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Monitoring of the global environment – Participation of Japan and other Asian countries

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Abstract- Global environmental issues are one of the most urgent problems in the present day world, not only in the field of sciences but also in the international social and political juncture. CFCs were found to deplete the ozone layer in the stratosphere, which covers the whole earth and protects the biosphere. The leakage of CFCs at any place in the world, therefore, is responsible for the biosphere. Greenhouse gases,CO_2, CH_4, N_2O, which are emerging from human activities, increase gradually in troposphere, raise the temperature and consequently make the climate change. Acid rain, marine pollution, deforestation and desertification are also the global issues.

Problems in the Asian area are particularly important and interesting in the sense that the natures and nations there full of varieties and that it covers a very large portion of the whole earth.

INTRODUCTION

In order to investigate any environmental problem, regional or global, the process of the monitoring, that is, to obtain the data of the fact with either chemical, physical or biological parameters is the first step to be performed (ref.1) After studying the results of the monitoring, the reason of the problem can be found and, therefore, the sequence of the events becomes clear, which will lead to the predicted consequence to come in next. This process of future estimation is called the environmental assessment. Monitoring and assessment is a set of procedure, therefore, to treat the problem of the environment. The actual regulatory control process may follow after the monitoring and assessment, but it is usually the part of the administration, and not of the scientists. However, in recent years, when the problems become global and the phenomena are usually unknown to anybody, often the process of monitoring, assessment and the idea of control would come as one set, which scientists should take into consideration all together.

The monitoring has long been performed in the field of meteorology, where one of popular out-comes is the weather forecast. But the parameters involved in this field are mostly physical, such as temperature, pressure, direction of wind flow etc. The measurement of these items is well established.

However, when the time of the environmental monitoring has arrived, the parameters for monitoring are mostly chemical, such as SO_x, NO_x, heavy metals, PCB etc. Consequently chemical analyses of these species consist in the major part of monitoring process. Needless to say then, the development of the methods of analytical chemistry for various chemical species in atmosphere, hydrosphere, soil and biological materials is required prior to use it for the actual monitoring. Not only for monitoring, but also for understanding of numerous environmental problems, the role of chemistry has become inevitably crucial. As the results, IUPAC (International Union of Pure and Applied Chemistry) decided in 1989 to introduce a new program of 'Chemistry and the Environment' in order to study such subjects of 1) environmentally safe chemical products, 2) reduction of levels of chemical pollutants, 3) transformation of chemical substances, and 4) their impact on ecosystems, man and climate.

Prior to it, however, International Council of Scientific Unions(ICSU) had already the Scientific Committee on Problems of the Environment (SCOPE), in the last twenty years, and more recently the International Geosphere-Biosphere Programme (IGBP) for a study of global environmental change. Various United Nations organizations are also handling the environmental problems and they include; the United Nations Environment Programme (UNEP), World Health Organization (WHO), Food and Agriculture Organization (FAO), World Climate Research Program (WCRP), World Meteorological Organization (WMO) and Man and the Biosphere Program of United Nations Educational, Scientific and Cultural Organization (MAB/UNESCO). Particularly for the global monitoring, GEMS (Global Environmental Monitoring System) has been working and more recently, IPCC (Intergovernmental Panel on Climatic Change) is very active together with GAW (Global Atmosphere Watch), BAPMON (Background Air Pollution Monitoring Network) and so forth. All or many Asian countries are participating with these international organizations related to the environmental problems, but there are other vehicles for scientists to carry out the studies in this field. Japan has bilateral research linkages with Korea, China, Thailand, Indonesia and others, and numerous cooperative projects in the field of the environment are prepared and in progress between scientists of each country, who belong to either governmental or private universities or institutes.

Modern environmental problems were said to be started when late Dr. Rachel Carson of United States published a book entitled 'Silent Spring' in 1962 (ref. 2). She made a warning for the first time through this book that synthesized agrochemicals or pesticides such as DDT and BHC had been spread carelessly into the environment, so that not only the pests themselves but also other lives of birds and animals were killed, and, as a result, many spots of beautiful American spring had become silent. In other words, total ecosystem has received serious damages. The J. F. Kennedy Administration received her warning as the true fact and later the US Environmental Protection Agency started in 1970. UNEP was established right after the UN conference on the Human Environment at Stockholm (1972), and all countries in the world had entered into the environmental age.

Global environmental problems such as ozone depletion at the stratosphere, CO_2 increase in the troposhere and acid rain were known and discussed for long time among scientists. But they became a big issue not only in the sicentific field but also among the societies and international administrations, after the governments of many countries signed for the Montreal Protocol on Substances that Deplete the Ozone Layer in 1987.

In the same year the report called 'Our Common Future' was published as the results of three years discussion among the members of UN World Commission on Environment and Development (WCED), chaired by G. H. Brundtland of Norway (ref. 3).

The keyword in this Brundtland report, that is, "sustainable development", has become very popular, and it is said to be the ultimate goal of global environmental issues. The balance between the economical development and the environmental protection is indeed needed for the future survival or sustainable development of mankind, but it is of course not easy to be realized.

The followings are the present day major global environmental problems, including the three above mentioned;

1) Ozone depletion at the stratosphere.
2) Increase of greenhouse gases (CO_2, CH_4, N_2O, etc.) and the climate change.
3) Acid rain.
4) Chemical substances and ocean pollution.
5) Decrease of tropical forest and desertification.
6) Decrease of precious biological species.

