Japan's Breath-Taking Battle with Traffic-Generated Particulate Air Pollution

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日本における車から排出される微粒子による大気汚染への取り組み

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要　　旨

本稿では，微粒子が与える健康への悪影響およびその影響を受けやすい人々について論じ，可能な対策を概論する。1950年代および1960年代に起こった，家庭や工場から排出される微粒子の大気汚染との戦いや，その数十年後に再現した微粒子問題について考察する。特に，1990年以降の日本の状況や，2003年に東京都が導入し論議を呼んだ厳しい規制を取り巻く状況を検討する。

Key Words
Environmental Studies, Japanese Studies, Particulate Air Pollution

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1. Introduction

Particulate air pollution is not a new phenomenon: records of smoke-related problems date back to the 13th century (Maynard 1999 : 1) and it was known in the Middle Ages that miners were likely to die early from lung diseases (Seaton 1999 : 11). Further recognition came in the early industrial revolution as various workers with close contact with dust became ill. Literary works in the 19th century by writers such as Charles Dickens describe the thick 'pea-souper' fogs that enveloped London (so-called because of their colour and density), and imbued them with a somewhat romantic flavour. The term 'smog', formed by combining the words 'smoke' and 'fog', was first coined in 1905 by Des Voeux, who was Secretary of the Coal Smoke Abatement Society (the fore-runner of the National Society for Clean Air. (Maynard 1999 : 1). Gradually the serious health hazards posed by air pollution became clearer with a succession of bad smogs in Belgium, Pennsylvania and then London in 1952. The latter smog was the event which ended any romantic connotations that London fogs had been associated with, and galvanized serious action by the authorities.

The infamous smog which enveloped London in early December 1952 is believed to have caused several thousand more deaths than would normally have occurred at that time of year. However, because many of the fatalities were elderly people, it was suggested that this might merely represent people who would have died anyway within a relatively short period of time, thus inferring that the smog might not have been as deadly as first appeared. If this were the case, though, there ought to have been a short-term decrease in the number of mortalities recorded (because the people who would have been expected to die at that time had already passed away). However, no such drop in the mortality rate was observed, indicating that the large number of deaths was indeed attributable to the air pollution (Maynard 2001 : 184).

It thus became established that severe air pollution can be directly responsible for a significant rise in acute mortality rates. This had been achieved by examining statistical data, and marked the effective birth of modern epidemiological studies (Bates 1999 : 1). The approach was gradually developed as an investigative tool for determining the relationship between different levels of pollutants and their possible impact on health. It was soon found that air pollution could aggravate bronchitis, but the model which proved to be a good standard was not developed until 1965 (Bates 1999 : 1). The approach revealed much valuable data, and indeed was to be the method that later exposed the full dangers of diesel particulates.

[It should perhaps be mentioned that at the time of the 1952 smog, epidemiology had not been established as a discipline, and this may have been a factor in the death toll being so high. Although the authorities would have known that the situation was serious, it is possible that they were not aware of the true scale. Nowadays, there are forecasting and monitoring systems to warn people of potentially hazardous air pollution so that preventative action can be taken (e.g. warning asthma sufferers to remain indoors, limiting traffic volumes etc.); also, reports of sudden increases in mortality or morbidity (including numbers of patients seeking emergency room assistance as well as hospitalizations etc.) are collected by a central source, where a judgement can be made as to the seriousness of any developing situation. However, such systems were not in place in 1952, so the authorities cannot have had any overall view of the developing catastrophe.]

2. The most vulnerable groups

In the intervening years much research into the effects of air pollution has been carried out. It has been discovered that the smaller particles are also potentially the most harmful, and can damage the cardiovascular and respiratory systems. Amongst the problems they can trigger or aggravate are cancer, heart disease, chronic bronchitis, decreased lung function, asthma, and emphysema. Not everybody is affected equally; the United States Environmental Protection Agency (EPA 1997) specifies four vulnerable groups: the elderly; individuals with pre-existing heart or lung disease; children; and asthmatics and asthmatic children.

Since the inhalation of small particulates can have a direct effect on the cardiovascular and respiratory systems (as will be explained further with regard to possible mechanisms), it is not surprising that individuals suffering from heart or lung ailments (especially asthma) form a particularly vulnerable group of the population.

Let us now consider the implications for first the elderly, and then children.

a) The elderly

Elderly people in general tend to suffer more health-related problems than younger people. But to what extent does this occur, and what are the implications for society, especially Japanese society?

It might not be surprising that elderly people are more vulnerable; with advancing age, their bodies have reduced resistance to disease and their recovery systems are weaker. As indicated, particulates can affect the cardiovascular and respiratory systems, and people who have a pre-existing weakness would be expected to be more susceptible to pollutant aggravation. However, what is the statistical data?

The London smog of 1952 clearly showed that the elderly are more susceptible to the effect of particulate air pollution. Later research in Britain looked at the relative risk of premature death due to particulate pollution for different age groups and compared the figures with the data for cause of death, and concluded that a full 92% of all particulate-related deaths occurred in people aged over 65 (Maddison & Pearce 1999 : 924). The EPA estimated that tens of thousands of elderly people in the US die early because of particulate pollution each year, with many thousands more hospitalized (in addition, there are many who seek outpatient treatment) (EPA 1997). Not surprisingly, many of these elderly people also have pre-existing heart or lung problems.

The implications of such data are particularly worrying for Japan, with the longevity of the Japanese and the low birth rate combining to make Japan the country with the greatest rate of aging. A website sponsored by the Japanese government states that the current rate of elderly in Japan is around 20% but this is expected to rise to over 30%; even by 2002, a full 49% of medical expenditure was for people aged over 65 years, with the average sum of money spent for each elderly person in the population amounting to four times what is spent per younger person (Web Japan). Fortunately (and unlike Western countries) many Japanese seem to want to continue to work or otherwise contribute to society after retirement; thus the Japanese government has a double incentive to reduce particulate concentrations in the atmosphere; not only should it lead to reduced medical costs, but it will also enable the elderly to contribute more to society and the economy.

