

Chapter 14

Risk Management of Chemical Pollution: Principles from the Japanese Experience

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Abstract This chapter discusses some experiences of environmental pollution management in Japan. Cases include air pollution, water pollution, and toxic chemical regulation. From those experiences, it is concluded that in-process management of pollutants has been the major cause of pollutant reduction. End-of-pipe technologies, such as flue gas and wastewater treatment, are costly and not as efficient as cleaner production processes. In addition, governmental policies in environmental management, such as setting regulatory values and guiding industries, sometimes lead industries to take inefficient countermeasures. Thus, regulating agencies should take care to ensure that their policy is leading society the right way and have the flexibility to adapt their policy as necessary.

Keywords End-of-pipe treatment • In-process management • Japanese experiences of environmental pollution • Toxic chemical regulation

14.1 Introduction

Japan's economic development was very rapid during the 1960–1970s, when the country was recovering from the economy's devastation as a result of World War II. As industrial development progressed, environmental pollution became evident and caused severe health damage to the people living around some industrial areas. These included four infamous cases of pollution-related health damage that resulted in major legal suits, namely, Minamata Disease around Minamata Bay in Kumamoto and Agano River in Niigata, Itai-Itai Disease on Jinzu River in Toyama, and

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Yokkaichi Asthma around Yokkaichi petrochemical complex in Mie. In these cases, the national and local governments were afraid of inhibiting economic development and were at first reluctant to take measures against the pollution and to compensate for the health damage. The victims therefore had to appeal to the courts to assert their rights. Indeed, the people affected by the pollution and the non-governmental groups that supported them played important roles in obtaining court decisions in favor of the victims, forcing the government and parliament to take countermeasures.

It has often been said that Japan successfully reduced pollution without hindering its economic growth. In my opinion, this statement is partially true, but not totally; there have been both merits and demerits in the way Japan acted. In this article, I would like to describe how the Japanese government and industries coped with the pollution problems and discuss what can be learned from Japanese experiences both good and bad.

14.2 How Pollution Loads Were Reduced

14.2.1 Air Pollution in Yokkaichi Petrochemical Complex

A large scale petrochemical industrial complex commenced operations in Yokkaichi City around 1960. It contributed about one fourth of total Japanese petrochemical production value in the early 1960s. In 1961, however, people in the surrounding area started to complain of asthma and the situation reached its worst level around 1963–1964. In those days, the sulfur content of heavy oil was about 3% and the emission of sulfur oxides as SO₂ was about 130,000–140,000 tons/year (Study Group on Global Environmental Economics 1991). In the Isodu area south of the complex, about 3% of the one-hour-average SO₂ concentration exceeded 0.5 ppm, which was 5 times higher than the current environmental standard, a one-hour-average concentration of 0.1 ppm. In 1967 the residents of the Isodu area, where the air pollution was most severe, appealed to the courts to stop the air pollution and to obtain compensation for their health damage. The courts acknowledged joint tort of the companies in the petrochemical complex and judged in favor of the plaintiffs. As a consequence, the following countermeasures were taken:

1. Introduction of environmental quality standards and stricter emissions regulation by the national government. The first regulation of individual companies' emission loads was introduced in Yokkaichi.
2. Shift to heavy oil with lower sulfur content in the petrochemical industry.
3. Construction of heavy oil desulfurization plants.
4. Installation of flue gas desulfurization equipment in the petrochemical industry.

As a result of these measures, the targeted environmental standard for SO₂ was attained by 1976. Annual average SO₂ concentrations at monitoring stations in Yokkaichi are shown in Fig. 14.1. Estimated emissions of SO₂ in the Yokkaichi area

