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Water Crisis in the Twenty First Century
——Prospect of Asian Population and Development——

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The Asian Population and Development
Association

Water Crisis in the Twenty First Century

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FOREWORD

The world population continues to grow at a rate of 80 million a year. It will exceed 6 billion in 2000, that is, in 2 years, break the 8 billion barrier in 2025, and is likely to reach 10 billion in 2050. Today when we deal with all the problems involving the physical existence of human beings, we have to take the support capability and endowments of the earth into account. In order for mankind to be able to continue to pursue its affluent life in peace, we have to look at things from a global viewpoint of mankind vis-à-vis the earth, transcending the barriers of national interests.

The issue of water as one such global phenomenon has come to the point where it constitutes a challenge to the existence of mankind in the 21st century. Water, freely given to mankind as a grace, is today becoming a commodity in crucially short supply, a problem which menaces our existence. From a medical viewpoint, mankind is said to be able to survive for 40 days or longer taking nothing but water. However, mankind cannot survive with neither food nor water.

Water is used as domestic-consumption water, agricultural water and industrial water. The utilization of water showed a drastic increase especially in the 1950s, that is, in the post World War II period. Needless to say, it was attributable to dramatic increases in population and standards of living: the abnormal multiplication of human beings with their absolute need of water and improvement of the quality of life benefited from accelerated development in science and technology.

Water shortage is a serious problem today in 80 countries and about 40% of the world population is suffering from water shortages. This situation will be further aggravated in the 21st century constituting an important issue at the trunk area of the life-support system.

It is said that there are over 200 rivers that flow across two or more countries in the world. In those countries disputes centered on water are serious international problems. In its downstream reaches, the Ganges River in India flows into Bangladesh, an leading agricultural nation, and there have been disputes between these two countries concerning water for many years. It is only recently that they have come to an agreement on water utilization. Domestically, too, many cities and farming villages coexist along the same rivers and their interests in water often conflict.

From a global point of view, there are 3 major areas of water-utilization, and arrangement of demand for and supply of water among them is an important issue. This document presents analyses made by specialists concerning these global water problems with a particular focus on Asia. That continent, which accounts for 60% of world population, is also the region whose industrial core is the agricultural area which consumes 50% of water available. Water demand in Asia is increasing dramatically in step with modernization. I would be happy if this document which presents visions of Asia in the 21st century from the standpoint of "water" makes a certain contribution to your study and understanding of Asia.

In conclusion, I would like to express my deepest gratitude To the Nippon Foundation (Ms. Ayako Sono, Chairman) and the United Nations Population Fund (Dr. Nafis Sadhik Executive Director) for their great support in the preparation of this document.

March 1998

Fukusaburo Maeda
Chairman
The Asian Population and
Development Association

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Introduction

Dilemma of the 21st Century

–Interlinking Crisis of Population, Water and Food in Asia–

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1. Double-edged Sword

Scientific and technological progress has made extremely great contributions to the well-being of mankind. There is no end to progress such as space development and life creation technology. However, progress is not one way; some opposite reaction is inevitably generated at the same time. The processes of progress themselves sometimes act against progress, posing danger to the existence of mankind itself. Science and technology is what is known as a double-edged sword.

The 1960s marked the beginning of an explosive increase of population, unprecedented in the history of mankind. However, remarkable progress in science and technology including medical science has achieved a rapid increase of food production on one hand, and progress in fertility control technology has achieved brilliant success in suppressing demographic increase on the other, perhaps beginning to throw light of hope on solving population explosion.

Man is a living being and cannot live without food and water. However, the era in which people could have water freely whenever and wherever they wanted and increase food production to such a degree that farmers had to worry about a decline in prices seems to be coming to an end. Mankind, who achieved highly luxurions life style, is now having to confront the shortage of basic elements for life such as food and water. The economic growth that contributed to a high standard of living has discharged industrial pollutants, while a drastically growing urban population has produced huge volume of domestic garbages and waste contaminating drinking water and over-consuming under ground water to the extent that people worry about their depletion. More importantly, the water necessary for food production, agriculture in particular, is now having to be reduced under the pressure of demand from expanding industrialization and increased population in the urban areas. Farmland itself is notably on the decline in the process of modernization.

2. Unbalanced Supply and Demand

Resources on the earth are limited. Water can be recycled and technological progress may increase the efficiency of water utilization, but it is obvious that water supply is not limitless. On the other hand, the water-using population is increasing abnormally, the so-called demographic explosion. Not only the numerical growth in population, but also improvement in the standard of living has increased the consumption of water per capita, and furthermore, continuous worldwide economic growth is increasing the amount of water needed for industrial use.

The use of water resources worldwide has been growing steeply since the 1950s. A drastic increase took place in the agricultural field first, followed by the industrial field in the 1970s, and is currently transferring to the domestic field, especially urban domestic life. Domestic water consumption worldwide grew by approximately 50% between 1950 and 1990. The demand for water for agricultural production is outstanding among the various areas that use fresh water resources, because irrigation on the paddy fields plays a great role in elevation of productivity. The characteristic changes in the increase of use of water resources as seen above are a faithful reflection of the epoch-making development of agricultural production corresponding to the abnormal population increase 1) starting from the 1950s, worldwide economic growth after the 1970s and drastic increase of urban population since 1980s.2)

Table 1 shows the annual use of water by sector in around 1990. According to a statement from the United Nations, water is running short in 80 countries around the world and approximately 40% of world population is suffering water shortages.3) It is estimated that this trend will become far more serious in the 21st century.

3. Increase of 1.6 billion in 20 years, at 80 million a year

Now let's touch on the tendency of world population that constitutes the basic factor of the issue of water resources. According to the latest revision (1996) of the United Nations World Population prospects, the world population will grow from 5.7 billion in 1995 to 7.3 billion in 2015, 20 years on, marking an increase of 1.6 billion over 20 years. This is an average increase of 80 million a year. In the meantime, it seems almost certain that the productive activities of the world population will increase together with the rising standard of living. This means that the demand for water will increase exponentially.

The Asian population accounts for 60% of the world population which is increasing so dramatically. However, its area of arable land is only 27.4% of that of the world. What is worse, a vast arid region extends in the Asian continental interior, the estimated annual average precipitation of which amounts to 742 mm. This is second only to Australia and Africa in terms of scarcity. Rapid development by modernization has drastically decreased the area of arable land. China is a gigantic country with a population of 1.2 billion. Since its liberation in 1949, the area of arable land for grain per capita has decreased by half from 0.17 hectares to 0.08 hectares in 40 years due to this population increase 4), which has converted China from a food exporting country to a food importing country today.

Asia has a population of 3.44 billion in 1995 and is estimated to rise to 5 billion in 2030 and 5.4 billion in 2050. Economic development in Asia is outstanding and its dynamism is highly evaluated as a pulling power of the world economy. However, there is an insecure factor of decreasing food production due to water shortage. An American expert reported on the food shortage in China in future as follows. Food production in China will amount to 263 million tons in 2030, but consumption will amount to 479 million tons, that is, the shortage will amount to 216 million tons. The amount of grain imported by China will exceed by far the capacity of world exports at that time.[4)]

However, it should be reminded that such long-range estimates are subject to many uncertain factors. But they are also significant in providing warning to policy makers.

4. Three Urgent Measures

As long as water resources, which have a direct or indirect impact on the existence of mankind, are limited, and especially at the present time when the world is concerned about the depletion of water resources, it is an urgent task to establish national and international measures. What is important is to keep in mind that there is severe competition or contention centered on the use of water among various sectors and regions to use water. It is necessary to set priorities in the allocation of water resources. This allocation plan involves the problem concerning allocation of water by industry, balancing agriculture and non-agriculture especially the industrial field, allocation by region, for example between rural and urban areas, or distribution by demand among different farming areas located along the same river.

The second problem is that of formulating a international plan for distribution of water by use. Currently there are at least 214 rivers which span two or more countries in the world.

There are complex and serious international disputes centered on the use of water. If the upstream, midstream and downstream of the same river belong to different countries, there are very rare cases where an effective and reasonable agreement on their right of utilization is established.

Today, when water shortage is becoming more and more serious, it is an urgent task to promote effective and reasonable agreements to prevent international disputes.

The 3rd urgent measure is the promotion of effective use and recycling of water. Scientific and technological progress, the concerns of industrial corporations, and careful consideration of use of water in individual life can be said to be the basis of measures for water resources.

5. Population control as basic measures

The most drastic growth of population in recorded history is reaching a scale threatening the earth's capacity to support it. The rate of population increase, and human activities, are threatening the water resources which form the origin of life. Since this is the case, the most fundamental measures that can be taken concern the control of world population itself.

On the other hand, however, the world population, and population growth rate and its scale in Asia are almost determined for the next 20 or 30 years. Assuming that this is so, it is indispensable to recognize, concurrently with the basic measures for population control, that planning and implementation of urgent measures for water resources are the imminent serious issue. It is inevitable that acquisition of water resources and improvement of utilization efficiency will emerge as issues inseparable from food problems in the 21st century.

References

1) The annual average growth rate of world population was 1.78% for 1950 to 1955, 1.85% for 1955 to 1960, 1.99% for 1960 to 1965, 2.04% for 1965 to 1970, 1.75% for 1970 to 1975. That was, an abnormal level of around 2%, whereafter it tended to decrease gradually. United Nations: World Population Prospects: The 1996 Revision Annex I Demographic indicators, 1996.

2) The proportion of urban population in the world population was at a level of 30% until 1975 but reached a 40% level after 1980 and 45.3% in 1995.

In particular, the urban population in developing countries grew from approximately 1.0 billion in 1980 to 1.7 billion in 1995, while that in developed countries grew from 0.77 billion to 0.88 billion in the same period. United Nations : World Urbanization Prospects : The 1996 Revision Annex tables, 1997.

3) Zenbei Uchijima; "Global Environment and Water Resources", Report on the 13th Asian Parliamentarians Meeting on Population and Development (Kobe, March 17th. and 18th., 1997), Asian Population and Development Association, p.53.

4) Lester R. Brown and Hal Kane : Full House, The Worldwatch Environmental Alert Series, W. W. Norton & Company, 1994, P.104.

5) Lester R. Brown and Hal Kane : Full House, The Worldwatch Environmental Alert Series, W. W. Nortin & Company, 1994, P.168.

Table 1 Present world water use

Sector	Use km^3/ye (%)	Evaporation loss %
Agriculture	2800 (41.8)	66
Industry	1000 (41.9)	12
Municipalities	300 (4.5)	27
Evaporation	260 (3.9)	100
Instream flow needs	6700 (100.0)	33

Source: Sandra et al., 1996. Zenbe Uchizima : "Gloval Environment and Water Resources", Report on the 13th Asian Parliamentarians Meeting on Population and development (Kove, March 17th and 18th, 1997), Asian Population and development Association, P.53.

Chapter 1

Water, Population, and the Environment in Asia

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Prologue

On July 14 this year, on the other side of Asia, a temporary wooden bridge snapped. Three Australian athletes, marching into the Maccabean Games in suburban Tel Aviv, died after they fell into the Yarkon River, not of the fall or drowning, but from unidentified chemicals in the water.[1] Prosperous Israel, renowned for the high-tech efficiency of its water use, is not coincidentally one of the ten Asian countries currently identified as "water stressed," with supply within its borders falling beneath the commonly adopted threshold of 1000 cu.m./capita (Table 1). Israel's appropriation of water from outside its pre-1967 borders to supplement this shortage underlies much of the intractability of the conflict with its neighbors. Is Israel the vision of the water future for the rest of Asia: prosperous, but with deadly waters and poisoned neighborly relations?[2]

1. Asian Characteristics

There are four topics that this chapter is asked to address and relate to each other: population, water, the environment, and the difference that is Asia. I will begin at the end of the list. It is hard to generalize about an area as vast and varied as Asia, but three features stand out about its water.

First is that by far most of Asia's water use—85 percent of withdrawals and an even higher share of consumptive use—is for irrigation (Table 2).[3] Only in Africa, with a much smaller level of overall water use, is the agricultural share larger. Naturally, this also means that most of the world's irrigating is done in Asia.

Second is that, even though half of the world's megalopolises over 5 million population are in Asia, two out of every three people here still live in the rural areas. Migration from rural to urban areas, already near an end in the Americas and Europe, may be expected to swell Asia's cities to unprecedented dimensions and place enormous burdens on their infrastructure requirements, in particular in the areas of water supply, waste disposal, and sanitation.[4]

Third is that, based on the data available to the Global Environment Monitoring System (GEMS), the water quality of Asia's rivers is already worse than that in other parts of the world (Table 3). Much of this is "traditional," organic pollution: suspended solids are four times the world average and rising rapidly, biological oxygen demand (BOD) is 40 percent higher, and fecal coliform counts are three times higher (median count 50 times the WHO guidelines). Ironically, nitrate levels, affected by runoff containing human and animal waste or chemical fertilizers, are lower than the world average. Urban areas concentrate these pollution loads, and add "modern" pollutants such as heavy metals from industrial wastewater. Add growth in populations and economies to this mixture and there are understandable grounds for concern about the future of water use and related parts of the environment in Asia.

2. Population and the Environment

It seems self-evident that population and environmental damage are related. Doomsayers (now known as "catastrophists") from Thomas Malthus, to the Club of Rome, to entropy theorists such as Georgescu-Roegen, to Paul Ehrlich and Lester Brown have all warned that disaster awaits us if we do not stabilize or reduce the population of the world. "Cornucopians" such as Julian Simon, Herman Kahn, and many economists note that so far at least there is little evidence of a direct linkage between population size and growth and the state of the environment.[5] Instead, they point to imperfect property rights, misguided subsidies, and poverty as the critical variables determining environmental degradation.[6]

There is a growing body of evidence that some environmental problems, in particular many of those related to water, tend to lessen with economic growth, for rather obvious reasons: investments in water supply, sewerage and effluent controls become easier to bear as an economy becomes wealthier.[7] This does not mean that poor countries can or should relax their efforts to clean up, however, nor does it imply that prosperity cures all environmental ills: municipal wastes and carbon dioxide emissions seem to accelerate with prosperity. Nonetheless, at present there appear to be few demonstrable linkages between population size per se and environmental degradation. To illustrate this point, I will turn to a discussion of one of the more commonly used indicators of the effect of population size on water resources.

3. Population and Water

Based on the research of the eminent Swedish hydrologist Malin Falkenmark, various "water stress indices," most commonly 1,000 cu.m./cap./ann. of internal renewable freshwater (see Table 1), have been used to indicate the level "below which most countries are likely to experience chronic water scarcity on a scale sufficient to impede development and harm human health."[8] Like many rules of thumb that are necessary for benchmarking and comparing, such a water stress index can be quite misleading as a guide to policy making. It does not count imported waters. It ignores the structure of water use, especially the weight of irrigated agriculture. Most importantly, at least as of the present, it does not seem to have a great deal of empirical evidence to back it up, at least in Asia.

As Table 1 shows, those countries in Asia currently falling below the 1,000 cu.m./cap./ann. benchmark are, with few exceptions (Yemen and Jordan), prosperous, with high life expectancies, and except for Singapore, in the Middle East. Even there, in western Asia, only three other countries are projected to drop below 1,000 cu.m./cap. by the year 2050 (Afghanistan, Iran, and Oman). In Pacific Asia, only the Republic of Korea is expected to fall to this level. It is highly improbable that water shortages will put a brake on the south Korean economy.

Actually, if the Falkenmark criterion were valid, it would seem that Asia east of Afghanistan has little to worry about. Even Mongolia, Kazakhstan and Uzbekistan are relatively flush with water, in the aggregate. Because of the size of some countries in the region, however, we need to look at the subnational level as well. There we certainly do find a number of important local areas facing serious shortages. For example, estimates of potential industrial and agricultural production lost due to chronic water shortage are high and growing in parts of China, such as much of Shanxi, Shandong, and Hebei provinces and in some of the rapidly growing economic areas in the small basins along the southeastern coast. Nonetheless, the economies there continue to grow, and except for Shanxi are among the most prosperous areas of China.

An alternative way of thinking about water stress that I find attractive, although it lacks the elegant precision of the Falkenmark criterion, is the concept of the maturing water economy, first presented by Alan Randall in 1981 to argue for establishing exchangeable property rights in water in Australia.[9] As indicated in Table 4, in an "expansion phase," a water economy operates under different conditions and different rules than when it enters into a "mature phase." In an expansion phase, unclaimed water sources are available, meaning that in economic terms their "opportunity cost" is zero, even though capital and delivery costs may sometimes be quite high. Still, those costs are reasonable enough that often they are heavily subsidized by the government, which is itself often in an expansion phase. A large portion of the cost is sunk into the original facilities, often absorbed into the national construction budget, making it easier to overlook the implicit subsidy — until the time comes to do repair, rehabilitation, or replacement. Each use sector (agriculture, industry, domestic) tends to develop its own supply system from different water sources, usually under a water rights system that grandfathers existing uses but does not allow the sale of rights to others, especially in other sectors, on the grounds that water ultimately belongs to the public.

A mature phase can be brought on by any of a number of factors, including an overall increase in water demands, a tightening of the state budget in response to rising subsidies, deterioration of projects due to age and insufficient maintenance, the recognition of new water uses such as the environment, fisheries, or recreation, or degradation of existing sources through overdraft of aquifers or pollution. The opportunity cost of water begins to rise, sometimes quite rapidly. What makes the idea of the maturing water economy attractive relative to the Falkenmark criterion is that it helps to explain how a crisis might occur even in places with abundant water, and therefore it is more applicable to Asia.

It also points to a way out. A water economy may move from a mature phase to one of expansion, either through building a new project to tap a new source, increasingly by means of technically, environmentally and politically complicated interbasin transfers, or to treat otherwise unusable water. Because of the rising expense of new projects and the growing reluctance of governments and international lenders to subsidize them, however, other alternatives begin to look economical. Prominent among these are the use of economic instruments and the transfer of water from lower-value uses to higher-value uses.