Monitoring technologies are required in all of these subjects, and so are the methods of chemical analyses. Some examples which have taken place in the world and particularly in Japan and other Asian countries will be given in this paper.

SELECTED RESULTS AND DISCUSSION

1. Stratospheric ozone depletion and its monitoring

The most enriched ozone layer locates at about altitude 20 km of the region of the stratosphere, which ranges altitude from 12 km to 50 km. This stratospheric ozone protects the lives on the earth surface due to its absorption capability of ultraviolet light from the sun. On the other hand, man-made ozone near the earth surface is called oxidant and is harmful to human body. Chemical analyses of ozone are varied according to the sample and the purpose of monitoring (Table 1).

TABLE 1. Methods for O_3 analysis

Sampling Site	Principle	Reagent, Light Source etc.	Wavelength, nm
Surface of the Earth Troposphere	Spectrophotometry	KI (neutral or alkaline)	352,365
	Electrochemical method	KI, KBr	
	Chemiluminescence	C_2H_2 etc	300-600
	UV Absorption		200-300, 254
Troposphere	Dobson Spectrometry	Sunlight	305.5, 325.4
Stratosphere	Brewer Spectrometry	Sunlight	317.6, 339.8
Total Ozone Column	Total Ozone Mapping Spectrometer	Surface Scattering (Satellite)	312.5-380
Stratosphere Vertical Variation	Spectrometry	Laser (Differential Absorption Lidar)	308, 353, 339
		Sunlight (Rocket with Sonde) (Satellite ; SBUV, SAGE)	250-340
	Electrochemical Method	KBr, KI (Sonde)	

In the year of 1974 and 1975, F. S. Rowland and M. J. Molina first predicted the stratospheric ozone depletion through the chain reaction of,

$$Cl + O_3 \longrightarrow ClO + O_2 \quad (1)$$
$$ClO + O \longrightarrow Cl + O_2 \quad (2)$$
$$O_3 + O \longrightarrow 2O_2 \quad (3)$$

in which Cl is supplied from the man-made chlorofluorocarbons (CFCs) such as CCl_2F_2, CCl_3F or CCl_2FCClF_2 (ref. 4). Concentrations of both O_3 and CFCs have been monitored at many places in the world. Clearly rising trend of atmospheric CFCs is shown in Fig. 1, for which Drs. T. Tominaga and Y. Makide of The University of Tokyo have contributed with their precise method of analysis (ref. 5).

On Sept. 4, 1982, Dr. S. Chubachi of Japan Meteorological Research Institute observed a substantial decrease of total ozone measured by Dobson Spectrometry at the Showa Station of Antarctica. This is the first observation of the 'Ozone hole' at the South Pole (ref. 6). The ozone hole has been confirmed since then by some researchers, and most remarkable observation, carried out on Sept. 16, 1987 by Dr. J. G. Anderson et al. (ref. 7), showed an exact anticorrelation between ClO and O_3 inside the hole, and convinced people that Cl from CFCs does indeed deplete ozone in the hole (Fig. 2). The argument between the dynamic theory supported by meteorologists and the chemistry theory supported by chemists, reached , then, to a compromised end, recognizing the idea of each other. The global ozone loss has been throughly re-examined by NASA Ozone Trend Panel, and figures are shown for the Northern Hemisphere (Fig. 3, ref.8). The monitoring and measurement of ozone in atmosphere should be carried out farther includidng in Asian countries and the Southern Hemisphere. Figure 4 gives an illustration of the apparatus of DIAL (differential absorption lider), which started to monitor a few years ago the vertical distribution of stratospheric ozone at the National Institute for Environmental Studies Japan. The location is Tsukuba, 60 km northeast off Tokyo, and a few observed data is shown in Fig. 5. (refs. 9 and 10).

2. Increase of CO_2 and the climate change

Carbon dioxide together with some other gases in atmosphere such as CH_4, N_2O, CFCs, and O_3 has absorption spectra in the region of IR, as illustrated in Fig. 6. Therefore, they give so-called greenhouse effect to the surface of the earth, and the increases of their concentrations will raise the temperature of the earth, which eventually cause the climate change as well as the rise in sea level. The well-known data of CO_2 in the air at Manna Loa and that of ice cores from Antarctica is shown in Fig. 7(a), together with the parallel increases of the world population and energy consumption (ref. 11). Prof. M. Tanaka and his colleagues started to monitor the CO_2 in air of Japan. Equal trends of rising CO_2 has been observed, and a part of his observation is shown in Fig. 7(b). Higher amounts near the surface of the earth indicate the

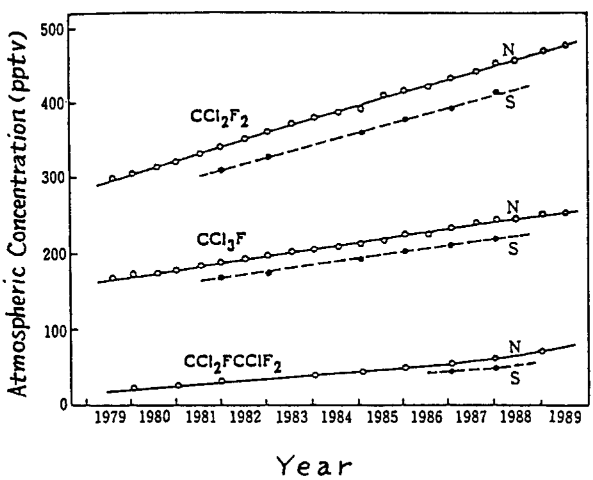


Fig. 1. Surface level atmospheric concentrations of CFCs in the Northern Hemisphere (Hokkaido, Japan) and the Southern Hemisphere (Antarctica) for the period 1979-1989. (ref. 5)
N : Northern Hemisphere S : Southern Hemisphere

