APPROACH TO GLOBAL ENVIRONMENTAL ISSUES MAINLY BY BIOLOGICAL APPLICATIONS

Dr. Jiro Kondo
President, The Science Council of Japan
Director General,
Research Institute of Innovative Technology for the Earth (RITE)
Japan

I. Progress of biology in recent times

Quantum mechanics and the theory of relativity were born in the 20th century, and great progress was made in physics in areas such as elementary particles and properties of matter. In chemistry, the progress introduced synthetic fibers and agriculture chemicals such as fertilizers and insecticides, and our living in food, clothing and shelter was greatly improved by successive synthesis of new materials. On the other hand, the atomic bomb, DDT and PCBs, organs of mass-obliteration, causes of cancer, and CFCs-which destroy the ozone layer-were also produced. In the area of biology, innovative theory comparable to the theory of evolution of C. Darwin (1809-1882) did not emerge, but L. von Bertalanffy (1901-1972) introduced the concept of ecosystem in ecology. This later had a large influence on environmental science.

With the progress of technology and chemical analysis, the chemical structure of ecological substances were gradually determined, and useful substances from microorganismsösuch as penicillin in 1929öwere isolated. But it was the discovery of the double helix structure of the gene by J.B. Watson (1928-) and F.H.C. Crick (1916-) in 1953 that had a great impact on biology. Later, in 1973, S. Cohen (1922-) and H.W. Boyer (1936-) invented DNA rearrangement technology. This opened the new era of biotechnology, and made it possible to introduce a part of the gene of an organism which has a certain property into the gene of another organism to produce a new organism. This technology holds great expectations in future use for environmental protection.

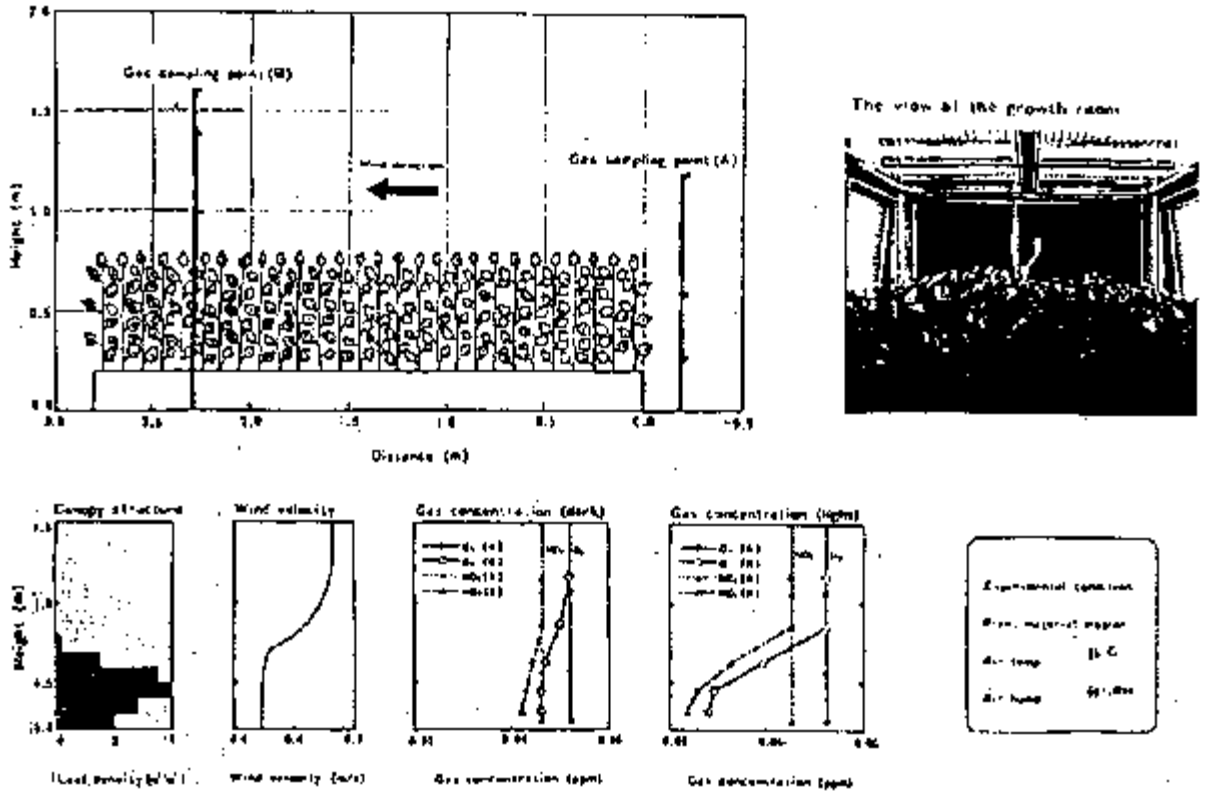
II. Purification of the atmosphere by vegetation

Plants have an ability to absorb nitrogen dioxide through stomata on leaves. The difference of this ability in the sunflower, tomato, castor-oil plant, morning glory, cucumber, and corn was studied. It is now being understood that the difference is due to the difference of the amount of gas absorption by opening of the stomata and leaf surface resistance. In the case of the sunflower, the absorption rate of 100 cm^2 of leaf surface is 0.29 mg per hour at a concentration of 1 ppm. The plane tree, used as roadside tree, has an absorption ability similar to that of the sunflower, but the gingko tree has only one half. A tree of 12 meters high with a branch length of 1.5 meters can absorb 1.75 g of nitrogen dioxide in one day at concentration of 0.05 ppm.

Nitrogen dioxide discharged in the four prefectures of Tokyo, Saitama, Chiba and Kanagawa in one year is estimated as 403,000 tons. In order to absorb this amount by a plane tree green belt, 35% of the total area must be the green belt. Forest area of the four prefectures of the Tokyo metropolitan area is some 420,000 ha, 31% of the total area. Bur this is the forest area close to the boundary of the prefectures, and there is not much green in the city area.

At a road where 500 cars pass each hour, if the nitrogen dioxide in the car exhaust is to be absorbed by roadside plane trees, it is necessary to plant densely, at a distance of 2 meters. The properties of a poplar tree are similar. Purification of the atmosphere by groups of plants, especially a forest, is a very interesting matter from an environmental management standpoint. The atmosphere purification effect of plants is by absorption of polluting gas into the stomata of the leaves. In case of a single leaf, it is possible to measure the amount of absorbed gas or resistance to gas flow at the stoma. But in the case of a standing tree, a large number of leaves are overlapping, and estimating the atmosphere purification effect of a group of trees by total surface area of leaves is not accurate. Poplar trees were placed in a configuration with a bottom of 3 meters and gas of constant concentration was allowed to flow from the front side, and vertical gas concentration distribution was measured at two cross sections. The results are shown in Figure 1 where, at cross-section A, the concentration distribution is identical in the vertical direction, but about 2m further back at cross section B, the concentration distribution is not identical in the vertical direction. For example, comparing oxidant concentration, from the leaf tips of the tree group towards the base, there is a large absorption of polluted atmosphere and the concentration drops rapidly.