The economic estimates of the damage caused by particulate air pollution are staggering (besides premature death, economic costs are incurred due to hospitalization, emergency room visits, and work days lost because of illness). The World Health Organization (WHO) has put the annual cost of increased mortality in the EU at 58–161 billion euros, with the cost due to particulate-related diseases running to 29 billion euros per year. (WHO 2005a : 2–3). The Clean Air Task Force has estimated costs in the US in 2010 are likely to run to 139 billion dollars (Clean Air Task Force 2005 : 3). [In Japan, work on quantifying the financial costs of particulate pollution lag well behind that of the EU and US (Kishikoto 2000)].

b) Children

A long-term epidemiological study on children covering six cities that was carried out by Harvard University found that the greatest association of symptoms occurred with the finer particulates and sulphate levels (which presumably would be in aerosol form). A fourteen-year follow-up study in those cities, which was adjusted for confounding factors such as smoking, found a significant correlation between ambient particulate concentrations and death due to lung cancer, cardiovascular and respiratory disease; the order of correlation was the same as found with the children. Even though the pollution levels were fairly low, the most polluted city had a mortality rate 30% greater than the least polluted city (Walters & Ayres 2001 : 277–278).

One concern about the effects of air pollution is that the children's bodies are growing and the pollution might adversely affect lung development. Research in both Europe and the US had indicated reduced lung function in children exposed to air pollution. A eight-year prospective study was therefore carried out involving nearly 2,000 children in a dozen locations in California that were subject to pollution. The decreases in lung function that were observed were statistically and clinically significant, with much greater decreases found with the greatest exposure to particulates (Gauderman et al 2004).

Much research has indicated that air pollution can increase mortality and morbidity in children. This in turn causes concern about the possible effect on infants. Reviewing the existing literature, Glinianaia et al (2004) found that there was a possible relationship between ambient particulate levels and certain types of infant mortality, and called for further research.

Medical studies have shown that fine particles can cause various adverse effects in children. Besides reduced lung function, children exhibit greater incidences of respiratory ailments such as asthma and bronchitis. Moreover, various measures (prevalence of asthma, allergies etc.) have a demonstrable link with proximity to traffic (Clean Air Task Force 2005 : 11).

There are a number of reasons why children may be more vulnerable to air pollution than adults. They tend to breathe more rapidly due to being more active; the ratio of the surface area of their lungs to their total body weight is greater (they breathe 50% more air per kilogram of body weight than adults, EPA 1997); and they tend to spend more time outdoors in the polluted air. In addition, their respiratory systems are still developing, rendering them more susceptible to pollutant damage. In the United States many children use school buses to commute, raising concerns that particulates produced from the diesel fuel may harm the children. A study that covered Chicago, Atlanta and Ann Arbor found the fears to be fully justified. Particulates were able to enter the bus both via the tailpipe and the open doors, resulting in particulate concentrations inside the bus up to ten times the levels in the air outside; peak levels were observed fifteen seconds after a bus halted at a bus stop. The dangers are increased when the windows are closed, thus trapping the exhaust fumes inside the bus (Clean Air Task Force 2005 : 11–13).

Summary of health effects

A large body of epidemiological evidence has now been accumulated. Long-term cohort studies which have taken account of other risk factors have also confirmed the adverse impact of air pollution; for example, the Harvard Six Cities Study and the American Cancer Society Study reached similar conclusions in studies lasting over twenty years (Thomas and Harrison 2004 : 147).

All the evidence thus shows that particulate air pollution produces substantial health and economic costs. One British government researcher has publicly stated that he regards particulate air pollution to be “perhaps the most important pollutant in terms of adverse effects on human health” (Williams 1999 : 97). In a similar vein, two authoritative British researchers refer to American research results at Harvard University and elsewhere indicating that “road traffic-generated particles may be more potent than particles from other sources in eliciting adverse effects on health” (Thomas and Harrison 2004 : 143).

3. Mechanism

As mentioned earlier, the London smog of 1952 clearly demonstrated the relationship between air pollution and acute mortality. But this then raised questions about the mechanism which led to the deaths. The London disaster occurred at a time of year when a temperature inversion trapped a layer of cold damp foggy air over the city. Since the main method of heating homes at that time was the burning of coal, large quantities of sulphur dioxide and smoke (non-combusted carbon particles) were being emitted into the damp atmosphere; persistent very high levels of these materials were recorded as meteorological conditions prevented the fog from clearing. The smoke particles could act as a point around which the water vapour molecules could coalesce; the sulphur dioxide could then dissolve in the liquid water, forming an acidic solution that people would breathe. Post-mortems on the deceased (which revealed that chronic sufferers of heart and lung complaints had merely had their diseases aggravated by sulphur dioxide and the particulates) led people to suspect that the acidity of the aerosols might indeed be the cause, although this was not proven conclusively (Maynard 2001 : 165–167).

4. Countermeasures

The scale of the disaster spurred the authorities into action. This led to the Clean Air Act of 1956 (Maynard 1999 : 3) and subsequent legislation to mitigate the effects of air pollution by encouraging smoke-free zones and the use of smokeless fuels. Coal for domestic heating was a major cause of the pollution, and gradually its use became banned in cities; cities in many other countries later enacted similar legislation. The regulations introduced in Britain to control domestic and industrial emissions brought about a 50% drop in sulphur dioxide emissions, while fuel-derived airborne particulates dropped by 70% (ApSimon 2005: 83). Factories and power stations were also responsible for emissions of particulates and sulphur dioxide due to fossil fuel combustion, but improved technology gradually reduced emissions by increasing the efficiency of combustion. Examples are fluidized bed systems, where combustion takes place using very finely divided coal on a 'bed' which contains many small holes; pressurized air is then forced through the holes from below. Although the powdered coal is a solid, with this arrangement it acts as if it were a fluid (hence the term 'fluidized bed'); this leads to much better mixing, and hence to both greater efficiency and less production of particulates.

A number of techniques were developed to combat the emissions of particles from industrial plants, with the underlying principles often being surprisingly simple (Open University 2000: 91–103). For example, large particles can be removed from gas flows by gravity; the gas passes through a horizontal settling chamber and the particles settle out in order of weight, after which they are collected via ducts. Inertial forces can also be employed (e.g. in a centrifuge); after impact, the heavier particles fall into a collector ('hopper').