One of the highest value uses is human health. Often, the relationship between population and water is phrased in terms of access to safe drinking water and sanitation facilities. The need to provide everyone possible with relative clean water for personal and household uses is self-evident. Although it is extremely difficult to trace the exact pathways, a high percentage of disease in Asia, especially among the poor, is related to water and sanitation (see Chapter 4). But this is a problem of water quality and in situ availability, of poverty and equity, not of the total amount of water available.

4. Water and the Environment

In a 1996 poll for the Asian Development Bank, 16 of 67 Asian environmental policy makers identified water pollution and freshwater depletion as the most important environmental problem in the region.[10] "Depletion" is a popular term used by those describing water crises. It may be useful to note that with water, depletion is a relative and ephemeral condition, and is very much related to economics. In most cases, the hydrological cycle (including precipitation, evapotranspiration, seepage and runoff) replenishes the resource regularly. Depleted aquifers and drained reservoirs, left alone, will refill, sometimes quite quickly. The Baiyangdian, a large but shallow lake in China's Hebei Province, ran dry during a string of droughty years in the 1980s. In one rainy year, it was restored to its full size. London was once worried about the overuse of its aquifer; now its principal concern is the flooding of underground facilities. Even saltwater intrusion can be pushed back to sea by a restoration of an adequate freshwater flow. In this way, water is a marvelous resource: it almost always gives us a second chance. The problem is usually not how much water there is but who uses it, how they use it, where they use it, and who winds up paying the costs.

Mark Rosegrant notes that true water losses in a river basin are those going into one of four "sinks": (1) the atmosphere, due to evapotranspiration, especially from agriculture (some of this returns in the form of precipitation, but not necessarily in the same basin); (2) salt sinks, such as the oceans; (3) pollution sinks, where salts or toxins render the water unusable; and (4) economic sinks, especially the deep groundwater, where it is not profitable to recover.[11] Actually, almost all of these are economic sinks — flows of water into these sinks can be stemmed by flows of money, or changes in the way water is used.

This is not to say that the concerns of environmental policy makers are misplaced. People's health is at risk; ecosystems are at risk. The complexity of the hydrological cycle and pollution makes it difficult to define property rights to water, and places great demands on intersectoral planning. We need to find effective, often innovative ways to address these problems. We find ourselves faced with the legacy of sectorally oriented, heavily subsidized large capital projects from the "expansion phase" of our water economies that complicate necessary adjustments, including economic ones, to put us on a track of sustainable development.

5. Cities, Water, and the Environment

Cities are often blamed for environmental degradation, and it is true that their ecological shadow spreads far, while by concentrating human activities in a relatively small space they also tend to generate huge amounts of waste and utterly transform local ecologies. In 1982, water of the Yamuna River entering Delhi had a fecal coliform count of 7,500 per 100 milliliters; when it left the city, it bore with it 24 million coliforms per 100 milliliter.[12] Historically, cities were very unhealthy places to live in, and often remain so, especially for the marginalized poor, many of them new migrants or squatters.

Catastrophists tend to view cities as the embodiment of the nightmare of overpopulation, especially when migration is combined with economic growth. For example, Lester Brown's vision of China in the year 2030 is one where "industrialization" (in the form of factories, houses, roads, and more profitable crops) has gobbled up nearly half of the grain harvested area and appropriated a heavy share of the water resources now being used to feed millions of people.[13] While Brown's scenario is excessively dark, it does illustrate a central fact of life, that where they can be used for either urban or agricultural uses, land and water, like people, almost always create more economic value in the city. There is nothing wrong with this. Rich countries tend to be more urban, and to use a lower percentage of water in agriculture.

I shall return to Brown's specter of a coming food crisis. For now, let me note that while there are tensions over water supply between thirsty cities such as Beijing or Madras and their irrigated peripheries, they do not always affect agricultural production adversely. The most pressing problems involving urban water are not in the next century or the reach to the suburbs for new supplies, but now, within the urban environment itself, and with the existing supply.

Take, for example, the UN's International Decade for Drinking Water

Supply and Sanitation, intended to provide safe water to all urban residents during the 1980s. It succeeded in extending water supply to 185 million people in the cities of Asia and the Pacific, far more than the 148 million unserved (by public supply) in 1980. Yet because of urban growth, the number unserved in 1990 had grown to 175 million!

The problem is not usually one of availability. Domestic water, especially for the poor, almost never consumes a very high percentage of total water, and people who are "unserved" still use some kind of water. The problem is not even a matter of the willingness of people with limited incomes to pay for clean water: the poor in Manila pay up to 20 percent of their income to purchase potable water from vendors. In general, the "market price" of water from vendors in poor areas of Asia is dozens of times higher than the official rate charged to those fortunate to be hooked up to taps.[14]

Even though Seoul is the capital of the most water-stressed country in East Asia, it does not face a conflict with irrigated agriculture, because there is still potential for building storage dams on the Han River. The most serious problem facing Seoul's water supply is deteriorating quality because of wastewater inflows from residences, industries, and livestock farms in the watershed of the Paldang Reservoir. The city has a number of options to face these challenges — to purify the water, build new intake facilities, or purchase more water from areawide waterworks — but any of these will raise the costs of supply.[15] Seoul is far from alone. Many cities are having to spend more money either to increase or even secure their present water supply — a survey of 10 water-short cities, seven in Asia, by Ramesh Bhatia and Malin Falkenmark, indicated that the cost of the "next" project would be more than twice that of the "current" project.[16]

6. Industry, Water, and the Environment

Lester Brown's indictment of industrialization has a ring of truth to it.

Industry is one of the culprits in the water conflict drama, both in terms of quantity and quality, although not necessarily the main one. Factories, including thermal power plants, tend to be located in cities, and to place sizable demands on the water supply and disposal capabilities (see Chapter 3). In most of Asia, industrial withdrawals exceed those for domestic purposes in urban areas. Plants often rely on their own pump wells, aggravating problems of excess groundwater withdrawal and land subsidence. Nonetheless, the experience of cities as disparate as Bangkok, Beijing, and Osaka indicates that it is possible to regulate large industrial users, especially when alternate surface supplies can be provided. Also, because most industrial water has lower quality standards than drinking water, and it is relatively easy for most production processes to recycle water several times, industrial water demand is perhaps the easiest to cut without reducing production. Total industrial consumptive water demands have fallen and stayed low despite, indeed to some extent because of, continued growth in output in both Japan and the United States after the imposition of strict emission standards in the 1970s. New capital investments have been able to employ greater water saving features, lending more force to the argument that, at least in some ways, economic growth can lead to an improved water environment.

Large urban enterprises reduced their water consumption rates and their wastewater discharges in China too during the 1980s. Of greatest concern now, and not just in China, are the smaller enterprises whose total water use may not be as high as their larger cousins, but whose discharges are more difficult to monitor (and therefore are considered "nonpoint sources") and which often operate under severe financial, equipment, and managerial constraints. Unfortunately, many of the most toxic industries are dominated by small operations, for example paper making, electroplating, textile dyeing, and leather processing.

What distinguishes China is its "township and village industries" (TVEs), including some rather large scale ones, that are providing much of the impetus for economic growth, but are also a focus of great concern in terms of their often unrestrained discharge of heavy metals and other toxics into the environment.[17] Areas of particular concern are Lake Tai, a source of drinking water for a heavily populated area between Nanjing and Shanghai, and the fragile Huai river basin, where a storm flushed pollutants into the mainstem of the river on 14 July 1994, causing extensive fish kills and disrupting drinking and industrial water supplies. In retrospect, this may turn out to have been one of those dramatic events, like the burning of the Cuyahoga River near Cleveland in the United States in the 1960s or the killer smog in London in the 1950s, that will impel a greater political and economic commitment to cleanup. Only time will tell.

7. Agriculture and Water

Since an extensive chapter on agricultural development and water resources with contributions by three eminent experts follows this one, I will not dwell on agriculture at length here, despite its central importance. Clearly, when the topic of intersectoral transfers comes up, all eyes turn to the farmlands that use such a large portion of the water in Asia. Many urban water supply agencies in the region have either already transferred some water from nearby agriculture or are making contingency plans to do so. Beijing and Shenyang have rerouted water from reservoirs, Madras has developed its own well-fields in rural areas, and some cities on the north China plain such as Handan and Cangzhou have apparently taken water more indirectly by drawing down the aquifer. Agricultural water use is considered a competitor for water supplies with cities as far flung as Bangkok, Delhi, Dhaka, Jakarta and Karachi.[18]

Such competition does not always have to lead to zero-sum results. Growing urban economies provide nearby farmers with expanding markets for high-value agricultural commodities such as fruits, vegetables, and fish, as well as employment opportunities that provide them with the wherewithal to adopt more expensive water-saving irrigating technologies. If they produce less grain, it is probably because it does not pay to do so, not because of a lack of water.

At a more macro scale, beyond the suburbs, even those who are relatively optimistic about the future of the world's grain and food supply, like Mark Rosegrant and Ruth Meinzen-Dick of the International Food Policy Research Institute (IFPRI), express concern about the slowdown in the net growth of irrigated area in Pacific Asia over the past two decades. They attribute this to a rise in the real capital costs of bringing new land under irrigation coupled with a significant decline in public expenditures for new projects in the 1980s.[19]

There are a number of reasons not to be too alarmed by this news. First, measures of irrigated area do not really tell us very much about the quality of irrigation. Improvements in water supply conditions and other inputs on existing irrigated (and unirrigated) land may have a much greater impact on crop production in the aggregate than increases on the margin in irrigated land. Certainly, grain output has continued to grow respectably in China since the late 1970s despite very little change in the overall irrigated area figure. [20]

Further, by and large, the increases in capital costs cited by the IFPRI analysts (in a 20-25 year period, over 100 percent in Indonesia, 50 percent in the Philippines, and 40 percent in Thailand) are quite modest compared to the growth in per capita incomes in the same time frame. The problem is not affordability, but a number of other factors.

One of those is a government unwillingness to continue public subsidies in the face of increasingly overcommitted budgets, and a growing insistence by financial donors that the beneficiaries of a project pay for it. Given that the price of project water to agriculture is almost universally kept low, often even below operating and maintenance costs, new projects based on more complete cost recovery require charges that are several orders of magnitude higher than those the farmers are accustomed to paying. Hence they tend to be politically unfeasible.

Another problem is that increasing portions of shrinking public works budgets have had to be used to patch up undermaintained old projects. In China, far more land goes out of irrigation each year from project obsolescence than from urban-industrial encroachment.

The final and perhaps most fundamental limiting factor is the continuing long-term decline in real grain prices in world markets.[21] Continued rapid expansion of irrigation to increase grain production and thereby further depress prices has little payoff to either state or farmer. As with petroleum, there has been some recent shrinkage in world strategic reserves, but this is little cause for alarm.

8. Is a Water Crisis Looming?

This brings us to the question of whether a water crisis is on the horizon, perhaps interwoven with a food crisis. Since the energy crises of the 1970s, a significant proportion of books analyzing the world's water situation, some of them quite scholarly, use the term "crisis" in their titles (others settle for a mere "scarcity"). I will not burden an already overworked footnote section with a listing of titles. By and large, most of these works argue that a crisis is not inevitable.

Certainly we are unlikely to see a world water crisis like the energy crises of the 1970s. Water is not a world commodity, and there is no international water cartel. Nonetheless, some, again notably Lester Brown, see generalized local water conflicts affecting the production of grain within a few decades, bringing with it rises in international food prices and political instability.

Brown does not give a projection as to the probable increase in prices under his worst-case scenario. Such an estimate was provided in these pages by Professor Hiroshi Tsujii, that international grain prices would rise by as much as 50% between 1993 and 2020.[22] In other words, they would return roughly to their 1980 levels. Another way of considering this figure is that it works out to about a 1.5% per annum price rise, well below the rate at which world per capita income is likely to rise. Thus even in the "worst-case" conditions, grain will continue to become ever more affordable, as will improvements in irrigation facilities.

In my own view, the biggest crises facing the use of water in Asia in the coming years will be local, and will center around urbanization continuing to outgrow the ability of infrastructure to provide water of adequate quality to large shares of the population. Other problems that may prove very difficult to solve lie in maintaining the ecological uses of water while satisfying human demands. The maturing water economies of Asia will demand reforms in a number of areas, beginning with the removal of explicit or implicit subsidies that keep the price of irrigation and tap water below its value for use by relatively advantaged populations. The long-term solution is not as simple as getting the prices and property rights right, but that may be a good place to start. The complexity of the hydrological cycle, and the growing interconnectedness of its users, will place increasing demands on the ingenuity of human institutions.

Epilogue

Is the rickety bridge over the troubled waters of the Yarkon the harbinger of the future for Asia? Probably not, not even for Israel, but it is a warning, and even a sad commentary on the state of many waters today. Restoring order in the water sector will require many adjustments. On that, catastrophists and cornucopians agree. What those adjustments should be is where they differ. Certainly a useful place to start is to regard water seriously as an economic good.

Notes

1 Rebecca Trounson, "Bridge Tragedy Reveals Pollution," Japan Times, 14 August 1997. The 27-kilometer long Yarkon is the longest of Israel's coastal rivers, and has been the object of an extensive cleanup effort since 1988. Shoshanna Gabbay, *The Environment in Israel.* Jerusalem: Ministry

of the Environment, 1994.

2 The "New politics of scarcity," according to Sandra Postel. Dividing the Waters: Food Security, Ecosystem Health, and the New Politics of Scarcity. Washington DC: Worldwatch Institute Paper 132, September 1996.

3 Water use is usually measured in terms of "withdrawals," either directly from sources or via projects such as reservoirs, "demand" at the site of production or consumption, or "consumptive use," which is the amount taken but not discharged in the form of waste water; in other words, the amount returned to the water cycle in less direct ways such as evaporation, seepage, or incorporation into the product. Postel (*Dividing the Waters,* 14) estimates that agriculture worldwide constitutes 65 percent of demand but 82 percent of consumptive use (the comparable figures for industry are 22 and 4 percent, reflecting a higher rate of recycling).

4 James E. Nickum and K. William Easter, eds. *Metropolitan Water Use Conflicts in Asia and the Pacific.* Boulder CO: Westview, 1994.

5 Lamont C. Hempel. *Environmental Governance: The Global Challenge.* Washington DC: Island Press, 1996 identifies a third category, "optimizers," such as U.S. Vice-President Gore, who use catastrophist rhetoric to make incremental diplomatic and political changes.

6 A recent example of these arguments is the chapter on environment in *Emerging Asia: Changes and Challenges.* Manila: The Asian Development Bank, May 1997, which was drafted by Theodore Panayotou of the Harvard Institute for International Development (HIID).

7 I believe the idea that it is possible to grow out of pollution was first presented to the broad public in the World Bank's *World Development Report 1992* and later codified as an upside-down U, or "environmental Kuznets curve," by Gene M. Grossman and Alan B. Krueger, "Economic Growth and the Environment," *Quarterly Journal of Economics,* 1995: 353-377, and *Emerging Asia,* 1997: 214.

8 *World Resources 1996-97.* New York: Oxford University Press, 1996:

302.

9 Alan Randall, "Property Entitlements and Pricing Policies for a Maturing Water Economy," *Australian Journal of Agricultural Economics* 25(3): 195-220.

10 *Emerging Asia*: 209. Next ranked as "most important issue" were air pollution and deforestation (9 each) and solid waste (8).

11 Mark W. Rosegrant, "Water Resources in the Twenty-First Century: Challenges and Implications for Action," Food, Agriculture, and the Environment Discussion Paper 20, International Food Policy Research Institute, Washington D.C., March 1997: 14.

12 Euisoon Shin, Maynard Hufschmidt, Yok-shiu Lee, James E. Nickum, and Chieko Umetsu, with Regina Gregory. *Valuating the Economic Impacts of Urban Environmental Problems: Asian Cities.* UNDP/UNCHS (Habitat)/World Bank Working Paper No. 13. Washington DC, June 1997: 44-45. For reference, the fecal coliform standards for drinking water in developed countries tend to be at or near zero per 100 milliliters.

13 Lester R. Brown, *Who Will Feed China? Wakeup Call for a Small Planet.* New York: Norton, 1995.

14 *Managing Water Resources to Meet Megacity Needs.* Manila: Asian Development Bank, 1994: 342.

15 Nickum and Easter, Chs. 1 and 7 (the latter by Euisoon Shin).

16 "Water Resources Policies and the Urban Poor: Innovative Approach and Policy Imperatives," *Water and Sanitation Currents,* UNDP-World Bank Water and Sanitation Program, 1993. The Asian cities (in increasing order of the cost of the next scheme) are Shenyang, Yingkuo, Bangalore, Surabaya, Dhaka, Hyderabad, and Amman.

17 See, for example, National Environmental Protection Bureau and the China Society of Environmental Sciences, Eds., *Xiangzhen qiye huanjing wuran fangzhi duice* (Environmental pollution prevention policy for TVEs). Beijing: China Environment Science Press, 1991.

18 *Managing Water Resources to Meet Megacity Needs*: 391.

19 Mark W. Rosegrant and Ruth S. Meinzen-Dick, "Water Resources in the Asia-Pacific Region: Managing Scarcity," *Asian-Pacific Economic Literature,* 10, November 1996: 35.

20 James E. Nickum, *Dam Lies and Other Statistics: Taking the Measure of Irrigation in China, 1931-91.* East-West Center Occasional Papers Environment Series No. 18, January 1995.

21 In China, the price to the farmer has risen over this period, but from a level much lower than the world market.

22 Hiroshi Tsujii, "Food Supply and Demand in the Year 2020 and the Necessary Reform in Japan's Agricultural, Forestry and Fishery System," *Population and Food Strategy for 21st Century — Asia and World —.* "Population and Development" Series No. 21, March 1997: 147.

