ENGINEERING AND THE ENVIRONMENT : AGRO-INDUSTRIAL PERSPECTIVE

by

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INTRODUCTION

The environmental concern has become a world-wide issue, as evidenced by the fact that even the World Bank is taking a serious look into the matter. In his speech at a conference in Tokyo (Conable, 1989) the World Bank President, Mr. Barber Conable emphasised that "the Bank and others in the development community have learned that protection of the environment warrants specific and discrete emphasis". He adds further that "conservation, energy efficiency, natural resource management, population and family planning, resource transfers, justice in the international marketplace, research and development ..... all these and more are part of the environmental challenge".

John Naisbitt and Patricia Aburdene (1990) in their lattest bestseller entitled "Magatrends 2000" identified that one of the forces in the decade of the 1990's is "our new attentiveness to the environment". This is a critical force which should move us towards a consensus that we all must work on the environment together.

Peter Drucker (1989) in his book, "The New Realities", describes the environmental concern as "the transnational ecology". He considers this as a new reality in the world economy. He argues that "concern for the ecology, the endangered habitat of the human race, will increasingly have to be build into economic policy". He further emphasised that "the destruction of the ecology on which humankind's survival depends is thus a common task. To tackle it as a national task is futile-though obviously a good deal of national, and indeed of local, implementation will be needed".

It would thus be beneficial for us, the engineering community in the country, to look into the problem together, and see what we can do to contribute with respect to the environmental issues. This paper will look into the issues from the agricultural and agro-based industrial point of view. Both macro and micro views will be discussed, and possible contributions of the engineering community will be indicated.

AGRICULTURE AND THE ENVIRONMENT

Advances in science and technology have created unprecedented growth in the world's population. This phenomena has been described as the population bomb (figure 1) which is fused by the revolutions in industrial production, transportation, medicine, agriculture and technology (Taiganides, 1981). This has caused tremendous pressure on the agricultural sector to produce more food for the ever growing population.

With the pressure faced by agriculture, it is not unrealistic to expect that it will transfer some of the pressure elsewhere, primarily on the environment. Thus, agriculture (which for our purpose includes the agro-based industries) can be considered as an activity which contributes to the degradation of the environment. At the same time, it can also function as an activity which can help to preserve the environment. Which way it goes actually depends greatly upon how it is being carried out, which is where engineering inputs can be used effectively. We will look into both facets of agriculture and discuss the possible engineering inputs.

Irrigation

Irrigation has been considered as a major factor in increasing the world food supply. One-third of the global harvest comes from the 17 percent of the world's cropland that is irrigated. In the first half of this century, irrigated areas in the world nearly doubled, with the estimated gross irrigated area in 1986 as given in table 1. Irrigated land peaked in 1978 at 0.48 hectare a person worldwide, but has since fallen about 6 percent (Postel, 1989). One reason given for this is that the demand for water is fast approaching the limits of resources. Many areas of the world could enter a period of chronic shortages during the 1990s. When there is scarcities, cities and farms begin to compete for available water, and farmers will typically lose out.

Suggestions for solution to the problem are increased efficiency of irrigation systems, greater emphasis on soil conservation, reforestation and stepped-up research into creating strains of crops that are more self-tolerant and drought resistant. As can be seen, the solutions suggested are related to the environmental problem which could have a dual effect of increasing the areas irrigated as well as preserving the environment.

The engineering community could contribute positively by devising systems which could increase the efficiency of irrigation operations. Soil conservation efforts should be emphasised when opening up areas, both for agriculture and other purposes. The importance of reforestation should be given high priority in increasing the catchment area for our water resources, both for agriculture and other uses. All these are directly related to engineering, which should be taken as challenges by us in convincing the decision makers.

