Sustainable Energy and Environmental Technologies for Asian Developing Countries

Masayoshi Sadakata

1. Introduction

In this lecture, I propose the research for solutions for environmental and economic problems in developing countries including China.

Environmental pollution of developing countries has become a more serious problem recently and it will lead to a catastrophe for the global environment.

The causes of environmental pollution and the destruction in developing countries are

1) Poverty
2) Rapid Increase of population

However, there is a close relationship between poverty and population. According to the Asahi Newspaper, the pregnancy frequency is anti proportional to annual income per head in each country. (Fig.1) When annual income per head is lower than 1000 dollars/year, pregnancy sharply increases by three times. Hence, only economic growth seems to be the solution for environmental problems in developing countries. However, the history of the developed countries teaches us that the growth of the economy is accompanied by an increase of energy consumption which leads to the increase of pollutants such as CO_2 and SO_2. Hence, developing countries should not follow the same path of economic growth as developed countries. The developing countries like China and India should follow "**Tunnel Routes**" which are the new short cut path as is shown in Fig. 2. The technologies required for the developing countries are generally,

1) Low input and low impact manufacturing technology.
2) Environmental protection technology useful for economic growth.

The transfer of the environmental technology from developed countries to the developing countries is now urgently required. However, the transfer of technology conventionally used in the developed country has often been unsuccessful because of its high cost, complicated operation, and significant energy consumption. Those conflict with economic growth in developing countries.

The requirements of an environmental technology which can be accepted by developing countries are

1) Suitable for the economical, technological and social situation of the developing country.
2) Useful for energy saving.
3) Producing valuable byproducts.
4) Creating new employment.

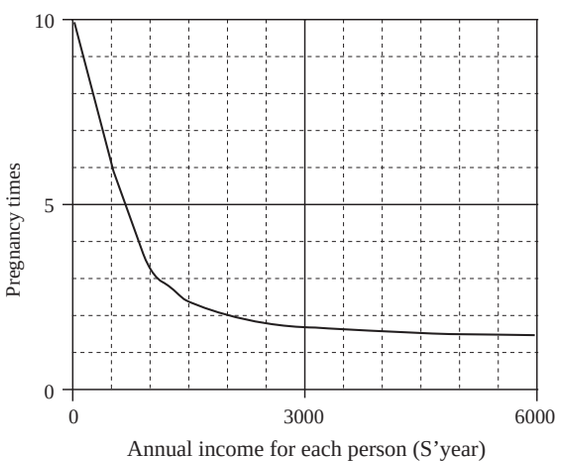

Fig. 1 Average of pregnancy times vs annual income for each person

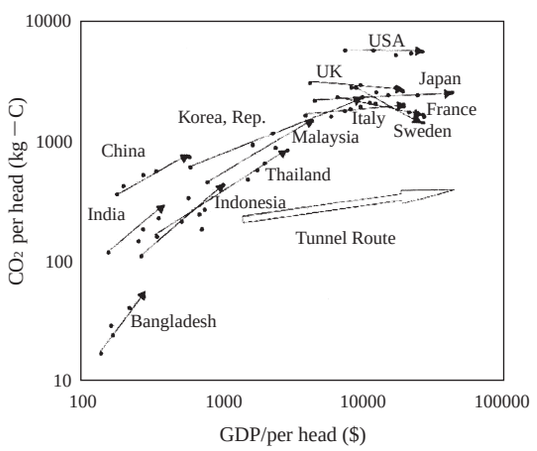

Fig. 2 CO_2 emission per head vs GDP per head (1975–1995)

In this presentation, energy and environmental technologies are selected as an example of technologies and systems useful for developing countries from the sustainable point of view.

2. Coal utilization technology for the developing countries

Coal is one of the main energy resources in China.

In order to solve environmental problems caused by coal utilization and to improve the efficiency of coal utilization furthermore, we need to develop the following technologies suitable to developing countries.