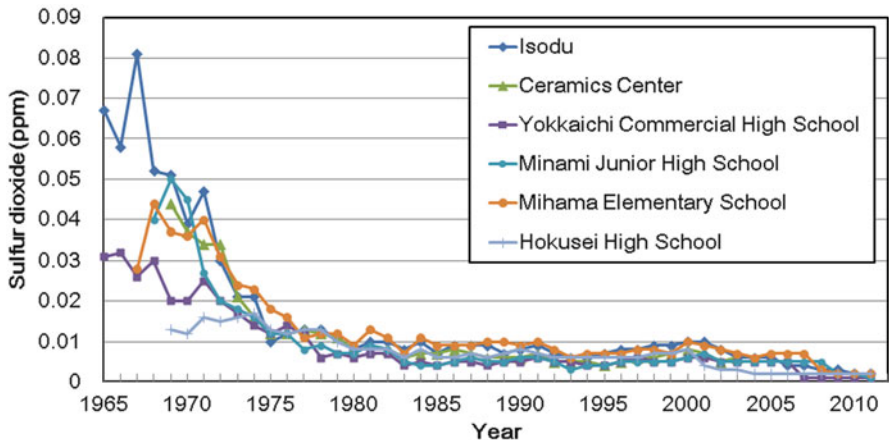


Fig. 14.1 Annual sulfur dioxide concentrations at monitoring stations in Yokkaichi City (based on data from Yokkaichi City (2000, 2012))

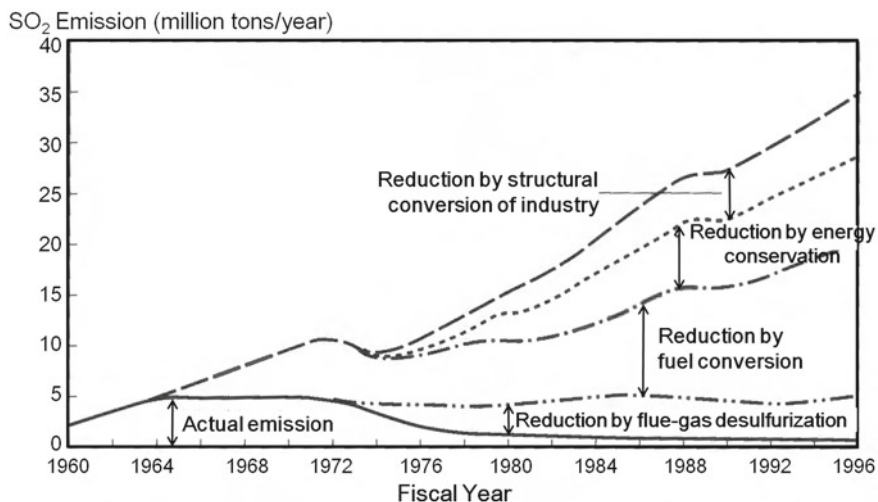


Fig. 14.2 Contribution of different factors that reduced sulfur dioxide emissions in Japan (Committee on Japan's Experience in the Battle Against Air Pollution 1997)

were drastically reduced from 140,000 tons/year in 1964 to 100,000 in 1971 and to 20,000 in 1975. After the late 1970s, gradual reduction continued. In contrast, fuel consumption in the area was relatively constant during the same period (about 4 million kL/year) (Mie Prefecture 1990). This situation could be explained by the analysis for the whole of Japan undertaken by the Committee on Japan's Experience in the Battle Against Air Pollution, as shown in Fig. 14.2 (Committee on Japan's Experience in the Battle Against Air Pollution 1997). This figure shows that fuel

