, 1988)?

At a recent Dahlem conference (McLaren and Skinner, 1987), there was discussion on the impact of heavy metals and "xenobiotic" organics that flood modem soil-water-atmosphere systems on ever-increasing scales. At least 50,000 organics, which may have no natural analogues, and of little known environmental behavior, are used today. Increasingly, there are moves to eliminate dispersion, to containment and, for organics, destruction often by incineration. In the rich world, regulations and controls are much improved (e.g. the Rhine river system) but, in much of the developing world, there is still little control. The impacts of strange chemicals on ecology, local and global, are little understood, but recent data from Eastern Europe are alarming (see World Resources Institute, 1996). The global influence of a group of simple chemicals on ozone destruction nicely illustrates the impact of what were once thought to be harmless chemicals.

There is no need to emphasize the impact on soil, water, air, ecological balance, of overuse of chemical fertilizers, herbicides and pesticides, which is now increasingly recognized. On the other hand, the limits of "organic" farming are also recognized. It has been shown that, if organic farming alone were used, a much greater land area would be needed to feed the present world population. Urbanization has removed any hope for quiet dispersion. Cities of 20 million will be common next century. Where will the garbage go?

Slowly we are returning to old systems of recycling and reuse. All animal, vegetable waste, with care, makes good fertilizer, or in some systems can be used to generate methane and hydrogen (Baccini, 1989). The key to all the energy saving recycling technologies is front end quality control. If we characterize well all the materials at the input of industry, then it is more economic to effectively recycle the waste products. We probably know more about trace elements on the moon than in city garbage. Landfills should be the last resort - we cannot afford to waste land. And there is growing interest in urban agriculture. We can produce food and reduce wastes in cities (see Nelson, 1996).

CONCLUSION

World data are hard (see World Resources Institute, 1996). In nations with a high level of education, and freedom of information, birth rates are falling, people are accepting limits to growth. Some gaseous emissions are also being dramatically reduced (e.g. S in Germany, 3743 x 10^3 metric tons of SO2 equivalent in 1970, reduced to 939 x 10^3 tons, 1990) and, in many countries, it is being shown that recycling is economically positive.

It is also obvious that, for the needed new development, we require new systems to integrate the needed expertise (see King and Schneider, 1991). For example, most developing nations need more energy. Who must be involved in planning the new developments? What are the alternatives and the long range economics? For certain, biologists, ecologists, agri-scientists, engineers, hydrogeologists, earth system scientists in general, many from advanced physics, chemistry, materials science, all working with social planners and economists. And such people must be involved in planning from the start! Perhaps Sir Krispin Tickell (1993) summarized it all when he said, 1 was recently asked if 1 was an optimist or a pessimist. The best answer was given by someone else. He said that he had optimism of the intellect but pessimism of the will. In short we have most of the means for cooping with the problems we face, but are distinctly short on our readiness to use them. It is never easy to bring the long term into the short term. Our leaders, whether in politics of business, rarely have a time horizon of more than five years."

There is reason for optimism. In the 40's Aldous Huxley said that we have treated nature with greed, violence and incomprehension. But, today, the incomprehension is no longer excusable. There is need for a totally new approach to the mega-problems, and the key for success is the combination of science with sound economics. The surface of this planet and our hydrosphere, atmosphere, biosphere systems must be managed with great care, if all people are to enjoy their planetary experience (Fyfe, 1992b).

We have many modern studies to show that environmental protection is economically advantageous. ECO-logy and ECO-onomy (Greek, Oikos, my house) are not in conflict when the time scale is decadal. And at our universities, it is time to change many of our programs and recognize the needs for the world of 2050.

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