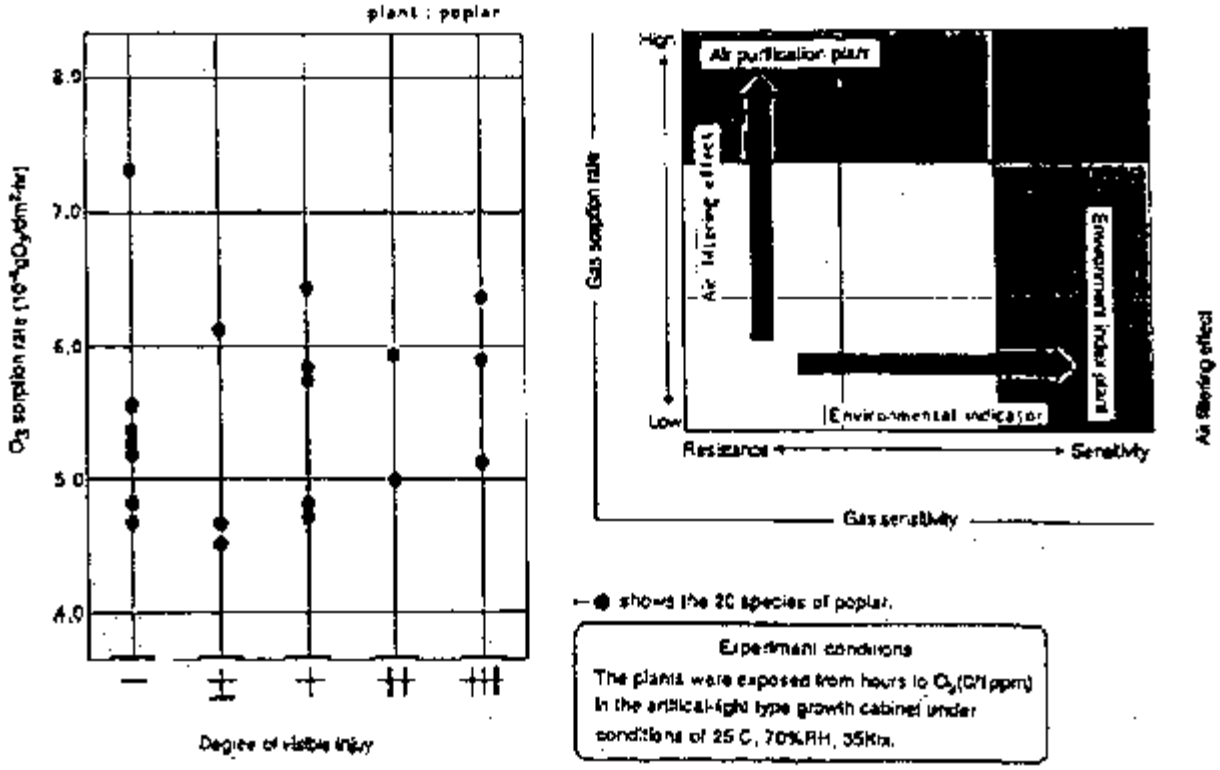
The experiment was carried out at daylight and at dark. At night when there is no light, absorption of polluting gas by plants can be observed, but the degree is very small compared to that at daylight condition. This is due to the fact that stomata are closed at night. 20 species of poplars were exposed to oxidant and visible injury of leaf surface and oxidant absorption rate were compared, giving the distribution of black dots in the left side of Figure 1.



(Note)
It is known that the concentration distribution of O3 and NO2 in Section A (front) and Section B (intermediate) of the community and the pollutant gas concentration of gas having passed through the community at Section B have remarkably decreased. The magnitude of decrease is related to the stoma opening and thus varies greatly between light and dark conditions. The community structure and wind speed distribution in the community are also shown.

Figure 1: Prediction of air pollution with natural environment simulator.

According to the species, some display few visible injuries while some suffer strong visible injuries. Also, in oxidant absorption ability, some absorb large amounts while others absorb small amounts. These results can be rearranged as in the right side of Figure 2. The abscissa represents the sensitivity to pollutant gas and the ordinate the degree of gas absorption ability. By this rearrangement, there are species with low gas absorption and very high sensitivity, and species with low sensitivity, and therefore strong resistance to atmosphere polluting gas as a plant, and absorb large amount of polluting gas. Sensitive species shown in the figure has low absorption ability for polluting gas, but can be utilized as an environment indicator plant. Species with high resistance and high polluting gas absorption ability can be used as atmosphere purifying plants.



(Note)
Experimental result of 20 species of poplar differs substantially depending on the degree of trouble caused by pollutant gas and of gas absorptive power. On the basis of such experimental result, the air purification plant and environment index plant can be selected.

Figure 2: Visible injury and oxidant absorptive power

Natural environment simulator

At the National Institute for Environmental Studies, research on the atmosphere purification ability of plants is being carried out. Figure 3 is the apparatus used for the experiments. Groups of plants are placed in a circulating wind chamber, and pollution gas concentration difference between up-stream and down-stream of the plants are measured to determine the abscriving ability of the plants close to natural conditions. Measurement part is 2.4 m wide, 2.4 m high and ca. 3 m long. About 200 pots of plants are placed and experiments are carried out with controlled soil moisture and light intensity. The wind speed can be controlled up to 2 m, since higher speed is not necessary. Temperature and humidity of atmosphere and soil temperature are also controlled.

The main power and air conditioning system are installed in a basement and the measuring section is located on the first floor of the laboratory building. A control room is located separately and performs precision condition setting automatically. Measurement is made automatically and measurement result recorded. There are two units of completely similar simulator in the laboratory.

This simulator reproduces severe meteorological conditions of desert, cold district, and tropical district, enabling selection of plants most appropriate to respective districts. This simulator will contribute greatly in future to realization of greening of the desert.

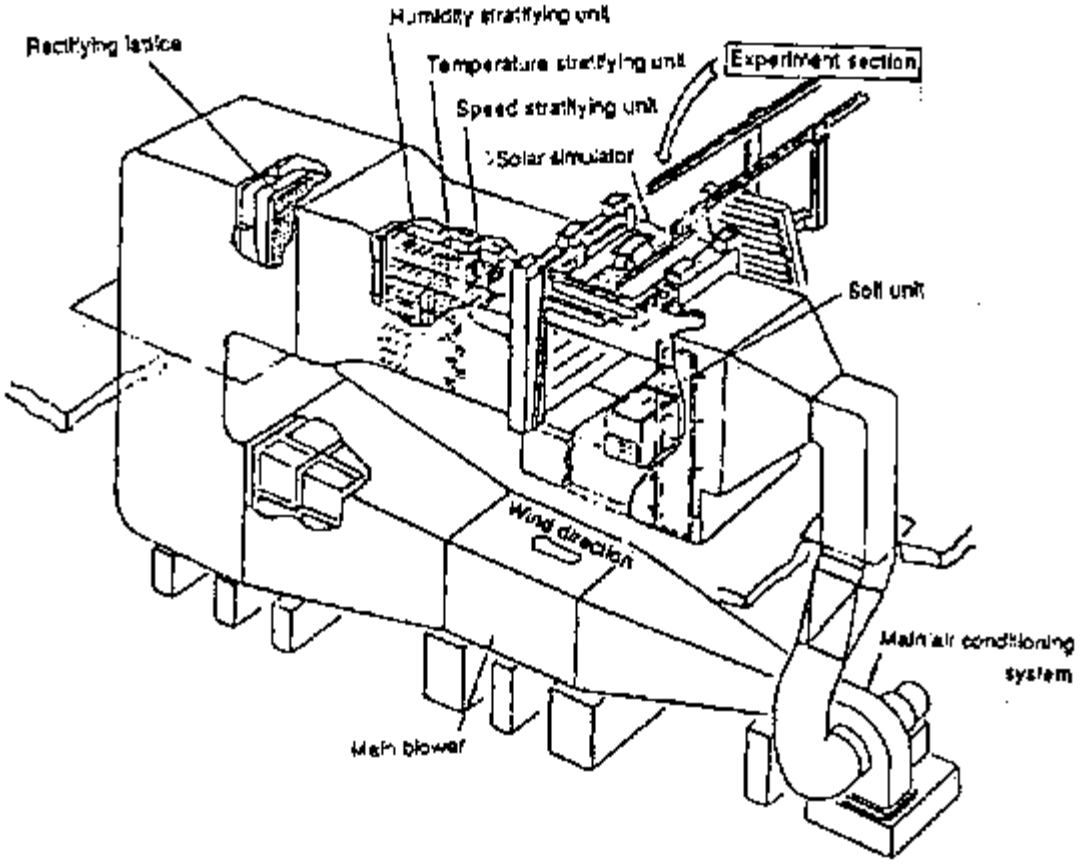
III. Generation of electricity by plants