Table 1 "Water Stressed" Asian Countries, 1990-2050

(units: cubic meters per capita, US dollars)

Country	1990	2050 (projected)	Life Expectancy 1990-95	1992 GNP/capita (PPP)
Kuwait	75	59	74.9	8,561
Qatar	103	68	N/A	N/A
Bahrain	184	104	N/A	N/A
Singapore	222	159	74.8	16,736
Saudia Arabia	284	67	69.7	9,390
U.A.R.	293	120	73.8	15,784
Jordan	308	68	67.9	4,039
Yemen	460	90	50.2	2,769
Israel	461	192	76.5	12,783
Rep. of Korea		964	71.1	9,565

Note: Figures for 2050 use low United Nations population growth projections. Higher population growth estimates create more stress.

Source: *World Resources 1996-97,* 1996: 302-303, based on Robert Engelman and Pamela LeRoy, *Sustaining Water: An Update* (population Action International, Washington, D.C., 1995) for water stress; Ibid., 166-167 for GDP per capita, 193 for life expectancy at birth.

Table 2 World's Freshwater Resources by Region and Use

	GDP per capita	Internal Renewable Water Resources		Annual Withdrawals		Sectoral Withdrawals (percent) 1987 (Israel 1989)		
	1992 Purchasing Power Parity (international $)	Total (cu.km./ann)	1995 per Capita (cu. m.)	Percent of Resource	Per Capita (cu. m.)	Domestic	Industry	Agriculture
WORLD		41022	7176	8	645	8	23	69
AFRICA		3996	5488	4	199	7	5	88
EUROPE		6235	8576	7	626	14	55	31
NORTH/CENTRAL AMERICA		6444	15369	9	626	14	42	49
SOUTH AMERICA		9526	29788	1	332	18	23	59
OCEANIA		1614	56543	1	586	64	2	34
ASIA		13208	3819	12	542	6	9	85
Bangladesh	1908	2357	19571	1	220	3	1	96
China	1838	2800	2292	16	461	6	7	87
India	1633	2083	2228	18	612	3	4	93
Indonesia	2601	2530	12804	1	96	13	11	76
Israel	12783	2	382	86	408	16	5	79
Japan	19920	547	4373	17	735	17	33	50
Jordan	4039	2	314	32	173	29	6	65
Korea (Dem. Rep.)	3067	67	2801	21	687	11	16	73
Korea (Rep.)	9565	66	1469	42	632	19	35	46
Pakistan	1793	468	3331	33	2053	1	1	98
Philippines	2172	323	4779	9	686	18	21	61
Singapore	16736	1	211	32	84	45	51	4
Thailand	5018	179	3045	18	602	4	6	90
Vietnam	665	376	5044	8	414	13	9	93

Note: Years vary for annual withdrawals. Particularly out of date are India, Jordan, Pakistan, Singapore (1975) and China (1980). Others are since 1987.

Source: World Resources 1996-97.

Table 3 Severity of Water Problems in Asia

Pollutant	East Asia	Southeast Asia	South Asia	China	India
Water pollution					
Suspended solids		XX	XX	XXX	XX
Fecal coliforms		XXX	XX	XX	XXX
BOD		XXX	XX		XXX
Nitrates	XX	X	XXX	XX	XXX
Lead	XX	XXX	X	X	X
Poor access					
to safe water		XXX	XXX	X	XXX
to sanitation		XX	XXX	XXX	XXX

Note: BOD = biological oxygen demand; xxx = very severe; xx = severe; x = moderate but rising

Source: *Emerging Asia,* 1997: 203.

Table 4 Phases of a Maturing Water Economy

	Expansion Phase	Mature Phase
Supply of water	Elastic	Inelastic
Social cost of subsidy for increased water use	Low	High
Physical condition of water facilities	New	Many old facilities
Competition between different uses	Low	High
Types of externalities	Drainage	Aquifer depletion; water pollution

Source: Adapted from Nickum and Easter, 1994: 7.

Chapter 2

Water Resources and Food Development from the Viewpoint of Agricultural Development - Agricultural Irrigation and Saline Damage in Arid Asian Regions

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1. Introduction

Almost two million years have passed since the emergence of mankind, and for most of this time, man has survived by hunting and gathering food. Then, about ten thousand years ago, we began to use the earth's environment (weather, soil) for food production to maintain our activities, and to produce carbohydrates by harnessing solar energy in a way suited to each region. In addition to this direct intake of carbohydrates, we learned how to acquire food by using carbohydrates to raise livestock. Consequently, mankind made a successful conversion from being hunters to farmers. This also enabled us to feed an enormous population and to develop into an affluent civilization. This affluence might have been supported by a mere several score centimeters of fertile topsoil, that exists like a cuticle around the earth. The fundamental condition for the development of civilization was that agricultural production, which initially was only to feed an agrarian population, began to produce surplus food and thus contributed to the development of other industries. In other words, fertile soil is indeed the foundation that supports mankind's activities and civilization today. However, today's mass production technologies and consumption are disintegrating this rich soil, in a process called desertification. Moreover, human waste is causing more environmental damage.

Ancient civilizations, for which agriculture was the only essential industry, originated around fertile lands in semi-arid regions, and most of them came to an end within 2,000 years. However, the Mesopotamian civilization, centered on the Tigris and Euphrates Rivers, and the Egyptian civilization along the Nile, existed at fertile alluvial areas along river valleys and lasted more than 2,000 years, longer than any other ancient civilizations. The Egyptian civilization actually thrived longer than the Mesopotamian one. Why did each ancient civilization flourish for a different length of time although they were all established on the basis of fertile soils and similar weather conditions?

Civilizations are established on surplus food, and supported by culture, technology and economies. The decline of a civilization represents the decline of surplus agricultural food production. The factors which allowed the Mesopotamian and Egyptian civilizations to last longer than other civilizations were that fertile soil was brought down from the upper reaches by annual flooding and deposited on the flat lands of the alluvial plains where both civilizations thrived as well as water for agricultural use was supplied by irrigation from the huge rivers. On the other hand, although the soil supplied by the floods had a positive effect on agricultural production as mentioned above, it also had some negative effects, such as burying irrigation ditches and raising the land surface, and caused various kinds of soil degradation through salination or erosion.

As mentioned previously, the main factor in the decline of all ancient civilizations was the deteriorating quality of the soil, and it is evident that the mismanagement of the soil by ignoring the permanence of agriculture prevents the maintenance and development of civilizations. Soil mismanagement results in desertification, and the end result of soil degradation through desertification is land erosion and saline accumulation. In this paper, I would like to discuss the effects of the present water resource and food production situation, and the use of water resources for irrigation on the degradation of the soil in Asia, from the viewpoint of saline accumulation, as well as the mechanism of its occurrence, the present situation and the future outlook.

2. The Natural Environment of Asia

1) The Asian Climate

One of the factors determining agricultural production is the climate. There are several climatic classifications such as Koeppen climatic classification, which takes vegetation into account as an index to show the climate of each region, and the Arisow climatic classification that puts weight on a formation mechanism for the climatic environment. Figure 1 shows the Arisow climatic classification. There is an 'equatorial air mass zone' around the equator, in which a tremendous amount of rain falls throughout the year with little or no seasonal changes. On the next higher latitudinal range, there is the 'equatorial monsoon zone' which experiences rainy and dry seasons due to the effects of the trade winds, and next to that is the 'tropical air mass zone' with almost no rain throughout the year. Then, we come to the 'subtropical zone', which is dry in summer, but is influenced by the frigid zone air mass in winter. In the Southeast Asian region, the Java region of Indonesia is within the 'equatorial air mass zone', while most other parts are classified as the 'equatorial monsoon zone'. Then, a large region from India to southern China falls within the 'subtropical zone'. It is important to note that within Southeast Asia, there is no 'tropical air mass zone', which is a desert climate, as only a part of western India in South Asia comes into that category.

In addition to the above, Kyuma et al. suggests a climatic classification based on rice growth, the fundamental crop of Asia, by adding statistical meteorological data to the Thornthwaite climatic classification, which is weighted more towards a soil water resume2). There are nine divisions (I to IX) in this climate classification, as shown in Figure 2. It points out that in divisions I, II, III, IV, VI and VIII, rice crops are possible once a year even at meteoric paddies, but in V, VII and XI, it is impossible to grow rice without irrigation facilities.

2) Geographic and Geological Features, and the Soil of Asia

The distribution of soil resources, an important factor in growing crops, can be understood through the relationship between climate and parent materials from geographical factors. The climatic factors include the tropical rainforest climate with its high-humidity all year round, the tropical monsoon climate with a long and strong dry season, and the damp tropical climate that is found in regions over 1,000m altitude. The parent material factors are volcanic rocks and ash from volcanoes, limestone, evaporite, delta sediment, littoral damp sediment, terrace sediment, and so on.

The volcanic soils which range from the Philippines to Indonesia, are volcanic ash soils such as those found in Japan at altitudes of 1,000m and above where weathering is mild, but are changed to reddish-brown latosols in lowlands by strong weathering. In regions where limestone is a parent material, from the relation of montmorillonite clay and calcic density reflecting soil water conditions, it becomes a red Terra Rossa in the high calcic leaching regions, and a black Rendzina in the low calcic leaching region. As a result, black and red soils are distributed like a mosaic. There are large delta areas within the estuaries where fresh soil is supplied from upland areas. The central area of the deltas sank, and the surrounding areas developed into terraces by the uplifting of the mountains. There are thick advanced laterites formed by weathering of the upper terraces, and thinner laterites formed in the middle terraces. In the lower terraces, the soils have iron and manganese concretions. Also at the apex of the deltas, there is a brackish sediment and an unusual acid sulfate soil. In the Khorat Plateau, there are evaporative rocks formed during the Jurassic and Cretaceous periods, and clastic rocks cover a thick rock-salt layer called the Mahasalacum layer at the highest strata. Because of the geographical characteristics, the salt from these clastic rocks is deposited on the surface in the dry season.

Offshore, the shallow Selat Sunda is not a delta, but is surrounded by low and dumped land, and the peat soils that are distributed are based on those in the tropical rainforests produced by the tropical rainforest climate. Dark red latosols and ferralsols are distributed in the region wherever the parent material is a basaltic base rock.

As shown above, a variety of soils are used for agriculture. Looking at FAO/UNESCO Soil Map of the World (1985) which shows soil distribution on a scale of 1:5 million based on each soil characteristic, these soils are used as arable land in South and Southeast Asia although they are not perfectly suited to grow crops, and whose wider use is expected shows the distribution ratio of 52% out of the total arable land. And Acrisols (acidic soil with a weathered clay accumulation layer) is, particularly, making up the highest proportion at 38%. Also, since most of the unsuitable soils have a clay accumulation layer, the ratio by area with a physical obstruction factor is also 24.5%, and poor drainage soils account for a high of 12.9%3).

3. Paddy Field Irrigation in Asia

Paddy fields symbolize land use in Asia, where rice is the staple food. It is widely acknowledged that growing rice in paddies is better from a productivity and durability point of view compared to upland field. The reasoning for this is that, since most paddy fields exist in alluvial plains, the sedimentation process is always working to maintain and improve fertility. On the other hand, upland field exacerbates soil erosion and leaching of nourishments, which are also accelerated by cultivation. In upland field, soil erosion can be controlled, but, other than using fertilizers, there is no way to maintain and improve soil fertility. In paddy fields, land is leveled and enclosed by a ridge to prevent erosion. Moreover, since the soils become diminished by irrigation, part of the nourishment is changed to a suppliable state, and also a nourishment supply can be expected from the irrigation. Therefore, generally it is not necessary to fallow the land in paddy fields, but the most important restriction is securing irrigated water.

The paddy fields of Asia used to have one crop a year, planting at the start of the rainy season and harvesting in the dry season, since they depended on the monsoon rains. The dependence of these paddy fields on rainwater greatly effected the timing for planting, as did droughts, and therefore, farmers have put much of their efforts into building small scale irrigation facilities.

The total area under irrigation increased rapidly with the installation of modern irrigation systems in Asia since the Second World War, and it is estimated to include about 50% of the total acreage of paddy fields. Securing sufficient water for irrigation is an absolute condition for stability and productivity in paddy fields. In particular, the 'Green Revolution' brought about by the popularization since 1966 of a high-yield rice released by the IRRI, resulted in the rapid growth in rice crops, and the importance of irrigation also increased. Since local rariety were light sensitive, the cultivation period had only been when monsoon rains could be used during the rainy seasons. However, since the high-yield rice is non-sensitive and a short-term variety, its cultivation term was not limited, but irrigation was an essential condition for intensive cultivation leading to high yield. As a result, the preparation of irrigation systems has led not only to the spread of high-yield rice, but also to the stabilization of planting times and crops of local variety, as well as to the agricultural structure of double cropping. As mentioned above, it can be said that the preparation of modern irrigation systems has led to the stabilization of agricultural production under the climatic environment of Southeast Asia. However, these irrigation preparations are only of main canals, and there are many places that still rely on traditional irrigation systems, and therefore, how to conduct water management is the main issue. The paddy irrigation systems in Asia today are classified into 4 categories: a) 'Simple Irrigation Systems' - the most simple systems without water meters or diversion facilities, often seen in intermediate hinterlands, b) 'Semi-technical Irrigation Systems' - with sluicing and diversion facilities at head works, c) 'Technical Irrigation Systems' - with all necessary facilities for water measurement, diversion and intake at the canal level also, and d) 'Advanced Technical Irrigation Systems' - which can conduct complete water measurements, diversion and sluicing even at the field level. 4) In Southeast Asia, the irrigation systems are generally of a) and b) categories, category c) can be found in parts of Thailand and Malaysia, but category d) which can completely control the whole can be found only in Japan. Since system d) requires a large amount of investment and maintenance costs, system b) and c) are expected to become the main irrigation systems in Southeast Asia. Further, water resources from rivers are the key to ensuring the stability of irrigated water. However, the situation of water resources used for irrigation has changed drastically with the recent economic development of Southeast Asia. The modernization of Southeast Asia has brought economic development through 'economic measures' which place more weight on revenues from unit area, but it is starting to affect agricultural production which has criteria other than 'economic measures'. Here, I would like to introduce a case from Bandung, Java Barat which has a comparatively large acreage of irrigated paddy fields for Indonesia, a country characterized by a tropical rainy climate, as an example of the influence of rapid industrialization and urbanization on agriculture by irrigation.

4. Industrialization and Agriculture by Irrigation in Asia

The Republic of Indonesia is composed of about 17,500 large and small islands with the total acreage reaching to about 2 million km^2. The total population rose above 200 million in February, 1997, and it is an island country with the world's forth largest population. The characteristic of this country is that population, food production, and urbanization and industrialization, are all concentrated in the Island of Java, and hence a striking disproportion has been brought about in employment and economic activities. On the aspect of population distribution, about 100 million people, two-thirds of the total population, are concentrated in Java, which constitutes only 7% of the total land in comparison with overdepopulated areas referred to as outer islands -

Kalimantan, Sulawesi, Sumatra, Irian Jaya, etc.. In food production, the total acreage of paddy fields is about 8.2 million hectares, 9% of the total land, and 32% of this is located in Java. Additionally, the high productivity of the paddy fields in Java can be judged from the fact that about 70% of its paddy fields have irrigation systems5).

Starting from Independence in 1949, President Sukarno built up the state, and under the Government of Suharto, who is called the 'father of development', economic development is under way through the long-term 25- year plan (Replita I-V). With respect to agricultural areas, the self-sufficiency in rice, which has been the most important issue since the Independence, was achieved in 1984. There are various agricultural products other than rice, and these yields have increased substantially since self-sufficiency in rice. Whereas in industrial areas, raw material production for domestic industries and production of export goods and half-finished goods is also developing steadily by the introduction of the industrial promotion policy. As a result of these economic developments, Indonesian society has changed drastically, not only in urban areas but also in the farming areas of Java where the food production of this country has been supported. Their way of life, farming style and technology have largely been transformed6).

The soil of this region can show high productivity if water is secured. This superior farmland is being converted into other uses because of the population and urban-area-increase of Bandung City, or sold for industrial use. As a result, decrease of farmland acreage owned by farmers, and the increase of cornering of land in anticipation of its value as real estate, are occurring at the same time. This trend is a reflection of the present agricultural situation in Java Barat.

The Citarum River flowing through the Bandung Plain has been polluted not only because it is utilized as industrial water, but also because of industrial waste water from 145 industrial complexes, and thus was one of the most polluted rivers in Java Barat in 1990. 31 factories around the Ciwarenk Canal located in the upper reaches of the Citarum River utilize this canal water at 0.8 t/sec. as industrial water. On the other hand, the water supply ability of the Wangisaguran Dam which supplies water to this canal is 2 t/sec. in dry seasons and 4 t/sec. in rainy seasons, and irrigated water necessary for an irrigated acreage of about 600 hectares is 2 t/sec. Thus, irrigated water shortages occur in dry seasons. As a result, although semi-annual rice crops and intercropping in dry seasons were possible in this irrigated area by the Ciwarenk Canal, intercropping become impossible because of this water shortage in dry seasons, and areas where even rice cropping once a year has become barely possible, are increasing. This trend is more conspicuous in the lowest area of the irrigation canal. Moreover, in the areas taking irrigated water directly from the tributaries of the Citarum River, there are fears not only of growth difficulties for crops but also of the possibility of the contamination of agricultural land.

5. Irrigation in the Arid Regions of Asia

Regions in which annual transpiration is more than annual precipitation are generally known as arid regions. Soil formations in these regions only suffer chemical weathering through water, but receive strong physical attacks from daily temperature differentials. As a result, soils that include plenty of water-soluble salts are formed. Figure 3 shows the distribution of these arid region soils. In Asia, they are found from northern India to Pakistan, and the Huang-Huai He Plains in China. In arid region soils, the soil water has a tendency to move from the lower layers to the upper layers. Additionally, they are subject to strong weathering right down to the lower layers, and even though the sub-surface may be sandy, an impervious strata of clay accumulated water exists in the lower layers. As a result, water-soluble salts are distributed throughout the soil.