1) Coal combustion technology

For the reduction of the SOx emissions from many small and medium sized combustion furnaces which are one of the main sources of air pollution in developing countries, it is preferable to improve the fuel rather than to put the desulfurization process in each furnace. The high pressure briqueting combustion method is one of the fuel improvement methods. In this method, the raw coal is pulverized to under 1 mm and mixed with limestone particles. The mixture of coal and limestone is fed to the high pressure briquetting machine, pressurized under 1t/cm^2 to 3t/cm^2 and changed to briquettes. This method can achieve an SOx removal rate of 60–70% and improve boiler efficiency by 10–20%.

According to my calculation, both environmental improvement and energy savings were realized when the supply and combustion system of high pressure briquettes is applied to medium and small size combustion facilities in Chongqing which is the most polluted city in China.

2) Gasification of coal

In developing countries, the coal combustion for the home cooking and heating is one of the main causes of local air pollution and indoor pollution and also workplace pollution. A clean city gas supply system is one of the methods of solving this problem. At present, city gas is supplied to around 30 million homes of 146 big cities in China. However, as most medium and small cities have no city gas supply system, domestic heating sources mainly depend on direct coal combustion. It is expected that the city gas supply system for domestic use will become more widespread, will improve local atmospheric environment and the energy usage efficiency of coal.

Prof. Horio and his group proposed to build a city gas manufacturing plant producing fertilizer as a byproduct near the conventional local ammonia production factory existing in each prefecture in China. This process can meet conditions existing in each developing country since it can make use of conventional ammonia plant and is capable of a producing ammonia sulfate fertilizer which is useful for the improvement of agricultural productivity in China.

3) Desulfurization process

Most of power stations in Asian developing countries do not have a desulfurization process at present. Although some desulfurization processes are supplied from developed countries such as Japan to developing countries with the aid of ODA or Yen loans, the supplied or transferred technologies are not widespread yet in developing countries. This is because in addition to its high cost, the desulfurization process given by developed countries is not suitable for the dirty flue gas from the boilers of developing countries as it is designed for relatively clean gas from the boilers of developed countries. In particular, the limestone-gypsum process which is popular in our country will not be accepted by the developing country because it requires a great amount of water and a large scale waste water treatment facility in addition to the high cost.

The conditions of the process which can be accepted by developing countries like China are 1) Dry process 2) Low cost 3) Useful byproduct. The possible processes which can meet the above conditions are as follows;

(1) The process producing hydrogen sulfate as a byproduct.
(2) The process producing ammonium sulfate as a byproduct.
(3) The dry high efficient limestone-gypsum process.

In China, hydrogen sulfate and ammonium sulfate are very useful for agricultural fertilizer or industrial raw material. Therefore, process (1) or (2) will be broadly accepted by developing countries if it can be commercialized. Although the conventional dry process has the demerits of a low desulfurization rate and a low value of gypsum as the byproduct, the dry process (3) will be accepted if a new usage of gypsum is developed and the desulfurization rate becomes high.

4) Coal fly ash usage technology

One of the important problems of coal combustion is the treatment of the residual ash after combustion. In China, technologies for the usage of coal ash have been developed since 1950. In 1990, the amount of ash used effectively is 1.8 million tons. Usage ratio is 26.5% which is half of Japanese ratio. At present, coal ash is used for building materials such as a bricks, block materials cement and as a packing material in coal-mines, as a roadbed and as a soil improvement material which has become very popular in China recently. In future, the problem of coal fly ash treatment will become more serious with an increase in the coal consumption usage in developing countries.

For the simultaneous solution of acid rain problems and desertification, we propose a new system that is a utilization of gypsum purged by a desulfurization process for improvement of a sodium soil (Ref. 4). This system might be useful for the solution of the food problem in China as well.

3. Short Summary

The real causes of environmental problems in the developing countries are the rapid increase of population and poverty. The coal utilization technology and environmental protection technology of developed countries tend to retard the economic growth and consequently make worth the environment of developing country as the technology of developed country is high cost and needs high energy consumption. The acceptable technology for a developing country should be cheap, safe and increase the chance of employment. These technologies cannot be developed as an extension of conventional technologies. We need to develop an innovative technology on the basis of a new principle capable of meeting the different requirements of developing countries.

4. How to realize the Ecotopia Society in developing countries

In the 21st century, people hope to realize an Ecotopia Society as in Fig. 3 where the main energy sources are natural energy like solar, wind and biomass, the materials are completely recycled and where people enjoy the life harmonized with nature.