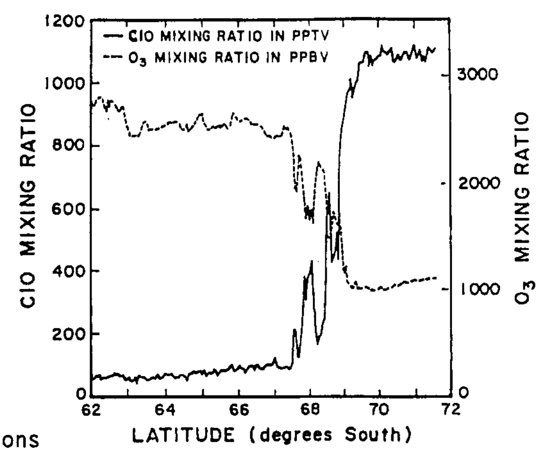
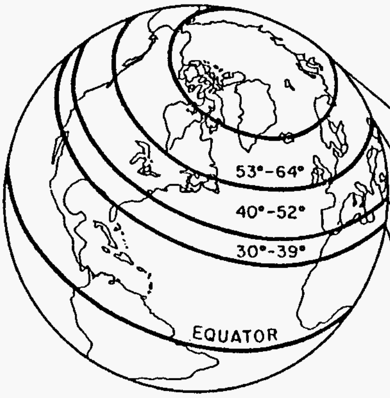


Fig. 2. Chlorine oxide and ozone concentration over Antarctica at 18 km Altitude.
Sept.16, 1987(J. G. Anderson)



AVERAGE % CHANGE 1969-86	WINTER CHANGE	SUMMER CHANGE
-2.3	-6.2	+0.4
-3.0	-4.7	-2.1
-1.7	-2.3	-1.9

Fig. 3. Changes in ozone concentration (ref. 8)

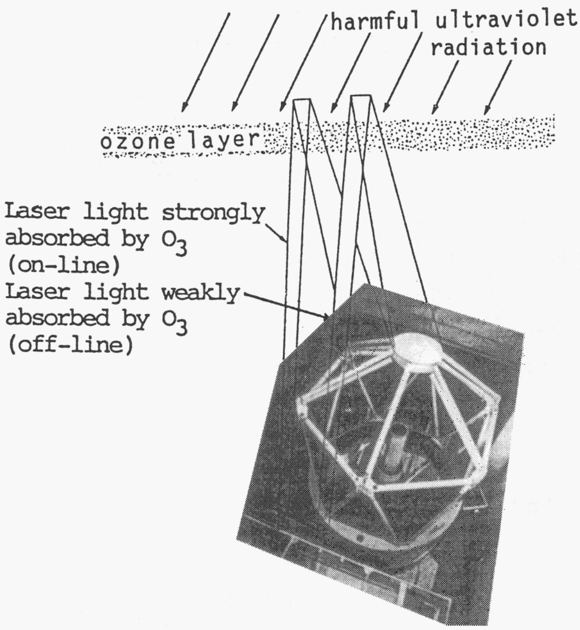


Fig. 4. Schematic diagram of differential absorption lidar for O_3 measurement (NIES, Japan)

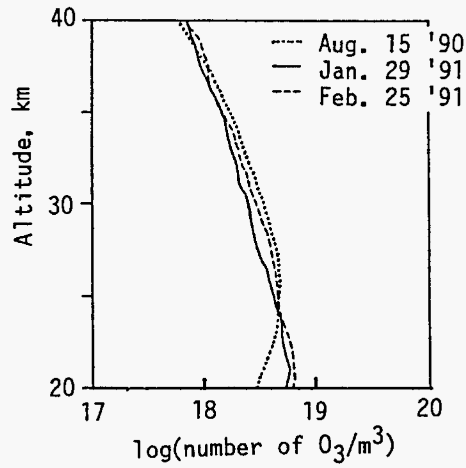


Fig. 5. Vertical distribution of ozone layer at stratosphere (NIES, Japan)

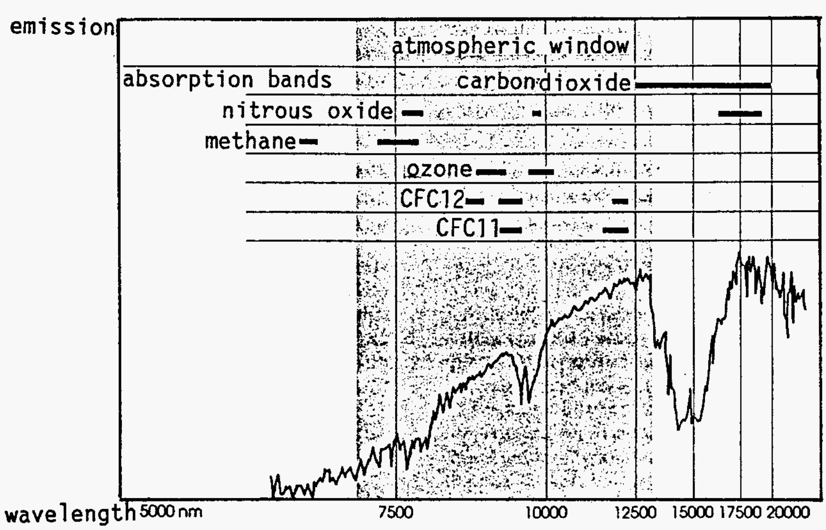
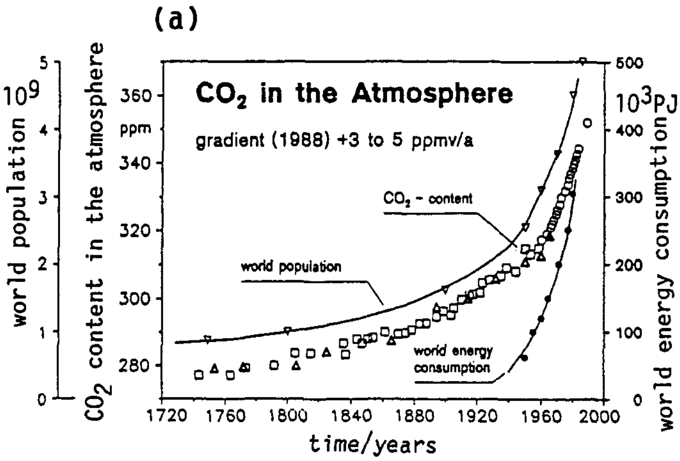