Another technique is to pass the gas through a set of filters (in a so-called 'bag house'), which prevents passage of the particulates; these can be then periodically removed by reversing the direction of flow (using pressurized air) and thus blowing the particles into a collector. This technique, however, suffers the disadvantage of being a possible fire (and explosion) risk; additionally, the filters can be damaged if the gas mixture is corrosive. This problem can be reduced by using a liquid to "scrub" the gas clean, although it is necessary to exercise caution when selecting the liquid for use. The disadvantage of this approach is the relative difficulty of handling and disposing of the resultant slurry. The scrubbing liquid may simply be sprayed from above, but frequently the arrangement will be altered in order to ensure better mixing of the liquid and gas so that particle removal is more efficient. This may be achieved by using e.g. baffles, which can be arranged to increase the degree of impingement; alternatively, the liquid can be broken up into a spray; or venturi scrubbers can be employed (in these, the gas is accelerated through a narrow neck, with the pressure difference causing the liquid jet to form a fine spray).

A further technique involves removal by electrostatic precipitators. The uncharged particles are given a negative electrical charge, and this causes them to migrate to an electrode, from which they can then be removed.

The above techniques were gradually developed and improved. However, emissions into the atmosphere continued, especially in the 1950s and 1960s. At that time, many scientists believed that a key solution to the problem of emissions was to build large chimneys so that the pollutants would be released higher into the atmosphere where wind etc. would ensure their dispersal to the point where the low concentrations which would be found in any one location would cause minimal harm. Unfortunately, this belief was wrong; the pollutants that were released did indeed travel vast distances, but when they eventually returned to earth (e.g. washed out of the atmosphere by precipitation) they caused significant problems due to the creation of acid rain.

In the 1950s and 1960s, however, the problems of acid rain had not been fully appreciated, and the combination of controls on domestic heating coal and industrial emissions seemed to lead to many people believing that the problem of particulates etc. had been essentially resolved. Attention then turned to other air pollution issues such as photochemical smog, which were seen as having greater importance.

It became generally accepted that there was a threshold level below which adverse health effects would not be observed. Accordingly, particulate concentrations in the atmosphere were measured in units such as SPM, which referred to total suspended particulate matter, or TSP, total suspended particulates, which was used as the regulatory standard in the US until 1987 (EPA 1997). This belief remained generally accepted until the late 1980s.

In the late 1980s and 1990s, however, several epidemiological studies suggested that even the much lower concentrations of particles in the atmosphere could have serious effects on health. These findings were at first extremely controversial as they seemed to go against common sense as well as accepted scientific views, and especially as the mechanism by which harm was caused was unknown; in addition, businesses that manufactured or used polluting devices realized that acceptance of such arguments would lead to requirements for difficult and expensive cleaning procedures. (Maynard 1999 : 3) One reason for the lack of understanding of a mechanism for small particles was that most of the knowledge concerning the action of particulates on the lung had been derived from occupational medicine, which involved much larger particles (Maynard 2001 : 171).

A technical committee reported to the American Conference of Governmental Industrial Hygienists in 1985 that the inhalability of particles with diameters between 100 μm and 30 μm was approximately constant, but that as the size decreased further there was a steady and steep increase in inhalability (Phalen 2002 : 56). It then gradually became realized that the small particles were more likely to harm health since the body has natural defences against the larger particles. Total lung and extrathoracic deposition rates actually decrease from 5 μm to 0.3 μm, but then increase again (and rapidly as particle size decreases); alveolar deposition rates increase steadily below 10 μm but rapidly at sizes under 0.4 μm, and bronchial deposition rates increase below 0.2 μm. Thus all deposition rates increase steadily with the smallest particles (Maynard 2001 : 170).

When particles are larger than 10 μm (microns) they are unlikely to pass the upper airways (i.e. the nose, mouth and larynx) and can be expelled by sneezing and coughing etc. Alternatively, they are deposited on mucosa, carried to the back of the throat, and then swallowed (Phalen 2002 : 61). However, smaller particles can bypass the defences and travel deeper into the body's airways and can thus cause greater harm. For this reason, a new unit became used to measure the smaller particulates, PM_{10}, where PM stands for 'particulate matter' and the subscript '10' indicates that the unit refers to particulates with a diameter of 10 μm or less. Particles in the range 4–10 μm tend to be deposited by impaction and sedimentation at points where the airways branch, and the frequent development of cancer at these points may be due to the deposited particles having carcinogens adsorbed to their surfaces (Maynard 2001 : 167). Particles of around 0.5 μm in diameter are not well deposited in the lung. However, as particle size decreases further, deposition rates increase because the mechanism of deposition changes. The particles are deposited by Brownian motion (diffusion). The very small ("ultrafine") particles can travel even more deeply and are deposited efficiently in the regions of the lung where gas exchange takes place: the alveoli and alveolar ducts. The alveolar region has a large surface area, which means that soluble articles can be absorbed rapidly (McAughey 1999 : 90); for particles 20 nm in diameter the efficiency of this process is nearly 50% (MacNee & Donaldson 1999 : 659). This can have potentially serious implications. The higher parts of the airways have cilia and mucus which can clear the particles out of the body; however, these are not present in the gas exchange zone; alveolar clearance occurs due the action of macrophages, but the time involved is hundreds of times slower than ciliary clearance from the airways; this means that the particles can bypass the defences and may then be able to cause inflammation (Maynard 2001: 167–171). In tests of this hypothesis, the greatest effects were indeed seen with ultrafine particles (Thomas & Harrison 2004). It was found that smaller particles can be especially harmful, which led to the introduction of units such as $PM_{2.5}$ and $PM_{0.5}$ (respectively indicating particles less than 2.5 μm and 0.5 μm in diameter).

The precise mechanisms involved have not yet been clarified. However, there is a consensus that small particulates pose a grave health risk. The reason for the recent controversies over diesel engines is due to the fact that they produce significant quantities of small particulates. The median diameter of diesel exhaust particulates is approximately 0.2 μm, which means that these particles are easily inhaled. They have a relatively large surface area, which means that organic compounds can be adsorbed (often 10–40% by weight); this can be serious because carcinogens such as PAHs (polycyclic aromatic hydrocarbons), which are also emitted in diesel exhaust, can be deposited deep inside the body (BeruBe et al 1999: 41–42).