Plants synthesize various organic compounds by photosynthesis by the function of the chloroplast. In this process, light (solar energy) and water are necessary. And by catabolism, part of the assimilated organic matter is decomposed to simpler substances while energy is generated in this process. If this energy is fed to an electrolyte, electric current will arise. This is the principle of solar energy power generation by biocells utilizing chloroplast as a "living electrode".

Professor Hideo Ochiai of Shimane University succeeded in extended power generation by using Ideyu ai midori (a blue-green algae). In this case an organ called lamella forms energy from light and water and electric current flows. An electrode is formed by laminating Ideyu ai midori solidified with calcium alginate onto tin oxide spread on a glass plate. When the electrode is immersed in electrolyte solution, 30 to 40 NA per 1 cm^2 electrode surface is obtained by 50,000 lux light. As the cells multiply, 1 to 2 mA can be obtained.

With technical improvements such as in electrolyte solution and solidifying reagents, a current of 1 A per 1 m^2 may be possible. This is an

attempt to obtain electricity from solar energy by using the physiological function of a plant as a medium. Environmental pollution can be avoided if waste water treatment is carried out carefully.



(Note) Technical data:
Type: Vertical rotary type wind tunnel for low wind speed
Overall dimensions: 17(D) x 5(W) x 12(H) m
Volume of the experiment section: 18.5m^3 [2.4m(H) x 2.4m(W) x 3.2m (H)]
Wind speed control range: 0.1 to 2.8 m/sec (speed stratified to 10 stages)
Air temperature control range: 10 to 35 C (temperature stratified to 10 stages)
Humidity control range: 30 to 80% RH (humidity stratified to 10 states)
Light quantity control range: 0 to 60 KLX (automatic light quantity and quality control)
Kind of control gas: SO2, NO2, O3, HC and CO2
Soil temperature control range: -5 to 351/2C
Figure 3: Natural environment simulator.

IV. Deforestation

About 10% of the total global surface and one fourth of the land surface is covered with forest where 90% of biomass and 60% of organic material produced by plants are produced. This forest is decreasing by 20,000,000 ha each year. The forest absorbs CO2 and one third of the evaporation of water from land area comes from the forest, so the loss of forest exerts a strong effect on the climate. 40 to 50% of forest is tropical rain forest, and forest damage in the five years from 1981 to 1985 amounted to 11,300,000 ha. Forestation in the same period equalled 1,110,000 ha. and therefore 10,190,000 ha. was lost, which is a 2,000,000 ha. decrease of tropical forest each year.

V. Afforestation of deserts

From a global environmental perspective, expansion of deserts is a big problem. In dry agricultural regions the desertification area equals 5,000,000 to 6,000,000 ha each year, while the loss of agricultural products due to desertification is estimated to be US$ 15.6 billion per year. Desertification can be caused by improper irrigation, degradation of pasture-land due to salt accumulation, and deteriorating conditions in precipitation-dependent areas of agriculture. Excessive irrigation without proper drainage can cause a phenomenon called water locking in which the salination of soil and alkaline accumulation proceed and crops cannot be grown. To avoid this, it is necessary to install appropriate irrigation and drainage.

Accumulation of salt is often seen in dry areas, but it is also related to inherent soil properties. Desertification by degradation of pasture land is very significant. For appropriate grazing 2 ha. of pasture land for every sheep and 10 ha. for every cattle is said to be necessary. When the

pasture land becomes dry, the productivity of the pasture decreases but the number of sheep and cattle do not decrease, reaching a condition called overgrazing. The grass is completely consumed by the animals and the ground is stamped down solid, accelerating the desertification.

In precipitation-dependent agriculture, soil moisture must be accumulated and preserved by the cyclic fallow method. Construction work during dry season can result in the loss of topsoil by wind erosion, decrease of water retaining ability, and a step towards desertification. The dry area is so called when the precipitation for most of the year is less than evaporation loss. When the ratio of precipitation is less than 3% of evaporation loss, the area is called super-dry, between 3 and 20% dry, between 20 and 50% semi-dry. The ratio of such dry area within the total area is especially significant in Africa. Latent arable land in the world is 3.1 billion ha., and potential grazing area 3.6 billion ha. and they are concentrated in Africa, South America and Australia, which means that, with proper soil management, there is room to greatly increase the cultivated area.

Afforestation of the Gobi desert

The afforestation of the Gobi Desert in China was designated by the Ministry of Education as Fiscal Year 1990 Priority Field Research and a research team has been organized and large-scale research is underway. The selection of plants suitable for dry land is proceeding now. This research is being promoted as a Ministry of Education Special Scientific Research Program. Afforestation of deserts by forestation will be explained below. Afforestation by planting trees is being sought, since 30% of the moisture in the atmosphere comes from evaporation from tree leaves. In addition, the reflection coefficient (albedo) of the land surface changes, allowing water droplets to form in the air above, changing climate and causing precipitation. This way plants will grow naturally and the green will increase, and the desert will be transformed into forests and agricultural land. It is my theory of afforestation of the desert to simply follow the process opposite to desertification.