Fig. 6. Absorption bands of greenhouse gases (ref. 12)



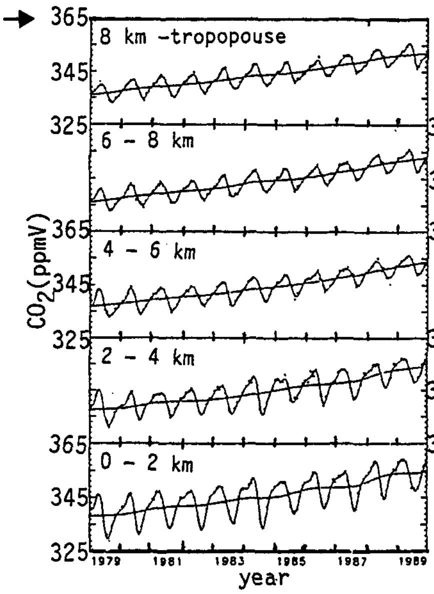
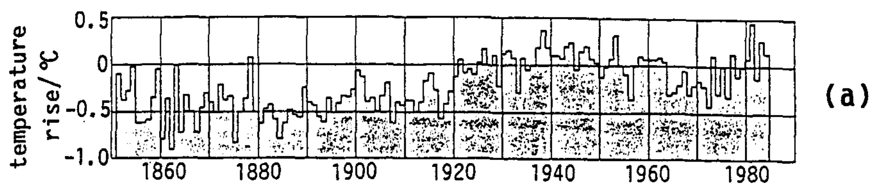


Fig. 7. CO_2 in the atmosphre (ref. 11).
(a) Mauna Loa Hawaii (○), Ice cores in Antarctica(□, △); (b) Over Japan



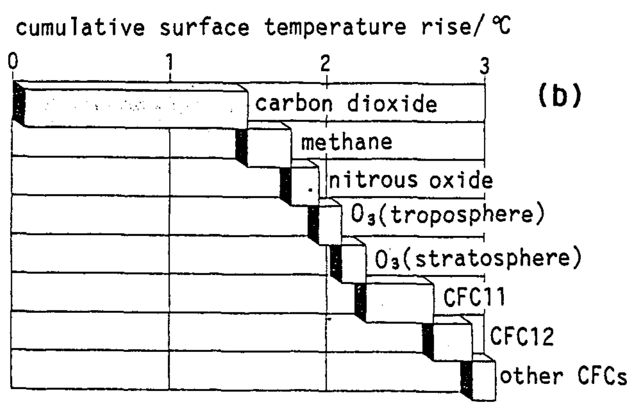


Fig. 8. Temperature rise due to greenhouse gases (ref. 12).
(a) Average annual temperature in the Northern Hemisphere.
(b) Predicted temperature rises caused by greenhouse gases by the year of 2030.

obvious source of CO_2 or the human activities (ref. 11). Observed temperature rises of the earth in last hundred years, and the predicted temperature rises by each greenhouse gas, about 3^oC all together by the year 2030, is illustrated in Fig. 8 (ref. 12).

The main methods of CO_2 analysis for its monitoring are shown in Table 2.

3. Atmospheric aerosol and Kosa phenomenon

Atmospheric aerosol is complex in its chemical characteristics such as elemental composition as well as in its physical characteristics such as size and shape. Moreover, aerosol moves by wind and causes climatic phenomena of formations of cloud and rain, and therefore it is very important for the environmental issues including acid rain.

Kosa (yellow sand) aerosol is originated from Gobi or Taklamakan desert of China, consisted of the surface soil materials and flows to the east in both spring and autumn with northwest monsoon.