Maynard (2001: 189–190) has suggested that if the dangers of ultrafine particles have been perceived correctly, even the units currently used for particulate matter (PM_{10}, $PM_{2.5}$ and even $PM_{0.5}$) may not be appropriate. Donaldson et al (1999: 123) note that because the size of particles is so small, the number of particles per unit mass is extremely large. Thus, it is possible that the critical factor is particle number counts. Animal experiments with high ambient concentrations of particulates seem to support this view, especially with results involving animals suffering from respiratory problems (which potentially has implications for humans suffering such illnesses) (Maynard 2001: 189–190). Nevertheless, Maynard also counsels caution since other theories also exist.

5. Reasons for the popularity of diesel engines

Given the realization that diesel exhausts pose such a serious health hazard, it may seem surprising that diesel engines became so popular and even acquired the reputation of being extremely benign to the environment.

As the policies introduced in the 1950s and 1960s began to alleviate the terrible air pollution caused by domestic combustion of coal and emissions from industrial plants, attention turned to the recently recognized problem of photochemical smog. The prime cause of this type of smog was the emission of exhaust gases from vehicles running on gasoline. The high combustion temperatures in gasoline engines meant that excess oxygen would combine with the plentiful nitrogen in the air to produce nitrogen oxides (NO_x), with this and other pollutants then being released directly into the atmosphere, where the action of sunlight would trigger a series of chemical reactions leading to the production of photochemical smog. Before catalytic converters were developed, the favoured mitigation option was to encourage the introduction of diesel engines.

Unlike gasoline engines, diesel engines can run at relatively low temperatures, thus preventing the formation of NO_x etc. The disadvantage of the low temperatures, however, is that combustion is less complete, which means that there is an increased release of unburned carbon particles into the atmosphere. There is thus a trade-off relationship, but the general opinion at the time was that the benefits far outweighed the risks, and diesel acquired an image of being environmentally friendly. Further advantages of diesel engines relative to gasoline engines were greater efficiency, increased durability and reliability, less need for maintenance, and less expense (on a life-cycle basis) (ITPS 2004: 418).

In Japan, diesel vehicles had the additional advantage of running on cheaper fuel than gasoline engines. When the oil shocks hit in the early 1970s, the price differential between the two fuels shot up from about 10 yen to nearly 50 yen per litre, with the difference only narrowing somewhat in the 1990s; this was perhaps the main reason why the percentage of trucks running on diesel rose from approximately 20% to over 60% of the total during the same time period. In recent years, diesel fuel has continued to be cheaper than gasoline by approximately 20 yen per litre, but this is due primarily to a favourable tax rate (in May 2003 the tax rate for diesel was 32.1 yen per litre, whereas the rate for gasoline was 53.8 yen) (TMG 2003 : 9–10).

Unscrupulous operators of diesel vehicles in Japan were able to obtain a further economic benefit. The light oil used for diesel vehicles was subjected to the above tax because it was foreseen that the purpose of the fuel was to power vehicles that would run on the roads. Heavy oils were viewed as being unfit for vehicles on the roads, and it was believed that the oil would be used for purposes such as firing boilers; consequently the heavy oil was not taxed. The unscrupulous operators were taking the heavy oil and mixing it with the light oil for use in diesel trucks, thereby making extra profits; unfortunately, the combustion of the heavier oil produced large quantities of black smoke. (Yoshida 2003) In fiscal 2000, no less that 14% of trucks stopped for roadside violations were found to be running on the mixed fuel; a clampdown by the TMG, however, reduced this figure to just 1% by fiscal 2002 (TMG 2003 : 25).

6. Ways of reducing PMs from diesel engines

There have been two approaches to the reduction of particulates from diesel vehicles. The first is to improve the performance of diesel operation, and the other the adoption of low-sulphur fuels. Let us consider each in turn.

a) Diesel improvements

Emission controls focused on improving the design of the combustion process in order to minimize the initial production of pollutants. Before the mid-1990s, most diesel engines relied on mechanical fuel injection systems, but later models tended to have electronic injection systems, which results in greater control over fuel metering as well as timing; in recent years systems employing on-board diagnostics (OBD) have been introduced, further enhancing control. One important technique that has brought about improvement is increasing the pressure of fuel injection in order to make the combustion process more efficient (and hence less polluting). A later development has been the development of a catalyst which can be effective at the lower temperatures found in diesel engines. The innovation which has enabled the current strict regulations to apply to older diesel vehicles is the particulate trap; these can remove over 90% of particulates from diesel exhausts, although previously they could become clogged easily (Holman 2001 : 340–343). Finally, however, these problems seem to have been overcome.

b) Low sulphur fuel

A certain amount of sulphur is contained in fossil fuels; while it might seem attractive to use fossil fuels that contain either no sulphur or only small quantities, this has historically been infeasible, particularly as (in the case of oil) the bulk of supplies come from the Middle East, where the oil has a relatively high sulphur content. Unfortunately, when fossil fuels are burned, not only are oxides of sulphur produced, but they interact with non-combusted carbon particles in a synergistic manner. It is well known that the sulphur oxides which are formed can then cause or aggravate respiratory diseases. A further problem is that the presence of sulphur can render less effective the catalysts which are used to clean vehicle exhaust gases.

There has thus been a clear need for fuels containing less sulphur, and in recent years the technology to reduce sulphur content has started to become feasible. Before 2003, Japanese government standards required diesel oil to be light oil with a sulphur content of less than 500 ppm (parts per million), but there were no detailed regulations about quality, and no fines (Yoshida 2003). In the summer of 2003, a specialist committee in Japan (Chuuou kankyou shinngikai taiki kankyou bukai) produced a report aimed at reducing the sulphur content of diesel fuel to 20% of the 2003 level by 2007 (Mainichi Shinbun 2003). In 2003 the permissible sulphur content in light oil was cut to 50 ppm, which was only 10% of the previous amount, with this being further reduced to 10 ppm in 2007.