VI. Agriculture in dry regions

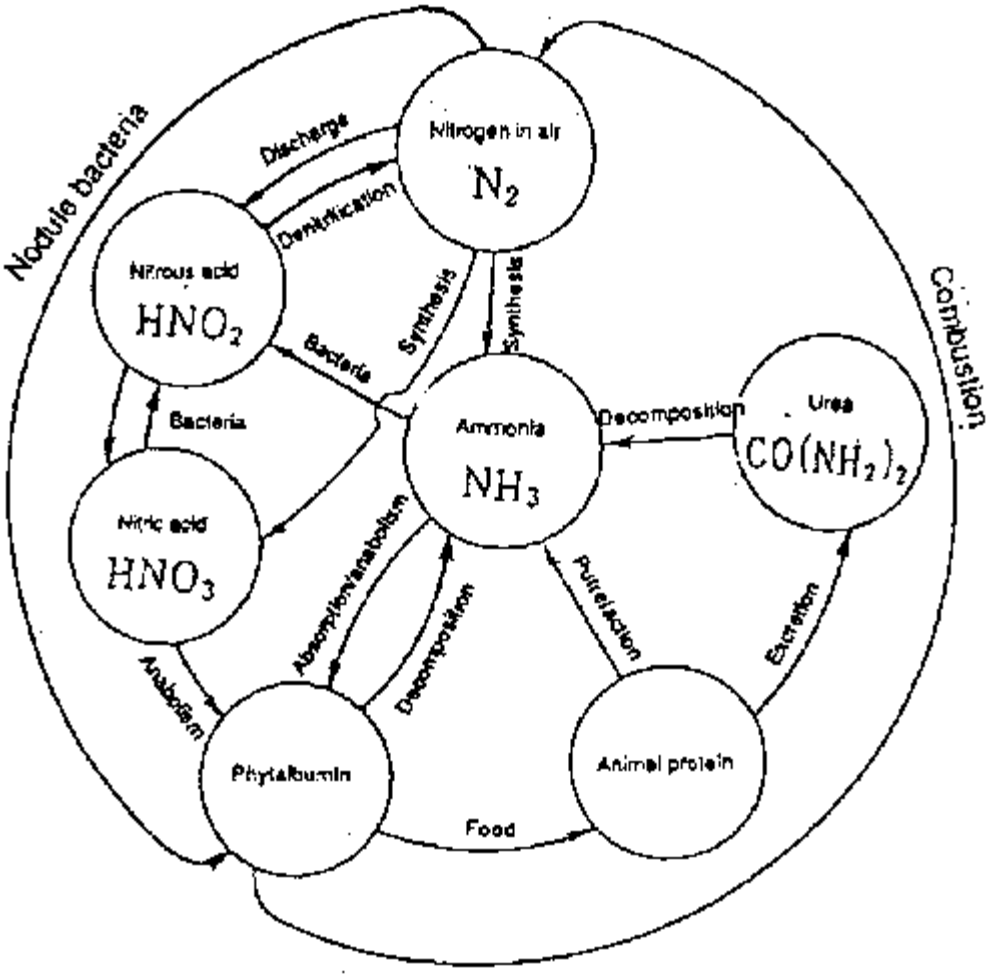
Extract the gene from the bacteria that produce proline (a type of amino acid), which acts to retain water within the cell even under dry or salty conditions and insert it in a plant. Thus rice, wheat, vegetables or trees with strong dryness-resistant and salt-resistant properties can be produced artificially.

In 1983, Professor Davis Kono and Professor Reymond Valentine of California University have succeeded in extracting the proline-producing gene from one bacterium and transplanting it in another bacterium. By using such gene technology, it is expected that a plant capable of holding water within its cell can be produced in the next ten years. If this can be done, afforestation of deserts will become much easier. And the food problem can be solved immediately. Its realization takes more time, but it is expected that the research will progress a certain extent by the year 2000.

VII. Treatment of waste

With the increase of social and economic activity of mankind, treatment of industrial waste and household refuse has become an important environmental problem. In 1962, R. Carson (1907-1964) wrote The Silent Spring in which she pointed out that by environmental residence of chemical substances such as DDT, pollution of a global scale is taking place. At last in 1971, the US Environmental Protection Agency (EPA) prohibited the use of DDT.

The waste treatment at large cities where the population is concentrated is also a big problem, so much for industrialized as for developing countries.



This shows circulation of nitrogen in a form of various compounds.Think lines show the number and function of bacteria. The similar diagram may be drawn for carbon and other atoms.

Figure 4: Nitrogen Circulation

Figure 4 illustrates the circulation of nitrogen in nature. Here, ammonia is placed in the center, nitrogen in the atmosphere above, and protein, which constitutes the body of animals and plants, below. Changes that occur naturally or artificially are shown in with fine lines and changes that occur biologically by germs and bacteria are written in with bold lines.

Nitrogen in the atmosphere transforms to nitrogen oxides by atmospheric discharge, dissolves in rain to form nitrous acid and nitric acid and seeps into the ground. Nitrogen fertilizer industrially produced by fixation of atmospheric nitrogen is absorbed by roots and constitutes the plant body as protein and other nitrogen compounds. Root nodule bacteria which are in a symbiotic relation with leguminous plants and certain types of algae grow by assimilating molecular nitrogen. This function's action is called biological nitrogen fixation. Plants are consumed by herbivorous animals, and herbivorous animals are consumed by carnivorous animals and animal protein is formed by means of this food chain.

After physiological decomposition in the animal body, nitrogen enters the ground as excrement. This, together with dead bodies of plants and animals, is decomposed to ammonium salt by microorganisms. This is taken in by plants and assimilated, but also transformed into nitrites and nitrates by micro-organisms. They are also transformed into free nitrogen by the action of denitrogen bacteria. This phenomenon, in which nitrogen circulates in the natural world, changing its form, is called nitrogen circulation. At this time, by the law of conservation of matter, the total number of nitrogen atoms on earth is constant. The principle of sewage treatment is to enhance the urea, protein and ammonia decomposing power of bacteria and germs.

VIII. Mercury concentrating moss

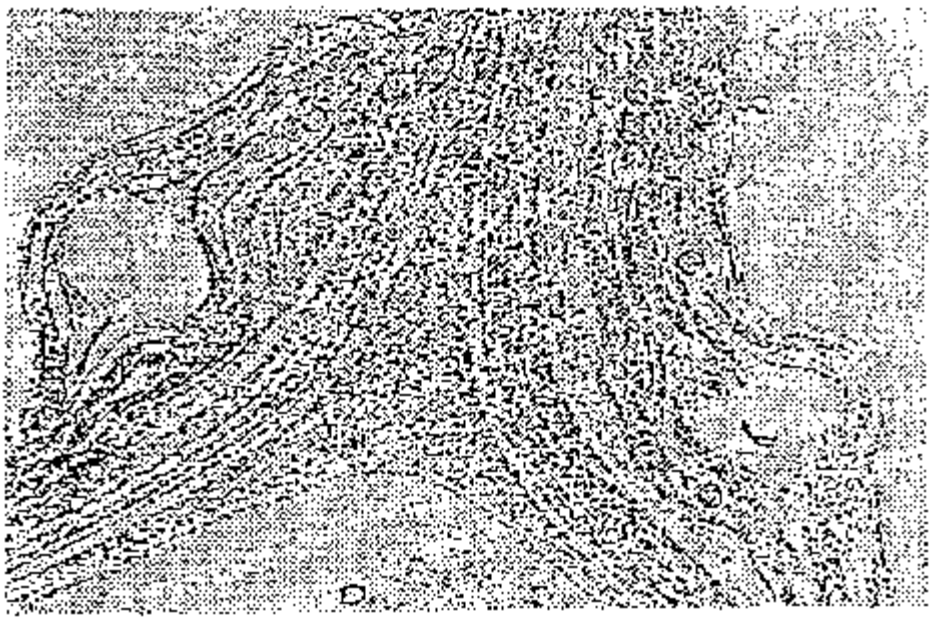
There are certain plants which have a property of concentrating inorganic mercury. For example, Hiroha tsubomi goke collected at Kusatsu and Chatsubomi goke and Murasaki hishaku goke which grow at Mt. Osorezan have extreme mercury concentrating property. The mercury concentration in the water environment in which these mosses grow is 1 ppb or one billionth, while the mercury concentration in the moss is

1% or one hundredth. From a simple calculation, a 10-million-fold concentration has taken place. If these kinds of moss are used as an indicator, analysis will be much easier because of the high degree of concentration of environmental mercury.

Figure 5 is an electron microscope photograph of a cell of Cha tsubomi goke. Black dots in the cell wall are fine grains of mercury sulphide. The details as to how the mercury dissolved in water is sulphurized and detoxified in the moss body are mostly unknown. At the Institute (NIES), research on the process of concentration of mercury in the moss is being carried out using radioactive mercury.