Some properties of Kosa aerosol including the capability of neutralizing of acid rain were investigated (ref. 13). Aerosol sample was

TABLE 2. Methods for CO_2 analysis

Sampling Site	Principle	Reagent, Light Source etc.	Wavelength, nm
Surface of the Earth	Titration	Solution to which CO_2 Absorpted.	
Troposphere	Gas Analysis	After CO_2 Condensation	
	Non-Dispersive -Infrared Gas Analyser(NDIR)	NiCr, W Lamp	Band Filter 4200 - 4300
	High Resolution FTIR	NiCr, W Lamp Longpath Cell Tunable-Diode Laser	Vibration Rortation Bands
	Laser Spectrometer	Longpath Cell	4800-10,000 ; 1575
Troposphere (High altitude observing point ; air craft)	High Resolution FTIR (Large Grating Spectrometer)	Sunlight	Ibid
Stratosphere (Baloon, Satellite)	High Resolution FTIR Laser Spectrometer	Sunlight (Rising and Setting) Tunable-diode Laser	Ibid

collected by a high volume sampler at the Yaku Island, located 60 km off from the southern end of Kyushu shown in the map of Fig. 9. Inductively coupled plasma emission spectrometer and ion chromatography were used for the analysis of both metallic and non-metallic species in the aerosol sample respectively, and the results are shown in Table 3. The higher amounts of Al, Ca, and Fe are seen, which is the characteristics of Kosa aerosol. A portion of the Kosa aerosol was immersed into the artificial acid rain solution, the pH of which vary from 4.1 to 5.1. All solutions were found to show pH 7, almost immediately after the experiment started, and the amounts of immersed alkali and alkaline earths are given in Fig. 10. Calcium is approximately 80% of the total. Therefore, Ca in Kosa aerosol, which was found to exist as calcite form, has remarkable capability of neutralization of acid rain. It may be acting naturally to raise the pH of rain fall in large area of northeast Asia including at least partially China, Korea, USSR, and Japan.

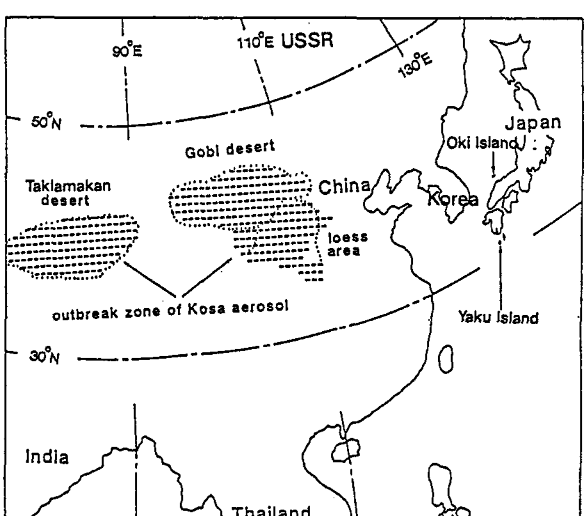


Fig. 9. Locations of sampling of aerosols.

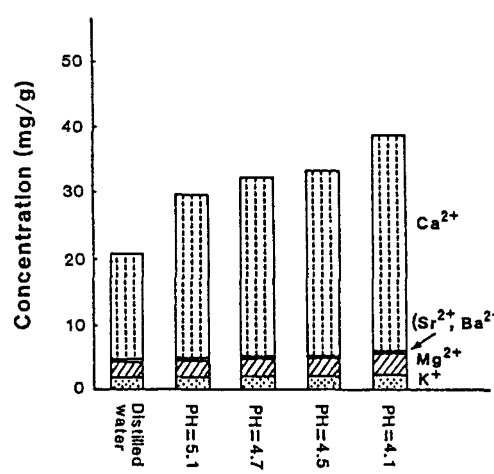


Fig. 10. Neutralization of acid rain by Kosa aerosol. (ref. 13).

TABLE 3. Chemical composition of aerosols sampled at Yaku Island and Oki Island, Japan. (Ref. 13, 14)

Sample / Composition	Kosa Aerosol[1] Yaku Island	Background Aerosol[2] Oki Island
Total	392 μg/m^3	12.2 μg/m^3
SO_4^{2-}	16.7	3.59
C	--	1.73
NH_4^+	0.753	0.51
Na	10	0.43
NO_3^-	2.87	0.114
Cl	7.6	0.045
Al	25.4	0.228
Fe	13.3	0.150
Ca	18.1	0.151
K	9.38	0.130
Mg	7.86	0.107
Zn	56.5ng/m^3	14.9ng/m^3
Pb	18.8	12.4
Ti	1250	12.4
Mn	346	5.61
As	—	3.28
Cu	72.8	1.65
V	52.7	1.58
Sr	127	1.34
Ni	--	0.903
Cd	0.35	0.276
Co	—	0.196
Sc	5.6	0.045
Cr	37.0	<2.0

1) Collected April 18-19, 1988 at Yaku Island.
2) Collected December 1983 - May 1988 at Oki Island. Arithmetic mean of approximately fifty samples is given.

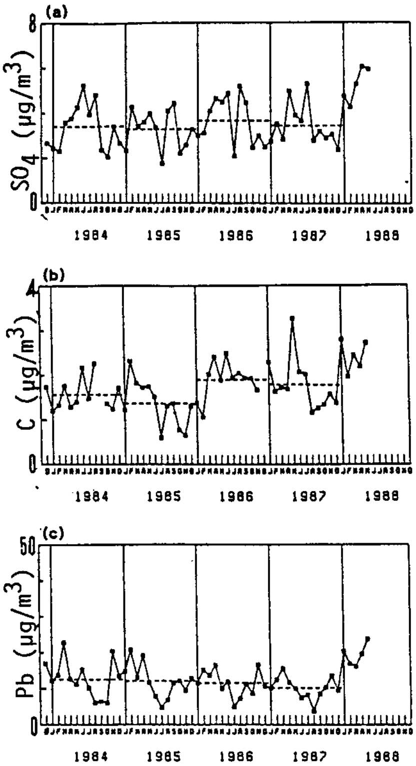


Fig. 11. Variation of (a) sulfate, (b) carbon, and (c) lead concentrations in the aerosol sampled at Oki Island, Japan.
Dashed lines are the annual averages. (ref.14)