The Tokyo Metropolitan Government (TMG) claims credit for the rapid moves in Japan towards stricter controls on sulphur in diesel fuel. Noting that no gas stations in the country had sold low-sulphur fuel in 1999, the TMG claims that its partnership with the Petroleum Association of Japan was responsible for enabling the early introduction nationwide of such fuel by April 2003, whereas the national government's schedule only aimed to achieve this target nearly two years later (TMG 2003: 17). In 1999, the national government had estimated the change in regulations would cost between 500 and 600 billion yen; in contrast, the TMG asserted that the increased cost would amount to a mere one yen per litre if absorbed over a period of one decade, and that this was entirely reasonable. The TMG also approached manufacturers directly, and the city's first low-sulphur buses began operating in late 2000 (TMG 2003: 17).

It is useful to consider these changes in the light of international moves for stricter standards. Part of the reason for the TMG's dissatisfaction with the national government's policy for low-sulphur fuel (defined as having a sulphur content of under 50 ppm) was the perceived lack of urgency. In 1999, Japan's regulations were the same standard as California's, but considerably more lax than Europe. However, by the end of 1998, the EU had already targeted a 50 ppm limit by the beginning of 2005, but the relevant committee advising the government in Japan only offered a recommendation for the strictest standards to be introduced by 2007 for diesel fuel and by 2008 for gasoline. Also, some European countries used tax incentives to introduce strict regulations ahead of the agreed target date; for example, in Britain this meant that most diesel fuel was already of the low-sulphur variety by summer 2003 (TMG 2003: 17). Similarly a number of European countries (e.g. Germany and Sweden) had employed tax incentives that had encouraged the early use of so-called "sulphur-free" diesel fuel. [The name is actually a slight misnomer; such fuel is not actually free of sulphur, but contains only very small quantities, and is defined as fuel with a sulphur content of below 10 ppm. Thus a more strictly correct term would be "ultra-low sulphur fuel".]. With cooperation from the Petroleum Association of Japan, general agreement was forthcoming to introduce standards similar to the strict EU ones and on a similar time scale; Japan planned to begin them in 2005, with the EU standards being phased in over a four-year period (California opted for a slightly higher regulation of 15 ppm to be enforced in 2006) (TMG 2003: 3–4). By the end of April 2005, both regular gasoline and light oil with a sulphur content less than half the previous amount were available at gasoline stations throughout all of mainland Japan, which was two years ahead of the schedule originally envisaged by the government in the case of diesel oil, and three years ahead for gasoline. One company (Honda) pointed out that even vehicles currently on sale would benefit from using the new fuel because it was better at preventing degradation of the catalysts (Asahi Shinbun 2005).

Parallel to the adoption of stricter emission standards, the government wanted to encourage the introduction of low-emission vehicles. To this end, financial assistance was extended to bus operators using less-polluting buses, with help also forthcoming for the establishment of facilities providing the fuel. Furthermore, tax incentives were also adopted (TMG 2004b: 8). Vehicles which met certain emission standards (not only for particulates) were designated as "ultra low-emission (ULEV) vehicles"; significant tax breaks were introduced to encourage the development and use of such vehicles, with stickers affixed that indicate the actual performance quality of the vehicle (using a star rating system). Tax incentives were introduced for both purchase and ownership taxes in 2002 while simultaneously increasing taxes for older vehicles. The various tax incentives and stricter fuel economy standards resulted in no less than seventeen of the top twenty best-selling models in the Japanese new car market already meeting the qualification for the lower rates by 2001 (ITPS 2004 : 355–356).

However, the government miscalculated and had not foreseen that such tax incentives would create such a widespread appeal. The increase in the number of ULEV cars was so great that tax revenues plummeted to such an extent that an urgent review was conducted to reconsider the level of tax incentives. However, it must be said that the government was far less to blame than in the financial problems surrounding subsidies for particulate filters etc. (discussed later) (Asahi Shinbun 2003c).

7. Legislation

As soon as the potential dangers of particulates were realized in the United States and Europe, regulations were drawn up and took effect in 1988 and 1992 respectively. Japan did not introduce regulations, however, until 1994, and these were over five times as lax, with no plans to close the gap till 2005 (TMG 2003 : 1–2). The national government explained that the slow introduction of the regulations was due to an emphasis on controlling NO_x emissions, with which there is a trade-off relationship. The TMG did not accept this argument, though, pointing out that although western nations might at first appear to have weaker regulations regarding NO_x, this was not actually the case since the test conditions employed in Europe and the US represented a more accurate representation of actual driving conditions and were performed for heavier trucks (which cause greater pollution).

The legislation that came into effect in 1994 has the full title of the "Special Measures Act for the Volume Reduction of Nitrogen Oxides and Particulate Matter Emitted by Automobiles in Designated Areas, 1992", but is usually referred to under the abbreviated name of the "Automobile NO_x Act". However, it only applied to Tokyo and Osaka, with the later addition of Nagoya (the latter being the result of lawsuits that had been filed). The Act was amended in 2001, with the amended version referred to as the "Automobile NO_x and PM Act" (Ministry of the Environment 2003). Further friction between the national and Tokyo governments ensued, though, following the decision of the national government to twice delay introduction of the revisions; as a result, controls on older trucks (which were the most polluting) were put back by two and a half years, with these vehicles allowed to operate as before (TMG 2003 : 7–8). Their numbers were not insignificant, accounting for more than 40% of the diesel vehicles in operation. (ITPS 2004 : 109–112). After this, the TMG even went as far as to accuse the national government of a breach of trust (TMG 2003 : 7–8).

One reason for the delay was supposedly that industry needed extra time to meet the more stringent requirements. However, this does not explain why the national government failed to act on the "top runner" approach, for which there had already been a precedent. Prior to the mid-1990s, fuel consumption rates had remained fairly constant in new car models for several years, and the regulations had been determined according to the technological standard of the average model on the market. With the "top runner" approach, however, a target standard was set based on the product which was technologically the best (i.e. the "top runner"); the base year for fuel consumption rates was taken to be 1995, and this led to rapid and sustained improvement in fuel consumption rates, with the long-term target on fuel economy being an average 22.8% reduction by 2010 (ITPS 2004 : 355–356). Such an approach would surely have also paid dividends with particulate emissions, especially as the TMG successfully introduced their own stricter standards in 2003.