IX. Soil microorganisms

In a lump of soil the size of the thumb, are living various microorganisms numbering some 100 million. They are named according to their function or their shape, such as aerobic bacteria, actinomyces, filamentous fungus, protein decomposition bacteria, dye resistant bacteria, ammonia oxidation bacteria, and nitrite oxidation bacteria. These seven types of microorganism usually increase by application of sludge. This tendency, that the dye resistant bacteria which reflects the nutritive condition and moisture condition of the soil is affected most sensitively should be given attention to further applications.



(Note)

Black dots observed between cell wall and chlorophyll are mercury particles. Mercury is turned into harmless mercury sulfide inside.

Figure 5: Electron photomicrograph of chatsubomi goke

Appropriate application of organic waste material will improve physical and chemical properties of soil, but some point out that continuous use of city waste compost hardens soil. Continuous use of organic waste may have an effect on the properties of soil. It has been found that recycling active sludge from sewage treatment plant to farm land has good effect. Since the content of nitrogen and phosphorus is sufficient, if potassium is added, nutrients necessary for plant growth are replenished.

X. Decomposition of trichloroethane and others

PCB (polychlorobephenyl) had been widely used as a heat medium and solvent, but due to its toxicity which can cause grave illness such as liver disease when it accidentally contaminates food, its use has been prohibited worldwide. Its production has ceased in Japan since 1972. This compound has a very low degradability, and it remains in its original structure. Measuring the concentration of remaining PCB on the earth since the prohibition of its use, it is known that it will not disappear for a long period if left alone in nature.

In 1979, the Institute (NIES) discovered that it can be decomposed by a soil bacteria called alkaligenes which make flagellum movement and are the size of 1 to 2 micron. Through experiments with soil bacteria collected from some 300 sites, a soil bacteria strain which can decompose 500 ppm PCB in 3 days has been separated from soil bacteria obtained from the Ishioka area in Ibaragi prefecture, Japan. To date, PCB with chemical structure of up to three chlorine atoms can be decomposed, but for those with four chlorine atoms or more, the efficiency is not yet sufficient. And the toxicity of chemical substances which arise during the decomposition process is not yet well known, therefore tests are now being continued. By this method, in the near future, the PCB problem will probably be solved to a certain extent. The Institute is now searching in this direction. Effective treatment of waste by microorganism can be widely applied to wastes other than PCB, and the preservation of biological resources is important from this viewpoint as well.

Trichloroethylene, tetrachloroethylene, and 1,1,1-trichloroethane have been detected in underground water. By testing soil bacteria capable of decomposing these materials with bacteria collected from soils of lotus ponds, paddy fields and dry fields, the results shown in Figure 6 were obtained. An aerobic decomposition path of tetrachloroethylene as shown in Figure 6 was obtained.

An anaerobic decomposition path of tetrachloroethylene is shown in Fig.7

XI. Red tide

Red tide is a phenomenon that occurs in semi-closed sea areas such as the Inland Sea by eutrophication, and lately it is being observed more frequently. Damage to fisheries, especially to cultivation fisheries is so severe that in 1978 the Diet passed a resolution for immediate implementation of countermeasures.