Modern agricultural irrigation has also introduced much irrigated water to the arid Asian regions, and increased agricultural production in these areas. However, the problem of the arid region soils following the introduction of a large quantity of irrigated water is salination. During irrigation, the movement of water within the soil is from the upper to the lower layers, resulting in large quantities of salt dissolving in the irrigated water and being stored as groundwater for the time being. Then, when the irrigation is halted, the salt accumulates in the sub-surface by capillary action. The accumulation of salt occurs in a short range when the impervious layer is shallow. Furthermore, a factor that quickens the salination of arid region soils is the water quality of irrigated waters. As a matter of course, the rivers and groundwater used for irrigation have high saline levels due to the soil condition,.

As a result, salt introduced through irrigation is added. From a plant cultivation point of view, there are no need to leach all of the salt from within the soil to improve salty soil, but one only needs to lower the salinity around the plant root zone. That is by improving the proportion of salt removed by seeing how much salt is removed from the irrigated water.

An example from Pakistan where agricultural production is greatly influenced by salinity is shown below.

1) Soil Deterioration and Agricultural Production in Pakistan

The population has increased more than threefold in the half a century since the revolution of 1947. Because of an agricultural production increase to feed this population, soil environmental problems became tangible.

The most critical problem is that, since most of this country falls in semi-arid or arid regions, water is the biggest restriction on agricultural production. To overcome this, an irrigation system has been developed to a degree unprecedented in the rest of the world. However, this, together with the concentration of salt in the plowed layer, the accumulation of salt in the soil surface and pondings by leakage from irrigation ditches, created an agricultural production crisis as saline soils and sodic soils become tangible in the late 1950's, mainly in the Indus Plain.

Also, because of geographical factors in this country, soil erosion by wind and rain is a serious problem in hills and mountains around the Indus Plain. Soil erosion causes the loss of topsoil that is important for agricultural production, and is a factor in desertification.

2) Morphology of Soil Degradation

Generally, regions whose groundwater level prevents normal growth of most plants are defined as waterlogging regions. Groundwater levels defined as waterlogging depend on plants, except fruit trees such as mangos, a loss of production is seen at the underground level of 1.5 m, and about a 25% decrease is caused at 0.75~1m.

The reduction and lack of oxygen at the plant root zone, the soil salination by bases emitted through soil weathering, the collapse of plants and the increase in harmful insects are effects on the soil and plants caused by waterlogging.

The best way to improve waterlogging regions is to lower the groundwater level. The drainage that has been conducted so far by SCRAP has been effective in some regions, but security for drainage canals and facilities such as over-drains, under-drains and mote drains adopted to the region's characteristics seem to be required. They are very important not only to lower the groundwater level but also to reduce saline damage.

On the other hand, prevention of leakage from the drainage canals is also very important and lining the canals is an effective way to do this.

Salination damage to soil is one of the most important issues for this country and is a restriction on farm production. Based on trial calculations, more than 1.2 million hectares of land out of the total cultivable land have been damaged in some way by salination. Also, it is estimated that it cost the Pakistani economy $47 million in damage a year⁷⁾. Saline damage to crops other than paddy fields caused a 20% drop in production in partially damaged areas and a 60% drop in strongly damaged areas.

These types of problem soils are developed under bad drainage conditions in arid and semi-arid regions. The parent materials for soils in this country, in particular, contain Na^+, Ca^{2+}, Mg^{2+}, K^+, Cl^-, SO_4^{2-}, HCO_3^- and CO_3^{2-} as their principal ions, since they are alluvial soils which are mainly made up of undeveloped marine deposits. Therefore, strong weathering by the arid climate increase the soluble salts in the soil solution. Using this groundwater, which includes these various soluble salts, for irrigation also causes an increase in soluble salinity. These enrichment and accumulation of soluble salts become a restriction for plant growth.

There are three types of problem soil; Saline soil, Sodic soil and Saline-sodic soil, which is a combination of the first two⁸⁾. Saline soil is soil of which the electric conductivity (EC) of water saturation extracted liquid is more than 4 mS/cm (25°C). This EC value is 10-100 times larger than normal soil. Sodic soil is soil of which more than 15% of exchangeable cations consists of sodium ion, and is evaluated by ESP (exchangeable sodium percentage). Also, because of the quality of irrigated water for agriculture, the accumulation of salt is accelerated in the arid regions. Electric conductivity (EC) and sodium absorption ratio (SAR) are combined to evaluate the irrigated water. SAR shows each ion in mg equivalent/L as a unit and is calculated by $Na/\sqrt{(Ca+Mg)/2}$.

In saline soil, most salts are chlorides, sulfates and nitrates. The main cations are calcium, magnesium and sodium, but the percentage of sodium ions is never more than 50%. By classification, $EC>4dS/m$ and $ESP<15$. The pH value of these soils is less than 8.5, and there is a white crust on the soil surface or an accumulation of salt in the soil during the dry season. In these soils, water absorption by plants is impeded by the increase in neutral salinity such as sodium chloride, sodium nitrate and sodium ions, and the rise in the osmotic pressure of the soil solution used by plant roots to a higher level than that of the plant roots. Additionally, because of the accumulation of salts, the withering coefficient of the soils increases and the water quantity decreases. Also, nourishment absorption by plants is through their root hairs and is controlled by the density and characteristics of other coexistent ions. Therefore, even in weakly saline soils that do not influence the water absorption of plants, there is some influence on the absorption of needed nourishment from the soil.

The characteristic of sodic soil is that it is a more alkaline soil than saline soil with a pH value of between 8.5 to 10, and the classification indices are EC<4dS/m and ESP>15% because it is almost entirely composed of sodium ions, with only a few calcium and magnesium ions in the soil solution. The soil clays are highly dispersed since it is saturated with sodium ions, and soil humus is in solution due to the alkaline soil solution. Additionally, even organic matter is dispersed by the surplus sodium and distributed on the surface of the sodium particles. Hence, the soil surface is black.

Plant growth is impeded in sodic soil as per the above saline soil, and the accumulation of highly dispersed clays in the soil surface make it difficult for soil to become cultivable and lowers its water permeability. Additionally, since the dispersed clays move to and accumulate in the lower layer, a close horizon is formed with the remaining topsoil in coarse soil texture. Thus, the soil is completely distracted in its physical aspect and the permeability is reduced which prevents drainage from the soil. The plant roots are unable to enter because of the increasing hardness of the soil, and harmful reductive compounds are formed in localized reduction by the loss of breathability.

Saline-sodic soil has the characteristic of high salinity of soluble salts (EC>4dS/m) just the same as saline soils, but the exchangeable sodium percentage (ESP>15%) is high compared to saline soil. This is a problem soil with the properties of both saline and sodic soils. In this soil, as long as there is an abundance of soluble soils other than sodium, there are no difficulties caused by high dispersion, as is the case in sodic soil. If soluble salts leach downwards, the pH value will show more than 8.5, and the problems become the same as sodic soil. If the soluble salts move upwards, then sodium adsorbed on the colloid will be exchanged to calcium, and the pH value will fall to less than 8.5, causing the same problems as in sodic soil.

3) The Distribution and the Reclamation of Salt-affected soils

The distribution of salt-affected soils in Pakistan has been surveyed by various research facilities. The acreage differs greatly because of differences in the survey's timing and methods, and classification standards. In this case, Chart 1 shows the estimation based on 'The Soil Survey Pakistan Report'.

About 1.05 million hectares out of the total surveyed acreage of 6.34 million hectares had soil with some kind of salination damage. Of these damaged soils, 550,000 hectares are saline-sodic soils, and 250,000 hectares are caused by irrigation using highly saline groundwater.

Remarkable salination damage can be found in the Indus Plain. This has not only been caused by topographic characteristics of this region, but is a man-made disaster caused by agricultural irrigation over thousands of years.

The most critical issue for reclamation of soil damaged by salination is the elimination of salts from the root zone by the eluviation of salts. A common reclamation method is to lower the groundwater level and secure the drainage course. Without lowering the groundwater level, saline damage will recur with any reclamation method.

Moreover, since there are three types of problem soil with different characteristics, a reclamation method suited for the characteristics of each soil should be used. The necessary quantity of water should be calculated correctly for the elimination of salts. Physical reclamation through eluviation using water is the only method for saline soil, but for sodic and saline-sodic soils, reclamation should be carried out in combination with chemical methods.

While eluviation by irrigation is the most effective way to eliminate salts from the root zone in reclamation of saline soil, it requires a huge amount of water. Therefore, the downward permeation of irrigation water should be carried out immediately. However, since there are some soils with a clay accumulation layer called an Argillic layer of Entisol and Aridisol which comprise most of the Indus Plain, fracturing the clay layer and under- and over-drainage facilities are required. Without these drainage facilities, the addition of large quantities of water raises the groundwater levels and ends up with the accumulation of salts in the sub-surface soils.

In reclamation of sodic and saline-sodic soils, the drainage facilities and the use of large quantities of water are the same as for the saline soil mentioned above, but a significant improvement can be expected by using chemicals such as sulfuric acid, hydrochloric acid, gypsum, or sulfur at the same time. The basis of this chemical treatment is: - firstly, exchange the exchangeable sodium absorbed to colloids of soil by calcium, and convert all the exchanged sodium and carbonates to sodium sulfates, followed by eluviation (see Chart 4). Also, there is a method of adding sulfuric or hydrochloric acid to dissociate the carbonates and extricate the calcium from $CaCO_3$ in the soil, and then exchanging it to the sodium. Adding sulfur, which forms sulfuric acid by oxidation within the soil, has the same effect as adding sulfuric acid. As a result, the congelation of colloids occurs by reducing the soil pH. Then, permeability is increased by the development of large pores, which in turn physically improves the soils.

Also, for modest reclamation of saline damaged soil, although it takes longer, the remove of salt by plants is efficient. In particular, deep rooted plants such as maize, millet, or sorghum are expected to have a beneficial effect not only in removing the salt, but also to reclaim the physical aspects of the soil. It is often thought that in inorganic excessive soils such as those with saline damage, there is little biological participation, but algae grows well. *Anabaena ssp.*, especially, can always be found in soils with saline damage. The characteristic of *Anabaena ssp.* is its high nitrogen fixing ability, and that is effective for supplying nitrogen to anti-saline plants.

The use of organic matter is also effective in the reclamation of saline damaged soil. The decomposition of carbonates by organic acids formed by the decomposition of organic matter and the exchange reaction to sodium ions through the dissolution of calcium ions, and the supply of organic matter and manure to the soil is expected through the use of agricultural waste to the soil. Additionally, the mulching of topsoils by vegetable waste is an effective method for preventing soil erosion, as well as having secondary benefits such as supplying organic matter to the soil and preventing transpiration of water from the soil.

Currently, eluviation using a large quantity of irrigated water is the main method for reclamation of saline damaged soil. However, according to a report by the International Development Center on the deterioration of farmland by salination or soil erosion, irrigated water in the Indus Plain is estimated to average about 800mm a year. If you add the total for the rainfall, it is still less than 1000mm, which is insufficient for the eluviation of salts. Furthermore, there seem to be many regions that have even less than this, and securing good quality water is a critical issue. The use of the plentiful water resources that exist as groundwater is one way to resolve this. The groundwater is not of a uniform quality, and differs greatly according to the distribution of clay layers in the soil. Therefore, one of the methods is to make a detailed survey on the quality of the groundwater per irrigation region, and positively use only such groundwater that meets the required conditions. This method of using groundwater with low salinity and irrigation water with no salts alternatively allow the eluviation effect to increase.

Various improvement projects, such as control of the groundwater level through the Salinity Control and Reclamation Project (SCARP), the Left Bank Outfall Drain (LBOD) drainage canals adjustment project and improvement projects concerning leakage and drainage of low level canals by the On-Farm Water Management Project have been carried out against such saline damage as was evident in the 1950/60's, and to some degree, have been successful.

Chart 2 shows the distribution of saline damage on sub-surface soils. The distribution ratios of the land damaged by salination in each state have steadily decreased from the 1950's to the 1970's. However, the Indus Plain as a whole still has more than a million hectares of saline damaged areas. This shows the need to pay attention to the increase in sodic soils in the future, because it can be estimated that although the reclamation of saline soil was carried out by eluviation using irrigated water, sodic soils were formed as a by-product due to the accumulation of sodium after the leaching of the salts.

The decrease in agricultural production in Pakistan is largely due to the state of the soils in the Indus Plain. To resolve this problem, various reclamation methods as mentioned above have been established.

Also, the technology of the research institutes of each university such as the one in Faisalabad, which is taking an initiative, is at a high level. However, the problem has not been completely solved. The reason is that reclamation methods have been adapted to the problem regions in accordance with their soil, geological, and environmental conditions as well as their social structure and economic condition.

Additionally, for post-reclamation maintenance, the necessary quantity of irrigated water and displacement should be determined considering salt quantity within soil. The calculation of Leaching Requirement (LR), which shows the appropriate quantity of irrigated water to control the salinity under established level, is an important issue for the future. As for irrigation and saline damaged soils, methods adapted to regional characteristics are required such as the reuse of groundwater resources whose quality is sufficiently good for irrigation, the removal of salt using vegetable resources and the lowering of groundwater levels. As for saline damage, the lack of a sufficient quantity of irrigated water necessary for improvement will be a restrictive factor. Also, the types of saline damage and distribution conditions of the damaged regions change every year. Therefore, without a detailed survey, accurate reclamation methods cannot be decided on.

6. Asian Agriculture by Irrigation

We, human beings, are supporting a population of almost 6 billion by utilizing both high and low productivity land which constitutes only 11% of the total land area of the Earth (Chart 5). Problem soils such as the excessively inorganic soils of Southeast Asia and the arid soils in South Asia will become important soil resources for increasing food production in the near future. The management of water resources through handling monsoon and the prevention of soil erosion is important in Southeast Asia. In South Asia, which has arid regions, securing water resources and utilizing them, and the reclamation of soils damaged by salination which has already spread widely, are key issues.

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Chart 1. Distribution Acreage of Saline Soil and Alkaline Soil

Type of saline damage	Acreage (million ha)
Strong saline / alkaline soil	1.21
Weak saline / alkaline soil	13.84
Gypsum used, strong saline soil	2.47
Pipe wells used, alkaline soil	2.50
Tortal	10.49
Saline surface / alkaline soil	3.96

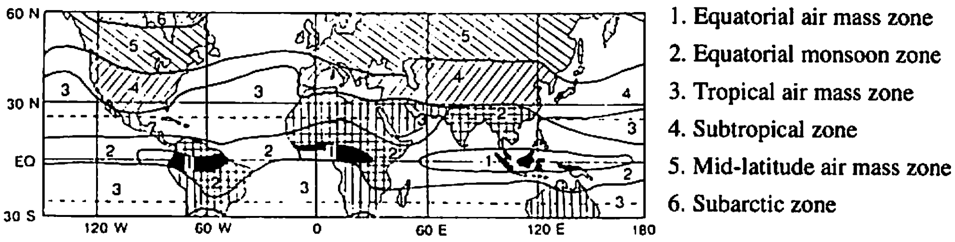
Source : SSP (1963-1988)

Chart 2. Annual Changes of Saline Damaged Surface Soils in the Indus Plain

State	Surveyed Year	Surveyed acreage (million ha)	EC<4 Undamaged	EC4-8 Weak-damaged	EC8-15 Moderate-damaged	EC>15 Strong-damaged	EC>4 Weak- to strong-damaged soils
					%		
Punjabu	1953-65	9.97	73.1	15.9	4.8	6.1	26.9
	1977-79	9.96	85.5	7.1	4.3	3.0	14.5
Shind	1953-65	5.48	26.3	28.5	17.5	27.7	73.7
	1977-79	5.42	51.7	19.2	10.7	18.5	48.3
Balochistan	1953-65	0.35	69.6	14.5	7.2	8.7	30.4
	1977-79	0.35	74.3	17.1	4.6	4.0	25.7
NEFP	1971-75	0.56	82.9	10.8	3.8	2.5	17.1
	1977-79	0.55	86.8	9.0	2.4	1.8	13.2
Pakistan	1953-65	16.37	57.6	20.0	9.1	13.3	42.4
	1977-79	16.28	74.1	11.4	6.4	8.1	25.9

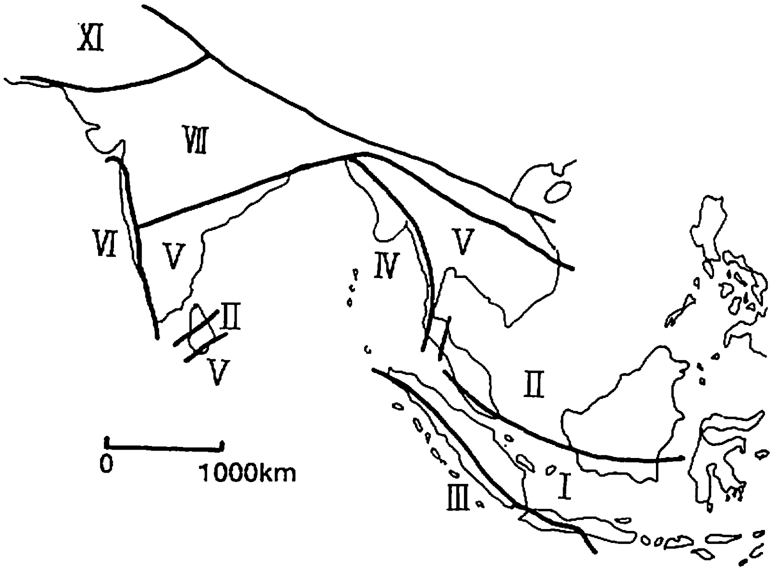
Saline surface soils were classified based on EC (Electric Conductivity) of top soils.
Source: WAPDA, Soil Salinity Survey Vol II, 1981

Figure 1. The Arisoff Climatic Classification



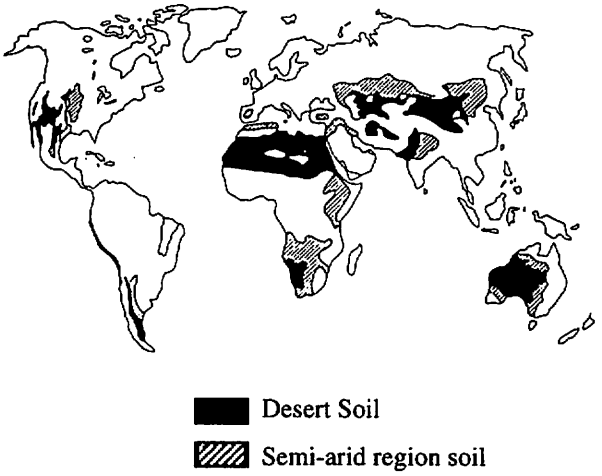
Source: Compiled by Eiichiro Fukui et al. : The Climatic Figure of the World - Japan, Tokyodo Shuppan (1985), partly alternation are made