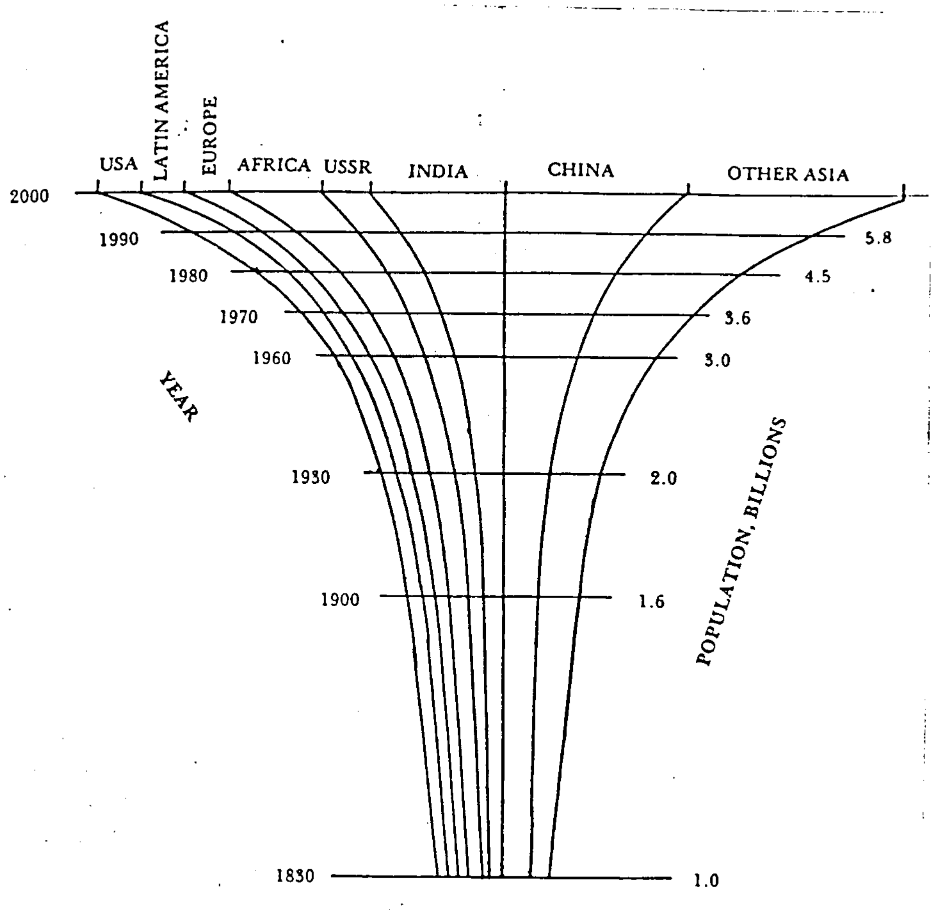


Figure 1 : The population bomb (Taiganides, 1981)

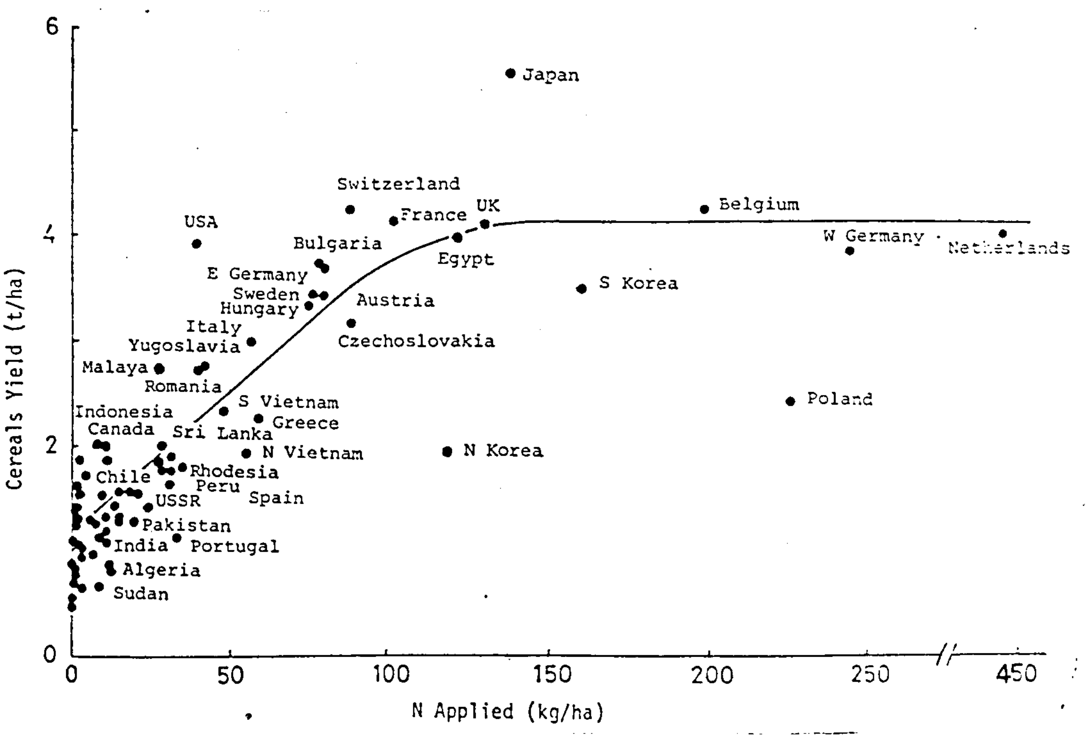


Figure 2 : Relationship between the amount of nitrogen applied per hectare and total cereals yield (Murata, 1977)

Table 1 : World Gross Irrigated Area (1986)

Country	Gross Irrigated Area (thousand hectares)	Share of Cropland That is Irrigated (Percent)
India	55,000	33
China	46,600	48
Soviet Union	21,000	9
United States	19,000	10
Pakistan	16,000	77
Indonesia	7,300	34
Iran	5,800	39
Mexico	5,300	21
Spain	3,300	16
Turkey	3,300	12
Egypt	3,200	100
Thailand	3,200	16
Italy	3,000	25
Japan	3,000	63
Romania	3,000	28
Others	52,200	9
World	250,200	17

Source : Postel (1989).

