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In: "Progress in Environmental Research"
Editor:
Irma C. Willis
ISBN:
978-1-60021-618-3
2007

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In: Progress in Environmental Research
Editor: Irma C. Willis, pp. 263-278
ISBN 978-1-60021-618-3

Chapter 9

EPIDEMIOLOGY AND ENVIRONMENTAL POLLUTION: A LESSON FROM YOKKAICHI ASTHMA, JAPAN

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ABSTRACT

Serious environmental problems occurred in the process of rapid growth of economy after World War II in Japan, including three water pollution (Kumamoto Minamata Disease, Niigata Minamata Disease, Itai-Itai Disease) and one air pollution (Yokkaichi Asthma), which had been called the Four Major Pollution in Japan.

Attention to Yokkaichi Asthma came from increasing patients of chronic obstructive pulmonary disease, such as bronchial asthma and chronic bronchitis, caused by very high concentration of SO_2 in the air. This problem occurred since around 1957, and was continued for about 20 years. By regulation of total emission of sulfur oxides from 1972, SO_2 concentration decreased greatly and the pollution problem was solved. In this article, many precious experiences in Yokkaichi Asthma are described.

1. INTRODUCTION

Japan lost about 80% of its industrial productivity in World War II by stoppage of import of industrial materials, such as oil, iron and bauxite, by attack of U.S. Navy submarines, and by large-scale bombing on about 200 cities by B29 bomber. The industrial production in 1945 of Japan decreased to the level of Taisho age (around 1910).

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However, the level of industrial production returned to that of prewar days in 1955. Till the end of the 20th century, annual growth rate of industrial production was exceeding 10~15%, and the period called "high economic growth" continued.

At this stage new industries were created to respond to technical innovations in U.S. or European nations. As a one leading field, large-scale petrochemical complex using Middle East crude oil was established in Yokkaichi, Mie Prefecture.

Since consideration given to environment was lacked in such great expansion of industrial production, serious environmental problems were caused, i.e. Yokkaichi Asthma (chronic obstructive pulmonary disease, COPD, by SO_x pollution), Minamata Disease (methyl mercury poisoning) of Kumamoto and Niigata, and Itai-Itai Disease (cadmium poisoning).

This article describes the discovery, way of aiding the patients, and solution of Yokkaichi Asthma.

2. THE DEVELOPMENT OF YOKKAICHI ASTHMA

Figure 1 shows the outline of oil complex built first in Yokkaichi (Shiohama district). From starting operations of the complex(1957), many patients had come to Shiohama Hospital, affiliated with Mie University Medical School, located in this district, complaining "a cough comes out," "sputum coming out," "a throat being painful," and "it being unable to sleep" by asthma attacks. The problems were also seen in Isozu, Mihama, and Akebono districts which were next to the complex. It was observed for about half a year including winter especially in Isozu district that was the lee of industrial complex.

The unusual frequent occurrence of asthma among the aged 50 years or above in Shiohama district raised questions, i.e., "Was it by chance?," "by unknown cause in this area?" It was thus necessary to conduct an extensive epidemiological investigation.

We investigated the Health Insurance Claim (called receipt) submitted to Yokkaichi City by each medical institution by the National Health Insurance Program [1]. Thus, with consent and assistance of Yokkaichi City, the incidence of illnesses of residents on respiratory diseases was surveyed, in 13 districts of the city.

Figure 2 shows the monthly rate of consultation of asthmatic disease among aged 50 years or above in Hobo (Mie) located far from the industrial complex and Shiohama districts. The rate of consultation showed changing in constant width at approximately around 0.5% level in Hobo. However, in Shiohama, the rate of consultation went up every month and increased 5~6 times at the end of study period.

Figure 3 shows the rate of consultation of asthma by sex and age. The ratio in the aged 50 years or above who lived near the industrial complex was particularly high, i.e. nearly 10 times of those in the control area.

Isozu district with the population of about 2,800, located in south of the industrial complex, showed the highest prevalence in Yokkaichi. Number of cases of asthma was expected to a few for this population size among the middle aged or elderly; only two cases were observed before operation of industrial complex. However, the number of patients reached 66 in 1963, as shown in Table 1, with unusual prevalence in the aged 50 years or above.

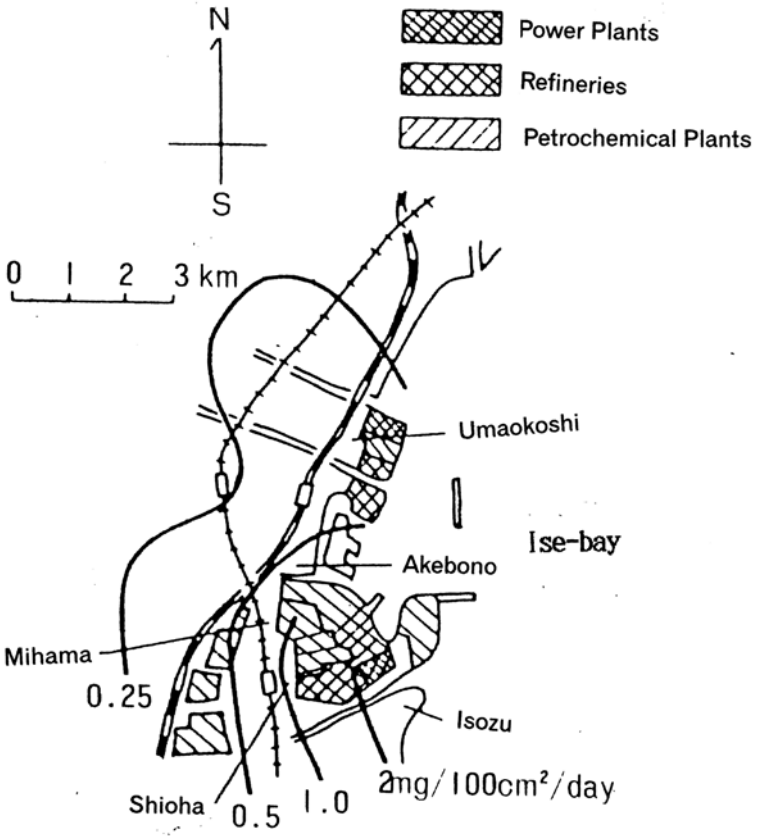

Figure 1. Shiohama oil industrial complex built first in Yokkaichi [1].