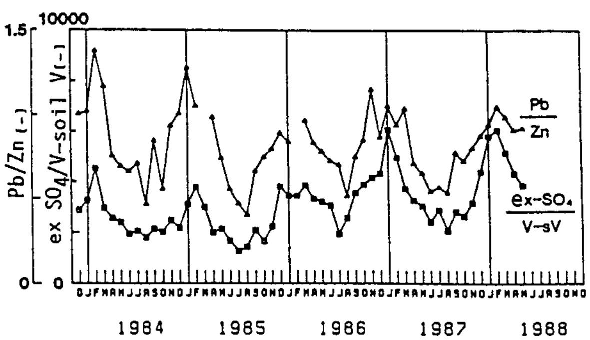


Fig. 12.
Pb/Zn, excess SO_4^{2-} /V-soil V ratios in aerosols from Oki Island, Japan (ref. 14)

Another study of aerosol has been carried out on the samples collected at the Oki Island of the Sea of Japan (Fig. 9) for the period from 1983 to 1988, in order to investigate the background level of aerosol in the area and the possible transport of the materials from both Japan and the Asian continent (ref. 14).

The average chemical composition of the aerosol is shown in Table 3. The values of all chemical species investigated do not show particularly unusual figures, and not much variations during the monitoring period, except a slight increase of C, which is shown in the curve (b) of Fig. 11. Curve (a) of the figure indicates the higher SO_4^{2-} content in all summer time, showing the possible influence from human activity in Japan which came with E-S wind. Curve (c), on the other hand, shows the slightly higher Pb values in winter, which is clearer, if Pb/Zn ratio is plotted (Fig. 12). This may indicate also the influence from the Continent but this time from the direction of China and/or Korea.

The ratio of (excess SO_4^{2-})/(V - soil V) gives a striking similarity with that of Pb/Zn, showing that these ratios instead of the value of single species may be the better indicator for environmental monitoring. These preliminary studies are uncertain yet and to be investigated further by the international group of scientists, in order to make more precise conclusions.

4. Chemical substances, HCH and TBT, in air and ocean

The number of so far synthesized compounds, most of which are organic chemicals, reached approximately one million, has been increasing everyday, and over one tenth of them are said to be in use for numerous purposes of modern human activities.

Some portion of them are inevitably released into the environment and become the pollution in air or water. When the compounds are stable, they will stay there.

Elemental and organic carbons in aerosol samples, collected on board of the research vessel "Shirase" during her voyage between Japan and Antarctica through south-western Pacific Ocean in 1988, were analyzed (ref. 15). The schematic diagram of carbon analysis system, and the results are shown in Figs. 13 and 14, respectively. There is an obvious decrease of both elemental and organic carbons, when the ship approached from Japan to Antarctica, indicating the decrease of total chemical substances released into the air.

HCH (hexachlorocyclohexane) is one of well-known pesticides but was abandoned over ten years in many countries, because of its harmful effects to ecosystem. However, the compound is volatile and stable so that it flows freely with wind, and even now can be found in global environment, besides there may be some places where the HCH is still used as the pesticide. Figure 15 is an example of monitoring results of air and surface water in the North Pacific, one of many devoted experiments of Prof. R. Tatsukawa and colleagues (ref. 16). For both cases, HCH were found much higher in northern North Pacific and even in polar regions, far away from the existing sources, suggesting the long distance transportation of this substance. The wide range transportation of chemicals can be studied by using a clearer lake as the receiver of air pollutions. Lake Mashu of Hokkaido has been studied for many years in Japan for this purpose (ref. 17).

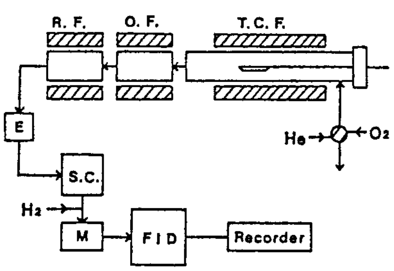


Fig. 13. Schematic diagram of the carbon analytical system.

T.C.F. : tunable combustion furnace
O. F. : oxidation furnace
R. F. : reduction furnace
E. : elimination trap for water vapor
S. C. : separation column
M : methanizer

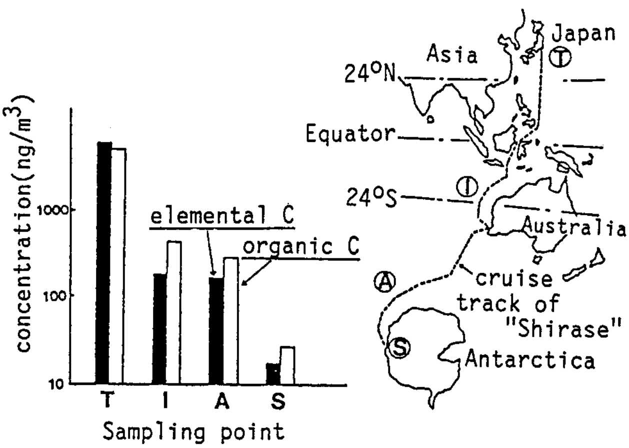


Fig. 14. Average concentration of elemental and organic carbon in the aerosol at each sampling point, and cruise track of R. V. Shirase from Japan (Nov. 15, 1988) to Antarctica (Dec. 18, 1988).