Another facet to irrigation is the fact that some of the water used in irrigation is obtained by pumping well water. In certain areas, the amount being pumped out is more than the replenished rate. The recharging of the underground aquifers occurs through the natural seepage of rain. Some of the pumping amounts to the mining of fossil aquifers, which accumulated water over the ages and will require similar time to recharge.

Overpumping of underground water is responsible for a wide range of environmental damage, including depletion of streams, lakes and aquifers. It also leaves deposits of salts and toxic chemicals on the land. Such damages, was estimated to have affected 7 percent to 72 percent of the irrigated land in the top 11 irrigated states, in the United States (Postel, 1989).

Some of the most dramatic damage due to irrigation, has been inflicted on the world's rivers and lakes, including the Aral Sea in the central Asian republics of the Soviet Union. Diversion of water from rivers that feed the Aral Sea, once the world's fourth largest freshwater lake, has reduced the streams to trickles. It has shrunk the Aral Sea's surface by 40 percent, reduced its volume by two-thirds, tripled its salinity and killed all native fish species, wiping out a once-flourishing fishing industry.

A comprehensive study of the effect of irrigation on the environment for our country has not be carried out. The author feels it should be looked into before its too late. However, as the engineering community in the country, it is possible for us to ensure that such degradation does not take place by ensuring proper design of irrigation systems which takes into consideration the recharge rate as well as the soil conservation measures.

Chemical Fertilizers

As a result of the earth's fast-growing population, the demand for food has rapidly increased. In the past, we have been able to meet the growing demand for food mainly by increasing the area of arable land. However, after the world population surpassed the 3,000 million mark, expansion of arable land has become more and more difficult, inevitably forcing us to meet the situation by increasing the per hectare crop yield. To attain this, efforts have been made not only on breeding new crop varieties but also on developing new cultural techniques. Heavy fertilization is one of the most effective means. Figure 2 shows the relationship between the amount of nitrogen applied per hectare arable land and total cereal's yield per hectare. The figure indicates that the more nitrogen applied per hectare in a country, the higher the per hectare yield of cereals. Heavy fertilization has been identified as one of the cause of eutrophication of rivers and lakes due to runoff of fertilizer elements. Accelerated eutrophication results in the production and accumulation of organic matter through the excessive growth of the algae and other plants.

When the accumulation of vegetation decomposes, a condition occurs which fouls the air and results in the consumption of the dissolved oxygen so vital to fish and other animal life. Ultimately, eutrophication may result in the filling up and disappearance of lakes and estuaries.

Eutrophication can have a significant effect on domestic, industrial, and recreational uses of water. Excessive growth of algae results in higher water-treatment costs to make the water potable. Even with proper treatment, certain residual tastes and odors are imparted to the water by algae. Color, also can result from large growths of algae.

What we can do to reduce the effect of eutrophication is to study the phenomena quantitatively. Modeling and simulation provide tools with which entrophication can be studied quantitatively. Although many factors and interrelationships are still obscure, sufficient information is known to construct a model for an aquatic ecosystem, the simulation of which will provide an insight into the factors influencing eutrophication (Rich, 1973).

Controlling of runoff from agricultural production areas will of course help in reducing the problem of eutrophication. Proper soil conservation measures, such as mulching, will be able to reduce runoff and nutrient losses (Mokhtaruddin and Maene, 1981).

Agricultural Pesticides

Pesticides embrace a wide variety of chemical compounds used in the control of undesirable forms of life. These compounds are used as insecticides, fungicides, and herbicides. Pesticides can be classified as nonpersistent, moderately persistent, persistent, and permanent, based on how long they last in the environment. Nonpersistent pesticides last from several days to about 12 weeks. Atrazine and 2,4-D are moderately persistent with lifetimes of 1 to 18 months. Most of the chlorinated hydrocarbons, such as DDT, aldrin, dieldrin, endrin, heptaclor, and toxaphene, are classified as persistent. DDT may persist in nature as long as 20 years. Pesticides containing mercury, lead, and arsenic are permanent.

Pesticides move through an ecosystem in many ways. Permanent pesticides are ingested by organisms and concentrated through the natural action of food chains as the organisms are consumed by others. Minute aquatic organisms and scavengers that live in water and bottom muds having pesticide concentrations of a few parts per billion can accumulate levels measured in a few parts per million - a thousandfold increase in concentration. Fish feeding on lower organisms can build up concentrations of pesticides in their visceral fat which may reach several thousand parts per million and levels in their edible flesh of hundreds of parts per million.

Pesticides enter water through spraying, runoff, and waste discharges. Percolation through soil to groundwater and accidental dumping are minor sources. Some pesticides are adsorbed tightly to soil particles ; therefore, pesticide pollution may result from silt and soil washed off agricultural lands into surface waters. Although a portion of the adsorbed pesticides is released to the water in solution and in suspended form, the remainder is incorporated in sediments. The sediments then continually release pesticides to the overlying water.

In Malaysia, it is estimated that the value of pesticides used for 1987 amounted to M$315 million, out of which 75% is accountable by the agricultural sector, as indicated in table 2 (Chen, 1989). With the large volume of pesticides use, there is a need to monitor and control their effects on the environment. Effort should also be made to reduce their use by employing alternative methods of pest controls.