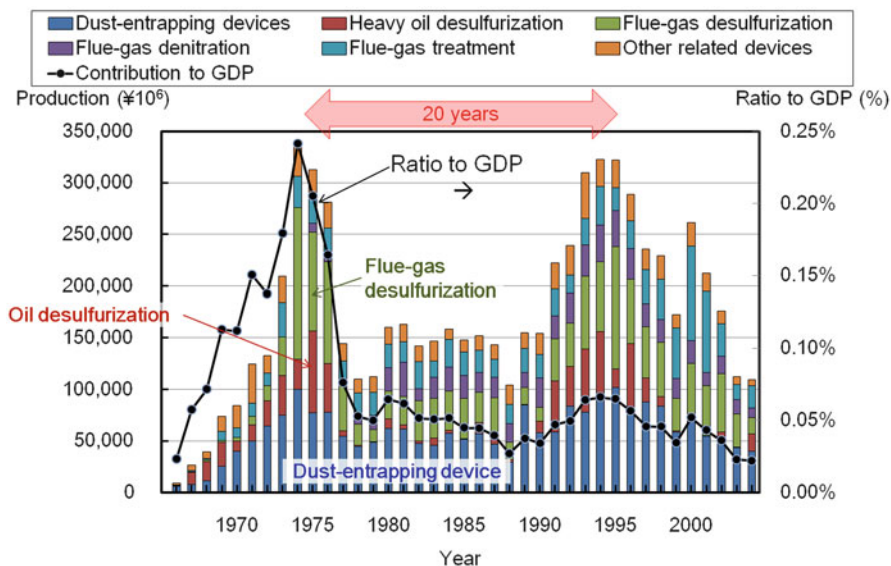
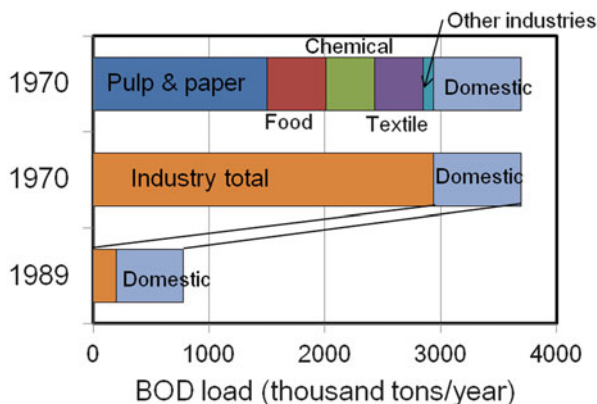


Fig. 14.3 Actual production values of air pollution prevention devices (*bar graph*) and their contributions to GNP (*line graph*) in Japan (FY1966–2004). Based on Statistics Japan (Statistics Bureau 2005)

conversion (shift to oil of lower sulfur content and desulfurization of fuel) was the major cause of the reduction, followed by energy conservation. Flue gas desulfurization made only a small contribution. This experience taught us that reduction at source is important and effective compared to end-of-pipe flue gas treatment.

The petrochemical sector had to invest a considerable amount of money to achieve the reduction. Figure 14.3 shows the production of air pollution prevention devices in Japan. The first installation peak appeared around 1974 and this corresponds to the rapid improvement of air quality discussed earlier in this section for the case of Yokkaichi. The largest amount of money was used for installation of flue-gas desulfurization facilities, followed by dust-entrapping devices and oil desulfurization. It should be noted that investment in oil desulfurization facilities was minimal, but it was much more cost effective in terms of reducing emissions. However, to reduce emissions further, flue-gas desulfurization had to be installed. Overall, the most effective technology may vary according to the region and the nation's economic situation; which technology to use therefore needs to be reconsidered in each individual case. As a percentage of gross national product (GNP), investment in devices to prevent air pollution was nearly 0.25% in 1974. This high number shows that Japan made quite a concentrated investment to counteract air pollution during the 1970s. The second peak of investment in air pollution prevention devices occurred in the mid-1990s, twenty years later. This was when the facilities built in the 1970s were updated. The second peak was almost as high as the first peak in terms of nominal value; however, the contribution to GNP was much smaller—dropping to as little as 0.07%—due to the growth of GNP during the 20 years.

Fig. 14.4 BOD loads and their contributions in Japan (Nakanishi 1994)



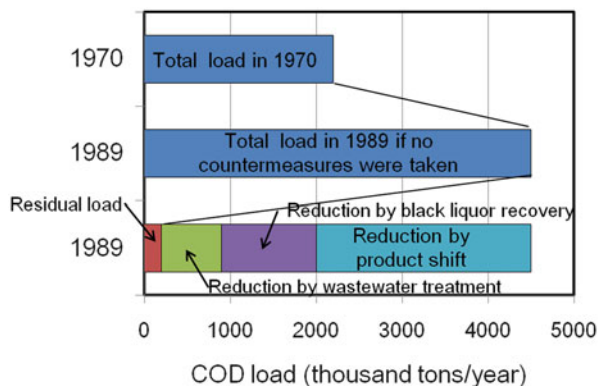
14.2.2 Preventing Water Pollution in the Pulp and Paper Industry