Frustration with what was perceived as a shocking lack of urgency led to the TMG (with Governor Ishihara Shintaro playing the key role) proposing and then introducing stricter regulations well in advance of the national government's proposed programme.

Various legal pressures were also building up. In Kansai, a lawsuit filed in Amagasaki in 1988 was finally resolved with an out-of-court settlement in which the plaintiffs failed in their demands for specific emission prohibition, but which required the government to introduce environmental conservation measures (ITPS 2004 : 412–413). A series of air pollution lawsuits were also filed in the southern part of Nagoya in 1989; the initial judgment came in 2000 and found that particulates were one of the factors causing the health damage to the plaintiffs; in an unprecedented ruling for Japan, the government was ordered to pay compensation and also reduce particulate concentrations below a certain level. During the appeals process, the government (and corporations) came to a settlement with the plaintiffs, which again involved financial payments and an agreement to strengthen regulations (ITPS 2004 : 356–358). In Tokyo in October 2002, seven asthma sufferers living within 50 metres of major roads won compensation because it was accepted that their condition had been affected by the particulates, although plaintiffs living at greater distances were denied compensation. [The reason for the ruling only applying to people living with 50 metres of a major road is that Japanese research indicated that the level of air pollutants dropped fairly rapidly and steadily for a distance of 20 to 30 metres from a road, but that at greater distances than that the concentrations tended to remain steady (ITPS 2004 : 129–130). However, it must be questioned whether this is an appropriate figure for dealing with fine particulates, which can be transported for significant distances. For example, in the United States, the EPA has noted that particulates originating from southern California cause one-third of the haze over the Grand Canyon, and on the worst days of poor visibility in the Rocky Mountains, approximately 20% of the problem is due to smog from Los Angeles (EPA 1997).]

This was the fifth time that the government had lost court cases deriving from air pollution along state-operated roads (Japan Times 2002). It also marked the first time that compensation was awarded to a person not officially registered as an official sufferer of air pollution (the registration of new air pollution sufferers was stopped in 1988 when air quality improvements had led to a decision that air pollution had ceased; thus the high school girl in Setagaya-ku did not qualify for official recognition) (Asahi Shinbun 2003c). The judge specifically stated that the government could have predicted the harmful effects of diesel emissions, and in effect indicated that the government had been negligent in not controlling the emissions. The Tokyo governor, Ishihara, immediately accepted the ruling (Japan Times 2002). The ruling clearly supported his drive for better air quality, but he was also probably aware that future lawsuits would also find against the government.

8. Stricter regulations

As justification for bringing in tough emission regulations on particulate emissions, the TMG noted that a full 52% of such emissions came from motor vehicles in the year 2000; however, the true figure was probably even higher because the 52% did not include emissions occurring at start-up or when vehicles in motion caused particulates to blow up (an additional 12% of the particulates in Tokyo were due to braking and tire friction) (TMG 2004a : 5–6).

The more stringent regulations took effect on October 1st 2003. They applied to all diesel vehicles except for passenger cars; the exemption was due to cars emitting less particulates per vehicle and being driven for shorter distances, and the fact that diesel cars were gradually being replaced by less-polluting models (TMG, date unknown). Additionally, only a relatively small 10% of cars in Japan run on diesel, a figure much lower than in the EU (30%), although greater than that of the US (1%) (ITPS 2004 : 107).

Exemptions were also given for trucks within the first seven years of initial registration (TMG 2004b : 5). However, the regulations did apply to older trucks, even though those trucks had been purchased before the stricter regulations were announced. While such an approach might be reasonably normal practice in the West (albeit it with grace periods), it was quite unusual in Japan, and provoked an outcry from the operators of fleets of diesel trucks. If those operators wished to continue in business, they had a few choices, but all the options involved substantial financial outlays. The options were to purchase a new truck (¥4～14 million); fit a diesel particulate filter to remove 60～70 % of the particulates as well as the black smoke (¥800,000～¥2 million); or to install an oxidation catalytic converter to eliminate carbon monoxide, hydrocarbons and the smell (¥400,000～¥500,000) (Asahi Shinbun 2003a); however, it would not reduce the filthy black smoke (Okumura & Nagayama 2003).

Large companies could absorb the costs and were careful to be seen as keeping to the law. For example, Sanyo Denki required their subcontractors to state in writing that they complied with the regulations. Fuji Film was another company taking precautions; they used 564 trucks from 19 companies, and checked to see that the trucks complied with the regulations. When 46 trucks were found to be non-compliant, Fuji instructed the subcontractors to take action, warning that failure to do so would mean an end to their business relationship (Asahi Shinbun 2003b).

However, the new regulations caused considerable hardship for small self-employed operators, whose annual income was often less than ¥3 million (Okumura 2003a). They were angry that only the operators and not the manufacturers were apparently being penalized, and felt that the large manufacturers viewed the whole situation as a chance to sell new vehicles and did not exert enough effort to developing cheaper retrofitting methods (Okumura 2003a). To express their dissatisfaction, an organization with approximately 8,000 members representing self-employed operators ("Hitori oyakata") held a protest rally in Shinjuku. They acknowledged that the new regulation would lead to health benefits, but wanted to register displeasure at the way the ordinance had been introduced and their subsequent hardship (Mainichi Shinbun 2003c). Slightly larger businesses also suffered; in western Tokyo, one company cut the wages of its employees by 10% in an attempt to absorb the extra costs of meeting the new standards (Asahi Shinbun 2003b). [The government did provide some subsidies to offset the extra costs incurred but, as will be discussed, the subsidies were far from adequate].