Figure 2. The Climatic Classification of Asia by Numerical Classification



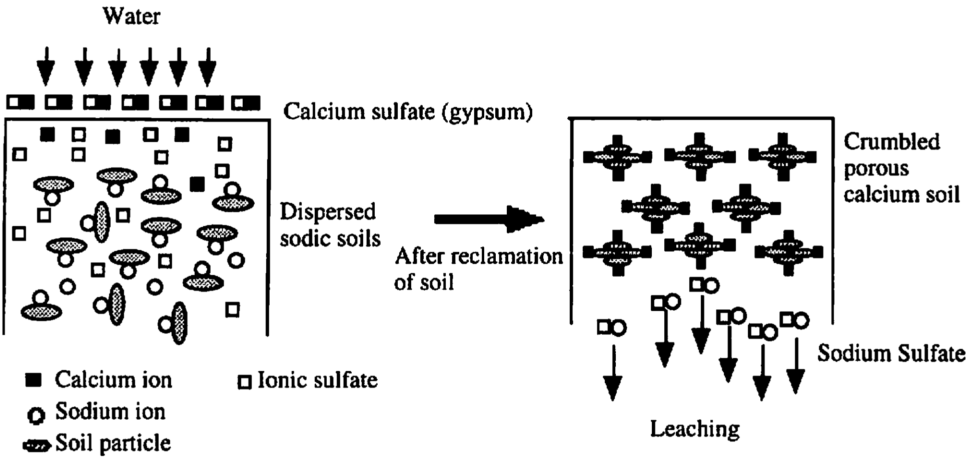
Source. K. Kawaguchi and K. Kyuma, Paddy soil in tropical Asia, The university press of Hawaii (1977)

Figure 3. The Distribution of Arid Region Soils in the World



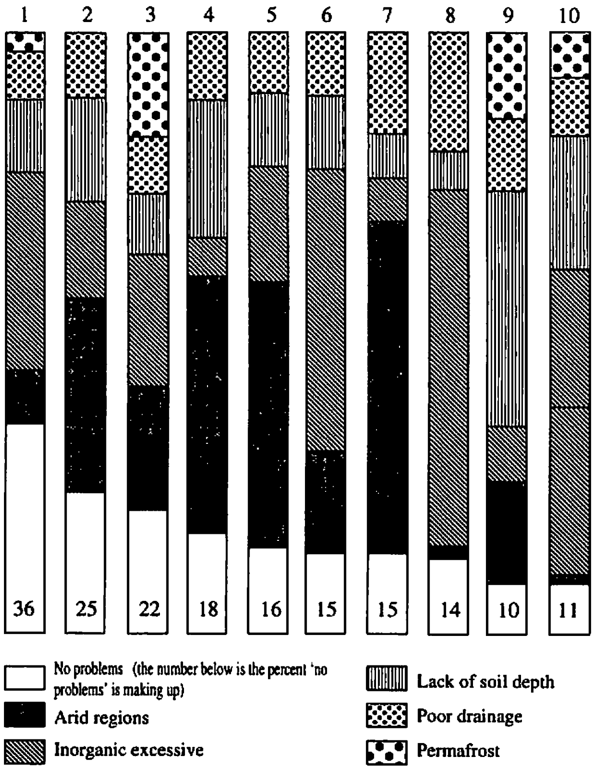
Source: M. Mainquet: Desertification, Springer-Veriag, alternation are made

Figure 4. The Outline of the Exchangeable Sodium Elimination by using Calcium Sulfate (gypsum)



Source: Chemical Amendments for Improving Sodium Soils, Agr. Inf. Bull., 195 USDA, 1959

Figure 5. Soil Resources of the World



1. Europe 2. Central America 3. North America
4. South Asia 5. Africa 6. South America
7. Australia 8. Southeast Asia 9. North / Central Asia
10. Total World

Source: R. Allen, How to save the world, Kogan Page (1980)

The Possibility of Water Resource Development and The Future Prospects of Rice Farming in the Asian Monsoon Asia Deltas

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1. Introduction

We need to feed a rapidly growing population in the world with limited resources. On the issue of food supply and demand a wide variety of views are asserted, rouging from pessimism predicting an impending shortage like that of Lester Brown, the Head of the Rice World Watch Research Institute, to is the case optimism anticipating sufficient supply through an increase of unit crop as with the International Food Policy Research Institute (IFPRI). However, as Professor Hayami of Aoyama Gakuin University pointed out, since grain prices have tended to decrease in the 80's, concern about food problems has been flagging and expenditure on R&D for food production has been stagnating, production growth by the diffusion of high yielding varieties is hitting its peak. Therefore, it is realistic that the possibility of a world food crisis is increasing. 1)

In the Monsoon post of Asia including Japan, the staple food is rice. There are also differences in the views about the future rice supply and demand situation. The prediction by the University of Arkansas, U. S., group supports the optimistic view, while Dr. M. Hossain, the chief of the Social Science Section at the International Rice Research Institute (IRRI), is rather pessimistic in his personal opinion, being skeptical about supply limitations of the rice exporting countries. 2) Thus we can not predict with certainty the future of rice supply and demand. In this situation, the expansion of rice export in the two major exporting countries, Thailand and Vietnam, which have enjoyed good economic growth, is now pending warning signals. Yet hope for an increase in rice production in Myanmar which has been stagnant despite its large potential supply of rice, is expanding.

In this report, I will xplain the current rice production situation and examine the possibility of water resource development for rice production and its future course, in three major deltas in Southeast Asia which are the centers of rice exports.

2. The current situation of rice policies and rice production in the three major rice growing areas

Despite the damaged inflicted by the oil crisis, the Thai economy had been developing comparatively well, and especially since the late 80's it had enjoyed rapid export-led economic growth until only one year ago.

Because of a recent rapid increase in labor wages, the labor-intensive industries which have driven exports by low wages and low prices are now forced to transform their industrial structure. The need for structural change is much stronger in the agricultural sector which is relatively labor-intensive compared to manufacturing sector.

Looking at changes in rice production after the latter half of the 80's, as shown in Table 1, the planted area in Thailand as a whole decreased 12% in these 10 years, while production increased 4.2% because of an increase in yield. In central Thailand around the Chao Phraya Delta, because of a remarkable increase in yield, production increased 0.3% in spite of a decrease of nearly 20% in planted area. In central Thailand, where farmland prices and wage levels have risen dramatically through industrialization and urbanization, paddy fields have been converted to other use on the one hand and land productivity increases have been promoted through the progress of mechanization or bio-chemical technologies supported by better irrigation conditions on the other.

After these big changes of the latter half of the 80's, rice policy has also changed drastically to support the structural changes in rice agriculture. In 1986, the rice export tax and rice premium were abolished and the transformation of the exploitation policy into a protection policy, including an increase in low-interest loans for rice farmers was carried out by the Bank of Agricultural Association Cooperative (BAAC).

Although Thailand's rice agriculture has made structural changes with the flexibility of keeping up with the nation's economic development, we can not hold an optimistic view about its future development. Reform seems not to be progressing smoothly in Thailand, despite the need for more structural reforms in the rice farming area to keep up with the rise in wage levels and farmland prices. This is because the ratio of irrigated area is low and can not be expected to increase, and also because an increase of non-agricultural water demand is anticipated. Therefore, exports might fall even if the demand for domestic rice will decrease and the international market will be strong. 3)

Vietnam's economy has been growing rapidly since the economic reform (doi moi) in 1986. The agricultural sector has also been developing and specially rice production has been constantly increasing (Table 2). Vietnam, which was a net rice importer till 1988, has become a huge rice exporter since 1989.

During these years, the rice planted area increased from 5.704 million hectares in 1985 to 6.766 million hectares in 1995, and yield also rose from 2.8 tons / hectare to 3.7 tons / hectare. As a result, production increased substantially 57% from 15.875 million tons to 24.904 million tons.

On the other hand, the area of paddy fields decreased during these years. This indicates that production increase was achieved by multiple cropping and increasing crop by the expansion of irrigated area.

We can see the development of the rice sector, focusing on the two main rice growing areas, the Hong Ha Delta and the Mekong Delta. In the Hong Ha Delta, although the planted area has decreased during these 10 years, production has increased 50% because of a rise in yield by 51%. The change from the winter crop to the spring crop with higher yield in the 90's, the progress in the introduction of high yielding varieties and the increased use of fertilizers, and the drastic rise in yield in both winter and spring crops can be pointed out as the determinants. 4) In the Mekong Delta, a rise in yield was about 30%, low compared to the Hong Ha Delta, but because the planted area increased more than 40%, production increased nearly twice. Still, in spite of the better performance of the rice sector in the Deltas in the past, we can not forecast favorablex future prospects.

As for the Hong Ha Delta, since there remains little scape expanding irrigated farmland and since the yield has reached a quite a high level such that productivity cannot be projected to rise at the same rate as in the early 90's, it is generally thought difficult to expect increases in production on the same scale as in the past. Also in the Mekong Delta, the growth in yield has gradually declined through the 70's, the 80's to the 90's. This implies that the modern rice technologies had already spread over the Delta and that no additional technological progress can be expected. Additionally, as will be discussed later, there is little arable land left. Therefore, it isfair to argue that we can not forecast an expansion of rice production, due to the above mentioned constraints. 5)

On the other hand, the Myanmar rice sector had remained stagnant until the 1991/92 crop year, except for the period from late the 1970's to the early 1980's. The main causes were that the new technology had spread over the country without an expansion of irrigated land, that imported fertilizer supplies could not be increased due to lack of foreign currency, and that the farmers were discouraged from increasing production by the military government through the compulsory procurement policy of a dual price system and a planned cultivation system. However, since the 92/93 crop year, because the government started to implement development policies under which farmers were encouraged to invest on irrigation pumps, the planted area in the dry seasons increased. In addition, fertilizer supplies by the government increased. As a result, rice production and export drastically increased from 92/93 to 94/95. From 95/96, however, due to bad weather, a rise in fertilizer prices, a shortage of diesel oil for pumping, and other factors, esports started to decrease again.

Myanmar, like Vietnam, has given up its own path to Socialism, "Burmese Socialism," by 1989, and is trying to push the market economy forward, but the pace is rather slow compared to Vietnam.

The drastic increase in rice production during 92/92 and 94/95 was led by the government through the improvement of irrigation infrastructures, not through the enhancement of farmers' motivation to increase production. 6) However, Myanmar's potential for rice production is seen as being quite high. On the optimistic assumption that a) fertilizer prices will fall 50% during 1990-2000 and that afterwards the input-output price ratios will remain constant, b) that rice prices will increase 1% per year, c) that fertilizer supply will increase 4% per year, and d) that the irrigated land area will expand 2% per year, the rice Myanmar will have available for export may reach 5.6 million tons by 2020. 7) This figure may seem too optimistic, but considering the existence of another 1 million hectares of arable land for rice, with the appropriate policies, this figure will not be impossible.

Consequently, while the negative views for sustaining or increasing an export surplus from the existing two rice exporting countries are spreading from a medium and long-term perspective, concern about Myammar's rice sector is constantly growing.

3. Development of Irrigated Rice Farming in Three Major Deltas in South East Asia; Current Situation and Problems

The development of medium and large scale irrigation systems for rice farming in the Chao Phraya Delta has a long history well known in the multi purpose watercourse including irrigation constructed in the Langsit region at the end of the 19th century. After World War II, starting from the Chai Nat Project in the 1950's, the Great Chao Phraya Project was constructed the early 1960's. From the late 60's, the Mae Klong Project for the irrigation of the Mae Klong Delta, and Pumipong and Siri Kit Dam construction upstream of the delta were completed. During these years, the potential for medium and large scale irrigation development had dwindled, and irrigation investment costs per unit area had risen. As a result, medium and large size irrigation projects in central Thailand decreased. Newly constructed medium and large scale irrigation areas between 1956 and 1985 were 1.5 million hectares in the Central Plain, 52% of the total irrigated area, and 60% of this as constructed by the early 60's. By the late 80's, the government had reduced its budgets for irrigation development, and irrigation development in the Central part has also remained stagnant since then. (Table 4)

Thus, new water development for rice farming remains stagnant in the Delta region, yet due to the rapid economic growth from the late 80's, household, industrial, commercial and other uses of water have rapidly increased since early 1990. This has made water conflicts a serious issue in the whole country. 8)

The Bangkok Metropolitan area which is the central zone of the Delta is the region with the fastest rate of industrialization and urbanization. Therefore, water conflicts were the most serious in this region. In the Delta, water allocation conflicts already exist between the irrigated rice farming sector and non-agricultural sectors in Bangkok, and because of the rapid increase of non-agricultural water demand, these conflicts have intensified. Also, the water supply from the Chao Phraya Delta in the central region depends on the Pumipong and Siri Kit Dams in the upstream port of the Delta, but because of the increase in water demand for various uses in the northern region, water supply to the central region is decreasing. This water conflict with the upstream area of the Delta has intensified the conflict within the Delta.

The water supply from the Chao Phraya River, especially in the dry season, cannot cover the increased water demand of the Bangkok Metropolitan region any more. Therefore, to solve the water shortage in the region, the government planned, in 1985 to link the Mae Klong River and Tha Chin River basins with the Chao Phraya River basin by canals. However, this plan faced opposition from the residents of the Mae Klong River and Tha Chin River basins, including farmers, so that the government had to replan the solution to the water shortage in the BMR and nearby areas. The agricultural sector of the central region was given priority in the government plan, so that 5 hundred million bahts were appropriated for farmers to dig 50 thousand wells.

As discussed above, since the scope for water resource development of rice farming in the Chao Phraya Delta is very limited and water conflicts with non-agricultural sector are serious, the development of irrigated rice farming in the Delta is under many limitations.

In Vietnam, the water conflicts with non-agricultural sectors are not so serious as in Thailand. However, the expansion of the irrigation infrastructure in the Delta is subject to many limitations. These are as follows. Here, we will focus on irrigation in the Mekong Delta which is the biggest rice growing and rice exporting exporting area of Vietnam. 9)

As for the Hong Ha Delta, there is little scope for further irrigation development. The ratio of irrigated area to total planted area for paddy cultivation is 90% and the drainage area ratio 68%. The most urgent tasks in the development of the irrigation infrastructure include the repairment and rehabilitation of the old facilities, and the maintenance.

The reclamation of the paddy fields in the Mekong Delta can be dated back to large-scale canal construction for commercial rice export under French rule. At that time rainted single rice crop was grown during the rainy season.

Irrigated rice farming started around 1970-71 when by the use of pump with improved American boat engines, double-cropping of rice had spread together with the diffusion of new technologies using high yielding varieties. After the Vietnam's War, the government repaired the water canals and the facilities for irrigation were also improved. Since the start of the Doi Moi, policy maintenance of irrigation facilities has taken place, and due mainly to the increase in planted area in the dry season, the planted irrigated area increased from 1.25 million hectares in 1985 to 1.98 million hectares in 1994, a 0.73 million hectare increase in 10 years. (see Table 5)

An integrated water control system to control irrigation and drainage water in the Mekong Delta as a whole still does not exist. Moreover, since most of the region is 2.5m under sea level, the fluctuation of the water levels is so dramatic that 25% of the Delta is flooded in the rainy season, while the water level falls belord sea level in the dry season. Hence the water resource development projects after the War have been focusing on flood water drainage in the rainy season and on the supply of coastal freshwater to the upstream areas, taking advantage of the wide variation ranges of the tide lines in the dry season. Also, the recent introduction of short-stalk varieties has made a solution to drainage problem in the rainy season more important.

As discussed above, although water canals and pumping facilities for irrigation and drainage have been constructed to some degree in the Mekong Delta, an integrated water control system has not yet been constructed. Not have counter measures against flooding in the rainy season and drought in the dry season been undertaken effectively, while the existing water canals are in need of repair and maintenance. Large funds are necessary for these projects, but government funds for irrigation are limited, and have tended to depend largely on financial aid from foreign countries. The implementation of these projects will therefore not be easy. Land reclamation is another problem that will not be easy to solve, because 200 thousand ha of prospective arable land are threatened by a sulfuric salt problems.

Whereas in Thailand and Vietnam, there are many limitations in terms of the expansion of irrigated land for rice , in Myanmar, only 5% of the utilizable water is used, with a remaining size of 1 million hectares of arable land for rice farming so that there will still be a large potential for development of irrigated rice farming. 10)

However, irrigation has not been so important in Myanmar's agricultural development strategy. As a result, the irrigated area and the its share in Myanmar have been very small. The irrigated area did increase in the 1960's once, but since then, both the irrigated area and its share remained almost constant till 1991/92. However, from the 91/92 to the 95/96 crop year, the government increased the irrigation budget for 1) construction of dams, weirs and reservoirs, 2) rehabilitation of existing dams and reservoirs, 3) construction of water gates to dam up and reserve river, creek and brook water at flood or high tide, 4) utilization of ground water, and 5) expansion of low-interest loan and low price supply of fuel to encourage farmers to use pumps for irrigation. These measures were taken in order to secure sufficient water supply.

As a result, the planted area of rice in the dry season using pumps increased, which is relatively independent of the government irrigation system, and the share of the irrigated area also increased to 19.2 % (in case of rice, about 30%) in 95/96. However, in fiscal 96/67, because of a shortage of diesel oil which is the fuel for the pumps, the pump irrigation acreage has decreased, and the share of irrigated area is expected to fall to 16.4%.

