

**A TALE OF THREE CITIES:
GLOBALIZATION'S IMPACT ON AIR ENVIRONMENT IN SANTIAGO,
WATER ENVIRONMENT IN OSAKA, AND
SOIL ENVIRONMENT IN SHANGHAI**

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Introduction

The three environmental spheres (atmosphere, hydrosphere, and pedosphere) are intimately linked through an array of complex interactions of mass and energy transport. Anthropogenic perturbations such as air pollution from combustion (Molina and Molina 2004; Brennan 1996), water pollution from raw sewage (Avcievala 1991; Brennan 1996), deforestation and land change resulting in loss of biodiversity (Sala 2000), can all profoundly impact these spheres (Benneh 1994).

Nearly every government around the world advocates for an environment free from harmful contamination for their citizens. However, the demand for a country's economic, agricultural and industrial development outweighs the demand for a safe, pure, and natural environment (please refer to the summary table in the appendix). Ironically, it is the economic, agricultural and industrial developments that are often linked to polluting the environment. Today, every city around the world is facing critical environmental degradations as a result of overloading air, water, and soil sources with pollutants. Despite technological advances and rising awareness, developed countries still continue their struggle against this tendency of global environmental degradation.

This paper describes a tale of three cities - Santiago, Osaka, and Shanghai, and their interrelatedness through the impact of globalization on the three environmental

spheres - air, water and soil. Due to the complexity of atmospheric, hydrospheric and pedospheric chemistry, it is necessary to consider and conduct research under the “one atmosphere, one hydrosphere, one pedosphere” or “one sphere” concept. For example, the same chemistry that produces ozone also results in the formation of fine particles, and we can see that the ozone and fine particles production in airshed are interrelated phenomena (Atkinson 2000). Thus, a new and innovative approach with a systemic and holistic perspective would be most urgently needed if we want to manage and sustain our environmental resources while enabling economic growth, especially in big cities like Santiago, Osaka, and Shanghai. Our hope is to highlight the importance of such an innovative and multidisciplinary approach, in accordance with the 2004 APRU Fellows Program theme of multidisciplinary collaboration on managing and possibly solving environmental problems in this age of globalization.

A Tale of Three Cities

1. The Once Beautiful City of Santiago, Chile

Santiago city (33.5° S, 70.6° W) is located in the main valley of the central zone of Chile – the Maipo-Mapocho basin. It was founded in 1541 by Pedro de Valdivia, the Spanish conquerer, with the name “Santiago de Nueva Extremadura”. Valdivia chose the location of Santiago because of its climate and the ease with which it could be defended. Today, Santiago is the capital city of Chile and its most important urban center. It is the main financial, cultural, commercial, industrial, and political center of Chile. The population in Santiago has grown from one and a half million in the 1960s to approximately six million in 2002, representing 40% of the country's population (INE 2002).

The city is nestled in two rings of hills, close to the highest mountain ranges of the Andes to the east and the Cordillera de la Costa to the west, presenting a slope from east to west of about 543 meters (1,800 feet) above sea level. The city is crossed by the Mapocho River, close to the Southern Andes on the east and the Cordillera de la Costa on the west. The city has a surface of about 140 square kilometers in size (14,000 ha), which is equivalent to 2.1% of the country's territory. It is 35 kilometers (22 miles) from north to south and 40 kilometers (25 miles) from east to west. The Mapocho River crosses the city from east to west, and the south side of the city crosses the valley of the

Maipo River. The weather in Santiago is Mediterranean-like. It is warm with an annual average temperature of 14° C and in winter, an average of 9° C. Rain occurs mainly between April and September (autumn and winter), and summer (November to March) is dry and hot. The annual average rainfall is 360 mm (IGM 1979).

The Santiago basin presents a very persistent valley-mountain breeze system that favors the enhancement of primary compounds emitted in this urban area. The predominant wind direction is from the southwest with low velocity (year average wind speed of 2.0 m/s). On the other hand, Santiago's prevailing anticyclonic conditions throughout the year lead to a permanent subsidence and thermal inversion layer, existing at between 400 and 1000 meters above the city, during the winter and summer time respectively. This condition provides a very stable atmospheric gradient that reduces the dispersion of air pollutants. Geographical, meteorological and urban development conditions also make Santiago one of the most heavily polluted cities in the world (Holton 1990).

1.1. Santiago: An Example of the Air Pollution Problem

The Chilean anthem has a part that says "*Pure, Chile, is thy blue sky, pure breezes flow through thee too...*", but this is no longer true because of the poor air quality in the city of Santiago. The two main problems are high concentration of ozone and aerosol particles, and pollutants from fixed and mobile sources. This is represented

by industries (over 70% at the national level) and motor vehicles of around 1,500,000 cars and buses (Lavados *et al.* 2004; Ihl 1998; CONAMA RM 2004; Romero *et al.* 1999).