Table 2 : Estimated Pesticides Used in Malaysia - 1987

Pesticide	M$ (Million)	Percent Share
Agriculture:		
Herbicides	174	55
Insecticides	38	12
Rodenticides	8	3
Fungicides	15	5
Household Pesticides	80	25
Total	315	100

Source: Chen, Y.S.(1989).

Effort is currently being directed towards developing techniques such as biological control of pests by predators, sterile male release and the use of pathogens for pest control (Jones and Solomon, 1972 ; Hussein and Ibrahim, 1986). While some progress has been made and these methods may hold hope for the future, there is little prospect that they will generally replace chemical control.

In many cases, persistent chemicals have already been replaced by less persistent ones. When no practical alternative to a persistent chemical for the control of a pest exists, the best approach to avoiding pollution is to improve the efficiency of its use, so that less is applied. Placing the chemical in the critical region of the soil rather than broadcasting it uniformly is a well established method of reducing rates of soil-applied pesticides. Method of application can also influence persistence. Granular formulations of insecticides usually persist longer than emulsions, and losses are fastest from dusts and wettable powders. With granules different rates of release can be obtained by varying the composition of the carrier and additives, and in theory matching the shape of the dose/time pulse released by the granule to the behavior and susceptibility of the pest should lead to more efficient use of the pesticide; but difficulties arise in practice because of variations in weather.

Application to the foliage is probably at least as inefficient as application to the soil. A large proportion of the chemical is rapidly lost from the targest site, particularly under our tropical conditions. For adequate pest control, it is therefore necessary to apply large amounts which compensate for these losses. Much of the resulting contamination of soil and the general environment could be avoided if persistence on the target area could be controlled and less used. The possibilities of using microencapsulation formulations for this purpose are being considered.

Thus, the challenge to our engineering community in this matter, is to develop more efficient methods of pesticide application. The development work should be carried out in collaboration with the biologists; with the engineers developing the appropriate techniques and devices which are needed.

Energy and Agriculture

Agriculture is a consumer of energy, since the production process requires energy inputs. In Malaysia, there has not been any comprehensive study on the energy inputs in agriculture. A look at the situation in the United States indicates that agriculture does consume a significant amount of energy. For the year 1974, about 22% of the total energy used was related to the production, processing, marketing and consumption of food, natural fibers, and forest products (Miller, 1978). Of this amount, 16.5% was used for food, from production through consumption. The remaining 5.5% was used for all aspects of natural fiber and forestry production and use.

At present, there have not been any comprehensive study done to assess the energy consumption for agriculture in Malaysia. However, to give an indication of the situation, a study on the energy inputs in the production of paddy was carried out (Zohadie and Ishak, 1981). This study was aimed at getting a clearer view on the intensity of energy use at the various stages of the production process.

The results of the study indicate that at the stages where mechanization is present, namely the land preparation and harvesting stages, energy input in the form of fuel tends to be the dominant figure. Thus, with the trend towards more mechanization due to the labor shortage, the input of fuel energy in agriculture will continue to increase. This will definitely contributes to the environmental pollution due to the burning of fuel, since currently practically all the fuel energy used in agriculture come solely from petroleum.

Agriculture also plays a dual role as a possible source of energy (Zohadie, 1981a). In the process of photosynthesis, solar energy absorbed by green plant tissue provides energy to reduce carbon dioxide and form cabohydrates, which are then utilized as energy sources and raw materials for all other synthetic reactions in the plant. Thus, solar energy is captured and stored in the form of chemical energy. Cellulosic plant material presents a vast, uptapped supply of energy. It is renewable, has a low content of sulphur and other pollutants, and storage of energy from the season in which it is produced until it is needed is simple and inexpensive.

The energy content of several different plant materials is shown in table 3. On a dry-weight basic these materials have an average energy content of 4,800 kcal/kg (for comparison, the heat content of gasoline is 10,500 kcal/kg). However, if combustible material is required for the energy-recovery process, the amount of water in the plant material will affect the recoverable energy. Thus, correction for water content must be made and the energy cost of drying must be considered when plant materials are evaluated as energy sources for combustion.

Table 3 : Energy Content of Plant Biomass

	Plant Part	Percent Water	kcal/kg
Sugarcame (Saccharum officinarum)	Bagasse	12	3,860
Sugarcane (Saccharum officinarum)	Bagasse	52	2,220
Bamboo (Phyllostachys spp.)	Cane	10.5	3,925
Buckwheat (Fagopyrum esculentum)	Hulls	10	4,030
Chamise (Adenostoma fasiculatum)	Leaves	0	5,160
Chemise (Adenostoma fasiculatum)	Steams	0	5,015
Coconut (Cocos nucifera)	Shells	13	4,010
Beech (Fagus sp.)	Wood	13	3,990
Birch (Betula sp.)	Wood	12	4,015
Oak (Quercus sp.)	Bark	13	3,810
Oak (Quercus sp.)	Wood	7	4,310
Oak (Quercus sp.)	Bark	0	4,450
Pine (Pinus sp.)	Wood	12	4,230
Pine (Pinus sp.)	Bark	0	4,790
Fir (Abies sp.)	Bark	0	4,675
Spruce (Picea sp.)	Bark	0	4,640
Redwood (Swqquoia sempervirents)	Bark	0	4,425
Oilseed crop	Seed	-	4,775

Source : Alich and Hinman (1974).