The ordinance stipulating the stricter standards came into effect on October 1st 2003. In the following November, observed concentrations of particulates had decreased significantly. Elemental carbon particles (soot) at Osakabashi had fallen by 30%, and carcinogens at Meguro-douri had dropped 36% (TMG 2004a : 10). However, it was the measurements in the Iogi tunnel of the No. 8 circular road in Suginami-ku that were seen as the most significant since they were unlikely to be influenced by meteorological conditions such as wind and rain. Soot had been reduced by 49%, and carcinogens (polycyclic aromatic hydrocarbons, PAHs) by 58%, thus allowing the TMG to claim that the ordinance was producing the desired effect (TMG 2004a : 10; Okumura 2003b).

9. Problems encountered during the introduction of the 2003 ordinance

Although the government may have claimed that the new regulations were a success, the process by which they came into force was anything but a success. In Chiba, the Liberal Dmocratic Party caused confusion with a late attempt to delay introduction of the regulations (Asahi Shinbun 2003b), causing some operators to cancel orders for anti-particulate devices. The proposal was later withdrawn, leaving those operators unable to operate their fleets (Yomiuri Shinbun 2003).

Many operators left it very late to order new vehicles, with manufacturers unable to meet the demand (Asahi Shinbun 2003b). Similarly, it was predicted that 60% of the 10,000 particulate filters ordered as of early September 2003 would be delivered late. Recognizing the problem, the TMG allowed a 3-month grace period to operators who could produce written evidence of having placed an order (Okumura 2003a). Non-compliance rates were high. It was estimated that in Tokyo 20% (of 200,000 vehicles) failed to meet the regulations, with the non-compliance in the surrounding prefectures being even higher (in Saitama, 50% of 130,000 vehicles; in Chiba, 40% of 180,000 vehicles; precise figures were unavailable for Kanagawa). The situation was also very unclear regarding the trucks coming to Tokyo from other parts of Japan, and which were estimated to account for about 15% of the total.

The government did offer subsidies, but badly miscalculated the demand, even though the demand should have been predicted correctly due to the ready availability of truck registration data. Although the Ministry of Land, Infrastructure and Transport had allotted ¥4,000 million for subsidies to offset 25% of the additional costs caused by retrofitting trucks over eight tons, the applications had already exceeded ¥6,000 million by June. Even though that was three months before implementation of the new regulations, the government refused to accept any more applications. A subsequent decision was made to increase the budget for subsidies, but only to ¥4,800 million (Asahi Shinbun 2003b). The TMG offered further assistance (50%), as did other prefectures (e.g. Tochigi offered 25%), but these were dependent on the operator being awarded a subsidy by the national government, and consequently many operators did not receive the money to which they were entitled (Okumura & Nagayama 2003).

Perhaps the problem that dominated the headlines the most was the scandal involving Mitsui Bussan. The company had been designated officially as a supplier of diesel particulate filters on the basis of their specifications stating that the filters reduced particulate emissions by 60%; indeed, the company had the top share of the market (30%) with sales of ¥194,000 million, which led to the government distributing ¥80,000 million in subsidies. However, it transpired that the specifications had been falsified; the true reduction of particulates was not sufficient to meet the stricter regulations. This led to the government referring the company to the police for fraud (Asahi Shinbun 2004b). The government later announced their attention to prosecute (TMG 2004d).

10. Ishihara's motivation

The early introduction of stringent regulations was primarily due to Governor Ishihara. In some ways, however, Ishihara is a rather unlikely figure to lead an environmental fight. In 1977 he was appointed as minister of the Environment Agency at a time when the severe pollution problems stemming from Japan's almost total emphasis on economic growth had spawned an active (although by then declining) environmental movement. However, far from being sympathetic to the green movement, he attacked their campaigns as being a "witch hunt" against the companies that had delivered Japan's economic miracle (Broadbent 1998 : 293). He wanted to dilute the anti-pollution laws that had been introduced, and his tenure at the ministry marked a decrease in its power and influence. Yet in the late 1990s his pledge to cut air pollution played a key role in his campaign to become Tokyo's governor, and his agitation for stricter controls continued during subsequent years, even though this meant opposing his erstwhile allies in the national government. His clear commitment to a clampdown on diesel emissions was perhaps most memorably demonstrated by his waving of a plastic bottle full of black particulates (soot) at a press conference to emphasize the harmful emissions that were emanating from diesel vehicles (TMG 2003a : 1).

The argument put forth by the TMG to tighten regulations on particulates stresses the need to safeguard health; the emphasis on this aspect is undoubtedly due to Ishihara. [Indeed, although the usual term used to refer to the ordinance that was passed in 2000 is "*Kankyou kakuho jourei*" ("Environmental preservation ordinance") the full official name is actually "*Tomin no kenkou to anzen* *wo kakuho suru kankyou ni kansuru jourei*" ("Environmental ordinance for the preservation of the health and safety of residents of metropolitan Tokyo"] (TMG 2003a : 1). Such an apparently altruistic motive on the part of a leading politician might be popular, but given Ishihara's background there is a suspicion that other factors may also have come into play (although this by no means implies a criticism of his actions).

First, with the aging of Japan's society and the proven vulnerability of the elderly to particulates, the health effects of serious air pollution (especially particulate pollution) are likely to be intensified. This would result in a double economic blow; not only would the sufferers be unable to contribute to the economy due to their inability to work, but there would be the additional costs due to medical treatment (including not only the cost of medication but the provision of hospital beds, and the extra burden placed on doctors and nurses, which also has an economic cost). As seen earlier from the estimated costs in Europe and the United States, this would probably result in a substantial financial burden.

Second, Ishihara was aware that in a succession of air pollution lawsuits, the courts were ruling against the government (although he publicly supported the verdicts). As mentioned earlier, lawsuits filed in Amagasaki in Kansai (1988) (ITPS 2004 : 412–413) and southern Nagoya (1989) (ITPS 2004 : 356–358) were both resolved in out-of-court settlements which required the government to reduce pollutant levels. In Tokyo in 2002, the government lost its fifth case involving air pollution on state-operated roads, with the judge stating that the effects of diesel emissions should have been foreseen (Japan Times 2002). When discussing the national situation, the ITPS referred to the health damage spawning the lawsuits and the government losses, and stated that "in consequence" laws have been progressively strengthened (ITPS 2004 : 406).