Santiago established an Air Quality Pollution Watch Program, managed by the Ministry of Health. The Program is supported by a network of monitoring stations distributed around the city to measure atmospheric pollutants and provide meteorological information supported by the Monitoring of Air Quality in the Metropolitan Area (MACAM) network (Silva and Quiroz 2003). This network is co-financed by the governments of Chile and Japan. This network systematically measures the concentration of ozone (O₃), nitrogen oxides (NO₂ and NO), carbon monoxide (CO), sulfur dioxide (SO₂) and aerosols (PM₁₀ and PM_{2.5}), as well as some metrological data such as wind speed and direction, temperature and relative humidity.

After the Environmental Law was established in 1994, in line with Air Pollution Regulations, Santiago was declared as a city saturated by ozone, nitrogen oxides, and respirable particulate material (PM). During the last six years, the Metropolitan Government had developed an Environmental Program in order to improve urban air quality. However, the ozone concentration to date is still over 80 parts per billion (ppb) and has persisted as one of the main air pollutants in Santiago (CONAMA 2004). Ozone is a secondary pollutant formed when oxides of nitrogen and volatile organic

hydrocarbons (a result of motor vehicle emissions, industry emissions, usage of various paints and solvents, as well as natural sources) combine in the atmosphere with oxygen in the presence of sunlight. It is necessary to characterize the chemical production at ground level and at various altitudes, and develop appropriate strategies for the controlled emission of precursor pollutants and prognostic models for ozone and particulate matter. The implementation of a monitoring network of this kind can be very beneficial for any large city or metropolitan region.

Air pollution has significant associated health effects, both acute (such as bronchitis, tightness in the chest and wheezing) and chronic (such as lung cancer and cardiopulmonary diseases). It has more direct negative impact on human health than other known health effects. Epidemiologic data have consistently shown the adverse health effects of various air pollutants (Adonis and Gil 1993; Cifuentes *et al.* 2001; Ostro *et al.* 1996). Particulate and SO₂ pollution were strongly implicated in the acute morbidity and mortality associated with severe pollution episodes in Pennsylvania, London, and New York in the 1940s, 1950s, and 1960s respectively. New evidence suggests that even current ambient levels of PM₁₀ (30 to 150 micrograms/m³) are associated with increases in daily cardiopulmonary mortality and total mortality (EPA-US 1998). These associations have been shown in many different communities with widely different atmospheric particle composition and climates. In a recent long-term

prospective study of adults in the United States, chronic levels of higher PM10 pollution are associated with increased mortality even after adjusting for several individual risk factors. Studies have shown total mortality to increase by 1% for each 10 micrograms/m³ increase in PM10, respiratory mortality to increase by 3.4% and cardiovascular mortality by 1.4%. Hospital admissions and emergency department visits increase approximately 1% for all respiratory complaints, and 2% to 3% for asthma.

1.2. Air Quality and Globalization

Japan is one of the main exporters of automobiles and electronic appliances to Chile. It is in this sense that the possibility of a free commercial trade agreement between Japan and Chile can lead to further atmospheric pollution in the cities of Chile. The automobiles driven by gasoline engines emit several gases, which when present in certain concentrations in our atmosphere can be toxic (Van Mierlo *et al.* 2003; Escudero 1991). The main gases emitted are nitrogen oxides, sulfur dioxide, volatile organic compounds and metals. The emission from heavy-duty vehicles is a large emission source, and for this reason, it is critical to develop plans for emission reduction from this source along with the signing of the new trade agreement (Harrington 1997; Rask 2004). One must consider the positive and possible negative consequences of such trade decisions.

Since automobiles, along with industries, are major contributors of air pollutants, the measurement, control and management of pollutants released from automobiles are the center of new emission and fuel standards, as well as the introduction of new clean technologies. Enhancing environmentally friendly vehicles with tax incentives to encourage the introduction of vehicles with PM filters and lower emissions of NO_x and VOCs can be an important policy guideline. Also, most diesel trucks and buses today do not use pollution control devices similar to those used in cars. In order to enable modern pollution-control technology to be effective on trucks and buses, diesel fuel must be significantly cleaner than it is today. Japan has the highest standard for combustion vehicles in the world. For this reason, signing of the free trade agreement between Chile and Japan can also serve to introduce new innovations and environment-friendly cars at a possible lower cost.

2. The Once Sustainable City of Osaka, Japan

2.1 An Admirable Past

Osaka is located near the geographic center of Japan (135.30° E, 34.40° N). Osaka is partially enveloped by the Uemachi Plateau lining its north and to the south surrounding lowlands. People have been living in the vicinity of Osaka for more than ten thousand years, and from the 5th century onwards, Osaka has become a major center of politics and culture in Japan. Since those early times, the first international harbor

“Naniwa-tsu” was constructed and trade and cultural exchange was established. The oldest canal in Japan “Naniwa no Horie” was built based on civil engineering advances brought by such exchange. After that, Osaka, and nearby Nara and Kyoto, had been the heart of Japan for more than a millennium before the relocation of the capital to Tokyo (Edo – ancient name of Tokyo) in the 17th century (beginning of the Edo Period).