The lower Burma Delta regions, including the Aeyarwady, Pegu, and Yangon districts, are the major rice growing area in Myanmar, and account for 60% of the total planted rice area. In these Delta regions, as in the Mekong Delta, an integrated water control system does not exit. Moreover, no network of water channels like the Mekong Delta has yet been constructed. The rainfed rice crop in the rainy season is still the major port in these these regions. However, since these regions are close to the estuary and there are few water level differences between the rainy and dry season, they are suited for pump irrigation. As mentioned above, the dry season crop by private use of the pump from rivers or waterways has recently increased. But this appears to have reverted to a decrease in the 96/97 crop year. If the domestic rice price is set at a considerably low level compared to world price under the government's rice procurement policy and if the low-price government supply of inputs such as diesel oil are not sufficient, the result will be that pulse crops which need no irrigation are more profitable than rice. It is also true that water gates to drain flood or surplus water in the rainy seasons and to store surface water of river (fresh water) at high tide in the dry seasons, and use of irrigation water, are constructed by the government, but the effect of this on rice growing is not yet obvious.

As explained above, the construction of official irrigation and drainage systems by communities in the lower Burma Delta region of Myanmar have not been settled, except for a few examples.

4. Conclusion

From the above discussion, it is clear that there are many limitations on water resource development for rice farming in the deltas of the Asian rice exporting countries, and the prospects for the medium- and long-term growth of rice production is not an optimistic one.

As for Thailand, one of the limitations is the water conflict with the non-agricultural sectors which cannot be avoided in the process of economic growth. In Vietnam, the limitations are that arable land, except for sulfuric salt land, is very limited, and that financial cost problems exist for further water resource development in the Delta.

In Myanmar, although there are many unused water resources, their exploitation is not sufficient, and under the current government policy of attaching more importance to self-sufficiency, it is hard to expect that the government will rapidly increase the irrigated area for rice farming.

However, compared to the possibility of water resource development and the development of rice sector in Thailand and Vietnam, the limitations in Myanmar are considered to be much smaller in terms of financial cost. In the near future when Thailand and Vietnam will have to decrease rice exports, the importance of the Myanmar rice sector's development will therefore be rising so that water resource development will be a, fuot the, the key issues.

[Notes]

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9) As for the irrigation system in Vietnam, see Hironori Yagi, "Institutions for water Management and Irrigation System," in Cho, K. and Iwamoto, I., eds., A Report on the Production and Distribution Problems of Vietnamese Rice Farming after the Introduction of Market Economy, submitted to Ministry of Education, Sports and Culture, 1996, pp. 61-91.

10) Tin Htut Oo, Myanmar Agriculture under the Economic Transition : Present Situation and Emergency Trends, VRF Series No. 265, IDE, March 1996, Tokyo, p14, and the data adquired by the author's personal communication with Mr. Yu Pa, Institute of Economics, Yangon.

Table 1 The Change of Rice Production in Thailand

Year	Planted area (1000 ha)	Paddy production whole country (1000 t)	Paddy yield (ton / ha)	Planted area (1000 ha)	Paddy production central region (1000 t)	Paddy yield (ton / ha)
1985	10148	20264	2.00	2512	6425	2.56
86	9852	18868	1.92	2408	6185	2.57
87	9356	18428	1.97	2382	6134	2.57
88	10348	21263	2.05	2572	7113	2.77
89	10310	20601	2.00	2470	5795	2.35
90	9905	17193	1.74	2075	3959	1.91
91	9547	20400	2.14	2065	6107	2.96
92	9160	19917	2.06	1996	5786	2.90
93	8482	18447	1.95	2007	5770	2.87
94	8975	21111	2.35	2069	6447	3.12

(Source) Ministry of Agriculture and Cooperatives, Agricultural Statistics of Thailand, various issues, Bangkok, Thailand.

Table 2 The Change of Rice Production and Trade in Vietnam

Year	1976	1985	1991	1995
Hong Ha Delta				
planted area (1000 ha)	1016	1052	1014	1042
paddy production (1000 t)	2903	3092	3038	4623
yield (ton / ha)	2.74	2.94	3.00	4.44
Mekong Delta				
planted area (1000 ha)	2063	2251	2807	3192
paddy production (1000 t)	4665	6860	1035	12832
yield (ton / ha)	2.26	3.05	3.69	4.02
Entire country				
planted area (1000 ha)	4414	5704	6303	6766
paddy production (1000 t)	11830	15875	19622	24964
yield (ton / ha)	2.68	2.78	3.11	3.69
Export *polished rice 1000 t)	-	-	1033	2150

(Source) Statistical Data of Vietnam's Agriculture Forestry and Fishery (1976-1991), (1985-1995), Department of Agriculture Forestry and Fishery Statistics, General Statistical Office, and the data from The Vietnam Ministry of Trade.

Table 3 The Change of Rice Production and Trade in Myanmar

Year	Planted area (1000 ha)	Paddy production (1000t)	Yield (t/ha)	Export (polished rice 1000t)
1961/62	4713	4552	0.97	1676
71/72	4978	5395	1.08	776
81/82	5232	9336	1.78	575
85/86	4902	14317	2.92	582
91/92	5407	12993	2.40	183
92/93	5160	14847	2.88	198
93/94	5674	16760	2.95	261
94/95	5926	18195	3.07	1041
95/96	6137	17953	2.93	354
96/97*	5833	17083	2.93	na

(Source) Ministry of Planning and Finance, Report to the Pyithu Hluttaw, various issues; and Ministry of National Planning and Economic Development, Review of the Financial, Economic and Social Conditions for 1996/97.

* provisional

Table 4 The Change of the Budget for Irrigation and the Irrigated Area for Rice in Thailand

Year	Budget for irrigation (1 million Baht)	Irrigated area for rice (1000 ha)
1961	262	1404
66	540	1745
71	1151	1853
76	1527	1909
81	3419	2100
85	4244	2376
86	3903	2376
87	3338	2390
88	na	2338
89	na	2485
90	na	2067
92	na	2206

(Source) World Rice Statistics, 1993-94, 1995, IRRI.

Table 5 The Change of Irrigation and Drainage Acreage for Rice in Delta Regions, Vietnam

Year	1985	1990	1994
Hong Delta			
irrigable acreage (1000 ha)	707	860	920
irrigation ratio (%)	77	87	90
drainage acreage (1000 ha)	519	597	696
drainage ratio (%)	56	60	68
Mekong Delta			
irrigable acreage (1000 ha)	1254	1608	1982
irrigation ratio (%)	56	62	65
drainage acreage (1000 ha)	1037	1298	1707
drainage ratio (%)	46	50	56

(source) documents in (note 9), p65

note) irrigation ratio and drainage ratio are calculated by dividing each acreage by planted acreage.

Table 6 The Change of Irrigated Area by Water Source in Myanmar

Year	Irrigated Area (1000 acre)						Irrigation
	Water canal	Reservoir	Well	Pump	Others	Total	Ratio (%)
1951/52	917	158	20	-	203	1298	9.1
61/62	944	163	24	-	193	1324	7.5
71/72	1566	199	28	154	250	2197	11.2
81/82	1628	198	37	360	356	2579	12.4
91/92	1244	460	65	323	375	2467	12.0
92/93	1282	511	69	469	412	2743	12.7
93/94	1252	488	75	1051	437	3303	15.3
94/95	1319	477	92	1551	404	3843	17.4
95/96	1294	444	99	2057	447	4341	19.2
96/97*	1385	528	115	1300	456	3784	16.4

(Source) 1951/52 - 91/92 documents in note 6), Table 1 and 2. Thereafter same as Table 3.

* provisional

The Strain on Water-Resources also from Agricultural Development

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While it is generally difficult to develop agriculture without the use of water, what should be noted is the fact that conversely agricultural development using water is itself putting a strain on water-resources.

Excessive application of agricultural chemicals and chemical fertilizers is causing pollution of underground water, which leads to restrictions on the use of water for potable water or other forms, resulting in so-called strain on water-resources.

1. Examples of the results of excessive application of agricultural chemicals

Wadomari-cho, Oshima-gun, Kagoshima Prefecture (Okinoerabujima island) is regarded as a prime production area for flowers known under the names "Erabuyuri" (Erabu lilies) and freesia. The amount of agricultural chemicals used annually (1993) is said to reach 130 tons, 3 times the national average. These chemicals are used to control harmful insects and viruses and so conserve the commercial value of the flowers. Since flowers are ornamental products, the presence of residual agricultural chemicals has not been questioned much by consumers.

However, because the town relies totally on underground water for its drinking water, experts conducted investigations in 1993 suspecting that agricultural chemicals may have infiltrated the underground water." The results showed that "although diazinon did not reach the safety limit for potable water, it reached 3/5 of the limit." Furthermore, "this investigation verified that diazinon does not decompose 100% in the soil." In the case of lilies in particular, to control viruses after harvest the bulbs are immersed in a disinfectant solution in large water tanks prepared at the cargo collection site. However, this highly concentrated waste liquid is sprayed onto upland fields just as it is, which leads to the pollution of underground water. The town installed a new waste liquid treatment plant subsidized by the government in 1996, but its utilization rate remains around 50%. People are still worried about the pollution of underground water and in reality the sales of PET bottled drinking water continue to soar.

2. Miyakojima, Okinawa Prefecture, an island in the subtropical zone like Okinoerabu.

In 1991, agricultural chemicals such as sumithion were detected in water in 3 wells at a depth of 20 m. The sumithion concentration fortunately did not reach the safety limit for potable water, but it shocked people who relied entirely upon underground water for their drinking water. Ryukyu limestone derives from upheaved coral reef which is porous like a strainer of a void ratio of 10%, so that organic phosphorous based agricultural chemicals which show rapid decomposition in soil are said easily to reach the deepest underground layer. For this reason, when a golf course construction plan near the drinking water source came up, people naturally enough united in a protest movement and forced its cancellation. In addition, in 1992, the "problem" of the pollution of underground waters came up again.

It turned out that part of an "underground dam," the first in Japan, which uses underground water for agricultural irrigation, had been completed and partial water flow to farmland started. The underground dam is a system for storing underground water involving the driving of a water stop deep into the ground and stopping the natural flow of underground water into the sea. People are afraid that if the drawn underground water is sprayed on farmland, polluted substances might be concentrated in underground water creating a vicious circle.

Fortunately, the results of water analyses so far have argued against that possibility, but anxieties apparently are not dissipated, as people essentially use water from the same water source repeatedly.

3. This is an example of the pollution of underground water caused by excessive application of chemical fertilizers experienced in a vast tea production zone in the Nansatsu district, Kagoshima Prefecture.

In 1993, the Ministry of Agriculture, Forestry and Fisheries established a committee on earth- and environmentally-friendly agriculture and selected 10 locations in the country which required immediate attention and reduction of pollution. The periphery of Lake Ikeda, and this Nansatsu district, were the places selected in Kyushu. In Lake Ikeda, abnormal reproduction of plankton was observed in 1994. The cause was needless to say the drastic growth in nitrogen content which brings about eutrophication. Surprisingly, the growth of nitrogen content was found to be attributable to the excessive use of nitrogen fertilizer in the large scale tea plantation zone near Lake Ikeda which uses water from the lake for irrigation. In this connection, it was reported that some people went as far as expressing the rather extreme idea of covering the vast tea plantation zone with a dome to somehow stop the outflow of soil components. What is certain is that the plan of diverting into Lake Ikeda the water from three rivers which flow through the tea zone and then pumping it back for irrigation of the tea plantations met unexpected opposition. The use of one of the three rivers for irrigation was then abandoned and the water allowed to flow directly to the sea.

However, the problem has not been solved completely. The problem of pollution of rivers and underground water still remains in the region. The use of river water whose diversion into Lake Ikeda was suspended, is not yet completely ignored as a possible measure in the event of drought.

Moreover, people say "the commercial value of tea lies in its sweetness; the source of sweetness is amino acids; tea which contains more nitrogen to compose amino acids tastes better; hence, there is every incentive to use excessive amounts of chemical fertilizers."

The above is no more than fragmentary information which be obtained by looking around us. As agricultural production becomes more diversified and agricultural technology becomes more sophisticated, the types of demand for water also become more diversified and more complicated, which conversely seems to restrict the general-purpose use of water, resulting in a strain on water-resources. All the material used in this paper is based on the special issue "New Food and Agricultural Methods" published by Minami Nippon Shimbun Co. (January 1996 to April 1997). (June 5, 1997)

Chapter 3

Industrialization and Water for Use of Industry

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1. Industrialization of the East Asia Pacific Area

Until the first half of the 20th century, the East Asia Pacific area faced stagnant economic growth and depended on agriculture to maintain its economy as it had also experienced colonialization. However, from the latter half of the 1950's to the beginning of the 1960's when countries began to support themselves after independence, they each began to work hard on economic self-sufficiency and changed over to an economic self-sufficiency policy by a strategy of emerging from total dependence on agriculture and industrialization. Rushing their growth through the 1960's, they employed the so-called import substitution industrial policy. But, they were urged to withdraw from this strategy because there was not much incentive to work in the capital-intensive and less employment offering materials industry in economies with rarecapital and surplus labor force.

On the other hand, the measures for the promotion of export which they employed in the 1970's not only just fit the labor-intensive processing industry policy taking advantage of their plentiful labor, but also attracted investment from industrially advanced nations saw the advantages. At the beginning, industrialization was mainly in low-level technologies such as food processing and fiber processing. As the world trade strategy of advanced nations developed, they gradually expanded to the machining industry and the tempo of their industrialization was amazing.

Except for Japan which rapidly accomplished postwar reconstruction and Hong Kong and Singapore unique as city-states in of a sort, in the 1970's a phenomenon, so to speak, a shift was observed from agriculture to non-agriculture where the manufacturing industry's share of the national economy exceeded that of agriculture in Korea, followed one after another by countries like Thailand, Philippine, Malaysia, and Indonesia at the beginning of the 1980's, and China became no exception.

The tempo of economic growth was accelerated with industrialization as the driving force. The plan of Korea, Taiwan, Hong Kong, and Singapore, which were called Asian NIES, followed by ASEAN nations, made an overwhelming impression as the miraculously grown symbol, or the East Asian area. The national income per capita which indicates economic growth was below 1,000 US dollars in every country except for Japan in 1975. Ten years later, in 1985, it had risen to about 2,000 dollars in Korea and Malaysia. It passed the 1,000 dollar line in China and Thailand in 1990. Indonesia and Philippine approached the 1,000 dollar level in 1994.

The times when the Asian NIES were limited to four countries ended in 1980. Singapore became an advanced nation while Malaysia is a part of the Asian NIES. The economy in the East Asian Pacific area including Japan and China successfully established a footing, dividing the world economy into a third part ranking with NAFTA and the EC. From the aspect of trade indicating their economic prospects, they were in the block with the U.S., and in merchandise, industrial goods exceeded primary products by the beginning of the 1990's. It should be kept in mind that 17.5% of world trade was in East Asia and exports were 18.3% there.

Due to such surprising development in industrialization, depending on resources the conventional situation is also changing. The underlying trend in human resources is also changing from labor surplus to labor shortage in some countries. Even with water resources discussed here, the use of water exclusively for agriculture has begun to shift to use for industry and the generation of electricity while a phenomenon of increased living water is becoming noticeable reflecting urbanization stemming from industrialization and a rise in living standards through economic growth. Also because of an increased value of resources due to increasing demand for water, the necessity of a so-called water resource development policy such as the construction of dams, which will lead to the systematic control of water quantities, is replacing a one-sided dependence on natural water discharge.

We will successively view the water for use of industry situations in the nations of South East Asia, beginning with the situation in Japan which is leading in industrialization.

2. Water Situation in Each Country

1) Water for use of industry in Japan

Not to speak of the 1950's when the economic reconstruction had stabilized for the time being and high economic growth was beginning, even at the beginning of the 1960's when the industrial sector greatly surpassed the agricultural sector, Japan's water consumption was mainly for agricultural use. Although the manufacturing industry used plenty of water for cooling and cleaning in the middle stages of production, conditions were definitely different from those in agriculture. Judging from the nature of the subject to be handled, there was a limit frequently to the amount of water saving technology agriculture will use because natural flow sufficed. On the other hand, the structure of the manufacturing industry switched from water consuming industries such as the steel, chemical and paper so pulp, to the machinery which used relatively little water and the potential for recycling water was technically easy.

Reflecting on this situation, when you look at the annual transition in water use, you find that even in the beginning of the 1970's when the agricultural sector showed a reduction of farming land and decline of production, the tempo of growth in agricultural water use dropped but did not lead to a reduction. In the meantime, industrial water consumption began to decrease in the latter half of the 1970's. Because of a high recycling rate of more than 70%, the fresh water supply showed a tendency to decrease at the beginning of the 1970's. This characteristic of the initial stages of industrialization, where the demand for industrial water takes away from agriculture's share, had already ended in the 1960's.

The table shows the overall breakdown of water consumption from 1975 on. Industrial water, if limited to the water consumed before that year, clearly increased by 2.5 times between 1965 and 1975, or the latter half of the days of galloping growth. Comparing this with an increase of 2.2 times in production in the mining and manufacturing industries in the same period, you can see how large the adaptability of demand for water for industrial production was. Looking at each industry, the water consumed increased by 3.7 times in the steel industry and was clearly contributed to the rate of increase. This figure is based on fresh water. Considering the consumption of seawater, you should recognize that an even greater increase in demand for water came from the steel industry while demand for agricultural water became even more stagnant.

Touching on the industrial changeover from the high water consumption industries, let's look at the situation of water consumption by industry. The amount of fresh water consumed per day (unit: million m^3) by industry in 1970 was 29 in the chemical industry, 17 in the cement industry followed by 14 in the paper pulp industry. In the beginning of the 1990's it increased to 49 in the chemical industry, 46 in the cement industry and 16 in the paper so pulp industry. In all cases, water was mainly used for cooling needed for the improved high pressure/high heat technology. While the steel industry was already a tendency to decline in the 1970's, the water it consumed reduced to one fifth of that in the chemical industry. This was because plants were located on the coasts where the import of materials was easier and seawater could be drawn for use in cooling sites.