Stored plant energy may be released by drying the material and burning it directly, or various processes may be utilized to obtain potential fuels such as ethanol, methane, or other gaseous or liquid fuels.

Alcohol fuels have been considered as the most competitive alternative to oil as liquid energy (Zohadie, 1981a). In comparison with other types of fuels, major advantages of alcohol fuels are, namely ; being liquid ; clean in respect to environmental pollution ; and can also be used as motor fuels (Zohadie and Janius, 1984). Alcohol fuels consist of two types, namely, ethanol produced from agricultural products, and methanol from natural gas, coal and wood. Ethanol is the more favorable since it can be produced from agricultural products, thus it is renewable, and it is easy to blend with gasoline.

Brazil is one of the country in the world, which has been using alcohol as fuel. It has been reported that, Brazil has been able to save a billion US dollars a year on its import bills, due to the use of alcohol (Rai, 1986). Over a billion litres of the fuel are exported annually to Israel and the United States. Even aeroplanes in Brazil have begun using alcohol fuel.

The technology for ethanol production through fermentation has been established. However new innovations need to be incorporated to improve the process of fuel production. Developing these new innovations are the challenge which should be taken up by the engineering community.

Currently, most of the ethanol production through fermentation has been carried out to produce alcohol for human consumptions. The conventional techniques need to be modified to suit the conditions of fuel production. The areas which could be given attention include the development of heat-resistant alcohol yeast, high-temperature ethanol fermentation, continuous fermentation process, and establishment of techniques to feed raw materials featuring high concentration.

Innovations on distillation techniques are also required. The azeotropic point of water and ethanol exists at 98% which thus requires considerable consumption of energy in making ethanol completely free from water. Research and development to lower the azeotropic point by raising the alcohol concentration and by adding distillation additives are underway and should be continued. Improvements on this aspect can be expected to reduce the cost of ethanol fermentation considerably. Other methods of reducing the external energy input in the distillation process, such as using solar energy, can also reduce the cost of production.

Agro-Industrial Byproducts

A great amount of byproducts are produced annually from our agriculture and agro-based industries. Table 4 gives the estimated annual yield per hectare of plant and animal wastes for the major agricultural activities in the country. The estimated total annual production of plant and animal waste in Peninsular Malaysia (1976) is given in table 5 (Tengku Ahmad, et.al.,1980). The total estimated annual production for 1976 is about 6.5 millions tonnes. The current value must have increased, considering the increased in hectarage of most of the agricultural activities listed in the table.

Table 4 : Estimated Annual Yield of Plant and Animal Wastes

Plant/Animal	By Products	Yield (tonne/ha)
1. Oil Palm	Press fibre Oil Palm sludge	1.0 0.05
2. Rubber	Rubber wood	9,000 cu ft/ha*
3. Coconut	Coconut husk Coconut shell	3.0 1.7
4. Padi	Rice straw Rice husk Rice bran	2.5 0.5 0.3
5. Cocoa	Cocoa Ponds	2.5
6. Tapioca	Tapioca refuse	9.9
7. Sugar cane	Sugar cane tops Bangasse	30.1 6.1
8. Pineapple	Pineapple bran	2.5
9. Sago	Sago refuse	11.5
10. Maize	Maize stalk Maize cob	5.0 0.6
11. Groundnut	Groundnut shell	0.6
12. Forest	logging wastes (wood residue)	20% of log intake capacity
13. Buffalo/Oxen	animal dung	3.7 tonne/ animal

* not an annual figure.

Table 5 : Estimated Annual Production of Plant and Animal Waste in Peninsular Malaysia for 1976

Materials	Total Production (tonnes)
1. Oil palm fibre	637,617
Oil palm sludge	51,426
2. Coconut hust	705,639
Coconut shell	399,862
3. Rice straw	894,725
Rice husk	178,945
Rice bran	107,367
4. Cocoa pods	51,987
5. Tapioca refuse	206,989
6. Sugar cane tops	737,372
Bagasse	149,438
7. Pineapple bran	50,927
8. Sago refuse	32,740
9. Maize stalk	12,799
Maize cob	2,130
10. Groundnut shell	3,476
11. Wood residue (logging waste)	67,876
12. Animal dung	2,301,507
TOTAL	6,592,823

Source : Tengku Ahmad et.al., (1980)

Looking into details for just one industry, namely the palm oil industry; a typical palm oil mill processes between 40 to 60 tonnes of fresh fruit bunches (ffb) per hour. Each tonne of ffb yields approximately 0.1 tonne dry pericarp fiber, 0.16 tonne shell, 0.08 tonne dry bunch, 0.2 tonne oil, 0.42 tonne water, 0.02 tonne kernel cake. In addition to this about 0.68 tonne of effluent is discharged per tonne of ffb processed in the palm oil mill.