The 'mussel watch' project has been carried out for the global monitoring of ocean pollutions where bivalves such as mussel and oyster are chosen as the accumulator of pollutants. Representative results of TBT (tributyltin) residue contained in bivalves in Japan compared with those from some parts of Europe, USA and Canada, are given in Fig. 16. The results show that TBT is a common pollutant in oceans of the world (ref. 18). The replace of TBT, a biocide used for anti-fouling of fishing nets and ships, is one of urgent projects for protection of coastal ocean, similar to that of CFCs for ozone layer protection.

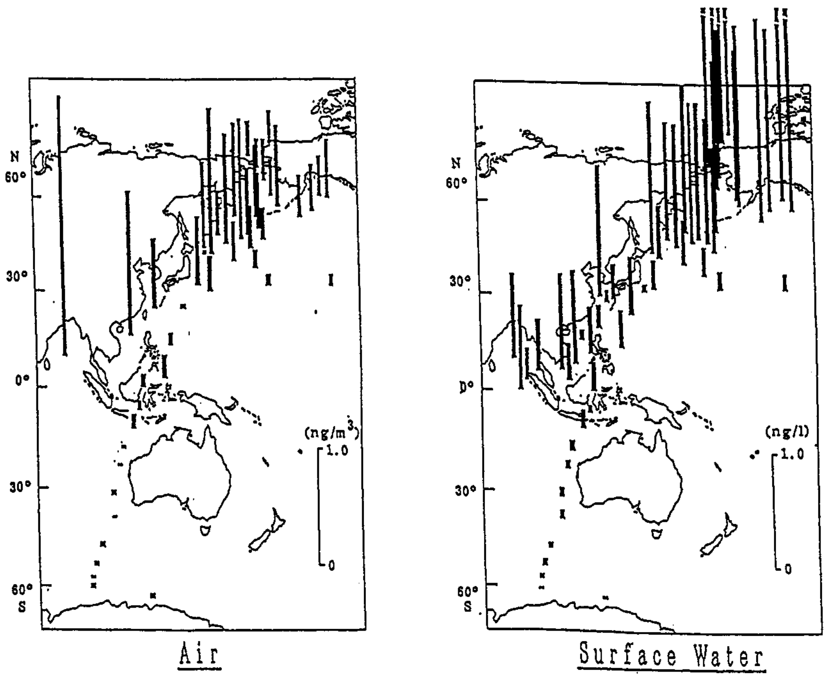


Fig. 15. Distribution of HCH concentrations in air and surface waters in the North Pacific (1989-1990).

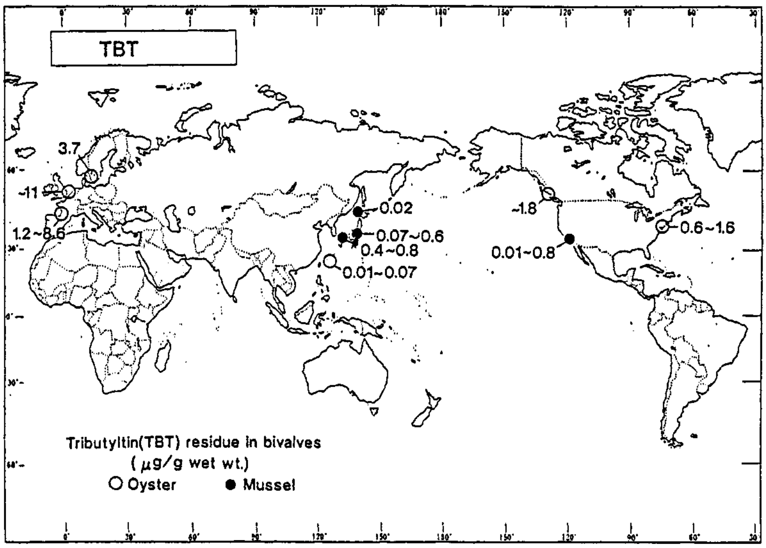
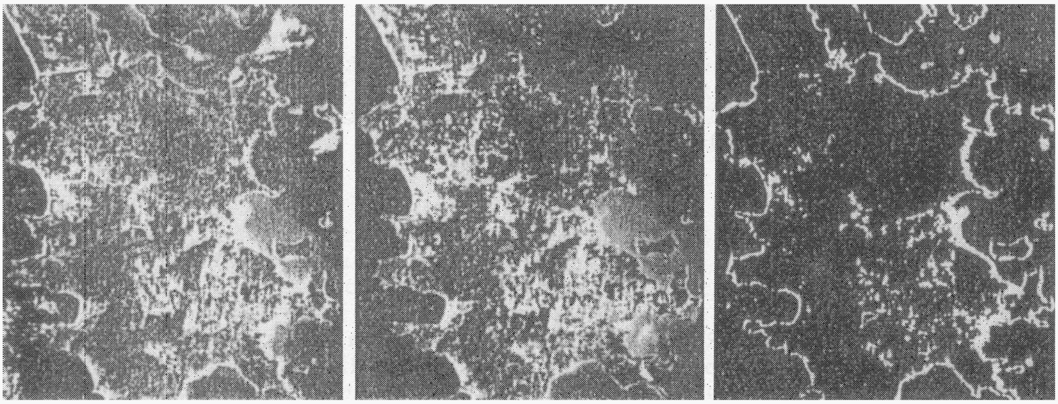


Fig. 16. Tributyltin (TBT) residue in bivalves (μg/g wet wt.)