The choice of industrial location may be based on considerations of materials, access to consumer markets, etc. From the point of view of water use, downstream areas of rivers seem suitable. Still, the use of water was not the primary consideration in the choice of location. This reflected relatively the low cost of water even in water intensive industries. However, as the switchover of electric power generation from "water-power main, followed by thermal-power" to "thermal-power main, followed by water-power" indicates Japan does not necessarily have favorable conditions for water resources when internationally compared in terms of physical aspect and climate. The annual amount of precipitation per capita is one fifth of the world average. Under changing conditions the construction of dams was treated separately from river improvement and became, so to speak, multipurpose dams for electric power generation, industrial water and living use, etc. Water became relatively high in cost and under the name of resource conservation, much stress was put on the recycling of water.

It should not be overlooked that in the light of these circumstances 36.8% of the fresh water supply for industrial water depends on the industrial water service supported by public payment. Although a rise in the water rate from 5 yen/m^3 to 21 yen/m^3 over the last 25 years helped make ends meet, the public payment for water resource development must be taken into consideration. The percentage of the general account budget was not necessarily small at 1.1% in 1991. It may be said that the maintenance of infrastructure in the course of Japan's industrial development roughly finished its role in the 1980's. Attention should be paid to the fact that even at the beginning of the 1990's, the water resource development cost spent was not low when compared with that of some countries described later.

Let us look at the quantity of industrial water by water source. Comparing fresh water and seawater use, the percentage of seawater slightly decreased from 30.2% in 1965 to 27.2% in 1975, then further decreased to 20.9% in 1980. This was because the position of the material industry represented by the steel industry decreased relatively from the later half of the 1970's. On the other hand, demand for water increased in the machinery sector particularly in the auto mbile and electrical machinery industries and consequently the percentage of water used in product processing and cleaning rather than in cooling increased. Thus, there were more circumstances under which seawater could not be used. Observing the uses of fresh water, a rise in percentage in the use of water for product processing and cleaning was not very large: from 15% in 1975 to 16% in 1990. Assuming that seawater is all for cooling, the percentage of water used for cooling as a part of total industrial water use dropped from 77% to 74% reflecting a decline in dependence on seawater.

Let us further limit the source of water for industrial water to fresh water. A percentage of dependence on public infrastructure such as industrial water service and waterworks changed little from 13% from 1965 on. The percentage of underground water drawn greatly dropped from 21% to 14% while the percentage of recycled water rose from 66% to 74%. It should be mentioned that measures to respond to the effect of subsidence of ground due to drawing up underground water are being taken. In the past, underground water was evaluated as the best source of water in terms of water quality and tended to be used extensively. But, it is natural to say that such use had to be inevitably reduced in response to so large an environmental problem as ground subsidence.

2) Circumstances in Korea

It was Korea which first pushed forward to industrialization following Japan. Observing the situation of water from 1980 on in which the results of the 1970's when the tempo of industrialization was fast were reflected, the quantity of industrial water used nearly tripled in little more than 10 years from 717 million m^3 in 1980 to 2,280 million m^3 in 1991. Since the growth rate in industrial production during this period was 100%, a tendency to consume much water was observed. The percentage of industrial water as part of total water considerably rose from 4.3% in 1980 to 9.4%, the opposite to Japan's tendency to drop. This reflected the tendency to increase production in water intensive industries which was much larger than that of Japan. Growth in the use of living water was larger than that of Japan in the same period, reflecting rapid growth in urbanization and the standard of living.

Observing the conditions of water resource development over the past 20 years, the cost of economic development increased by about 30 times while the cost of water resource development increased by more than 40 times. In addition to the annual precipitation of 1,159mm, or about half of the 2,010 to 2,600mm in ASEAN nations, circumstances under which the country is not blessed with rivers of large capacity result in the necessity of bearing the cost of water resource development. The high percentage of the cost for multipurpose dams as part of the overall water resource development cost when compared with surrounding countries reflects the same situation. The number of multiple-purpose dams also began to increase in the ASEAN nations in the latter half of the 1980's as described later. In Korea, it can be said that their faster development of industrialization when compared with those nations also promoted the increase in the water resource development outlay.

3) Condition of water supply in Malaysia

Next by, let us look at the water situation in Malaysia where industrialization is progressing following Korea. Malaysia achieved an economic growth rate over 7% from the 1970's on, and high growth at an average of 8% particularly in the 1990's. The country achieved remarkable industrialization as the ratio of the manufacturing industry to GNP reached 44% in the 1993. Looking closely at the manufacturing industry, the country is characterized by its emphasis on the machinery industry, especially in high technology fields such as the electronics industry while the shares of lower-level technologies such as food processing and fiber processing remain high in neighboring countries. It can be said that this is largely attributable to their policy of positive cooperation with foreign capital.

Malaysia has worked very hard to have achieve economic development through the successive Malaysia plans (five-year plans). For the supply of water in the recent 7th plan, they expect an increase rate of 18% up to the year 2000 on the premise that the increase rate for 1990 to 1995 was 20%. No data showing the breakdown of water by use is available, since the use of water is classified by cities and agricultural districts. The total of industrial water and living water may be routhly assumed to be demand by cities. The growth rate in cities was 22% in 1990 to 1995 and is expected to be 21% from 1995 to 2000. Whatever the case, the growth rate is well over that of agricultural districts so there is clearly a change in demand for water due to industrialization.

The 5th Malaysia plan which ended about 10 years ago contained plans to construct multipurpose dams and build provincial water service systems to make available 56% of the amount of precipitation. Construction of dams from the first half of the 1980's was actively pursued. Many cases of dam construction at that time had water supply and irrigation for farming as their main purpose. However, from the beginning of the 1990's, dam construction projects aimed at supplying water (water for use of living) to cities and industrial water were increasing. In the 10 years up to 1990, the supply of water increased by 40%. The supply program for 1986 to 1990 assumed 94% of the supply would be for cities. Coupled with the quick tempo of urbanization, these make clear the effect of industrialization.

Adopting a federal system, Malaysia has been prudent in controlling the provincial water supply. Based on the guidelines mentioned in the master plan, which had already been elaborated on in the national water resource research of 1982, a policy was disclosed to push forward and streamline a zoning plan, managing the data base for water resources, efficiency of improvement, etc. They also emphasized in the 7th plan a policy of pushing forward to take measures for water resources to achieve the said policy such as laws, systems, and application of funds. This may be described as a political response to the wide area characteristics of water resources.

4) Condition of water supply in Thailand

Let us review the situation in Thailand whose grade of industrialization is high. The latest percentage of industrialization in Thailand is 39%, about the same as in other ASEAN nations. It is not necessarily low when considered in light of changes in recent years. Recently, they have received international support for monetary crisis such as depreciation of the Thai currency, the baht, and there is not no anxiety about future growth. Also, they may display a stronger tendency to place emphasis on the market economy than the economic-planning-oriented tendencies of Malaysia and Indonesia.

Such circumstances may help explain the delay in attending to the maintenance of infrastructure and draw attention to environmental changes and traffic jams. It cannot be denied that the above circumstances may be common to the aspect of water resources in Thailand. While each country predicts intensive demand for water adjustment by government authorities, Thailand has nothing but predictions by the government energy resource corporation. And what really draws our attention is that they estimate that the share of agricultural water as part of the total water available will actually increase.

The share of water for use of industry (mainly in manufacturing) is extremely small. Observing the present situation of the manufacturing industry in Thailand, measures to pump underground water with costs borne by companies are overlooked. Since the supply of water to meet demand has not been studied as aforementioned, we fear that the middle- and long-term supply and demand problem may put a ceiling on growth.

Since this is the prediction of the government resource corporation and is not regarded as a function in the national plan, this evaluation should be out of the question. However, the deficiency in the capacity to supply given as supplementary data in this prediction increases from 3.5% in 1993 to 7.1% in 2006. Since the growth rate of demand is not necessarily excessive in view of the present economic situation in Thailand, it is proper to regard the deficiency as the insufficient response of the country. It is also difficult to understand that demand for environmental protection remains unchanged in light of the considerable deficiency.

5) Condition of water supply in Indonesia

Among the ASEAN nations, Indonesia started industrialization rather late as did the Philippines. However, while they changed to an active policy by making an economic development plan. Lately they have become the country receiving the greatest investment from advanced nations, especially Japan. In the 6th development plan announced in 1993, the target economic growth was set as a long term rate of 6.2%

Until recently (1969 to 1993), 12,500 weirs and 40 dams had been constructed to increase the water resource supply capacity. The target of the 6th plan, as listed in the table, is 110m^3/second for use in the industrial sector and tourism industry and is ambitious at more than twice the record of the 5th plan. As compared with 1.05 times growth for the same period for agricultural water, it also directly indicates a desire to promote industrialization and positive measures to provide water resources. In concrete terms, six dams will be restored and five new dams will be constructed. As compared with the record over the past about 20 years, the speed is more than twice. They have appropriated 445 trillion rupiahs in the five-year water resource development budget.

Such measures to promote water resource development allow the allotment of water for use in the manufacturing and tourist industries to be doubled in the five years before 1999. Then in 2020, the final year of the 2nd long-term development plan, it is expected to be 3.8 times the record of 1994, thereby increasing the percentage as part of the whole water supply from the present 1.2% to 3.2%. On the other hand, a change is also observable as the percentage of water for living is expected to increase by sixfold. Although the percentage of agricultural water is expected to decrease from the present 96% to 85%, the attitude toward water resources with agricultural water as the main will not change greatly. The fact that the share of agricultural water will not change as much as the drop in the share of agricultural production may reflect the nonefficiency of the agricultural irrigation reflected in the multiple-island nature of the country.

6) Condition of water supply in Singapore

Singapore was the first country in the East Asian area to join the advanced nations as a city-state. Coupled with its peculiar conditions after separation and independence from Malaysia in 1965, Singapore has realized export-oriented industrialization mainly receiving foreign capital in a favorable manner. The population growth rate is low following Hong Kong and the annual percentage increase of population is expected to quickly become less than 3%. In spite of that, the percentage increase in income per capita was recorded as the top in this area in both the first and second halves of the 1990's. Since they have almost completely been released from dependence on agriculture, the structure of water resources depends on the division into water for industrial and water for living.

The total quantity of water consumed was 404.5 million m^3 in 1995, an increase of 2.2% over the previous year, and seemed to be slightly less as compared with the tempo of the increase in GNP. The Public Utilities Board (PUB) handling electric power and gas was changed to the Corporate Bureau in 1995, but it will be reorganized into the Water and Regulation Bureau. This indicates that measures to control water resources came to have importance almost equal to that of other energy resources.

Looking at the record over the long run, water was increased by 44% from 324.7 million m^3 to 469.0 million m^3 in the 10 years up to 1995. The annual rate was slightly lower than 3% and it may not have been an satisfactory situation when compared with the economic growth rate at that time in Singapore. Of the total water sales, the industrial use increased from 29% or 117 million m^3 in 1991 to 32% or 152 million m^3 in 1995. The share increased naturally and indicates that industrial demand exceeded the total supply. At the same time, domestic customers and non-domestic customers were respectively 54% and 46%, respectively in 1995. In the classification of charges, attention should be paid to the fact that the share of living water consumption is greater than that for industrial water consumption. The newly-established Water Resource Control Bureau controls the existing 19 riverheads and three rivers. They are planning conservancy of Johore River by investing 32.2 million dollars and construction of a 32.5km pipeline by investing 54 million dollars. These water resource development costs are 2% as compared with the general account budget, and are not necessarily small.

7) Condition of water supply in China

Although China slightly lagged behind other nations in modernization and industrialization, it switched to economic reform and an open economy to follow a double-digit growth line from the latter half of the 1980's and the tempo of its industrialization has been remarkable. Having a population of 1.3

billion, it has maintained a double-digit growth rate in per capita GDP over the past 10 years.

Observing the conditions of China with regards to water resources, the amount of rainfall is 600mm per year, which is about one fourth of the average of the ASEAN nations, and although there are large rivers in its vast landmass, the volume of flowing water of the seven largest rivers comprises 55% of the total volume. Under these conditions, it cannot be denied that the country lags behind in effective use of water resources. Also, because of its geographical condition on the continent, floods occur rather frequently. Historically, flood control has been an important political subject.

The Irrigation Department was established by the National Committee in 1949 when the present national structure was established. The Irrigation Department was merged into the Resource Department but separated again in 1988. At present, the irrigation department is under the control of the state planning committee and has functions of unified management, multiplepurpose development, and utilization and protection of water resources for the whole country. For unified management and protection of water resources, they make alternative plans for water distribution between provinces and long-term water demand plans. For instance, they executed a project for transferring water from the Chang-chiang to the Huang-ho.

In China the total annual average water resource volume is 2,812.4 billion m^3 and the outflow volume per capita is $2,600m^3$ which is one fourth of the world average. Therefore, it is judged that the supply condition is not good. The effect of water control over the past 40 years has been mainly to irrigate agricultural land by increasing the flood control capacity in the existing framework. It is estimated that farm products in irrigated land have reached two thirds of the national output. For the supply of city and industrial water, it is estimated that 50 billion m^3 of city and industrial water is supplied every year through many projects. This is less than just 2% of the total water resource volume.

Furthermore, let us also look at hydroelectric power generation, which is connected with industrial water, as a point of reference. As the table shows, power generation increased greatly, centering on the 70's and 80's which witnessed a strengthening of the tempo of industrialization, showing a 6-fold increase over about 20 years.

Conclusion

So far, the condition of the supply of industrial water under industrialization in the East Asian Pacific area has been described while relating it to overall water resources. Also, because of differences in natural conditions between countries, a supply of well-coordinated industrial water in the face of industrialization is not effectively executed in every country. Also, since national measures are taken with emphasis placed on agricultural water in many countries, a phenomenon similar to the lagging maintenance of infrastructure is occurring in the manufacturing industries in terms of securing the supply of water resources. What I would like to point out in relation to this is that the World Bank refers to the necessity of the maintenance of infrastructure in the countries of East Asia over the next 10 years and predicts 0.7% of GNP 6.8% for water-related items. Although industrial estates have been developed in ASEAN nations, there are cases of companies moving into such nations stagnating because of the insufficient security of industrial water, ground subsidence due to pumping up of underground water and, though not mentioned here, environmental problems such as water pollution due to deficient drain control.

Water resource problems are also deeply intertwined with environmental problems. Therefore, OECD also has had the environmental policy planning committee take charge of water resource problems. ESCAP has the Sustainable Development and Environmental Committee to deal with these. Either economic cooperation services or projects based on private economy are often concerned with those problems. Therefore, bilateral conferences, for example, the Japan-China Water Resource Exchange Conference (Tokyo, 1985) dealt with these and the Mekong River Development Committee deals with these because of the many countries bordering it. As explained in the Mekong River Development Plan, contributions to the growth of each country concerned vary depending on the scenario. Consequently, efforts to coordinate their interests should be taken seriously.

In the process of industrialization, interest coordination widely affects capital relations, trade problems in the stage of bringing products into production, etc. Actually, water resource problems due to industrialization have tasks different from those with materials of high mobility. However, for sustainable development and environment preservation, it is important to cooperate in the aspects of know-how, funding and technology.

Change in industrial structure (percentage distribution of GNP)

		1950-60	60-70	70-81	90	93
Japan	Agriculture	12.8	8.6	5.4	2.6	2.0
	Manufacturing industry	34.3	34.5	32.0	31.3	30.9
Korea	Agriculture	39.2	32.0	20.3	9.8	7.0
	Manufacturing industry	13.1	19.0	27.0	32.9	43.0
Malaysia	Agriculture	36.0	32.1	26.9	20.1	17.0
	Manufacturing industry	8.7	10.8	19.2	31.2	44.0
China	Agriculture	52.2	40.4	38.3	28.3	20.9
	Manufacturing industry	23.9	40.9	44.9	43.6	51.7
Thailand	Agriculture	39.8	33.6	30.3	14.7	10.0
	Manufacturing industry	12.6	14.7	17.9	31.3	39.0
Philippines	Agriculture	25.7	26.7	25.9	23.8	22.0
	Manufacturing industry	20.3	20.8	24.6	27.0	33.1
Indonesia	Agriculture	50.0	49.5	34.2	28.0	19.1
	Manufacturing industry	8.4	8.5	19.1	29.1	39.2
Singapore	Agriculture	3.5	2.9	2.0	0.3	0.0
	Manufacturing industry	11.6	16.3	23.3	32.1	37.1
Hong Kong	Agriculture	3.4	2.6	1.3	0.1	0.0
	Manufacturing industry	15.5	30.9	27.4	25.5	21.0

Data World Bank

Per capital GDP (in dollars)

	1960's	70's	80's	90's
Japan	966	4,789	14,387	32,496
Korea	143	7.4	2,741	8,044
Taiwan	234	984	3,940	10,543
Hong Kong	647	2,446	7,374	19,140
Malaysia	305	830	2,041	3,264
Thailand	133	354	877	1,948
Indonesia	62	213	525	839
Philippines	213	365	637	840
China	-	-	307	471