In the palm oil industry, effort has been made to utilize the wastes in various ways. Palm oil mill effluent (POME) has been use in land application for the plantation, as fertilizer. Empty fruit bunches (EFB), which were formerly burnt in incinerators to produce bunch ash, are now used as mulch. Leftover shell and fiber of fruitlets are used to feed the boiler.

The raw mill effluent is put into an anaerobic digester for between 9 to 13 days. A by-product, biogas is tapped, collected in tanks and stored under pressure. It is then used to generate power for the mills, via a gas generating set. The liquid residue is pumped into an anaerobic pond, then to a holding pond before being diverted to the fields for land application. The solid fraction is pumped into the land, where it is dried and dug up and sold as garden fertilizer.

The above mentioned system is an effective way of controlling pollution, while at the same time gaining benefits from the wastes. However, this system is not practiced in all the palm oil mills, where there are more than 200 operating in the country (Business Times, 1989). Thus, it is our duty, as engineering community in the country to convince those concerned that it pays to control pollution by utilizing these wastes.

With regards to the other crops residue, most of them are managed by open burning, incorporating into the soil, or just dumped somewhere to be decomposed naturally. Some residue are used as growing media for mushroom culture, composts, and animal feed.

It is thus a challenge to the engineering community in the country to devise systems and/or methods in utilizing these byproducts. They could be utilized as energy sources (Larkin and Radley, 1982), as components for engineering materials (Salam, 1982 ; Asia Technology, 1990a), the production of feed for animal and/or human (Asia Technology, 1990b), and other innovative usage.

Soil-Vegatation Biosystem for Pollution Control

Disposal of waste effluents on the land is an alternative pollution control method whereby the entire biosystem, soil and vegetation, is utilized as a "living filter" to renovate these effluents for groundwater recharge. Under controlled application rates to maintain aerobic conditions within the soil, the mineral nutrients and detergent residual might be removed and degraded by various processes, namely a) microorganisms in the surface soil horizons, b) chemical precipitation, c) ion exchange, d) biological transformation, and e) biological absorption through the root systems of the vegetative cover. The utilization of the higher plants as an integral part of the system to complement the microbiological and physiochemical systems in the soil is an essential component of the living filter concept and provides maximum renovation capacity and durability to the system.

Research and development work on this subject has been started since 1930 (EPA, 1974). Active developments have been taking place during the 60s and 70s (Sand and Asano, 1976 ; EPA, 1975a, 1975b). Active R&D works have been going on at Cornell University, where a system has been developed for treating sewage that can produce reservoir-quality water (Brody, 1987). By using a bacterial technique to filter out heavy pollutants and then growing plants on the partially cleansed waste water, the Cornell system produces such commercial products as natural gas and nursery plants and trees while it cleans the water. According to the head researcher, Dr. William Jewell, the Cornell system produces no sludge or other waste matter.

These studies have indicated that the living filter system for renovation and conservation of wastewater is feasible and that the combinations of agronomic and forested areas provide the greater flexibility in operation. Such a system is more adaptable to small cities and suburbs than to large metropolitan areas because of the availability of open land. Thus, it is up to us to use the available technology for the benefit of the communities in our country.

Soil Erosion Control

The main activities that contribute to soil erosion are housing, road and highway construction, mining, and logging. In order to control soil erosion caused by rain, various techniques are available. These include mulching, contour cultivation, and terracing. The construction of silt pits has also been found to be effective. Ponds, when constructed at strategic locations, can also help to regulate the runoff water, thus reducing erosion.

In development activities where slopes are created, a method of controlling soil erosion is the use of wire mesh protection, which is netted over the slope surface. The construction of concrete structures or concrete walls is another method to control erosion. However, these methods can be quite expensive.

The use of natural rubber latex emulsion has also been applied for erosion control (Soong, 1979). The spraying of bituminous products or latex on the soil surface provide some measure on erosion control. These products form a protective film on the soil surface. However, with the heavy tropical rainfalls and the high temperatures, the protective cover will deteriorate in time and a new layer will have to be sprayed on the soil surface again.

Vegetation can be used as an effective long term erosion control device. One of the problem is in the initial establishment of the vegetation, especially where the slope is quite steep. A method of combining the latex emulsion and the more permanent vegetation has been suggested by the Rubber Research Institute of Malaysia (Yew and Pushparajah, 1983). The later emulsion will provide the initial control of soil erosion, and a more permanent protection is obtained with vegetation. The method calls for establishing seeds in the soil prior to the spraying of the latex emulsion. This method has been found to be effective, easy to use and competetively priced.

Agriculture,can thus be used as an effective erosion control device. Innovative approaches, such as the one mentioned above, are required to effectively use agriculture for prevention of environmental degradation.