The total organic pollutant load in terms of biochemical oxygen demand (BOD) from domestic sewage was reduced from 750 thousand tons/year in 1970 to 580 thousand tons/year in 1989 (Nakanishi 1994). This reduction was to only three-fourths of the original amount. In comparison, the total BOD discharged into public water bodies as wastewater from all Japanese industries was significantly reduced to about one fifteenth of its original value, from 3 million tons/year (in 1970) to 200 thousand tons/year (in the late 1980s) (Fig. 14.4). As the organic pollutant load from the pulp and paper industry was quite large and contributed about half of the total BOD load from all industries, here we will discuss reduction of the wastewater organic pollutant load from the pulp and paper industry in particular.

The organic pollutant load from the pulp and paper industry was about 2.2 million tons/year in terms of chemical oxygen demand (COD) in 1970, and it was reduced to only 200 thousand tons/year in 1989. Assuming no reduction measures had been taken, however, it was estimated that it would have been 4.5 million tons/year in 1989 based on the amount of pulp and paper production (Nakanishi 1994). The COD reduction was attained mainly by a product shift (58%) and by black liquor recovery (26%) (Fig. 14.5). The pulp and paper companies shifted their product from pulp with high unit COD emission load to that of low unit emission load such as Kraft pulp. In addition, waste paper was used as a raw material in place of virgin pulp, which also reduced the emission load.

Black liquor is the spent cooking liquor that is formed when pulpwood is digested into paper pulp by removing lignin, hemicelluloses, and other extractives from wood. This liquor contains a very high concentration of organic pollutants that are hard to remove by biological wastewater treatment processes. Thus, instead of discharging black liquor to treatment plants or directly into water bodies, companies started to concentrate the liquor and burn it to recover heat energy to generate steam

Fig. 14.5 Reduction of COD load in pulp and paper industry (Nakanishi 1994)



and cooking chemicals (sodium hydroxides and sodium sulfide). This process change not only reduced the COD emission but was economically beneficial in terms of energy and chemical use.

The third reduction measure was wastewater treatment, which contributed about 16% of the total reduction. It should be emphasized, however, that the reduction of waste load by improving the production process was much more effective and economical than end-of-pipe wastewater treatment. In-process reduction also often saved raw materials and energy.

In contrast to industrial wastewater, domestic wastewater load cannot be reduced at the source but is instead reduced by municipal wastewater treatment plants or by small community-based sewage treatment systems. These sewage treatments are usually more expensive and take a longer time to implement than industrial wastewater treatment measures as long sewer pipes have to be installed.

14.2.3 *Environmental Standards for Toxic Chemical Substances*

As stated in the introduction section, Japan experienced some cases of environmental pollution that caused damage to human health. Because of those experiences, the Japanese government started to regulate a limited number of toxic pollutants that caused problems, such as mercury, cadmium, lead, and PCBs, by setting strict effluent standards (Table 14.1). As a result of these measures, rates of compliance with environmental water quality standards were significantly improved during the 1970s. The number of regulated pollutants in water did not change, however, for about 20 years until the 1990s. In 1993, fifteen new substances including organochlorines and pesticides were added to the items subject to the environmental quality standards. Three more items were added in 1999 and one item was added in 2009. The reason that itemized regulation developed so slowly was that setting an

Table 14.1 Items subject to water quality standards during the 1970s in Japan

Items	Standard (original value)	Year first introduced (revised)
Cadmium	0.01 mg/L	1970 (2011: 0.01 → 0.003 mg/L)
Cyanide	ND	1970
Lead	0.1 mg/L	1970 (1993: 0.1 → 0.01 mg/L)
Hexavalent chromium	0.05 mg/L	1970
Arsenic	0.05 mg/L	1970 (1993: 0.05 → 0.01 mg/L)
Total mercury	0.0005 mg/L	1970
Alkyl mercury	ND	1970
Organophosphate	ND	1970 (1993: deleted from the list)
PCB	ND	1975