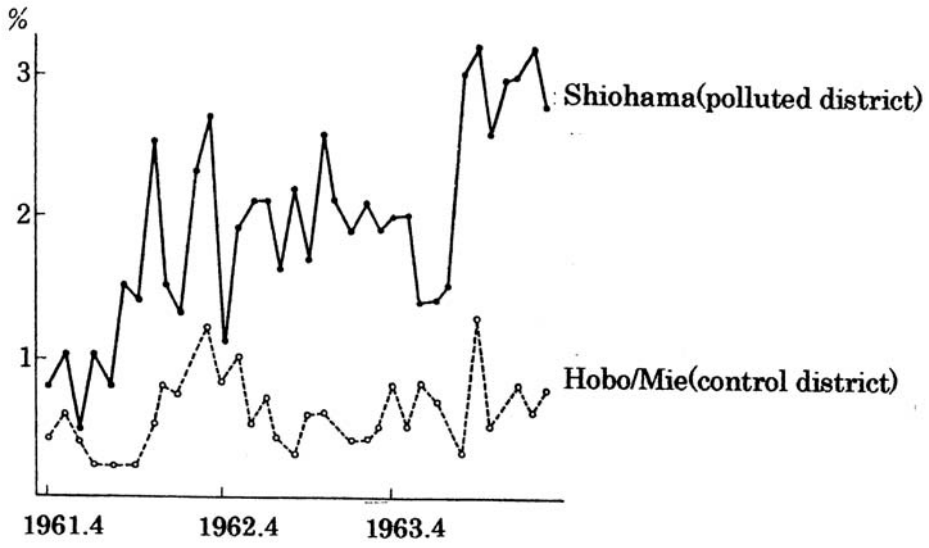

Figure 2. Monthly rate of consultation of asthma [1].

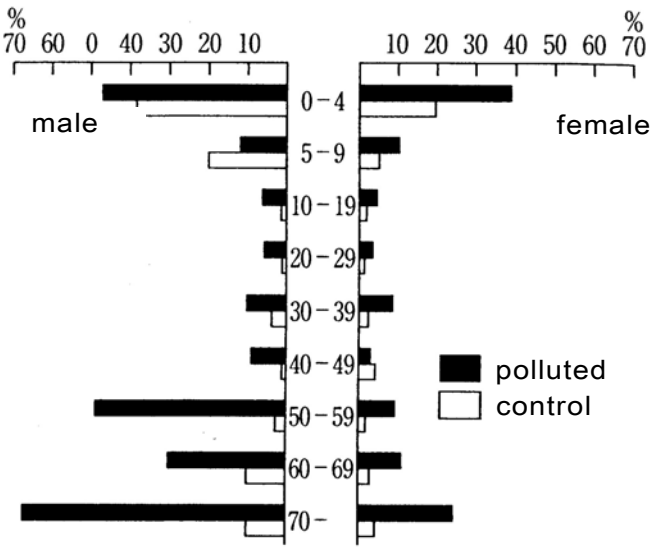

Figure 3. Annual rate of consultation of asthma by sex and age [2].

What was the reason for such high incidence of asthma? An investigation on occupation and life situation of patients revealed no particular causes. However, unusually high concentration of SO_2 was observed in Isozu district, as shown in Figure 4. Eleven observation points of air pollution were established in Yokkaichi; the amount of dust-fall, which was an index of air pollution in Britain, and SO_2 concentration (PbO_2 method) was measured. As shown in Figure 5, a strong "dose-response relationship" was seen between SO_2 concentration and incidence of asthma.

Table 1. Asthma patients in Isozu district (as of 1963) [3].

Age group	Population	Number of patients	Percentage
0-4 years old	261	1	0.38
5～9	276	3	1.09
10～19	509	1	0.20
20～29	612	4	0.65
30～39	467	8	1.71
40～49	260	8	3.08
50～59	210	17	8.10
60～69	148	10	6.76
70～79	47	13	27.66
80 years old or more	25	1	4.00
Total	**2,815**	**66**	**2.34**