An additional factor could be related to the competitiveness of Japanese motor corporations. The European Union and United States have for several years adopted regulations much stronger than in Japan, and have been (and are) tightening emission regulations further. If Japanese companies were unable to manufacture vehicles that could meet the stricter requirements, their business would suffer accordingly. Conversely, if the companies could develop the necessary technology faster than their foreign rivals, they would have a competitive advantage.

Finally, it should of course also be remembered that Ishihara is a politician, and he no doubt recognized the appeal to the electorate of policies which could be viewed as being both anti-pollution and anti-central government. It is quite likely that many if not all of these factors played a role in Ishihara's advocacy of tighter controls on particulate emissions.

11. Discussion

The battle to enact and then enforce tough regulations on diesel emissions clearly became quite controversial, and pitted the metropolitan and national governments strongly against each other. It also raises a number of interesting points.

Firstly, the particulate concentrations in the Tokyo metropolitan region undoubtedly fell after the introduction of the tighter regulations on diesel emissions. With the further planned measures such as the switch to low sulphur fuels, the air quality should continue to improve, and this should hopefully lead to health benefits for all Tokyo residents (but especially for the elderly) with the attendant economic gains.

It is clear, however, that the national restrictions were introduced much too slowly in comparison to other nations. The reasons for this are unclear, although with fast modern communications it surely cannot have been due to a lack of knowledge about the concern that particulates were causing in Europe and the United States, or about the actions being taken there. One possible reason is that bureaucratic in-fighting and politics prevented action; certainly, the Environment Agency has not been noted for its power, and when a change in tax rates was proposed in 2002 to encourage the introduction of low-emission vehicles by introducing a low tax rate for them while simultaneously increasing the rate on old diesel vehicles, the bill was delayed for a year due to opposition from the Roads Bureau in the Ministry of Construction (As the ITPS notes, such delays outside of public scrutiny can often occur with important policy matters in Japan) (ITPS 2004 : 413–414). It is also possible that politicians with links to the motor corporations etc. were less than willing to push through legislation that might be unwelcome to their benefactors.

A further possibility is that in Japan generally, new regulations tend to apply to products only after the announcement of the regulations has taken place (or at least until after a considerable grace period is given to the parties that are thus affected). It may be that the national government wanted to maintain what were considered to be the standard practices and did not feel a sense of urgency about the situation.

In the events leading up to the tightened regulations in Tokyo in 2003, the TMG (and specifically Governor Ishihara) clearly took a different view – and indeed one of the key points of their argument was the pressing need for the swift introduction of tight controls on the very vehicles that would have been eligible for a longer exemption. This view took precedence over the conventional way of doing things.

This then raises the question of whether the actions are a reflection of Ishihara being a strong leader who is able to push through his pet projects, or whether this is the start of a new trend in Japan generally (or possibly in just environmental matters). There certainly seems to be general support in Japan for environmentally-friendly policies, as indicated by the large numbers of products being advertised on television or in shops that have environmental or energy-savings features as one of their key sales points, and also shown by the brisk sales of environmentally-friendly cars such as hybrid cars etc. The 2003 ordinance clearly attracted a high degree of public support, which suggests that although Ishihara's strong leadership may well have been a decisive factor in changing the conventional ways of doing things in this particular case, it would be dangerous to extrapolate the argument to non-environmental areas. The potential for huge financial gains resulting from an improvement in air quality (because of the effect on the health system and the ability of the aged to work etc.) increases the likelihood that more measures will be introduced in future to improve the environment (and that they will be implemented relatively rapidly), whether or not Ishihara remains in power. However, as to whether the over-riding of conventional ways of conducting affairs will become an established manner of implementing policies outside the environmental field, the situation is much more uncertain, and it will probably be some years after Ishihara has departed the political scene before a definitive judgment can be made.

In the intervening period between announcing the tightening of the emissions regulations in December 2000 and their implementation in 2003, the TMG received the support of the surrounding prefectural governments (Saitama, Chiba and Kanagawa), which all introduced similar legislation. The alliance also attracted support from the major cities near Tokyo (Chiba, Yokohama, Kawasaki and Saitama cities). Such an agreement was seen as essential for combating air pollution in Tokyo, since air pollution is a trans-boundary issue and because a considerable amount of the traffic in Tokyo comes from the surrounding regions (TMG 2003a : 15–16).

Ishihara also managed to gather support from other areas in Japan, especially from major areas of population, with the increase of designated areas to be covered by the NOx and PM Act, the tightening of further restrictions in places such as Hyogo prefecture, and promotion of policies favouring low-emission vehicles in Osaka (Okumura & Nagayama 2003). Aichi prefecture also began an expanded environmental strategy in 2002 (ITPS 2004 : 356–357). No doubt noting the favourable public response to the initiatives, in September

2003 reports stated that the prime minister, Koizumi, had instructed the new Environment Minister, Koike Yuriko, to place importance on strengthening emissions regulations (Okumura & Nagayama 2003). Certainly, in the autumn of the following year, the minister announced plans to further strengthen regulations and require diesel particulate emissions to be reduced to almost the limit of detectability (essentially zero emissions) by 2009 (Asahi Shinbun 2004c).

It thus seems clear that much greater emphasis will in future be placed on not just particulates but air pollution generally. The drive for this has come predominantly from the Tokyo municipal government, but this has spurred moves in other major conurbations in Japan to also push ahead with similar ordinances and initiatives in advance of moves by the national government. This represents a major change from the situation in the past when the national government would set the parameters and local government would decide how to best implement the national policies. It seems possible (even likely) that future moves for environmental improvement will be led by the local governments in areas with large populations and no longer by the national government. This is indeed a highly significant event, and suggests that moves to improve air quality may accelerate in the future.

A major negative aspect of the particulates controversy in Tokyo was the inadequacy (one might say incompetency) of the government planning. The situation regarding the provision of subsidies was nothing short of a farce, for which the relative departments duly apologized. However, it seems incomprehensible that the situation was not foreseen; presumably all the data necessary for calculating the number of people eligible to claim subsidies (plus the amounts likely to be applied for) were surely available to the government from vehicle registration records. There is thus a pressing need for the relevant government departments to act more professionally; whether this happens may well depend on the amount of media pressures applied.

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