Japan during the Edo period had been in international isolation (1639-1858) as a result of the policy by Tokugawa Shogunate, a feudal military dictatorship of Japan. Such isolation procedures are the opposite of globalization. The Shogunate strengthened its feudal system by excluding Christianity and free trade. Because international trade was restricted, Japan had to supply food, water, and energy for 30 million people primarily by domestic resources. Under those restricted conditions, the population was kept constant and quality of life was improved by the development of a recycle-oriented society for self-sufficiency. Forests were soundly managed for wood production was a renewable resource. Sewage and night soil were recycled into organic fertilizers for rice and vegetable fields. Broken material such as paper, clothes, ceramics, and wood crafts were repaired and reused. Waste wax, oil, and metals were collected and reprocessed. It was a low- or zero-emission society. The lifestyle in the Edo period was not luxurious but relatively sanitary. Although there were local environmental pollutions and famines by natural disasters, some scientists and

historians considered the closed self-sufficient country to be a sustainable society (Harada and Glasby 2000).

Osaka with 350 thousand people played an important role as a center of economics and logistics in the sustainable Japanese society during the Edo Period. It was called “Tenka no Daidokoro”, the largest mercantile city in Japan. One of the reasons was the fact that Osaka was navigable. Osaka was also called “Mizu no Miyako”, the water capital, because of the many rivers, including the Yodo river, flowing from Lake Biwa to Osaka Bay as well as a network of artificial canals connecting those rivers developed in the Edo period. Water from Lake Biwa has been the central supply for drinking, agriculture, and industry in Kyoto and the Osaka region. The canals played a main role in the transportation of people, materials, and wastes in a non-automotive society. Osaka Bay also had enough capacity to receive environmental loadings of organics and nutrients and served as a reservoir of fish and shellfish supply to the country.

2.2 Environmental Problems from Modernization

The once sustainable water capital Osaka has changed as a result of modernization. Osaka as a “Tenka no Daidokoro” was deeply-impacted by the Meiji Restoration in 1868 (the end of the Edo Period), which devastated its economy. Since then, Osaka changed its industrial structures: firstly, to support textile industries such as

hosiery and towel manufacturers, and then heavy industries such as chemicals, metal refining, and petrochemical plants until the end of World War II. Matsushita Electric Industrial Co., Ltd. (visited by 2004 APRU fellows) was established in 1918, during a period when Osaka was called “En-to (the city of smoke)”. After World War II, Osaka was faced with the difficulties of converting military factories to nonmilitary use because of the excess concentration of population and industry in the Tokyo Metropolitan area. Many of the medium and small companies did not develop until the oil shock in the 1970s and the burst of the bubble economy in the 1990s. However, the heavy industries remain as the base industry in Osaka even to the present day. As a result, water and air pollution have emerged as serious problems in Osaka and its surrounding areas.

The population in Osaka city and the Osaka prefecture at the end of the 20th century reached 2.5 million and 8 million, respectively. Environmental problems, especially the water environment in Osaka, were key topics during the 2004 APRU Fellows Program. We studied the development and preservation of Lake Biwa in the inspection tour to Lake Biwa Research Institute, Shiga Prefectural Science Museum of Water-Environment, Biyo Center, Lake Biwa Museum, and Lake Biwa Canal Museum of Kyoto. Urbanization caused eutrophication and water shortage in Lake Biwa. Although Osaka has a high precipitation of about 1,800 mm/year, large amounts of

bottled water are now imported for drinking because the supply from Lake Biwa has an offensive odor derived from algal blooms, chloramines and carcinogenic by-products produced in the water purification process. As compared to the dry state of California (the other 2004 APRU site - Sedgwick Reserve and Santa Cruz Island Reserve) with low precipitation of about 500 mm/year, people in Osaka consume much more bottled water. Ironically, the water problems in Osaka resulted in a large net positive import of water (including “Crystal Geyser” from California's Shasta Trinity National Forest) from cities or countries with less precipitation.

Automobiles have replaced ships in the role of transportation and cause air pollution by emitting exhaust gas containing nitrogen oxides and suspended particulate matters. The canals and vegetation turned to asphalt-paved roads and concrete buildings. Traditional townscapes like Machiya in Kyoto became cosmopolitan townscapes. Urbanized ground surface and anthropogenic exhaust heat bring about the heat island phenomena. Mass production and mass consumption lead to mass waste disposal. Inadequate operation of incineration plants for combustible wastes has produced dioxins. Generation of large amounts of incombustible solid wastes results in seaside reclamation of Osaka Bay. Now, less than 1% of the natural coastal line in Osaka Prefecture remains. Dioxins, heavy metals and endocrine disruptors causing

long-term negative effects on living organisms are detected from fish and benthic animals in Osaka Bay.

2.3 The Link to Globalization

As mentioned above, there are many serious environmental problems in Osaka. One of the more recent problems is groundwater pollution by selenium, an element with atomic number of 34. Selenium, with a density of about 1,600 times the level of the environmental quality standard of 0.01 mg/L, has been detected in the water that leaked from an office building belonging to a metal processing company near Osaka Castle in 2004. The metal processing company said the water also contained arsenic with a density of 36 times the environmental quality standard of 0.01 mg/L.