FUTURE TRENDS

This section of the paper will discuss the future trends on the relations between agriculture and the environment. The emphasis is on how we can effectively integrate agriculture with the environment, while maintaining the objective of increasing food production, and at the same time improving the environment. We would like to create a synegic situation, whereby both will benefit from the co-existance.

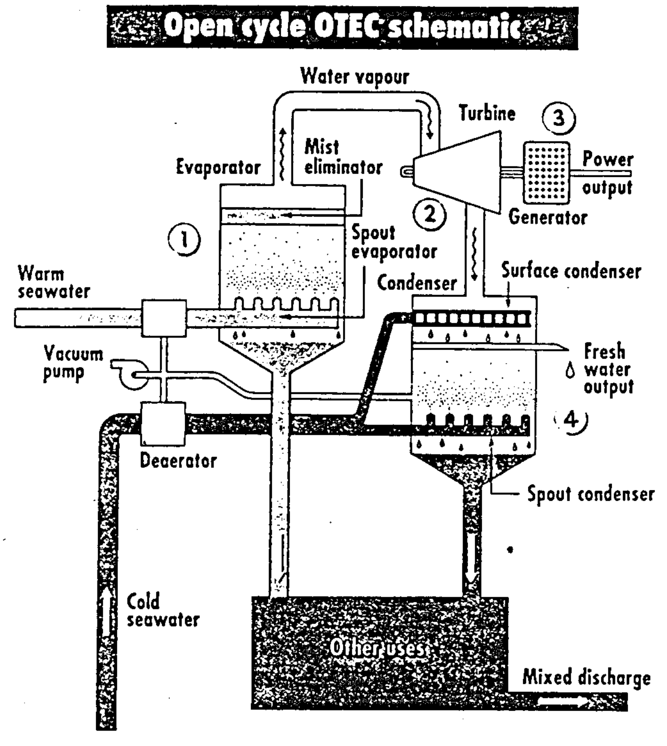
Ocean Thermal Energy Conversion (OTEC)

OTEC is an alternative method of producing power without pollution. The method hold the greatest promise of all alternate forms of power generation for tropical coastal regions, the areas in which a large percentage of the world's population lives.

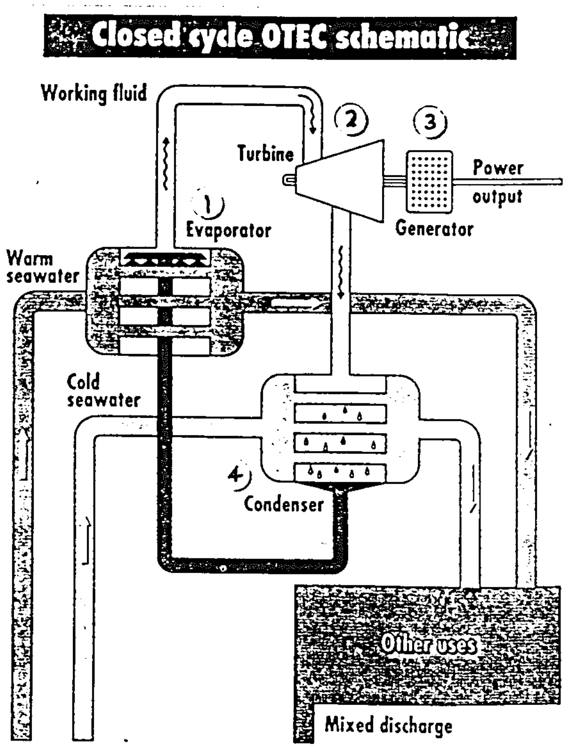
The principle by which OTEC operates is that the difference in temperature between warm surface water and cold deeper water can be harnessed to turn a turbine that drives an electrical generator. OTEC comes in two varieties, namely the closed and open-cycle, as shown in figure 3.

The closed-cycle form involves recycling a fluid that boils at low tempeature, such as ammonia, between two separate radiator-like heat exchangers. Warm surface seawater heats liquid ammonia circulating inside the first exchanger. As the ammonia boils, its expanding vapour sets in motion a turbine that drives an electrical generator. The ammonia vapour then passes through a second heat exchanger, in which cold seawater causes it to recondense to a liquid.

Open-cycle OTEC uses only seawater as the working fluid. Warm sea water is sprayed into a vacuum chamber, where a small fraction boils. The water vapour produced by the boiling is drawn towards a low pressure region created downstream ; on the way, it drives a large diameter turbine. The low pressure region is created by condensing the water vapour on the surface of aluminium plates, chilled by cold seawater pumped up from the deep.



Open cycle systems use the warm seawater itself as the working fluid. Warm surface seawater is evaporated under a partial vacuum (1). The low-pressure steam produced turns a turbine (2), driving an electrical generator (3). The steam is condensed either by direct contact and mixing with the cold seawater (4) or by chilling in a heat exchanger through which the cold seawater is pumped. In this second case, the condensate is fresh water.



Warm surface seawater is pumped through a heat exchanger (1) where a low-boiling point "working" fluid such as ammonia is vapourised. The expanding vapour turns a turbine (2) driving an electrical generator (3). Cold deep seawater pumped through a second heat exchanger (4) condenses the vapour back to a fluid which is then returned to the first heat exchanger (1), recycling the fluid.