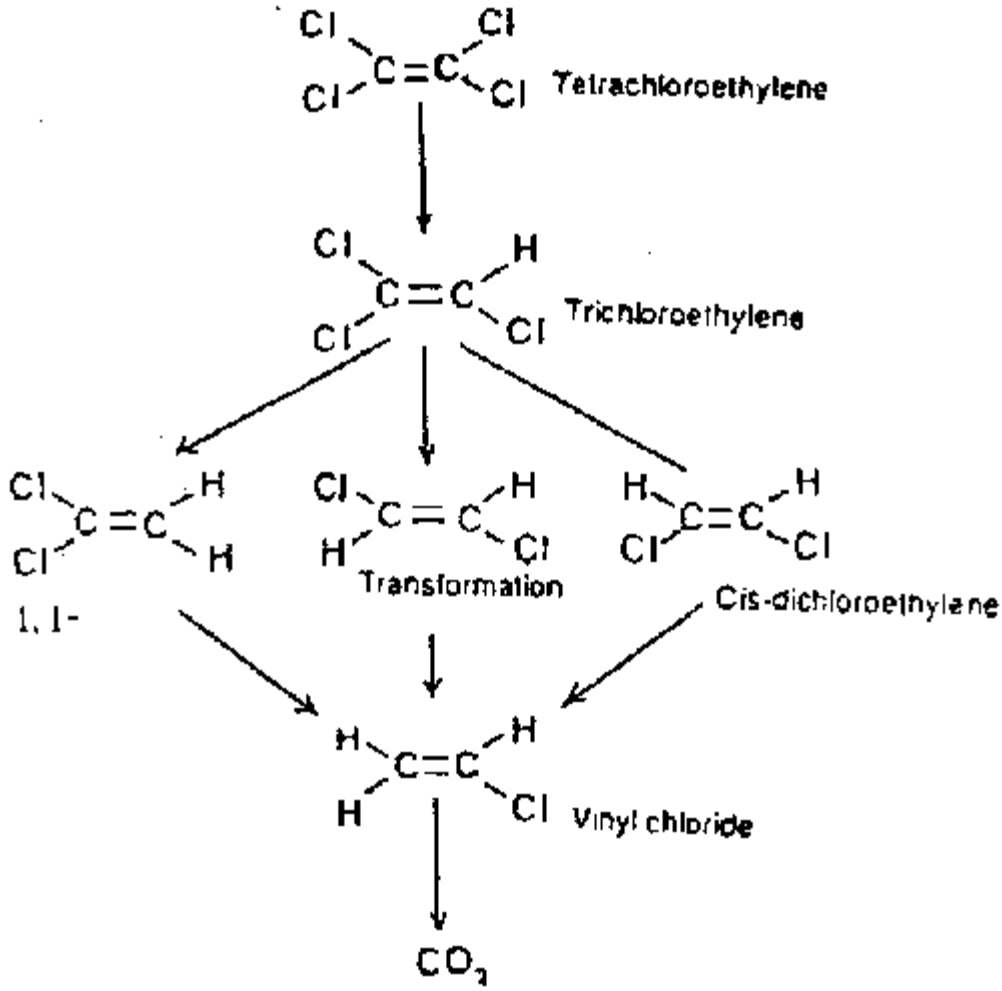


Figure 6: Decomposition of Chloroethylene in soil

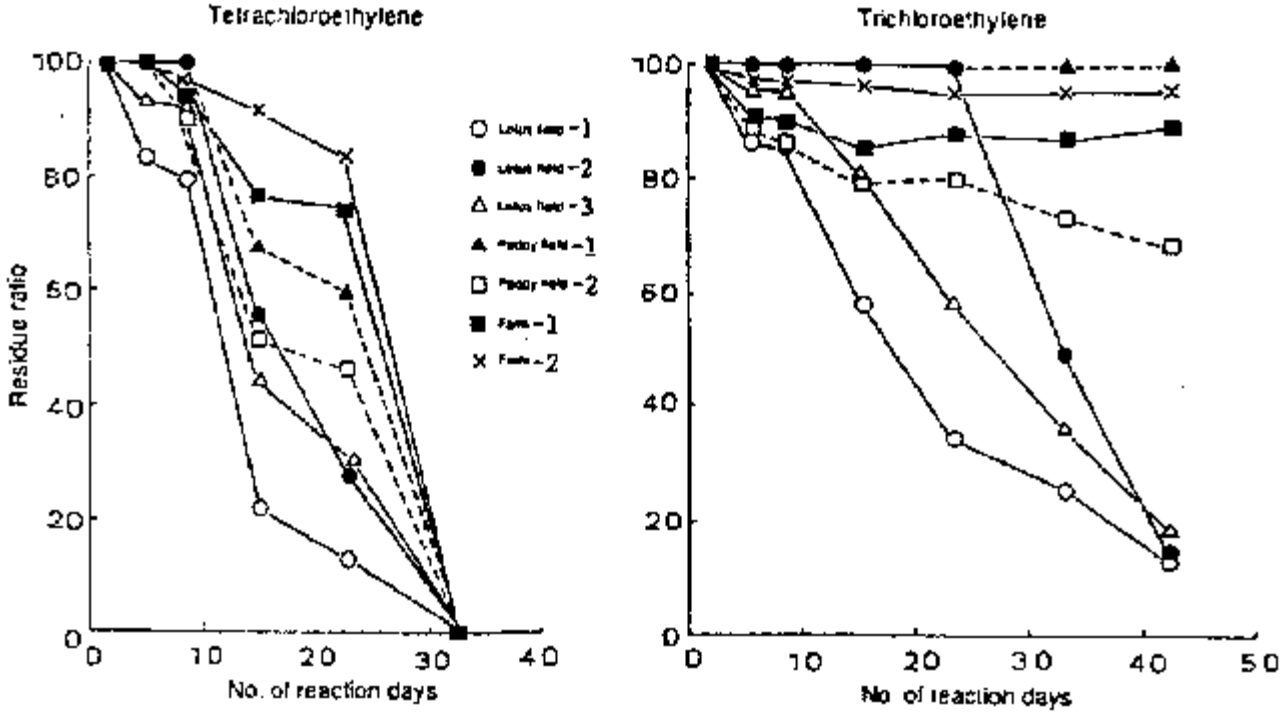
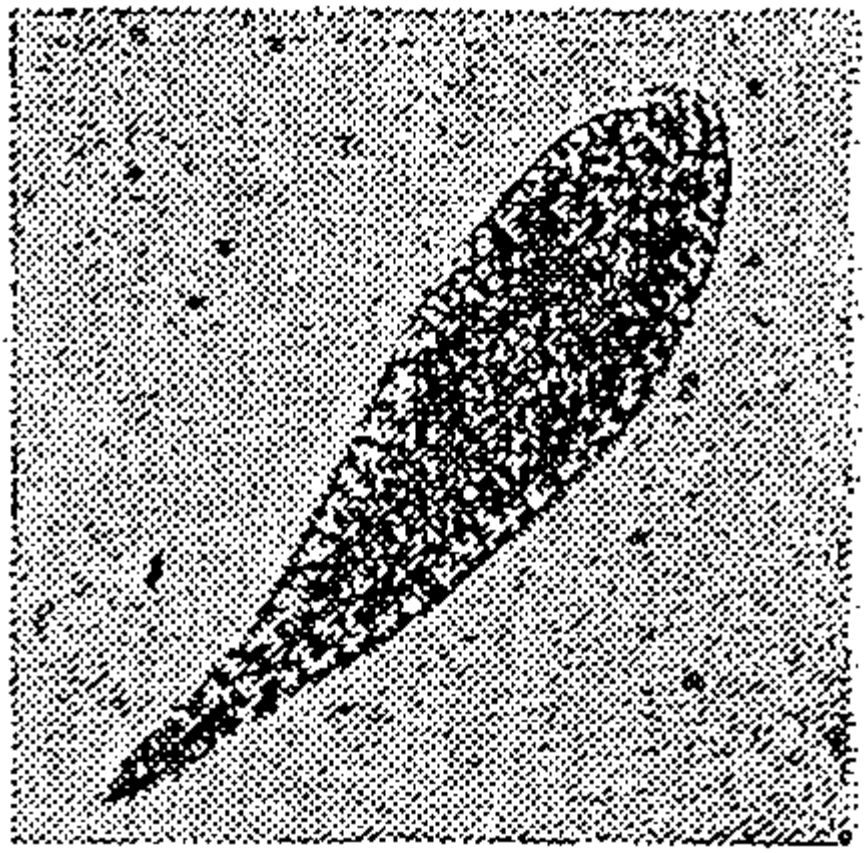


Figure 7: Anaerobic decomposition route of tetrachloroethylene

It is well known that red tide is due to an abnormal outbreak of the flagellum algae Chataunella heterosigma shown in Figure 8. These algae consume dissolved oxygen (DO) suffocating fish. At present, rather than developing removal technology, we are still at the stage of understanding the phenomenon. In order to understand the phenomenon of red tide, all factors related to the phenomenon must be picked up, and the abnormal multiplication of the flagellum algae reproduced under controlled artificial conditions. This is the basis for understanding red tide with respect to all related factors. If the type of flagellum algae and its multiplication conditions can be established, research for prevention of red tide could be started by removing the underlying factors.

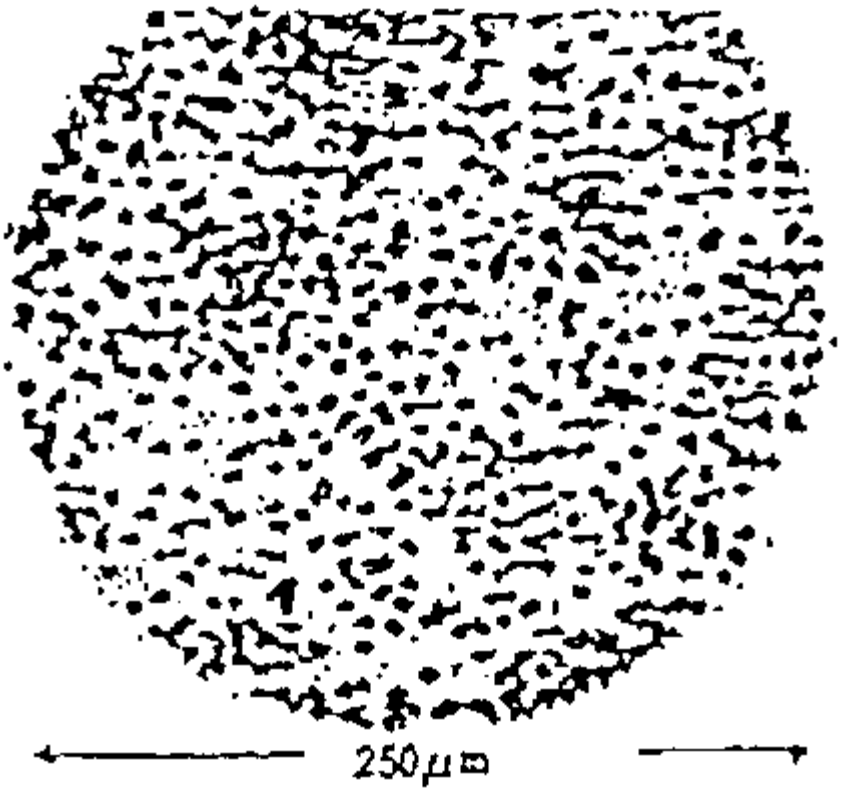


(Note)

Photomicrograph (approx. x300) of algae Chataunella, which causes red tide. The original color is brown.
Figure 8: Chataunella

A phenomenon similar to red tide is Aoko. The Institute separated and collected the cells which amount to 1 million in 1 cc and cultivated the blue-green algae Microkishitis and studied the effect of nutrient. When the amount of nitrogen is N and the amount of phosphorus P, the amount of Microkishitis is 950 P at N/P less than 17.3 and 55 N at N/P greater than 17.3. Thus, it depends on phosphorus when the ratio of nitrogen and phosphorus is above 17.3 and on nitrogen when the ration is below that value. In most of the lakes in our country it is above 17.3, and is refered to as the phosphorus-controlled state. It was also found that at up to 500 lux the multiplication rate is proportional to light intensity, and a temperature of 30 degrees is the optimum temperature for the growth.