Selenium, which is a component of an unusual amino acid selenocysteine, is called “essential toxins” because it is required in trace amounts for growth and metabolism but is toxic at high concentrations. In fact, Keshan diseases, a cardiomyopathy in the low-selenium Keshan region of China, and Kashin-Beck disease, a destructive bone and joint disease in parts of China and Siberia, are related to selenium deficiency (Tan *et al.* 1994). However, high concentrations of selenium have acute and chronic toxicity. The result of the contamination is death and reproductive failure of living things. In the early-1980s, it was at Kesterson Reservoir in California where selenium contamination at high concentration was first observed in the world.

Mass graves of aquatic birds were reported (Ohlendolf *et al.* 1986). Selenium is essential for the proper functioning of an antioxidant enzyme called glutathione peroxidase. This enzyme protects cell membranes from damage caused by the peroxidation of lipids. Selenium deficiency can cause health problems to human and livestock, but it can be easily corrected with the introduction of selenium supplement. On the other hand, selenium toxicity is not so easily reversible. In food and water, the bioavailability and toxicity of selenium depends on its chemical form. Generally, organic forms of selenium are more bioavailable and less toxic than the inorganic forms (selenites, selenates).

In Japan, a high possibility of selenium contamination has been pointed out because Japan is one of the countries that refines and consumes the largest amount of selenium in the world. Selenium occurs as selenide in many sulfide ores, such as copper, silver, or lead. It is obtained as a by-product of the processing of these ores, from the anode mud of copper refineries. The mud can be processed by a number of means to obtain free selenium. The amount of this by-product produced from several copper refineries is estimated at 600-700 ton/year in Japan. Because of its photovoltaic and photoconductive properties, selenium is used extensively in electronics, such as photocells and solar cells. Selenium is also extensively used in rectifiers. The selenium production exceeds domestic consumption because of the large amount of copper ore

imported and its easy refinery process. The refined selenium of 300-350 ton/year is exported to foreign countries.

Wastewater from the copper refining industry contains quite high concentrations of selenium, e.g. 20 - 60 mg-Se/L from the copper refining industry (Yarita and Yukawa 2000) and 620 mg-Se/L from Se compound industry (Shimomura *et al.* 1997). Environmental quality standards for water pollution were amended in 1993 for selenium in Japan. The maximum concentration of selenium permissible in industrial wastewater was set at 0.1 mg-Se/L. However, since appropriate practical methods for removing soluble selenium from industrial wastewater have not been established yet, provisional standards have been set at 1.5, 1.6, 4.0, and 20 mg-Se/L for wastewater from the Se refinery/purification industry, color glass production, industry of Se compounds, and the copper refinery/purification industry, respectively. Further selenium contamination may arise in the near future.

One of the potential reasons for the selenium contamination in Osaka is globalization. Selenium and arsenic are produced as by-products of copper refinery. Copper has been refined and produced in domestic mines such as Ashio and Besshi in the closed society in the Edo period. However, the domestic copper mines were closed at the beginning of the 20th century due to low profit and local water pollution near the mines. Today, most of the copper ore in Japan is imported from the Republic of Chile.

Japan imports 130 thousand tons per year of refined copper and 4.2 million tons per year of copper ore (42% and 36% are from Chile, respectively). Chile is one of the most geographically distant countries from Japan (about 15,000 km), but as a result of globalization, it is the most economically favorable country for the importation of copper. In the last Asia Pacific Economic Cooperation meeting (APEC) in Santiago, Chile, in November 2004, Chile and Japan established a task force to examine the possibility of signing a bilateral free trade agreement between the two countries. President Ricardo Lagos and Prime Minister Junichiro Koizumi made the announcement at a joint press conference held in the La Moneda government palace in Santiago. Similarly, in the same meeting, the president of Chile and the president of China, Hu Jintao, decided to initiate talks on a free trade agreement between the two countries. The importation of copper from Chile and the subsequent refinery processes, although economically favorable, are worsening the water problem in Osaka. Japan is also exporting a variety of products equivalent to 560 million US dollars such as automobiles (60%) and home appliances/industrial machines (25%) to Chile, leading to the worsening air pollution in its capital city, Santiago. Thus, the economic growth for both Osaka and Santiago are mutually beneficial, but their environmental sustainability are also closely linked.