5. Monitoring of tropical forest by remote sensing

Remote sensing using the signals from airplane or satellite provides an efficient tool for monitoring of environmental changes in a large area. Multispectral signals are to be processed properly in order to prevent the interfering factors such as water vapour and aerosol. A cooperative research has been carried out between scientists from the governmental institutes of both Thailand and Japan in last five years. A successful result of the detection of vegetation change was obtained at the Phuket Island of Thailand utilizing the Landsat MSS images (ref. 19). In Fig. 17 (c), the loss of forest or vegetation area in only one year between 1986 and 1987 is clearly seen, which is proved very close to the actual land observations.



(a) (b) (c)

Fig. 17. Change detection using LANDSAT MSS images (Phuket Island of Thailand). (a) and (b) LANDSAT MSS images for 4 Feb. 1986 and 15 Feb. 1987. (c) change detection map.

CONCLUSION AND PERSPECTIVE

The environment is defined as 'everything except me' by some group of ecologists, where 'me' could be an individual person, a group of persons, a particular region, or even one nation. When it becomes the earth itself, it is the global environment and 'everything including me' may be more appropriate definition, since there is nothing but the vacant space in the surroundings. In any case, air, water, soil and living bodies are all subjected to be investigated or monitored for solving the environmental problems.

Metals, non-metals and organic compounds should be measured utilizing various ways of analysis. Therefore, any method of chemical analysis is used for the purpose depending on the sample. A characteristic part for the global environment is, however, the atmospheric, and both stratosphere and troposhere should be observed. Spectroscopic techniques are usually appropriate, because often the sample is not obtained at hand. Then so-called remote sensing has to be applied and it may not be called chemical analysis, although the species to be detected is always chemical. The precision and accuracy concept in analytical chemistry may not be applied in such remote measurement, but it should not be ignored but tried if the method is available. Checking the stratospheric ozone content measured by lidar with baloon carrying chemical method is a good example. Moreover, monitoring of higher atmosphere by the sensors on the satillite will be expanded farther in near future.

Similar way of study of the ocean may be required in future as the analysis or monitoring of either deep or remote sea water will be needed, where the in situ measurement without sample is inevitable (ref. 20).

In other words, for the future monitoring of global environment, fundamental analytical sciences need to be developed further with the multidisciplinary principles beyond the analytical chemistry alone.

Considering the whole world, the Asian area including the West Pacific Ocean shares, of course, a most important part of the global environment. The countries located there vary in the sense of both natural circumstances and human activities. One can consider it from positive and negative point, in terms of environmental protection. In other words, still growing economical development may make larger emission of pollutants such as SO_x, NO_x, and CO_2, but on the other hand, large forest area is remaining and contributes on environmental protections as the sink for CO_2 and the reservation of precious biota. Monitoring, assessment and the proper control of the environment of Asia ought to be studied and developed much further through the cooperations of all countries involved.

The balance of these apparently contradicting two items, reservation of nature and activity of mankind, are to be achieved, thereafter, in order to make the real 'sustainable development' in the Asian area as well as in the whole world.

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REFERENCES

1. R.E. Munn, Global Environmental Monitoring System, ICSU-SCOPE (1973): K. Fuwa, et al. ,trans., CEIS, Japan (1975)
2. R. Carson, Silent Spring, H. Mifflin Co., Boston (1962)
3. UNWCED, Our Common Future, Oxford Press, Oxford (1987)
4. M.J. Molina, F. S. Rowland, Nature, **249**, 810-812 (1974); F. S. Rowland, M. J. Molina, Rev. Geophys. Space Phys., **13**, 1-35 (1975)
5. T. Tominaga and Y. Makide, Nippon Kagaku Kaishi, 351 (1991)
6. S.Chubachi, Dordrecht, Holland, D. Reidel, Ed., 285-289 (1984); Gakushikai Report, **786**, 139-143 (1990)
7. J. G. Anderson, et al., J. Geophys, Res., **94**, 11465-11479 (1989)
8. F. S. Rowland, Proc. Fukuoka Inst. Sym., 11-18 (1990)
9. K. Fuwa, Sym. Public's Perception of Chemistry, PACIFICHEM '89
10. H. Akimoto, et al., Ann. Report, Environmen Agency, 17 (1991)
11. K. H. Kim, Proc. Fukuoka Int. Sym., 43-49 (1990); C. J. Winter, Hydrogen Energy Progress VIII, Vol. 1, 3-47, Pergamon press, New York, 1990 ; M. Tanaka, et al. Tellus., **39B**, 29-41 (1987)
12. UNEP/GEMS Environment Library, **1**, 12 ; **2**, 25 (1987)
13. M. Nishikawa, T. Mizoguchi, et al., Weather, **38**, 39-46 (1991); J. Aerosol Research Japan, **6**, 157-164 (1991)
14. H. Mukai, Y. Ambe, and K. Shibata, Atmospheric Environment, **24A**, 1379-1390 (1990)
15. M. Nishikawa, S. Kanamori, et al., Proc. NIPR Symp. Polar Glaciol., **4**, 52-57 (1991)
16. R. Tatsukawa, MAB-UNESCO, Japan Report, 39-46 (190-1991)
17. A. Otsuki, et al.,Res. Rep. NIES, **79**, 37-44(1985)
18. M. Morita, personal communication
19. Y. Yasuoka, Y. Iikura, et al., Proc. 9th Asian Conf. on Remote Sensing, Bangkok, G-3-1-6 (1988), Int. J. Remote Sensing, **12**, 55-67 (1991)
20. K. Fuwa, Science, Iwanami **60**, 290-294 (1990)