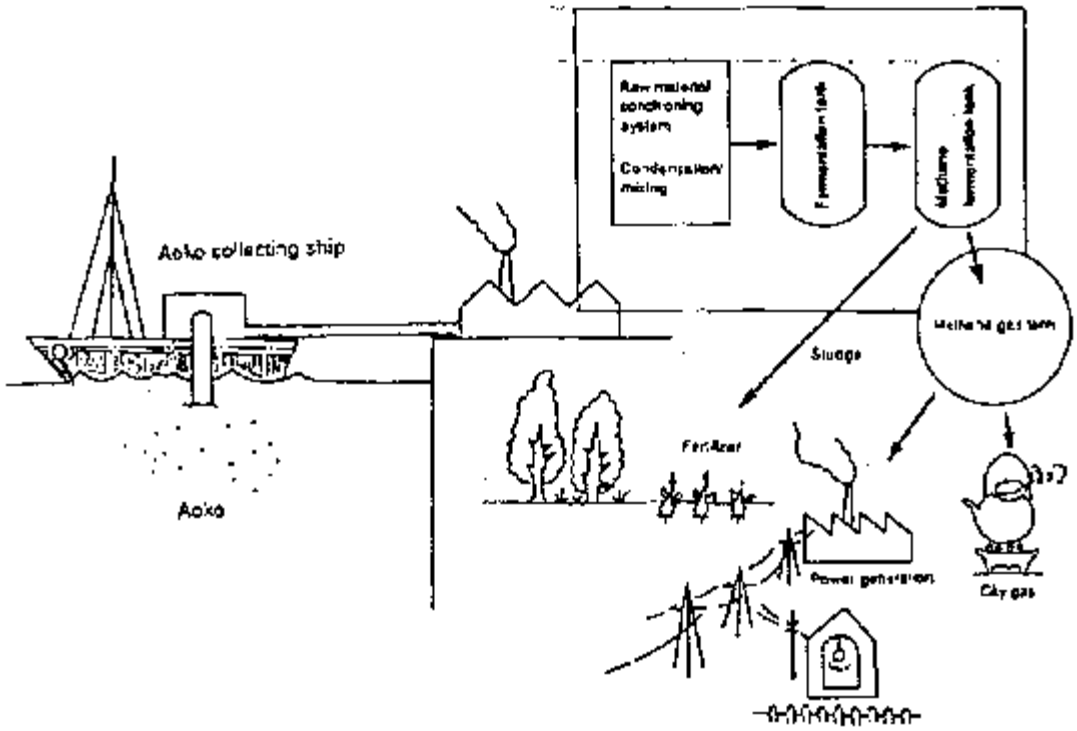
Also by experiments in the microcosm (artificial lake), it was found that the results also apply to actual lakes. For red tide, it is known that other than nutrient, vitamins also have an effect. It may take more time to understand the phenomenon, but by utilizing the method which succeeded with Aoko, we believe we will be able to understand the phenomenon of red tide. Abnormal outbreaks of red tide and Aoko are one process of water purification in nature. Therefore, research of removing it by use of the natural ecosystem is being carried out. For example, the phytoplankton that cause the Aoko phenomenon in Lake Kasumigaura were cultivated in large amounts, and when water fleas were added it was observed that the Aoko were almost completely consumed by the water fleas. Removal of Aoko by use of such ecosystems must be utilized in the future. On the other hand, cultivating large amounts of zooplankton by this method and preparing feed for fish and animal is also being studied.



(Note) Photomicrograph of "water flower", a group of Microkishitis which causes eutrophication of lakes.Diameter of the group is 0.25m. Source: Institute Report, R-25-1981,NIES
Figure 9: Microkishitis

XII. Conversion of "Aoko" into useful resources

Aoko (Microkishitis), which belongs to the blue-green algae group, is shown in Figure 10. It is a single-cell organism of a diameter of about 5 ì, and from June to October when the temperature rises, it multiplies up to 1 million times in 1 cm^3 lake water. It takes in and accumulates 80-90% of nitrogen and phosphorus contained in the waste water discharged into lakes from households, and multiplies close to the water surface, consuming large amounts of oxygen and killing fish. When it accumulates, transparency of the lake water decreases, making it a water polluting factor. At lake Kasumigaura a large- scale outbreak in summer is seen each year, and the lake surface turns green as if paint has been poured into it. Since Aoko contains 40% carbon, it can be gasified by methane fermentation. The system is as shown in Figure 10.



(Note)
Illustrated above is a system to collect Aoko from lake water to generate the energy
Figure 10: Methane fermentation system from Aoko

Aoko is collected by pumping the lake water onto the boat followed by filtering and centrifuging, and transported to the fermentation plant onshore and stored in a condition favorable for microorganism decomposition. Later, in order to allow full functioning of methane bacteria, acid bacteria is applied to cut structural material of Aoko to low molecular weight intermediate products such as propionic acid, acetic acid, etc. When methane bacteria is applied to this mixture, methane gas is produced. The methane gas is collected in a tank and utilized as domestic or power-generating fuel. If 50g of dry weight Aoko is available from 1 ton of lake water, available purified methane gas is about 10 liters, or 0.01 m^3.

XIII. The RITE

Rapid growth of our socioeconomic activities has already seriously influenced the environment all over the world. The global warming and desertification are regarded as the outcome of man's influence on the environment. In order to sustain the growth and prosperity of humankind, one must improve or at least preserve the environment and avoid its destruction caused by inadequately planned development.

Our knowledge of the Earth has increased as much as we can consider the Earth as a system. Because of the significant achievements in science and technology in recent years, there is a growing demand for knowledge to be used to predict global phenomena and improve the natural environment as well as to study unknown phenomena. At the same time, the earth's environmental problems that are thought to be due to increased human activities are becoming of major international concern. There is thus a growing issue for science and technology that enables us to achieve sustainable development in harmony with nature.

Global warming caused by increasing CO2 content in the atmosphere is now considered the most serious threat to the environment. Major drought and increasing desertification are seen every year, and can be attributed mainly to CO2 released from combustion of fossil fuels. The more CO2 that is being released into the atmosphere, the warmer the earth is becoming.

It is a fact that chlorofluorocarbons (CFCs), considered one of the most useful chemical substances of the 20th century, are destroying the ozone layer. Rain, snow and fog high in acid content are killing the world's forests and making more water unsuitable for aquatic life. Tropical rain forests that recycle are being significantly destroyed, industrial waste and disposed plastic are accumulating at a frightening rate, and the oceans are being poisoned by discharge of hazardous chemicals from land. Environmental pollution and destruction are progressing and becoming more complex problems to solve.

In the past, these problems were approached by efforts to limit destruction brought about by humans. Now the situation is more serious-so serious that limitation may not suffice. Limitations are important, but the rise in population and in consumption of energy cannot be stemmed. With non-regulated industrialization in developing countries progressing as well, slogans like "Let's Save Nature" will not solve problems.