ND Should not be detected

The number of items regulated for protection of human health is currently 27

environmental standard for each item meant extensive and costly monitoring as well as control of emissions in a range of industrial sectors across the nation. It was therefore difficult to get support from all the sectors to add new items. Faced with the difficulty of increasing the number of items subject to standards, in 1993 the Japanese government designated a group of chemicals that should be monitored (currently 26 items) and another group of chemicals that should be under observation (about 300 chemicals). Chemicals in these new groups are not yet regulated by the law but they are being monitored or information is being collected about them. Based on the information collected, new pollutants will be selected for inclusion among the items subject to environmental standards. This type of soft regulation gives warning to industry that, although some of the chemicals they use are not currently regulated, those chemicals should be used with care. Another mechanism that provides companies with an incentive to reduce their pollutant emissions is the pollutant release and transfer register (PRTR) system, whereby companies are requested to report the amounts of listed pollutants they discharge into the environment or transfer to wastewater and solid waste treatment facilities.

14.2.4 Case of Administrative Guidance Relating to Toxic Chemicals

The chlor-alkali industry produces sodium hydroxide (caustic soda) and chlorine, as well as hydrogen, by electrolysis of sodium chloride solution. It is one of the key industries in the chemical sector. There are a few different methods, but the mercury cell process employing inorganic mercury was the main one used in Japan after World War II.

In 1956 the first Minamata disease patient was officially identified in the city of Minamata and in 1959 organic mercury was found to be the cause of the disease by Kumamoto University researchers. In 1965, a second case of Minamata disease was

identified in the downstream area of Agano River. In both cases, discharge of organic mercury from the acetaldehyde production process, rather than the chlor-alkali production process, was officially confirmed as the cause of the disease by the national government in 1968.

However, mercury was also emitted from the chlor-alkali production process, which was linked to a third case of Minamata disease reported in the Ariake Sea area in 1973. This case in particular caused great fear among the Japanese public, although the link with chlor-alkali production was later disproved. As a result of the public outcry, in June 1973 the Japanese government decided to minimize mercury loss from the mercury cell process by introducing a closed system. In addition, it decided in November 1973 that one third of Japan's mercury cell operations would be converted to the diaphragm cell process by September 1975, with the remainder to be converted by March 1978. Although at that time it had not been established that inorganic mercury could be transformed into organic mercury in the environment, a committee appointed by the government had submitted a report saying that the mercury problem would not be solved without totally phasing out the mercury cell process. Consequently the Japanese government made the drastic decision of ordering the chlor-alkali industry to change their production process.

Following the emergence of the chlor-alkali industry in the 1920s, the production capacity of the mercury cell and diaphragm cell processes became comparable during the 1930s. This situation continued until the mid-1950s, when demand for high quality sodium hydroxide increased. The mercury cell process could produce better quality sodium hydroxide, but mercury was expensive; the diaphragm cell process, on the other hand, produced an inferior quality product, but without the need for mercury. When the Japanese chlor-alkali industry was converting its mercury cell operations to diaphragm cell operations, it became evident that the sodium hydroxide produced by the diaphragm cell process contained about 1% sodium chloride and other impurities such as sodium chlorate. This made it unusable for the production of chemical fiber, cellophane, inorganic chemicals and so on, which account for about 25% of total sodium hydroxide demand (Kameyama 2008). Its chlorine gas was not suitable as a raw material for products such as vinyl chloride, which account for 41% of total demand (Kameyama 2008). In addition, the prices of diaphragm cell products were expected to be 40% more expensive than those of mercury cell products. To promote conversion from one process to the other, therefore, the Japanese government had to align the prices of corresponding products from the two processes by introducing a system for paying the price difference. The resulting lack of incentive to innovate was not favorable considering that international competition and innovative technology were desired.