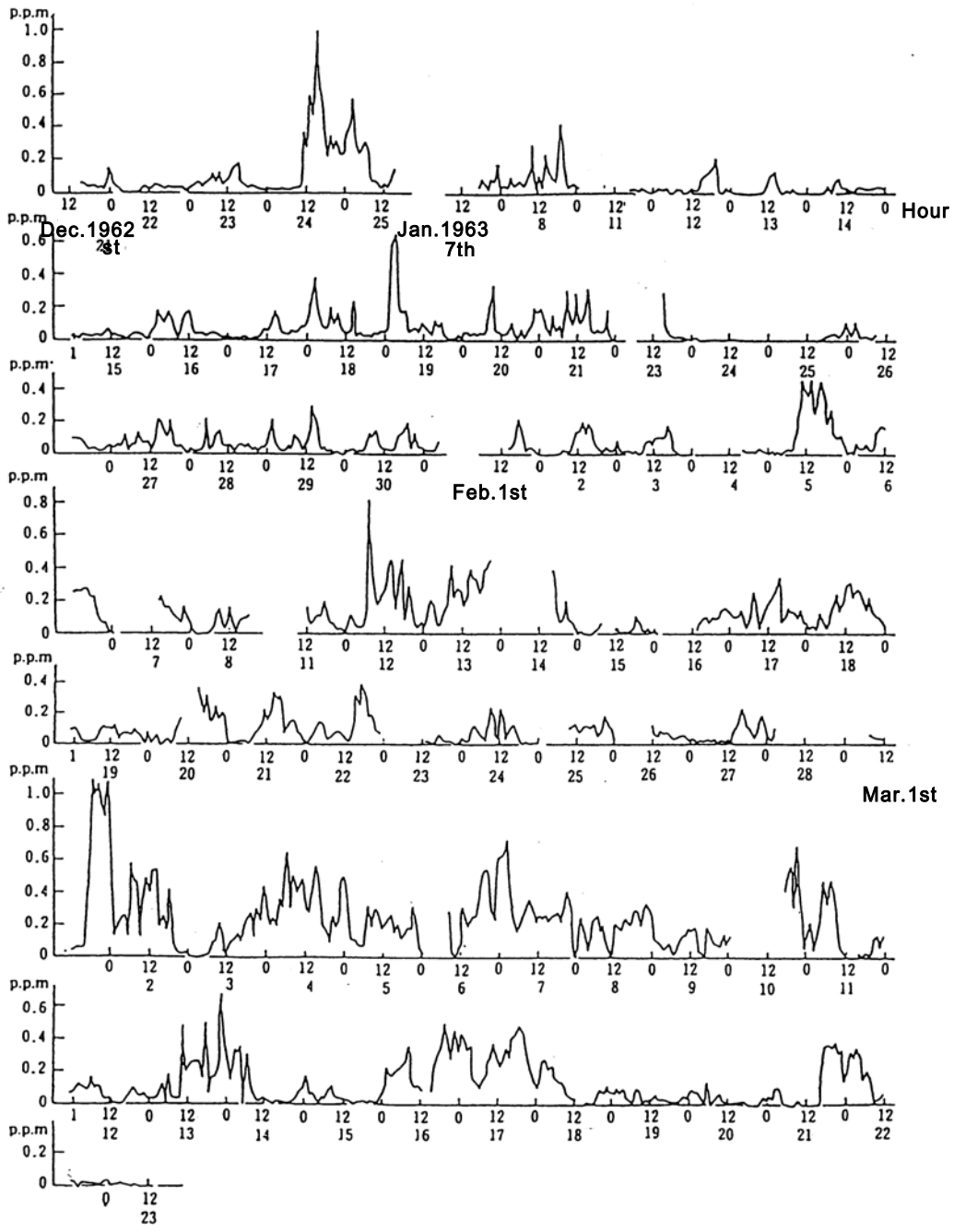

Figure 4. SO_2 concentrations in Isozu (1963.12-1964.3) [2].

The Middle East crude oil used in industrial complex had as high as about 4% of sulfur content. Therefore, SO_2 concentration around petroleum industrial complex unusually elevated. The total emission of SO_2 from the all factories were estimated at 120,000~200,000 t/year.

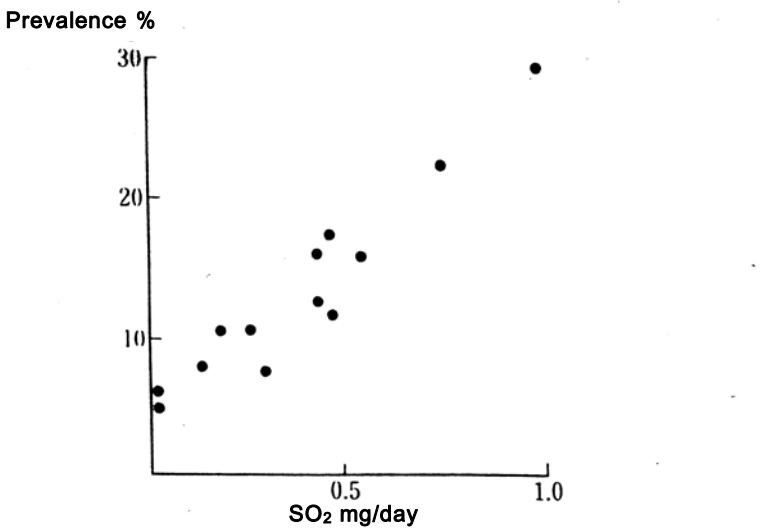

Figure 5. Yearly accumulated prevalences of asthma and sulfur oxides concentrations [1].
The prevalences over 50 years agers of enlistend to National Health Insurrance system in 13 districts and sulfation-rates(PbO2-method,Mar. 63'-Apr.64')

3. CLINICAL FEATURES OF PATIENTS IN ISOZU DISTRICT

Table 2 shows the medical checkup results of asthma patients in Isozu district. As in this table, intracutaneous allergic reaction was negative for most of the cases. This rate was very low in contrast to the observation that intracutaneous allergic reaction to house dust was positive among 60% of asthmatic patients.

Most of the patients developed the disease less than four years after industrial complex operation, except for two cases with ten years of history and three unknowns. Nevertheless, in many patients, the forced expiratory volume one second percent was depressed gratefully. Patients with pulmonary P in electrocardiogram were seen, suggesting seriously impaired cardiopulmonary function.

Also, only seven cases had history of asthma in relations. On the other hand, the spouse had the same disease for four cases, which may be attributed to an environmental factor such as living in the same house, sharing pollution rather than heredity relations.

Table 3 shows the characteristics of asthma patients found in Isozu. As in Figure 6, asthmatic attacks increased especially during the period when SO_2 concentration was high. Moreover, when patients left Isozu district, they showed the remission.

The clean air rooms with charcoal air filter (98% of rates of SO_2 removal) were placed in Shiohama Hospital aiming at an improvement of clinical conditions of patients [4]. The result was shown in Figure 7.

The patients were divided into two groups. One was suffered from asthma before the operation of industrial complex (i.e., not related to air pollution). The other developed asthma after the operation started. As in Figure 7, effects of air filtration (SO_2 elimination) were remarkable in patients of the later group.

Table 2. Medical checkup results of asthma patients in Isozu district(January 1964) [2].