In the search for fundamental solutions, fresh approaches have become necessary. The idea of making positive use of CO2 as a source of clean energy or converting it to other useful substances is one such approach. This approach is now being pursued enthusiastically. To face this situation, the Research Institute of Innovative Technology for the Earth (RITE) was established in July 1990 at the Kansai Science City, an area covering regions of Kyoto, Osaka and Nara. The institute aims to develop the research in advanced industrial technologies that will work in harmony with the environment. Research on finding useful applications of CO2 microorganisms, and enzymes will be conducted.

Technology reducing the effects of global warming

We should develop technology to reduce other gases causing the green-house effect based on the knowledge of the generation mechanism of these gases. In addition, we must develop technologies for adaptation of global warming; agricultural technologies such as methods of developing new types of plants which adapt to changes in temperature, solar radiation, rainfall and other environmental conditions; technologies for flood control and optimum utilization of water resources to cope with rainfall change; and technologies for protection against the rise of the sea level due to warming such as the construction of the tide banks and the reconstruction of cities.

We should develop innovative technologies of recovering carbon dioxide by absorption and fixation using living organisms on land and in the sea for instance, through forestation and cultivation of plants having high ability of CO2 fixation, technologies of artificial photosynthesis, and technologies of separation and recovery using high-performance, low-cost absorbents of high-performance membrane. In addition, we must develop the technology to fix recovered CO2 for long periods of time. We also expect to develop technologies to change CO2 to methanol and chemical fertilizer using catalytic hydrogenation processes, for example. Biological and chemical approaches will be used in finding means of converting CO2 into useful resources.

The Biological Approach. One approach is to make use of the natural mechanism of photosynthetic microorganisms such as photosynthetic bacteria and microalgae. This approach will apply the principles of biotechnology to increase the rate of photosynthetic activities of these organisms through more efficient use of sunlight and improved culture methods. Further studies on bringing about a more efficient process of photosynthesis and on the possibilities of using the end products as energy resources or converting them into more useful substances such as protein, lipids and carbohydrate will be conducted.

The Chemical Approach. At the same time, research applying the principles of chemistry will also be promoted. The key to fixing CO2 lies in finding a highly efficient catalyst, so that CO2 released from combustion of fossil fuels can be collected and converted into methanol and other useful compounds.

Prevention of destruction of the ozone layer

We should find substitutes to material such as certain freon and halon gases which destroy the ozone layer. These substitutes should not excessively load the environment. We should also develop the technology for their decomposition, recovery, and reutilization. In the meantime, substitutes for CFCs must be found. Substances that will replace CFCs but will neither diminish the ozone layer nor contribute to the greenhouse effect are necessary. CFCs continue to be used, and the quest for substitutes has just begun. Particularly important is the development of a new refrigerant to substitute for the CFCs 144 refrigerant used in the compressive heat pump which is necessary for the effective ulitization of waste heat. The development of a substitute refrigerant for the conventional one will be carried out, although so far researchers have only come up with substitutes that will not affect the ozone layer but may contribute to the greenhouse effect.

Friendly technologies for the earth

We should develop manufacturing technology applying biological reaction mechanisms at normal temperature and pressure without consuming large amount of energy and try to invent new materials which are taken into the biogeochemical cycles through biological decomposition, thereby reducing the environmental load. The goal is to replace the present production system which consumes both resources and energy at an excessive rate with a moderate resource-saving and energy-saving system. An advanced synthetic bioreactor system will be developed. This system will be an attempt at combining natural elements such as useful microorganisms and enzymes with chemical techniques. For instance, hydrogen fuels, high-energy chemical compounds and various other compounds will be produced, employing the reaction mechanism of microorganisms and enzymes.

Microorgamisms and enzymes are essential in such research. According to one of the pioneers of biotechnology, Professor Isao Karube of Tokyo University's Research Center for Advance Science and Technology, "the rates of reaction and efficiency of microorganisms and enzymes are low compared to chemical processes in industries, but they neither upset the ecosystem nor harm other organisms. A little sacrifice is needed to help the earth. With progress in research on techniques such as gene recombination in microorganisms of algae, production that is less harmful to the environment is possible."

XIV. Development and improvement of innovative technology

For innovative technology considered in RITE, part of the system is already available as unit technology. The following steps are now being considered:

- Realization. Realize solidification of CO2, new material such as bio-decomposable plastic and CFC alternatives, and a new processing method as system.
- Improvement. Improve to minimize necessary material and energy in implementation and operation of system, and evaluate as a whole system.
- Technology transfer. Global environment technology is developed for mankind, so it should be disclosed internationally, technology transfer made simpler, and wide application promoted. For this purpose, necessary measures should be taken to protect intellectual property and set up technical training centers.

XV. Summary

By recent progress in gene technology, it has become possible to artificially produce bacteria with high waste-decomposing ability by gene rearrangement, and future technology will proceed in this direction. Reversible changesödoing work only outsideöcannot return to its original state by the second law of thermodynamics, but perpetual motion of the first kind can be formed by receiving heat from the sun. That is, it can be turned into reversible changes which return to its original state. This is called the fourth law of thermodynamics. For the future, technology under the condition of energy conservation and resource conservation will be more frequently used and will be more important. For work to be done until the product is complete, use of less material and less energy will be desired. For that purpose, it is necessary to make the transition take place at low speed, which may be called low-speed technology compared to conventional high-speed production process. Transition utilizing organisms is slow-speed compared to mechanical process, scientific change or chemical change, but is worthwhile if energy consumption and material is low.

In developed countries, the population of the young work force is decreasing, and medium- to high-age workers are increasing. Therefore, promotion of industries which requires not heavy, manual labor but intellectual work, and can be completed by light labor of the knowledge-accumulating type and man-power accumulating type is necessary. All assets have the usefulness of giving happiness to people. Development effort will be focused on things that have such utility and requires less energy and resources for its production. This is the reason why there is high expectation on the future of information industry.

Conversion of the principle of growth

People have an inclination to look for progress or growth. In order to remain satisfied, it is necessary always to have progress or growth. For example in gross national product (GNP) some growth each year is expected. When a GNP of 7% against the previous year is referred to, it means growth of 7% by compound interest calculation. In this way, as years go by, even if the growth rate is constant, amount of growth or width of growth will increase. In order to increase production, more resources are required, consumption of resources will increase compared to the previous year. Even with 7% against the previous year, since it is compound interest, it will be more than twice that of ten years ago, and a large amount of resources is being consumed unknowingly. The fact that such behavior endangers the environment is clear without waiting for an indication by the Club of Rome in Limit of Growth.

Now, let us consider keeping the increment of growth constant, that is growth of the first year can be 7% against the previous year, but thereafter the growth amount will be kept constant. The growth in this way will mean a certain slow-down. In this way, for example, the growth rate 10 years later can be limited to the growth rate of 4%. If the growth rate of the first year is 5%, 5 years later it can decrease by 1% to 4%. Even so, there is a certain amount of growth compared to the previous year which gives a satisfactory feeling for the people. It is believed that this kind of restriction to economic growth in industrialized countries will be useful for preserving the global environment.

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Professor Jiro Kondo is Director General of the Research Laboratory of Innovative Technology for the Earth (RITE). His is also Professor at the University of Tokyo and Dean of the Engineering School, as well as Professor of Mathematics at the Chiba University. Professor Kondo directs the National Institute of Environmental Studies and has also served as President of the Science Council of Japan, as well as President of the Central Council for Environmental Pollution Control. He has been awarded the Ouchi Medal, the Deming Medal, the Purple Ribbon Medal and the Grand Cordon of the Order of the Sacred Treasure.