Subsequently, following the appearance of an innovative ion-exchange membrane cell process developed by Asahi Glass Co., completion of the conversion plan's second stage was postponed to await confirmation of the applicability of the innovative technology. The new process, which could produce better quality products with high energy efficiency, was adopted instead, and accounted for 60% of Japan's production capacity in 1987 and 100% in 2005. This process of transition within the chlor-alkali industry is shown in Fig. 14.6.

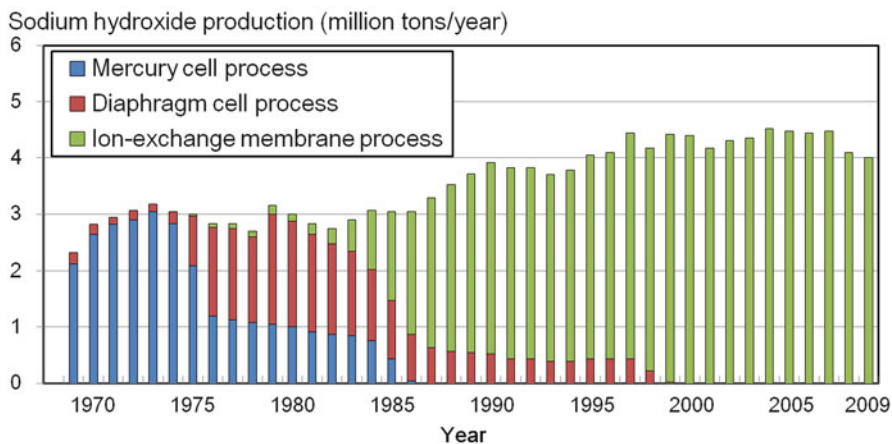


Fig. 14.6 Transitions in chlor-alkali processes in Japan (Ministry of the Environment and Japan 2011)

The conversion between processes in Japan's chlor-alkali industry was a peculiar case, but it was instructive. The Japanese government had been compelled to take quite a precautionary policy after Minamata disease had such a large impact on society. However, its administrative guidance conflicted with economic principles and could not be adopted by the industry without a price adjustment system. The chlor-alkali industry had to waste a significant amount of money to change their process first from mercury cell to diaphragm cell, and then to the membrane cell process. The Japan Soda Industry Association estimated that the chlor-alkali industry invested about 10 years-worth of benefit for the process conversion in 1978 alone (Nakanishi 1995). In fact, the closed-system mercury process reduced mercury loss from 114 to 2.3 g per ton of sodium hydroxide production and, with hindsight, was good enough to bridge the time-gap until the membrane process emerged (Kameyama 2008). Delaying the transition would have been much more cost efficient. On the other hand, it can be said that without the government order, the industry might not have worked hard enough to develop an innovative technology in such a short period.

It is likely that the Japanese chlor-alkali industry could bear the high cost of process change in the 1970s and 1980s because they faced less pressure from foreign countries' imports than is the case now that world trade is more open. It is becoming increasingly difficult for industries to bear the increase in costs for better environmental management if a similar degree of management is not required in other countries. At any rate, management policies should be readjusted to fit the current situation so that both environmental protection and economic development can progress.

14.3 Conclusion: Lessons from the Japanese Experience

This chapter introduced some examples of environmental pollution and associated countermeasures in Japan. Successful pollution reductions are often achieved by in-process technological innovation and efforts, not by wastewater or flue gas treatment. In-process pollution reductions are referred to as “cleaner production,” and are often much more economical than end-of-pipe treatment. In addition, wise water use, such as recycling and counter flow washing, contributes to raising the concentration of pollutants in the water and making treatment more efficient. Perhaps the key lesson to be drawn from the Japanese experience, however, is that governmental regulation and guidance should be introduced carefully and adaptively.

Acknowledgment The author referred to the books and reports written by Dr. Junko Nakanishi (Nakanishi 1994, 1995), Dr. Tetsuya Kameyama (Kameyama 2008), Dr. Takamitsu Sawa (Committee on Japan’s Experience in the Battle Against Air Pollution 1997), and others to prepare this manuscript.

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