However, at present, environmental destruction is progressing rapidly especially in developing countries. For example, the increase of desert in China is averaging out at 2000 km^2 per year. The tropical forest disappears rapidly in Thailand. Another cause of the enviromentaly destruction in the developing countries is the destruction of symbiosis relationship between Town-Village-Forest. As Fig. 3 shows, farmers leave village and move to the town when the agricultural land becomes poor and the productivity

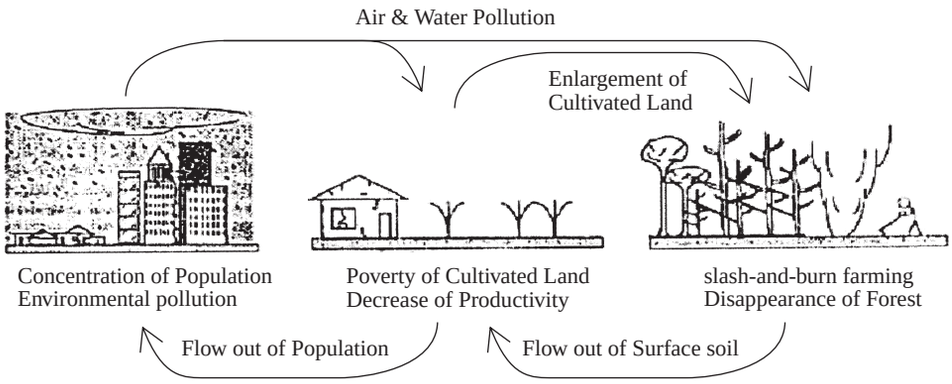

Fig. 3 Chain cycle to poverty and Environmental pollution

of crops goes down. The population of the town is increased and consequently air and water is rapidly polluted. The polluted air and water damages the agricultural land of village and forest surrounding the town. Consequently, it lowers the productivity of the agriculture field furthermore and accelerate the movement of village people to the town. On the other hand, once the agricultural land becomes poor, the farmers have to cut the trees of the forest around the village to increase the agricultural land. The decrease of forest around the agricultural land reduces the productivity of the land because the forest plays the important role of supplying natural fertilizer and protecting the water flood which removes the surface soil that is very important for ground production. Therefore, it is urgently required to stop the destruction of a symbiosis relationship and create the positive chain cycle leading to the economic growth and cleanliness of the environment.

The following are examples of technologies those can realize symbiosis relationship between town, village and forest.

5. Improvement of alkali soil by using desulfurization gypsum

Alkalization of soils has expanded rapidly in many irrigated areas of the world due to the man misuse of the land. Alkalization of soils once formed change to much poorer soils for vegetation than the case of salinization. Their adverse effects on plant growth can be attribute to impaired aeration, restricted rooting depth, interference in nutrient uptake and plant metabolism, corrosion of root surface and sodium toxicity[1)].

The total area of the alkali soils in the arid and semi-arid regions of China reaches to 320,000 km^2[2)]. The most important fact has been revealed from the recent soil surveys carried out by Japanese and Chinese soil scientists that more than 50,000 km^2 of Mollisol distributed in semi-arid regions of China are suffered from alkalization.[3)] Therefore, it will contribute to the better condition of self-sufficiency of food in China to rehabilitate these Mollisol suffered from alkalinization, because normal Mollisol shows generally high productivity.

Alkalization of soils is characterized by the formation of soils with a high percentage of exchangeable sodium; often sodium carbonate and sodium bicarbonate are present too, increasing the pH beyond 8.5, often to 9 or 10. To reclaim alkali soils, a two-step process has been done. The first step involved the replacement of exchangeable sodium with calcium; the second step is to leach the resulting sodium salt from the soil. Leaching, alone, of a calcareous soil on which a crop is growing can reclaim alkali soils but the process usually is slow. Of the amendments used to bring about exchangeable sodium replacement with calcium, gypsum (hydrated calcium sulfate) is far and away the most-used material.[4)] It has the advantage of being nontoxic to plants, easy to handle, and moderately soluble.