Figure 3 : OTEC cycles schematic
(Asia Technology, 1989a)

Besides for generating power in OTEC, the excess cold seawater is excellent for aquaculture because it has a high nutrient content and lacks bacteria and other disease-causing micro-organisms. It has been shown that lobster grow faster in a mixture of cold OTEC and warm surface water than they do in nature (Asia Technology, 1989b).

Food Irradiation

Irradiation is an emerging method for food preservation. Food irradiation has been proven to be able to kill most of the bacteria that occur naturally in food. The process also slows down the development of plants by affecting the way in which their cells divide or by inhibiting growth hormones. It has been promoted as an alternative to chemical treatment for such tasks as preventing potatoes and onions from sprouting while in store and for controlling insect infestation in harvested crops (Ghosh, 1990).

It has also been said that irradiation can replace, or drastically reduce, the use of food additives and fumigants which pose hazards for the consumer as well as workers in food processing factories. Developing countries, in particular, could reduce their losses of harvested crops.

On the other hand, it has been argued that irradiation can reduce the nutritional value of food or even make it dangerously radioactive. Thus, it is the duty of the engineering community to develop methods whereby it can be effectively used without the negative effects.

Biotechnology

Biotechnology applies scientific and engineering principles to enable materials to be processed by biological agents, resulting in faster and more accurate breeding programs for animals, plants and micro-organisms. Naisbitt and Aburdene (1990) asserted that "biotechnology can end hunger through a new green revolution". Advances are being made in genetic techniques to grow fish and beef faster and put more protein in potatoes and rice. Endangered species can be kept from extinction through the transplanting of embryos into surrogate mothers.

The development and commercializaation of biotechnology have been compared with the unfolding history of the computer. Investors have poured more than US$3 billion into biotechnology. More than 600 biotechnology companies have been founded. However, biotechnology is still largely a matter for developed countries. Many techniques relevant to less developed countries are at an early stage of development, and the application of those currently available is constrained by limited local research facilities, a dependence on public funds, and patent difficulties.

A number of 'engineered' seeds are likely to be available commercially by 1992 in industrialised countries, including herbicide-resistant tobacco, and pest-resistant tobacco, potato and tomato (Anon, 1990). These developments will entail reduction in use of pesticides, which will of course be beneficial to the environment.

By using biotechnology, a commercial company believes that it has developed the ideal way to clean up some of the world's most polluted industrial wastelands. Scientists at the company have developed strains of bacteria that feast on various pollutants (Asia Technology, 1990c). The techniques was first used with great success on a 10 hectare site in Blackburn, Northern England, heavily contaminated with tars, phenols, cyanides, spent oxides and other toxins.

Other developments in biotechnology which will be beneficial for the environment should be forthcoming in the future. There are environmentalists who fear that biotechnology could transform nature itself-according to a blueprint designed by humans instead of nature. However, the author concurs with Naisbitt and Aburdene (1990) is saying that "technology is not inherently evil. It is neutral. How we use it is the key. There is a lot more positive than negative that will be coming out of biotechnology, but we need to know what we are getting into".

Other Developments

Other developments currently being investigated which could have an effect on agriculture and the environment include such investigations as conservation tillage, solar irrigation system and artificial biosphere.

In conservation tillage, the system tend to leave at least 30 percent of the old crop residue on the soil surface at planting. This system will enable the control of soil erosion and encourages moderate use of chemicals (Johnson, 1988).

Solar irrigation system is a development whereby it can cuts water consumption by 60% and works on extremely low levels of light (Asia Technology, 1990d). Unlike other similar systems, it need no storage batteries, mains power source or solar panels. A small lens collects surrounding light and focuses it on a high-efficiency photovoltaic module for conversion into electricity. The microelectronic system stores the energy directly within its circuitry. The system utilizes controllers which did not need any outside power source, and water valves which use minimal power to operate with the controller. Another feature is an advanced moisture sensor unit. This is a small solid-state device buried in the watering zone. It constantly monitors moisture levels and sends the data by wire to the computer.

An experimental biosphere has been developed in the Southern Arizona desert, where eight men and women will enter a sealed glass and stainless-steel habitat, within which five distinct ecosystems found on Earth have been recreated in miniature (Asia Technology, 1990e). Once inside this biosphere, they plan to remain there for two years, cut off from direct contact with the world and relying on its interacting systems to keep them alive. The group behind the experiment hopes that it will help future generations to create self-sustaining colonies in space.

CONCLUSION

The paper has highlighted some of the issues relating agriculture (including agro-based industries) to the environment, and indicated the engineering implications within the relations. The issues highlighted are by no-means comprehensive. There are others which may have been overlooked. However, it is hope that the discussions in the paper will provoke our thoughts in addressing the problems and prospects.

It is the hope of the author that the engineering community in the country will take these issues as challanges. Thus, it is imperative that we face these challenges with determination and discipline for the benefit of us all.

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