2.4 Towards a New Sustainable Society in the Age of Globalization

Globalization increases connection of the world markets and makes it easier to travel, communicate, and do business internationally (Sazanami 1996). However, globalization can also result in the degradation of environmental spheres across the world. Taking the example of selenium, the environmental sphere of one country or city can be polluted by an element from the most geographically distant country on earth. It could be said that the sustainability of Japanese cities, including the water capital, Osaka, was damaged by modernization and globalization. Now, 60% of food (calorie base) and 96% of energy consumed in Japan comes from foreign countries. Every year, Japan imports 710 million tons of resources and 70 million tons of products and exports 120 million tons of various products in total (Moriguchi 2003). All of those imports/exports are not reused nor recycled although some industries such as Matsushita Electric Industrial Co., Ltd. have just started material recycling of home appliances such as televisions, air conditioners, washing machines, and refrigerators with the aim of a more environmentally sustainable society. In order for the realization of a new sustainable global society to occur, we have to elucidate the end-effects (environment, health, others) of imports/exports and their unintentionally accompanying chemicals and elements. Although a new sustainable society in Japan would be drastically

different from the closed society during the Edo period, Japan and the water capital, Osaka, should strive towards a more sustainable society in the globalization age.

3. The Model City of Globalization - Shanghai, China

China is a country in Asia with great impact on economy, culture and politics as well as ecology and environment on a global scale. It is the third largest country (9.6 million km²) and the most populated country in the world (1.3 billion people in 2004). In fact, more than 20% of the world population is Chinese. In accordance with its geographical and demographical significance, China is gaining major economic power through rapid economic growth. Its GDP is more than 140 million dollars with an economic growth rate of 9.1%. The Chinese economy has experienced explosive growth after the start of Deng Xiaoping's economic reform programs, especially with the approval of the Shenzhen Special Economic Zone in 1993. More importantly, the Chinese economy is booming with strong correlation to the global economy - China did not develop its economy in isolation. Import and export has drastically increased in China during the last decade. For example, China is now the largest exporter to Japan in terms of agricultural products, raw materials, and machineries. US was the former largest exporter until 2001. Correspondingly, Japan has been increasing the export of automobiles, electronics (TV, video, camera etc.) and chemical products to China. In

this sense, these phenomena can be considered as an expression of globalization through trade.

3.1 The City and its Past

Shanghai is well known as one of the largest cities in China with more than 16 million people in an area of 6340 km² in 2000. It is also known as the most international and economically prosperous city in China. It is located in central-eastern China, at the mouth of Yangzi River exposed to the East China Sea (31.1°N, 121.2°E). Historically, Shanghai was a barely developed marshland and modern Shanghai only turned up in the 17th century when a complex web of canals was built to drain the region. It became one of the first Special Economic Zones soon after International Settlement was established in 1840s and 1850s due to the first wave of globalization (The Bund area is famous for its old-fashioned western-style buildings at the time of International Settlement). Now it is one of the greatest industrial, financial and trading centers in China. This city reflects the recent Chinese economic boom as a result of a second wave of globalization. In this sense, Shanghai can be considered the “city of globalization.” Unfortunately, environmental degradation has also been reported in China, including the Shanghai region, as associated with the economic explosion in the last decade. Environmental sustainability has been traded-off for economic growth. As a consequence, air, water, and soil pollution have been reported to be more serious than

ever before. What we need to be mindful of is the fact that economic expansion in China may be far greater than those in other countries in the past, and so could the environmental degradation, especially given the population density in Chinese cities. In this context, environmental conservation in Shanghai city would be the most symbolic case study in the 21st century in which economic growth is balanced with environmental sustainability in the age of globalization.

3.2 Soil Pollution in Shanghai Region

Soil pollution, defined as contamination of soils with toxic materials such as heavy metals, organic chemicals and radioactive elements etc., has been a major environmental problem worldwide. Since the beginning of the industrial revolution, soil pollution by toxic metals has accelerated dramatically. About 90 % of the anthropogenic emissions of heavy metals have occurred since 1900 A.D. (Nriagu 1996). Accordingly, it is now well recognized that human activities lead to a substantial accumulation of heavy metals in soils on a global scale (e.g. $5.6 - 38 \times 10^6$ kg Cd yr⁻¹). Toxic heavy metals accumulate in soils due to many processes such as atmospheric deposition from industrial activities or power generation; disposal of wastes such as sewage sludge, animal manures, ash, domestic wastes or by-products; irrigation and flood or seepage waters and the utilization of fertilizers, lime, or agrochemicals (Alloway 1990). Their accumulation in soil can result in a decrease in soil microbial

activity, biodiversity and soil fertility, yield losses of crops, and even damage on animal and human health through the food chain, such as the Itai-itai disease (Cd poisoning). Itai-itai disease is the softening of the bones and the induction of kidney failures caused by excessive cadmium (Nogawa 1984). Cadmium is also currently considered as a human carcinogen by the International Agency for Research and Cancer.

Soil pollution has several characteristics when compared with air or water pollution. Firstly, soil pollution tends to be chronic due to the buffering capacity of the soil. It is the main reason why soil pollution is more often ignored compared with air and water pollution. Secondly, in relation to this, available fraction is more important than total amount of toxic materials for evaluating the level of pollution. Thirdly, it is much more difficult to clean up polluted soils for the same reason as mentioned above. Some experts have suggested that soils are like livers – a silent organ in the human body. Its function is to clean up or filter toxic materials steadily, but when the toxicity has accumulated to a disorderly state, it is often too late to recover from it. This directly leads to the fact that remediation of soil pollution is very costly. Therefore, to conserve soil environment by preventing soil pollution is cost effective and economically desirable as well as environmentally sound. Fourthly, soil pollution is often more site-specific and heterogeneous because of the variety of soils in space and time. Lastly, soil tends to accumulate contaminants of air and water pollution because soil is the central

basis of the terrestrial environment, that is, soil pollution can be resulting from air and water pollution. Minimizing air and water pollution should also minimize soil pollution.