	Age Gender	Allergic reaction		Eosin in blood	Vital capacity (after inhaling alotec)	Forced expiratory volume one second percent (after inhaling alotec)	Views on electrocardio gram	Family history	Phonacos copy	The number of years after the development of asthma	Peak flow
		Allergic reaction	Tatami matting								
1	52♂	−	−	0	60 (61)	100 (100)	Pulmonary P			4	240
2	73♂	−	−	8	96 (100)	45 (70)		Grandchild	Dry rale	3	187
3	57♀	−	−	3	70 (70)	60 (90)	Pulmonary P	Husband	Rough	3	100
4	58♂	−	−	4	66 (73)	55 (58)		Wife	Rough	3	180
5	72♂	−	−	2	66 (68)	50 (57)				10	186
6	31♀	−	−	6	58 (60)	66 (76)				4	120
7	70♂	−	−	1			Myocardial		Rough	0.5	
8	59♂	−	−	4	95 (95)	67 (86)	infarction		Rough	1	400
9	63♂	−	−	0	68 (75)	88 (98)	Pulmonary P		Rough	1	380
10	59♂	−	−	2	75 (82)	58 (58)	Coronary insufficiency		Dry rale	2	200
11	54♀	−	−	0	84	53		Husband		Unknown	260
12	32♂	−	−	6	91 (96)	60 (73)			Dry rale	1	
13	69♂	−	−	0	87 (100)	58 (64)			Rough	10	180
14	53♂	−	−	2	100 (105)	69 (81)			Rough	1	260
15	76♀	−	−	3	65 (65)	80 (82)		Younger sister	Rough	Unknown	100
16	49♂	++−	−	1	78 (78)	87 (94)	Pulmonary P	Wife	Rough	1	360
17	63♀	−	−	2	68 (68)	82 (87)		Grandchild		1	360
18	32♂	−	−	9	105 (105)	81 (83)			Dry rale	2	340
19	12♂	+	−	6				Grandfather	Dry rale	3	160
20	62♂	−	+	1	73 (78)	45 (75)		Grandfather	Dry rale	1	260
21	55♂	−	−	1	73 (80)	72 (89)	Pulmonary P		Rough	1	460
22	76♂	−	−	1	78 (80)	54 (60)				0.2	
23	63♂	++	−	7	98 (98)	63 (71)	Pulmonary P	Mother	Rough	0.2	340
24	8♂	−	−	10				Grandfather		5	120
25	61♂	−	−	1	74 (78)	62 (82)	Pulmonary P LAD LVH			3	335
26	37♂	−	−	8	95 (95)	66 (88)	Pulmonary P		Dry rale	1	340
27	75♀	−	−	3			LAD	Unknown	Rough	Unknown	
28	54♂	−	±	2	92 (92)	88 (88)				1	270
29	28♀	−	+	5	80 (80)	60 (70)			Dry rale	3	320
30	46♂	−	−	6	78 (78)	66 (87)			Dry rale	3	385
31	68♂		−	6	94 (100)	62 (71)				1	480

Table 3. The characteristics of asthma patients in Isozu[2].

1. The incidence is relatively high among elderly and males.
2. The hereditary history is weak and intracutaneous reaction by house dust is almost negative.
3. There are many patients who smoke heavily (average: 23.1 cigarettes/day), but asthma also occurred with nonsmokers.
4. There is a great frequency of asthma attacks in periods when SO_2 is high.
5. When patients left the district, they began to have clear temporary remission.
6. The disease began to occur relatively suddenly in most cases.
7. Although patients react to a bronchodilator, the reaction is relatively low compared with classic asthma.
8. Leukocytosis is recognized, and patients often show abnormality in a liver function test (serum protein reaction).
9. Asthmatic sputum component is not recognized, and the degree of appearance degree of eosinophilic cell is low.
10. About one-thirds of patients showed pulmonary P in electrocardiogram (EKG), and had a tendency of moving to P wave in a relatively short period after the development of asthma.

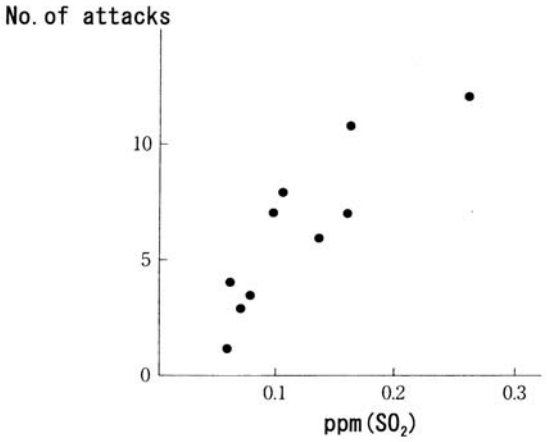

Figure 6. Number of asthmatic attacks and average weekly SO_2 concentrations in Isozu (13 cases, Jan.-Mar.1963) [1].

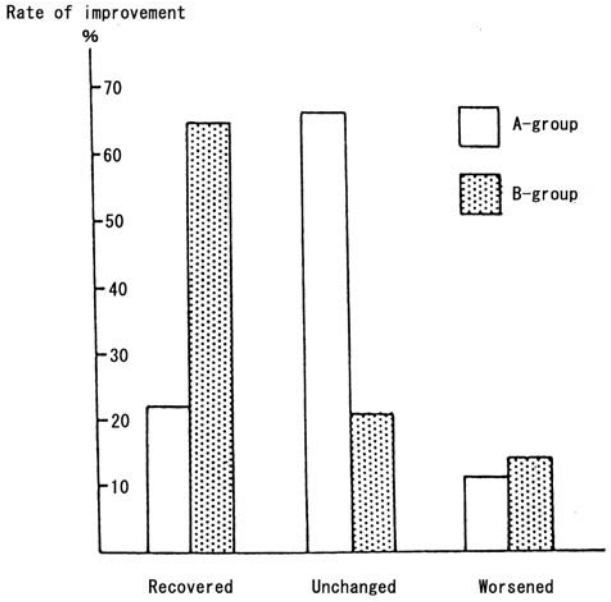

Figure 7. Pulmonary symptoms of the patients hospitalized in the clean air room[2].
A-group: Patients who suffered from asthma before the petroleum-complex started its operation
B-group: Patients who developed asthma after the operation started

4. INCREASE OF CHRONIC BRONCHITIS

Thus, bronchial asthma was increased by air pollution. The health problem was not only bronchial asthma but also chronic bronchitis characterized mainly by stubborn cough and

sputum. In Japan, it is warm as compared with Britain and Northern Europe; chronic bronchitis was less seen. Thus, only few clinicians were concerned with this problem.