However, to use gypsum as an amendment material for alkali soils has badly been put into practice in

China. The main reason comes from the Chinese situation that gypsum is pressed for demands and its distribution as a soil amendment is not available. Hence, it can be considered to use a gypsum from the desulfurization process in China as an improvement reagent of sodic soil. The most spreaded desulfurization process in the developed countries is the wet lime slurry method whose byproduct is mostly pure gypsum. In the developing countries, on the other hand, a semi-dry process tends to be adopted owing to its low construction cost and running cost.

In order to examine whether the alkali soil can be improved by the gypsum at the actual alkalic field, the field experiment was carried out at the alkali soil field of Kangping Province located at 150km north from the center of Sheng Yang City (China) from May to September in 1996. Considering that the corn is the staple crop around these area, the growth of the corn on the sodic soil was examined. The gypsum from the wet process or the semi-dry process was mixed with the different mixture ratio at each unit area with the chemical analysis results of the each unit soil where unit 3 and 4 are the control area without gypsum. The gypsum powder was scattered on the ground uniformly and mixed into the soil of 20cm depth layer from the surface by the scoop.

The corn fruits were harvested 4 months after the seeding. There were no significant difference between the unit area of the gypsum from wet process and that of the gypsum from the semi dry process if the mixing ratio of gypsum is the same.

The following results were obtained:

1) 1% of the byproduct application to the alkali surface soil by weight gave the almost same yield of wheat and corn in non-alkali soils, and the once application effect continue for three years at least.
2) The pH and ESP of the alkali soil decrease to the normal level of non-alkali soils within three months from the application time of the byproduct.
3) The addition effect on the pH of the alkali soils by the contamination of $Ca(OH)_2$, $CaCO_3$ and fly ash was not recognized.

6. Recovery of forest and reduction of CO_2 by using Biobrequett

More than 70% of total SO_2 and CO_2 from coal in China comes from the small and medium size industrial boilers those are mainly storker type firnace. It is mostly impossible to facilitate the De-SOx process after each furnace because the number of this type furnace are more than 450–500 thousand in China. The most probable method for the control of SO_2 from the industrial furnace is the brequett combustion method since the emission of SO_2 can be reduced by 60–70% by mixing calcium into the brequett and the boiler efficiency can be incresed from 50% to 60 or 70% by the improvement of combustion efficiency. However, there are some disadvantages in the brequett combustion. The cost of brequett coal is 1.5 to 2 times higher than that of the raw coal and black smoke is sometimes generated during combustion.

Biobrequett is more advanced brequett which was invented by Dr. Maruyama of Hokkaido Industrial Research Center more than 20 year ago. Biobrequett has some merits as follows.

Biobriquett is the brequett in which 20–30% biomass like corn leaf or wheat straw is mixed in the brequett. The merits of biobrequett are

1) The cost becomes lower because the agricultural byproduct is free.
2) The soot emission during the combustion is significantry reduced because of easy ignition.
3) The 20–30% CO_2 emission can be reduced by mixing 20–30% biomass in the brequett.

We introduced biobrequett machine made in Japan into Shengyang and produced bio-coal with the help of Shengyang Environment Protection Agency. I hope to report the experimental result of biobrequett combustion in near future.

7. Summary

In conclusion, the most important thing to solve the environmental problem of developing countries like China is to make them rich without environmental destructions. For that purpose we should study how to develop agricultural area of developing countries from the point of view of technology and policies.

References

1) Buringh, P., Introduction to the study of soils in tropical and subtropical regions, 29–44, *Center for Agricultural Publishing and Documentation*, Wageningen (1970)
2) S. Matsumoto and M. Aoki, *Journal of the Japan Institute of Energy*, 74, 1023 (1995)
3) S. Matsumoto, Zhao, Q. G., J., Zhu, S., and Li, L., Soil Salinization and its Environmental Hazard on Sustainable Agriculture in East Asia and Neighboring Regions, *Global Environment*, 1, 75–81 (1998)
4) F. Iino, N. Aoki, Y. Nitta, S. Matsumoto and M. Sadakata, *Journal of the Japan Institute of Energy*, 76, 119–124 (1997)