In Shanghai, soil pollution with heavy metals and organic chemicals has become more and more serious in tandem with its economic development. The source of contamination would be from industries and municipal waste in the central urban areas as well as agricultural input, such as fertilizers and pesticides in relatively rural areas. For example, Nanjing Institute of Soil Science, a member of the Chinese Academy of Science, pointed out that soil pollution with heavy metals including Cd, Cr, Cu, Pb and Zn is reaching critical levels. In an extreme case, damage to human health was reported in an anonymous site around Shanghai in relation to Cd pollution of agricultural soils due to contaminated irrigation water applied to paddy fields. In this case, patients showed symptoms similar to the Itai-itai disease. These human health problems and environmental or ecological degradation occurred because we could not control or minimize environmental pollution for the purpose of economic growth. Such information strongly indicates that soil pollution in Shanghai city is not a problem of the past but a present and ever-increasing problem. We really believe that now is the best time to learn from the past and not to repeat our past mistakes.

3.3 Challenges to Combat Soil Pollution in Shanghai

In order to combat soil pollution in Shanghai city, it would be urgently necessary and very important to prepare/propose several countermeasures concomitantly:

1) Evaluation and monitoring of current situation of soil pollution

As a first step, we need to establish some monitoring systems for the soil pollution and soil quality. Toxic materials should be monitored at some spatial and temporal intervals as well as general soil characteristics including pH, organic matter content and water content. Data should be obtained at selected agricultural/industrial/residential sites at least every several months. A data-logger system, connected with data-transfer system, should be introduced to manage data from remote places. Hopefully, we would like to collect the data for several years (with a minimum of at least one year) to demonstrate spatial heterogeneity and temporal dynamics of the environmental quality. We will be able to publish datasets of the soil pollution levels in Shanghai city to be compared with similar data in other regions or countries including Pacific Rim countries.

2) Risk assessment and establishment of standard or criteria for soil pollution

To interpret the data from monitoring the soil conditions, in relation to ecological impact and human health, it is crucial to carry out risk assessment of soil pollution (McGrath *et al.* 1995). This study area has been intensively investigated and

now more and more assessment data is available. By using such information, it would be possible to establish standard levels or criteria of soil pollution in Shanghai, with reference to ecological risk and human health risk. Criteria could be set up universally regardless of the area considered but in some cases, they should be set up to determine and assess the level of soil pollution in the area concerned. For example, in Shanghai city, so that established criteria can be appropriate and effective.

3) Remediation of soil pollution

Judging from the fact that soil pollution is already present in some parts of the Shanghai region, it is necessary to remediate or clean up such polluted sites. Conventionally, engineering measures have been used, such as digging out polluted soils to be thrown away or to put unpolluted soils on top of polluted ones. These measures require lots of energy and cost, and will spoil original soils completely. Recently, phytoremediation, defined as the use of green plants to remediate contaminated soils, has been highlighted as a promising alternative technique for the removal of heavy metals from soils or for degrading organic chemicals in soils (McGrath *et al.* 2002). For heavy metals including Cd, phytoextraction, in which metal-accumulating plants are used to transport and concentrate metals from the soil into the harvestable parts of plants, is considered to be a promising method. It offers the benefits of operating *in situ*, that is, being low cost and environmentally sustainable

because the soil can be reclaimed without a concomitant decrease in soil fertility. One approach for phytoextraction is to use hyperaccumulator plants with exceptional metal-accumulating capacity to extract metals from the soil. This area of research would lead to practical application of phytoremediation for the clean up of polluted soils even though it is still at the stage of theoretical or laboratory testing.

4) Prevention of soil pollution

Prevention of soil pollution is a very effective way to minimize soil pollution because remediation of once-polluted soils is very difficult, as mentioned above. In this context, prevention of soil pollution is far more necessary than ever. Establishment of appropriate regulations or laws would be necessary. Strengthening the relationship between scientists, policy makers and industry is needed. This is especially important in Shanghai because regulations or the “polluters pay” policy has not yet been fully established.

3.4 A Tale of Three Cities

Prevention, evaluation and remediation of soil pollution in Shanghai city would be a symbolic case study that would exhibit the example of an urban region environmental challenge, in harmony with economic development and environmental conservation in the age of globalization. In addition, lessons learned in Osaka with water pollution and importation of elemental materials and heavy industry can be used

in Shanghai as it develops chemical and electronic industries. Similarly, lessons from Santiago with air pollution and automobile density can be used in Shanghai as automobiles were forecasted to reach unprecedented density in the region. Finally, soil pollution in Shanghai cannot be managed without simultaneous consideration of air and water pollution challenges facing this new “city of globalization” in Asia.