After finding the problem of air pollution in Yokkaichi, chronic bronchitis had been worthy of noticing. In Yokkaichi and Osaka, prevalence of chronic bronchitis was surveyed by the Ministry of Health and Welfare using British Medical Research Council's Committee on the Etiology of Chronic Bronchitis-questionnaires (BMRC).

Figure 8 shows the prevalence of chronic bronchitis by BMRC questionnaires. In Yokkaichi, differences in prevalence of chronic bronchitis between polluted and non-polluted areas were greater than those between polluted (Nishi-Yodogawa-ku) and non-polluted areas in Osaka.

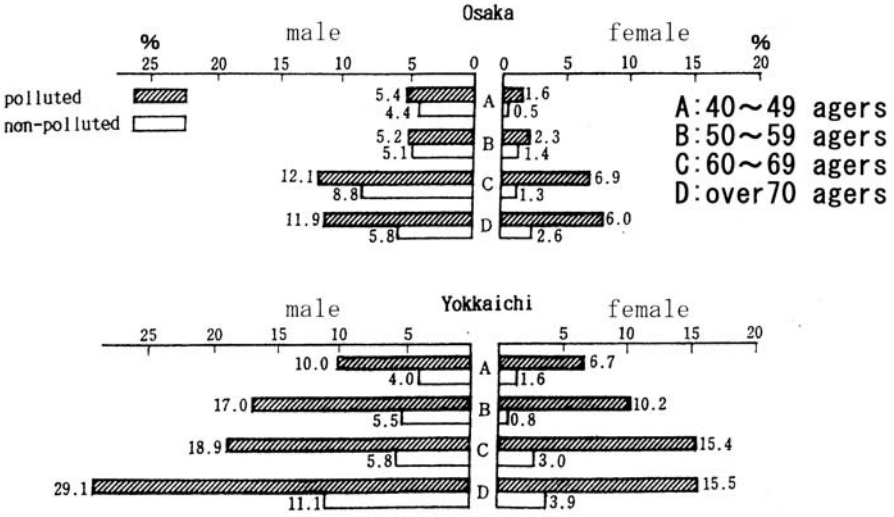

Figure 8. Prevalences of chronic bronchitis by BMRC-questionnaires[2].

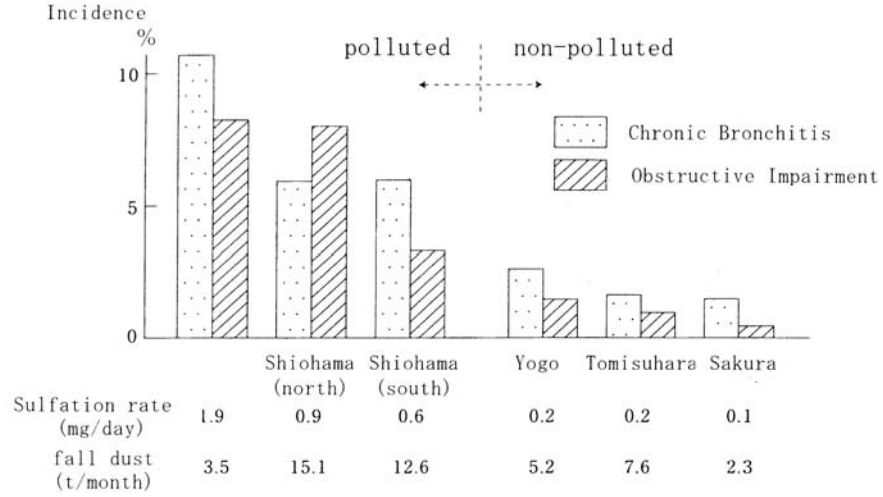

Figure 9. Health effects of air pollution estimated by BMRC-questionnaires and pulmonary function test[5].

Figure 9 shows the adverse health effects of air pollution evaluated by the BMRC questionnaires and pulmonary function test. They were increased with SO2 pollution.

5. INAUGURATION OF MEDICAL AID PROGRAMS

The Medical Aid Program for air pollution was established by Yokkaichi City for the first time in the world. Later, this program was expanded to the national one, resulting in "Pollution-Related Health Damage Special Measures Law."

Installation of the program was due to an increase of asthmatic and chronic bronchitis patients, who needed assistance for medical expenses. However, bronchial asthma and chronic bronchitis were the diseases which had existed since ancient times. It became a matter how their relations to air pollution were authorized.

It was a fact that there was an excessive out break of asthma in air pollution area in Yokkaichi. The distinction between these asthmas and classical ones by clinical conditions was impossible. Asthma was common disease in contrast to Minamata Disease, which was defined as methyl mercurially poisoning. Therefore, it was unable to make a specified standard for diagnosis.

Then, "Law Concerning Medical Service for the Atomic Bomb Exposed" was considered as a good guide to the program for Yokkaichi cases. Patients with cancer such as leukemia increased greatly in the atomic-bombed areas, Hiroshima and Nagasaki, in Japan. Leukemia and other cancers were seen before the exposure to atomic bomb; clinical conditions were not different between ordinal leukemia and atomic-bomb induced one. The situation was similar to the relation between air pollution and Yokkaichi asthma.

In “Law Concerning Medical Service for the Atomic Bomb Exposed,” the areas where leukemia occurred excessively were specified; medical aid program was taken to the patients within these areas. Thus, medical expenses of patients who met the following three criterions were paid by the program for Yokkaichi cases.

1) With Specified Disease: Diseases (bronchial asthma, chronic bronchitis, pulmonary emphysema, and their complication), of which excessive occurrence in the polluted area had been confirmed epidemiologically.
2) In Specified Area: Areas where prevalences of the specified diseases had been increased.
3) During Specified Period: Three years of residence in the specified area (prevalence of the above diseases reached to the maximum, 10~15%, in populations 3 years after their migration to the specified areas).

Yokkaichi City decided that those who met the above 3 conditions should be recognized as the certified patients, and asked Ministry of Health and Welfare for the aid of medical expenses. However, it was not approved; Yokkaichi City had to carry out the program since June, 1965, by them.

For about one year later, public opinion against air pollution changed greatly. Ministry of Health and Welfare agreed to make payment as experimental and research expenses to the

program of Yokkaichi City. Two years after, the "Pollution-Related Health Damage Special Measures Law" was enacted and enforced (1969).

6. YOKKAICHI POLLUTION SUIT

Medical aid programs for the patients were invoked as mentioned. However, remedy remained as a social problem for patients of bronchial asthma in the middle aged and elderly with impaired lung function. Improvement of clinical conditions could not be expected under the situation where air pollution was continued. Recurrent asthmatic attacks caused numbers of shocking incidents of suicide. As a result, a great number of people insisted that a powerful social movement was necessary for the elimination of air pollution.

Citizens' campaign raised a lawsuit against Yokkaichi pollution in September 1967 for the patient, who had been suffered from serious damage. They also wished to perform vastly and radical reform of the measure against air pollution. Nine patients of Isozu district agreed to become the plaintiff and the complaint was submitted to the Tsu District Court Yokkaichi branch.

The lawsuit was taken based on Article 719 (joint tort) and Article 709 (illegal act) of Civil Code. Here, two major issues were raised. One is the legal causal relationship between air pollution mainly due to SO_2 (possible cause) and the infringement of the right of health (having become sick) in 709 articles.

Yokkaichi City paid half of the medical bill of the patients certified according to the above-mentioned three criterions. The city carried out resident protection rather than investigation of the cause of disease. The causal relationship between the self-inflicted causing (development of air pollution) and the infringement (development of disease) in Article 709 of Civil Code needed arguments. The dispute in medical and law fields started on the ability of epidemiological causal relationship as legal causal relationship in Article 709 of Civil Code.

The second issue was that exhaust emission from the six companies (power plant which used petroleum with high sulfur content, petroleum-refining places, and petrochemical factories) were mixed, polluting Isozu and other districts. Therefore, it was impossible to relate each smokestack’s exhaust emission to each patient. It was an issue whether this could be recognized as a joint tort determined by Article 719 of Civil Code.

These issues had hardly been discussed though they were fundamental about the responsibility for air pollution. Whether the opinion by the plaintiff accepted was important; this might affect measures against air pollution, especially environmental pollution control by the Government. Output of air pollutant was scarcely controlled by Air Pollution Control Law at that time.

The causal relationship which was argued in the Yokkaichi lawsuit attracted attentions. A great number of medical scientists and the Civil Code scholars concerned this matter and many editorials were published in mass communications and law magazines.

In such situation, Yoshida wrote a paper entitled "Epidemiological Causality and Legal Causality" in “Jurist”, which was the most leading law magazine in Japan [6]. He insisted that the epidemiological causality satisfied causation of Article 709 of Civil Code enough. This gained popularity support of the Civil Code scholars. Judgment was given based on the

epidemiological causal relationship; the plaintiff (patient side) won the case. The defendants (company side) obeyed this judgment and gave up the appeal.

7. IMPLEMENTATION OF TOTAL EMISSION CONTROL

The Yokkaichi pollution suit attracted much attention in Japan; nearness the trial finished, winning the case of a complainant was expected mostly. The conclusion of trial also led to change of measures against air pollution in Yokkaichi.

Mie Prefecture established the project team with Yoshida, director of Mie Pollution Control Institute (Public Health and Environment Research Division, Mie Prefecture Science and Technology Promotion Center, at present), as the person in charge to improve the air pollution.

Until then, only building high smokestacks had been the measure against air pollution. There were no essential measures for eliminating contaminations (e.g. desulfurization, and changing of fuel). High smokestacks decreased concentration of SO_2 near the industrial complex. However, they spread SO_2 in wide areas; pollution was increased in areas far from huge plants (industrial complex) because pollutants of high concentrations were combined.

To find the way out from this problem, the only possible solution was control of total SO_2 emission. It was necessary to cut down the total emission to reduce the environmental level lower than an acceptable limit which was the level by which no excessive COPD incidence was expected based on epidemiological survey (annual average of 0.017 ppm over the whole area in Yokkaichi City).

However, there was a problem of desulphurization, which was unsolved to practical use. The cost of desulphurization was higher than building high smokestacks. Moreover, there were about 400 smokestacks with varying height which had different amounts of emission in Yokkaichi district. Therefore, in order to cut down the emission from each factory to the proper output at fair burden, the influence of each smokestack had to be estimated as exactly as possible. It was necessary to repeat the air diffusion simulation to calculate emission reductions and to decide the permission of output. Whether the simulation was possible was a problem with technology of those days.

In order to carry out such simulation, there were two procedures. One was the repeating wind tunnel experiments, and the other was the air diffusion numerical calculation by computer. Because the former had a problem of facilities supply (Mitsubishi Shipbuilding of Nagasaki was the only institution which had a large-sized wind tunnel) and limitation to the experiment number of times, the latter was the only way in fact. Nonetheless, it was a problem whether calculated and actual values conform in the Yokkaichi district.

A trial calculation was done in Kyoto University Data Processing Center which was founded as a joint use facility among universities in Kansai area. As the result was seen useful, a decision was made to carry out the regulation of total emission using this method and to prepare the prefectural regulations.