Conclusion

A summary of the environmental problems in the three spheres are as follows:

- **AtmoSPHERE - air pollution:** In general, all big cities have serious problems with air pollution. This is contributed primarily by industrialization and population growth, also for the sake of modernization, thermal power and traffic. The increase of private vehicles, aged vehicles, poor quality roads and congestion is a main cause of air pollution. The more important pollutants include Ozone (O₃), respirable particulate matter, (PM10), nitrogen oxides (NO_x), volatile organic compounds (VOCs) and carbon monoxide (CO).

- **HydroSPHERE - water pollution:** Major sources of water pollution are caused by organic pollutants from industries, discharge of domestic sewage and run-off from land-based activities. These affect water bodies such as lakes, rivers and underground sources. High bacteriological and heavy metal contamination adds to the severity of the problem.

- **PedoSPHERE - soil pollution:** Soil pollution may come from many different sources, such as farming, mining, quarrying, household waste, construction, factory waste and others. In most cases, this type of pollution is related to metal, pesticides, and oil products.

We used the three cities and their tales as examples to demonstrate and to describe the specific details regarding the pollution of these three spheres, and some of the management strategies, current or future possibilities.

In alignment with the “one sphere” theme we proposed in this paper on a more innovative approach to environmental issues, we would also like to briefly address the following specifically:

- *Scientific solutions.* Processes that control formation, transformation, the removal of various pollutants in the three environmental spheres are of great interest to the research community. Further efforts and research have to be directed in this area to help with the practicality of improving existing atmospheric, hydrospheric, and pedospheric environments.

- *Health effect of various pollutants.* Various trace gases, water and soil contaminants can affect human health and have adverse effects on the ecosystem. Exposure to air pollutants by humans is associated with increased respiratory symptoms or decreased lung function and premature mortality. As such, it is necessary to study and understand the effects and risks of the pollutants to humans and other living things.

- *Research group linkage.* It is necessary to improve the linkage between the groups that are already working at numerous cities across the world with other regional and international programs. The improved cooperation between groups can lead to the

generation of common databases with all the relevant information made accessible to every working group.

- *Research community and government institutions.* It is necessary to strengthen the relationships between the research groups, government institutions and policymakers across the world in order to achieve well-informed management decisions.

Appendix

Summary Table

Comparison of the economic parameters between Chile, Japan and China

	Chile	Japan	China
National name	República de Chile	Nippon	Zhonghua Renmin Gongheguo
President	Ricardo Lagos (2000)	Emperor: Akihito (1989) Prime Minister: Junichiro Koizumi (2001)	Hu Jintao (2003) Prime Minister: Wen Jiabao (2003)
Area	756,950 sq km 292,258 sq mi	377,835 sq km 145,882 sq mi	9,596,960 sq km 3,705,386 sq mi
Population (2004 est.)	15,823,957	127,333,002	1,298,847,624
Population growth rate	1.0%	0.1%	0.6%
Capital (2003 est.)	Santiago 5,333,100 (metro.area) 4,372,800 (city proper)	Tokyo 31,139,900 (metro. area) 8,240,100 (city proper)	Beijing 9,376,200 (metro. area) 6,619,000 (city proper)
Large cities	Viña del Mar, 303,100; Valparaíso, 274,100; Talcahuano, 252,800; Temuco, 247,200; Concepción, 217,600	Yokohama, 3,494,900 (part of Tokyo metro. area); Osaka , 2,597,000; Nagoya, 2,189,700; Sapporo, 1,848,000; Kobe, 1,529,900 (part of Osaka metro. area); Kyoto, 1,470,600 (part of Osaka metro. area); Fukuoka, 1,368,900; Kawasaki, 1,276,200 (part of Tokyo metro. area); Hiroshima, 1,132,700	Shanghai , 12,039,900 (metro. area), 9,005,600 (city proper); Tianjin (Tientsin), 4,333,900; Wuhan, 3,959,700; Shenyang (Mukden), 3,574,100; Guangzhou, 3,473,800; Haerbin, 2,904,900; Xian, 2,642,100; Chungking (Chongqing) 2,370,100; Chengdu, 2,011,000; Hong Kong (Xianggang), 1,361,200
Language	Spanish	Japanese	Standard Chinese (Mandarin/Putonghua), Yue (Cantonese), Wu (Shanghaiese), Minbei (Fuzhou), Minnan (Hokkien-Taiwanese), Xiang, Gan, Hakka dialects, minority languages
Ethnicity/race	White and white-Amerindian 95%, Amerindian 3%, Others 2%	Japanese 99%, Others 1% (mostly Korean)	Han Chinese 91.9%, Zhuang, Uygur, Hui, Yi, Tibetan, Miao, Manchu, Mongol, Buyi, Korean, and other nationalities 8.1%

Source: <http://www.infoplease.com/ipa/A0107407.html>

(continuation)