In order to actually perform regulation, it was necessary to investigate the propriety of various types of regulation systems by repeated survey on the emission conditions of each smokestack and diffusion simulation based on the survey. Eight specialists were assigned to carry out it; regulation of total emission to each rise industrial source was started. The total

emission control was started in Japan in 1972. This resulted in a great change to the air pollution of Yokkaichi. It was the first trial in the whole country.

Figure 10 shows year-on-year change in SO_x emission and fuel consumption and in SO_2 concentration. SO_2 concentrations at monitoring stations fell greatly with because of emission of sulfur oxides. Reduction of air pollution had reached the goal.

The goal of prefecture regulations was to reduce about 80% of the total emission. The imposition for compensation to each company was decided according to the emission of SO_2 by "Pollution-related Health Damage Compensation Law" enforced after the Yokkaichi judgment. The imposition was higher than the old “Pollution-Health Damage Compensation Law” which had been already abolished. Measures against air pollution, such as desulfurization of heavy oil and exhaust emissions, shift of fuel (to natural gas from heavy oil), and energy saving to reduce emission of pollutants by reduction in fuel consumption, were taken because of both the total emission control and the imposition system. A plant-and-equipment investment to measure against air pollution was increased. Figure 11 shows the sulfur oxides emission reductions and its means in Japan.

The project team submitted a proposal to the governor, asking for investigation on incidence of respiratory diseases in Yokkaichi, by the survey on the Health Insurance Claim (receipt) to clarify the effects of total emission control. The investigation was continued for about 15 years, and demonstrated that the new incidence of COPD, such as bronchial asthma and chronic bronchitis, fell with decrease of pollution. As shown in Figure 12, there were no significant differences in incidence of bronchial asthma and chronic bronchitis between the polluted and non-polluted areas since 1979, showing no excessive incidence in Yokkaichi [7].

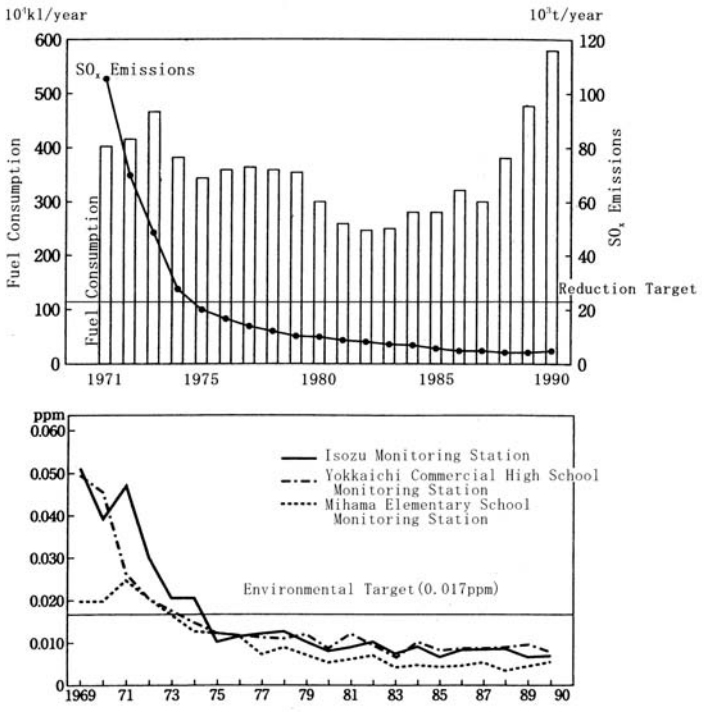

Figure 10. SO_x emission and fuel consumption (upper graph) and SO_2 concentrations (lower graph) [2].

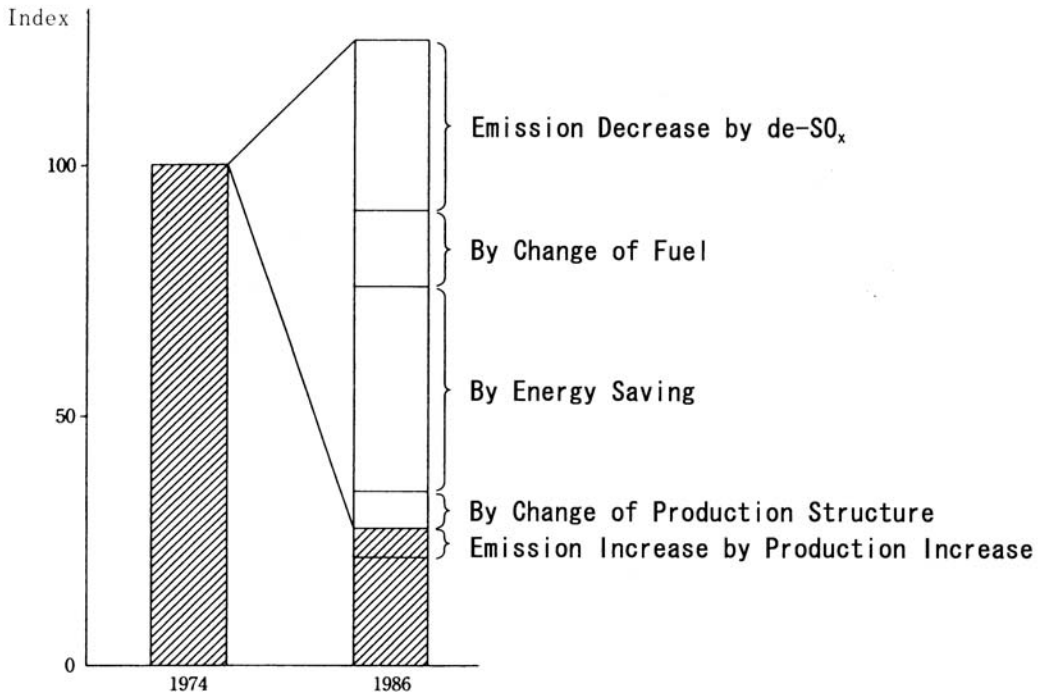

Figure 11. Sulfur oxides emission reductions and its means (in Japan) [2].

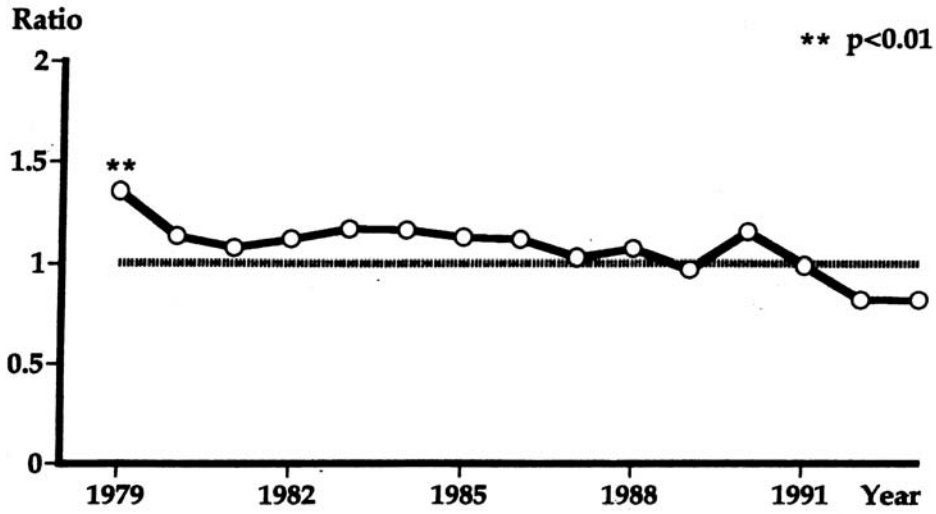

Figure 12. Ratio of annual incidences of chronic obstructive pulmonary diseases between the polluted and non-polluted districts[2].

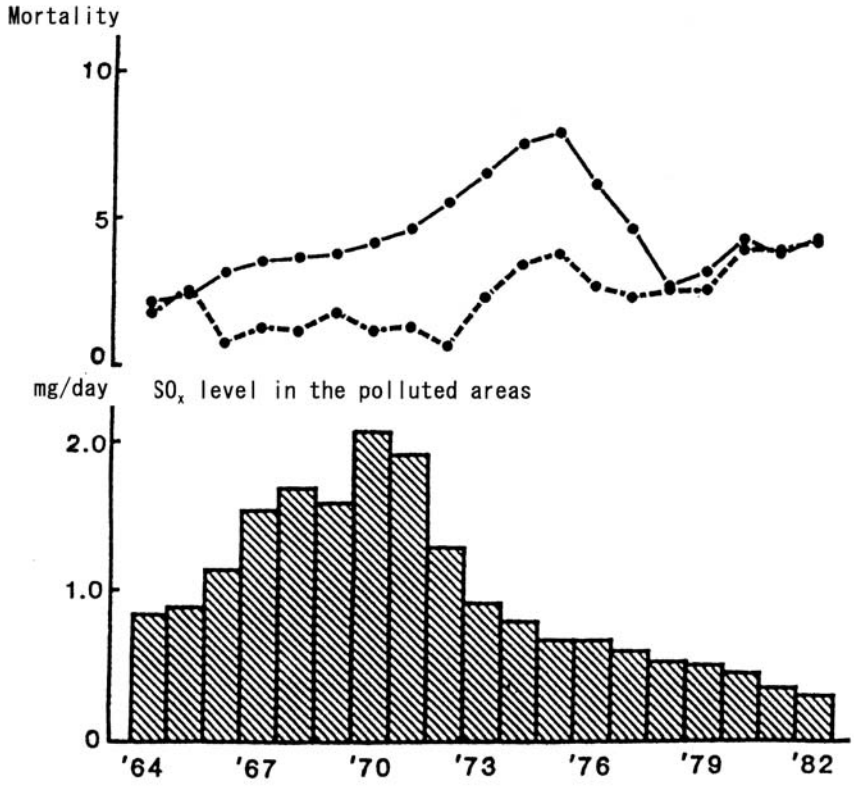

Figure 13. SO_x and mortality from bronchial asthma and chronic bronchitis (3-year running average) [8].

Table 4. Changing of the mortality of bronchial asthma in youth(less than 20 years old) in Yokkaichi

Polluted Area	Mortality of Asthma
1963～1966	2.05
1967～1970	4.36
1971～1974	1.61
1975～1978	0.94
1979～1982	0
Non-polluted Area	0.44

Figure 13 shows the transition of SO_x and mortality due to bronchial asthma and chronic bronchitis. By falling of pollution, with a delay of 3~4 years, the mortality rate of chronic bronchitis, which had increased every year, was also set to the almost same level as the non-polluted areas [8].

Also, as shown in Table 4, the mortality of bronchial asthma greatly decreased, which had been increased in youth with pollution.

Regulation of total emission started by Mie Prefecture was included into amendment of Air Pollution Control Law, two years after (1972), and carried out in about 40 heavy

contaminated areas in Japan specified by the law. Similarly to Yokkaichi, concentration of sulfur oxides fell greatly in these areas; air pollution problems were solved completely in Japan.

CONCLUSION

This article was described the air pollution by starting operations of Japanese greatest petrochemical complex in Yokkaichi, health hazard of residents, and the measures against is problem. The air pollution caused bronchial asthma, chronic bronchitis, and pulmonary emphysema among residents especially the middle-aged and elderly. Intracutaneous allergic reactions were negative in these patients.

Also, when accommodated in the clean air room with charcoal air filter, the patients developed asthma after the operation of industrial complex showed improvement of clinical conditions more greatly than the patients suffered from asthma before the operation.

Mie Prefecture established the environmental quality standard to keep the rate of new development of COPD a normal level for each company. And regulation of total emission which reduced total emission of SO_2 of each company was enacted to reduce source of pollution. As a result, it was normalized that the rate of new development of COPD in polluted areas were decreased the same as natural increase rate in non-polluted areas.

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