	Chile	Japan	China
Monetary unit	Chilean Peso	Yen	Yuan/Renminbi
Religions	Roman Catholic 89%, Protestant 11%, small Jewish and Muslim populations	Shintoist and Buddhist 84%, Other 16%	Christian 3%-4%; Daoist (Taoist), Buddhist, Muslim 1%-2%. Officially atheist (2002 est.)
GDP/PPP (2003 est.)	\$154.6 billion; per capita \$9,900	\$3.567 trillion; per capita \$28,000	\$6.449 trillion; per capita \$5,000
Real growth rate	3.2%	2.3%	9.1%
Inflation	1.1%	-0.3%	1.2%
Unemployment	8.5%	5.3%	urban 10%
Arable land	3%	12%	13%
Agriculture	Wheat, corn, grapes, beans, sugar beets, potatoes, fruit, beef, poultry, wool, fish, timber	Rice, sugar beets, vegetables, fruit, pork, poultry, dairy products, eggs, fish	Rice, wheat, potatoes, sorghum, peanuts, tea, millet, barley, cotton, oilseed, pork, fish
Labor force	5.68 million (2000 est.); agriculture 14%, industry 27%, services 59% (1997 est.)	66.66 million; services 70%, industry 25%, agriculture 5% (2002 est.)	753.6 million (2002 est.); agriculture 50%, industry 22%, services 28% (2001 est.)
Industries	Copper, other minerals, foodstuffs, fish processing, iron and steel, wood and wood products, transport equipment, cement, textiles	Among world's largest and technologically advanced producers of motor vehicles, electronic equipment, machine tools, steel and nonferrous metals, ships, chemicals; textiles, processed foods	Iron and steel, coal, machine building, armaments, textiles and apparel, petroleum, cement, chemical fertilizers, footwear, toys, food processing, automobiles, consumer electronics, telecommunications
Natural	Copper, timber, iron ore, nitrates, precious metals, molybdenum, hydropower	Negligible mineral resources, fish	Coal, iron ore, petroleum, natural gas, mercury, tin, tungsten, antimony, manganese, molybdenum, vanadium, magnetite, aluminum, lead, zinc, uranium, hydropower potential (world's largest)
Exports	\$20.44 billion (f.o.b., 2003 est.): copper, fish, fruits, paper and pulp, chemicals	\$447.1 billion (f.o.b., 2003 est.) motor vehicles, semiconductors, office machinery, chemicals	\$436.1 billion (f.o.b., 2003 est.) machinery and equipment, textiles and clothing, footwear, toys and sporting goods, mineral fuels
Imports	\$17.4 billion (f.o.b., 2003 est.) consumer goods, chemicals, motor vehicles, fuels, electrical machinery, heavy industrial machinery, food	\$346.6 billion (f.o.b., 2003 est.) machinery and equipment, fuels, foodstuffs, chemicals, textiles, raw materials (2001)	\$397.4 billion (f.o.b., 2003 est.) machinery and equipment, mineral fuels, plastics, iron and steel, chemicals

Source: <http://www.infoplease.com/ipa/A0107407.html>

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	Chile	Japan	China
Major trading partners	U.S. Japan China Mexico Italy UK Argentina Brazil Germany	U.S. China South Korea Taiwan Hong Kong Indonesia Australia	U.S. Hong Kong Japan South Korea Taiwan Germany
Communications	Telephones main lines in use: 2.603 million (1998); mobile cellular: 944,225 (1998); Internet users: 3.1 million (2002)	Telephones main lines in use: 60.381 million (1997); mobile cellular: 63.88 million (2000); Internet users: 56 million (2002)	Telephones main lines in use: 135 million (2000); mobile cellular: 65 million (Jan, 2001); Internet users: 45.8 million (2002)
Transportation	Railways - total: 6,585 km (2002); highways - total: 79,814 km; paved: 15,484 km; unpaved: 64,330 km (2000)	Railways - total: 23,168 km (2002); highways -total: 1,161,894 km; paved: 534,471 km (including 6,455 km of expressways); unpaved: 627,423 km (1999)	Railways - total: 71,600 (2002); highways - total: 1,402,698 km; paved: 314,204 km (with at least 16,314 km of expressways); unpaved: 1,088,494 km (2000)
Ports and harbors	Antofagasta, Arica, Chanaral, Coquimbo, Iquique, Puerto Montt, Punta Arenas, San Antonio, San Vicente, Talcahuano, Valparaiso	Akita, Amagasaki, Chiba, Hachinohe, Hakodate, Higashi-Harima, Himeji, Hiroshima, Kawasaki, Kinuura, Kobe, Kushiro, Mizushima, Moji, Nagoya, Osaka, Sakai, Sakaide, Shimizu, Tokyo, Tomakomai	Dalian, Fuzhou, Guangzhou, Haikou, Huangpu, Lianyungang, Nanjing, Nantong, Ningbo, Qingdao, Qinhuangdao, Shanghai, Shantou, Shenzhen, Tianjin, Wenzhou, Xiamen, Xingang, Yantai, Zhanjiang (2001)

Source: <http://www.infoplease.com/ipa/A0107407.html>

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