Data: World Bank

Quantity of water used throughout Japan

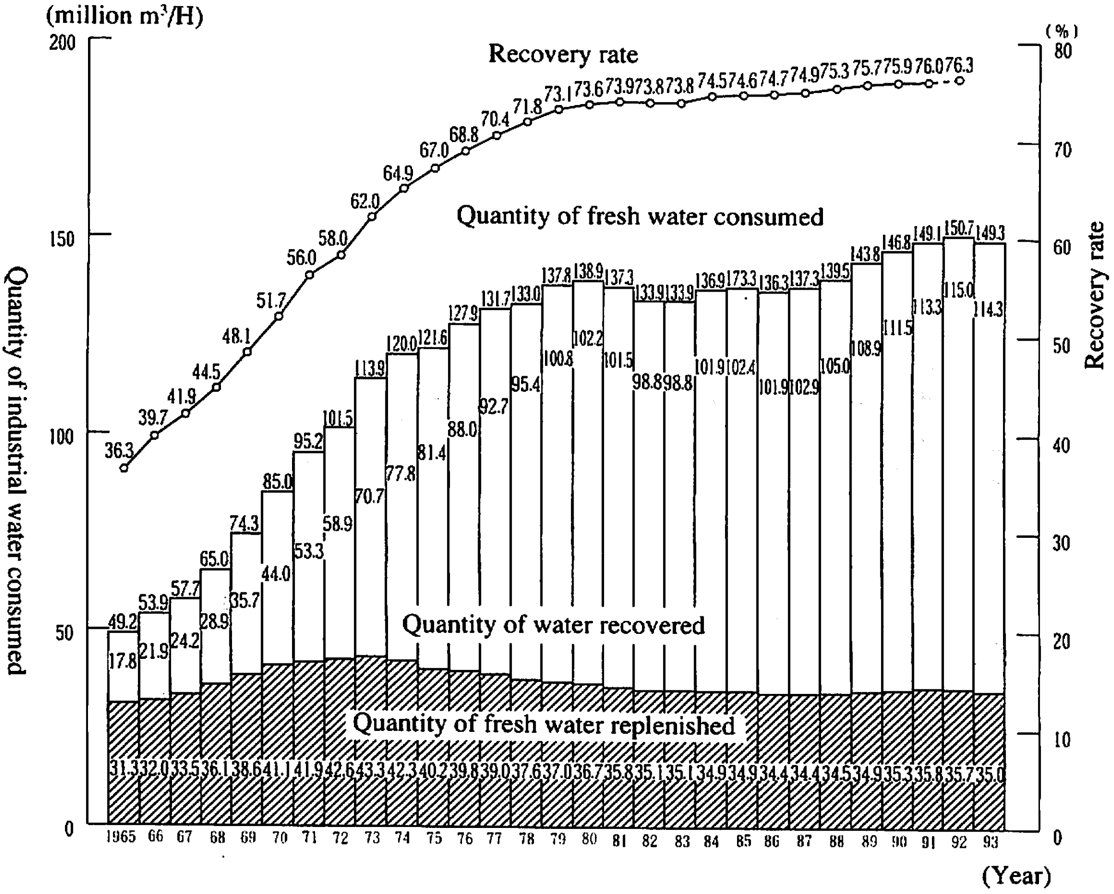
(Based on quantity of water intake, unit: 100 m^3/year)

Year Water	'75	'80	'85	'90	'91	'92	'93
City water	306	302	307	322	327	328	324
Living water	123	137	151	166	168	170	169
Industrial water	183	165	156	156	159	158	155
Agricultural water (Notes)	570	580	585	586	586	586	586
Total	876	882	892	908	914	914	910

Data: "Japan's Water Resources" by the National Land Agency (Aug., 1995)

Notes:
1. The values of agricultural water in 1980, 1983 and 1989 were calculated by the National Land Agency. The quantity demanded in 1983 was used for the value in 1985 and the quantity demanded in 1989 for the values in 1990 through 1993.
2. Industrial water is the supply of fresh water.
3. The values of living water and industrial water in 1993 are provisional calculations.

Change in quantity of industrial water consumed in Japan



Notes: 1. Prepared based on "T. Industry Statistics" by MITI.
2. Values at business establishments with 30 employees or more.

Korea: Prospect of water supply and demand (Unit: million m^3, %)

Percentage distribution of quantity of water

Division	1980		1986		1991	
	Quantity of water	Percentage distribution	Quantity of water	Percentage distribution	Quantity of water	Percentage distribution
Total water demand	16,875	100.0	21,727	100.0	24,227	100.0
Living water	2,302	13.6	3,871	17.8	5,201	21.4
Industrial water	717	4.3	1,689	7.8	2,289	9.4
Agricultural water	10,807	64.0	13,118	60.4	13,738	56.6
Preservation water	3,049	18.1	3,049	14.0	3,049	12.6
Total water supply	17,498	100.0	25,871	10010	29,735	10010
River water	12,821	73.3	14,118	54.6	14,994	50.3
Underground water	1,363	7.8	1,683	6.5	1,691	5.7
Dam	3,314	18.9	10,070	38.9	13,100	44.0
Excess and deficiency	623	-	4,144	-	5,458	-

Cui Rong Bo, Li Xiang Joint work "Resources and Environmental Theory"

Change of water resource development costs in Korea

(In million wons)

	Economic development costs		Water resource development costs	
1976 year	546,385	(25.2)%	9,476	(0.4)%
77	623,383	(22.8)	15,919	(0.6)
78	725,067	(20.5)	35,227	(1.0)
79	1,405,352	(27.8)	56,946	(1.1)
80	1,397,440	(21.6)	34,946	(1.1)
81	1,493,743	(18.9)	30,424	(0.4)
82	1,607,817	(17.5)	63,444	(0.7)
83	1,752,640	(17.2)	111,286	(1.1)
84	3,081,828	(18.8)	78,143	(0.7)
85	2,499,542	(20.2)	119,550	(1.0)
86	2,620,136	(19.0)	110,430	(0.8)
87	3,070,716	(19.4)	88,177	(0.6)
97	17,174,521	(25.4)	442,738	(0.65)
			(Administrative expense: 332,188)	(0.47)

Data: "Budget Outline for Reference" by the Economic Planning Board

Malaysia Water supply (per 1,000 persons)

	1996	1995	2000
Total	15,098	18,142	21,496
Cities	9,170	11,185	13,609
Agricultural districts	5,928	6,957	7,886

Data: 7th Malaysia Plan (1996 - 2000)

Demand for water in Thailand (Million m^3)

	1993		2006	
Total	88,695	(100)	109,356	(100)
Public	3,118	(3.5)	6,593	(6.0)
Industrial	1,312	(1.5)	2,154	(2.0)
Irrigation	48,172	(54.3)	61,747	(56.4)
Environmental protection	15,326		15,434	
Electric power	20,695		23,425	

Data: Thailand NESDB (Energy Resource Bureau)

Raw water demand during Indonesia's 2nd long-term development plan period

(m^3/sec.)

Item	Final year (1999) of 5th plan	2ns long-term development plan				
		Final year (1999) of 6th plan	Final year of 7th plan	Final year of 8th plan	Final year of 9th plan	Final year (2020) of 10th plan
1.Residence	105	210	320	430	520	660
2.Agriculture	3,900	4,100	4,400	4,500	4,800	5,000
3. Manufacturing industry/tourist industry	50	110	150	170	180	190
Total	4,055	4,420	4,870	5,100	5,500	5,850

Data: Long Term Development Plan

Total water sales in Singapore

(Million m^3)

1986	324.7	(100)
87	334.07	
88	344.1	
89	355.6	
90	374.2	
1991	399.6	
92	419.6	
93	433.9	
94	455.9	
95	469.0	(144)

(Data) Public Utilities Board

Growth of Chinese Hydroelectric Power Generation

	Hydroelectric power generation (unit: hundred million KWH)	Proportion of all electric power generation (%)
1950	8	17.4
60	74	12.5
70	205	17.7
75	476	24.3
80	582	19.4
85	924	22.5
90	1,264	20.3
91	1,248	18.4

(Data) China ‘Water Utilization Year Book’

Chapter 4

Water and Health

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1. Water and Health/Maternal and Child Health

From the perspective of public health

1) Water and the Human Body

Life on earth cannot be sustained without water. Water accounts for 60~70% of man's body weight, approximately 40% of which exists within cells, 20% in tissue, and 5% in the blood. Water plays a crucial role as a vital medium for the activities of all organs within the living body, such as ensuring all tissues are sufficiently moist and dissolving salts and discharge. It also plays an important role in maintaining the functions of living organisms, such as the digestion of food, absorption and movement of nutrients, discharge of waste materials, breathing/circulation, and control of perspiration/body temperature.

People need to intake between 2 and 2.5 liters of water a day to maintain life, which is taken in the form of drinking water, beverages, and food, and then discharged from the body as urine, perspiration, expiration, or through the discharge organs. In addition, large quantities of water are used for cooking, washing, bathing, cleaning, industrial uses, extinguishing fires, hospitals, and research, and water consumption has increased in proportion to the advancement of each culture.

The average water consumption of a service water system per person per day is 400~600 liters in major cities throughout Japan.

2) Water Demand

When we look at the relationship between man and water, although rivers, lakes and marsh, and spring waters have been used as water sources since prehistoric times, wells have been dug and groundwater started to be used as a water source after villages developed. The demand for water steadily increased as those villages eventually developed into cities, and water shortages became a serious problem for people, resulting in the development of water supplies through waterworks.

The concentration of populations in cities and their expansion over larger areas requires enormous amounts of water, and shortages in absolute quantity and a decline in water quality cannot be avoided. Furthermore, the increasing population and urbanization leads to increased water demand, which causes some agricultural water being used in cities.

Supplying water is necessary for agriculture, because an increase in the population obviously leads to an increase in food requirements. It is estimated that 65% of the water collected from rivers, lakes, and reservoirs throughout the world is for agricultural use, 25% for industrial use, and 10% for domestic and urban use.

If we try to collect the actual amount of water required to produce our foodstuffs, it would cause such a reduction in the water level of rivers, and lower the groundwater table level to such an extent, that it would be impossible to satisfy the demand for water in the cities. Conversely, if we try to secure sufficient water supplies for our cities, this would cause an agricultural water supply shortage. This is our modern dilemma.

Besides, the number of large dams with a depth of 15m or more was about 5,000 worldwide in 1950, but have increased to about 38,000 by 1996. In Japan, 19% of the annual water supply relied on dams in 1970, a percentage rose to 35% in 1991. The volume of river water has become completely controlled by dams, but this means that the ecological function is no longer preserved, resulting in damage of aquatic environment, such as declining river deltas, shrinking lakes, less marshlands, and the impending crisis in extinction of some animals and plants.

Such effects on our life and health due to this environmental destruction cannot be ignored.

Use of desalinated seawater has been promoted in areas facing water shortages, and attempts being made to reduce the costs compared to those in the initial stages. Water sources for good quality water need to be secured to ensure safe water supplies in the future. However, a variety of problems exist, such as the concentration of populations in urban areas, pollution of aqueduct water sources due to industrial developments and advances in industrial technology, and the diversification of water pollution.

3) Importance of Water for Hygiene

As mankind progressed from the era when river, lake and marsh water was used as it is as drinking water, so waterworks became necessary from the viewpoint of solving the problem of insufficient water supply due to urbanization and population concentration and to ease the use of water.

However, in the early days, the water supply was not safe for drinking, and the first water filtration methods were used at the beginning of the 19th century in order to remove the muddiness. It was not for removing bacteria, which is currently done as a matter of course. P. Frankland confirmed that bacteria are removed by water filtration in 1885. When there was a cholera epidemic in both Hamburg and Altona in 1892, unfiltered water continued to be supplied as the drinking water in Hamburg, where the death rate due to cholera reached 134 per 10,000 people. On the other hand, that in Altona was only 23 per 10,000 people, because sand-filtered drinking water was supplied there. This was conclusive proof of the effectiveness of filtration for reducing the number of cholera related deaths.

Both H. F. Mills in America and J. J. Reincke in Germany confirmed that filtered water supplies reduced the overall death rate, as well as infectious diseases of the digestive organs, by sampling water from the Merrimack and Elbe rivers respectively, and reported their results in 1893.

This is known as the Mills-Reincke phenomena. Purification using sand filtration and waterworks have been established throughout Europe since then.

In Japan, waterworks originated in the 1590's when the Shogun, Ieyasu Tokugawa, who built a metropolis in Edo(nowadays Tokyo) to govern the whole of Japan, created a waterway running continuously without purification. About 60% of the residents in Edo enjoyed the benefit of this waterway by the end of the 18th century. Later, pressurized clean water was supplied in Yokohama in 1887.

Legal regulations have been adopted in developed countries to ensure the supply of safe drinking water. Safe water is provided after sedimentation of the original water, sand filtration, followed by chlorination, which are the treatments for relevant pollutants such as bacteria, excreta, metals/heavy metals, toxic chemicals, and agricultural chemicals, and conducted based on the pH and removing turbidity, odors, and discoloration, etc.

However, an increasing number of countries and facilities have adopted advanced water purification treatments, using ozone before filtration and then chlorination, due to the increasing deterioration in the quality of the original water.

From a biological point of view, 99% or more of water-borne diseases are attributable to polluted water, a percentage that is estimated to be a couple of hundred times greater than diseases caused by chemically polluted drinking water.

It is reported that 25 million people die annually in developing countries as a result of drinking water polluted by pathogens. Nonetheless, 3 million children under five years old die annually due to dehydration, resulting from diarrhea, and malnutrition. Although this figure is equivalent to a quarter of all fatalities amongst children of that age, these are preventable and treatable using oral re-hydration treatment (ORT). When we consider that less than 5% of all diarrhea cases require an drop instillation, the important and urgent task so far is spreading ORT.

In order to cure the infant diarrhea problem currently seen in developing countries, it is necessary to build up a system to supply safe drinking water without reliance on ORT.

At the same time, we must prevent the deterioration of the rivers and lakes and marsh that are used as the sources for waterworks. The reduction in the volume of water, the increase in domestic sewage in line with the population increases, water pollution due to industrialization, and eutrophication of water can all be considered as causes for the deterioration in the water supply, but chlorinating water to disinfect it may also lead to the creation of carcinogens, and it may become polluted by viruses. In America, there have been problems of Cryptosporidium and Giardia lamblia pollution through the waterworks that caused infectious stomach and intestinal diseases, and it is reported that 400,000 people were infected, of whom 104 died, in Milwaukee. These protozoa cannot be killed off by ordinary disinfectants. This is a big problem in developed countries.

4) Water Hygiene and Maternal and Child Health

Filtration of water alone enables us to reduce the death rates due to digestive diseases as well as the general death rate as confirmed by the Mills-Reincke phenomena. In particular, the supply and use of safe purified water has contributed significantly to the reduction in the infant mortality rate. Amongst ten leading causes of death in China in 1984, digestive diseases ranked fifth. The death rate in cities was 23.8 per 100,000 people, and the ratio out of the total number of deaths was 4.3%. The fifth ranking the mortality ratio by causes of death in Vietnam (1990) was diarrhea, which affected 0.05 per 100,000 people, while the incidence rate was also ranked fifth at 184 per 100,000 people.

Gastrointestinal diseases were the fifth ranked of the ten leading causes of death amongst inpatients in Sri Lanka (1991), which represents 6.6%, or 11.0 per 100,000 people.

The ninth ranked cause of population mortality in the Philippines (1992) was diarrhea, which was also the forth ranked cause of infant mortality, and it was also the top ranked of the ten leading incidences of illness amongst the population (1,587 per 100,000 people), which clearly shows that the ratio of digestive organ diseases is high.

Thus, it is clear that the high infant mortality rate in developing countries is caused by diarrhea, dehydration, and malnutrition, and it is also considerably affected by the medical service systems (number of doctors, hospitals, beds, and medical expenses) that support the above and education on using safe water.

Although oral re-hydration treatment has recently become much more popular, it may take some time for it to be widely spread in developing countries. However, the above stomach and intestinal diseases seriously affect adults' health as well as that of infants.

Although the maternal mortality ratio is not so closely related to water as that of infant mortality, it is considered that this can also be reduced by using safe water. It can be said that health education is necessary as shown by the positive correlation between the percentage of water usage and education for women.

Development of an aqueduct network is naturally related to an increase in water consumption volume and percentage, and must contribute to a reduction in the number of diseases, especially digestive diseases. An aqueduct network has been built up in Japan, and the average rate of water supply diffusion is 95% throughout Japan and 99% in Tokyo, whereas in Vietnam, the usage rate of safe water is 65% in cities, and 43% in agricultural districts; and in Laos, 57.1% in cities and 6.4% in agricultural districts, so the differential between countries is big. Despite the best efforts in developing countries to apply the technology to supply safe water and to carry out maintenance and management of the aqueduct network properly, it seems that currently polluted water is being discharged due to damaged water pipes and the inflow of sewage.

2. Industrial Water Pollution

Service water systems has been developed in line with the concentration of the population and urbanization, and resulted in an increase in the volume of water consumed, so a sufficient supply source for drinking water from rivers, lakes and marsh and groundwater is required. Supplying safe water is necessary to satisfy urban life and maintain health, while plenty of water at a reasonable cost must also be guaranteed for the development of industry.

On the other hand, environmental pollution and the effects on our health may be a significant problem depending on the quality and volume of materials contained in the drains when supplied water is later discharged as drainage.

1) Industrial Waste Pollution

The quality of water discharged from factories varies depending on the types of the industry as follows.

Divided in a rough way, there are three types; 1) food processing, paper pulping, and textile related factories discharge thick oils and fats, phenols, and organic matter in the drainage, 2) Electroplating works, machine works, iron works, and the metal refinery industry related factories discharging harmful materials in the drainage, such as cyanogens, heavy metals, and organic solvents, and 3) factories discharging strong acids and alkalis.

(1) Water Pollution caused by Organochlorine Compounds

These are organic compounds that do not exist naturally, to which chlorine and bromine become attached, and are difficult to degrade in the body, and thus are easily accumulated. They have a toxic effect on the liver, may cause defects in DNA chains, and many of them are mutagenic and carcinogenic.

Trichloroethylene is a typical organic solvent, and is widely used throughout the world in dry cleaners, electroplating works, and as a metal cleaner in semiconductor plants.

It is uncertain whether it is carcinogenic, but if it is discharged within the plant area, it can flow out into the public water area or penetrate the groundwater. If the groundwater is disinfected with chlorine, it is converted into trihalomethane, generated a known carcinogen.

(2) Water Pollution caused by Heavy Metals

Serious health damage can be caused by heavy metal pollution. The case of Minamata Disease in Japan is a classic example of that.

Organic mercury that was included in the drainage from plants became concentrated in seafood, which is part of the food chain, and eventually poisoned the human body. The first recorded patient was in 1956, and the damage caused to the cerebro-nerve system, in particular, was remarkable.

Minamata Disease was also seen among the native Indians in Ontario, Canada, in 1975. This was caused by mercury polluted water discharged from a chemical plant and a pulp plant further upstream. Itai-itai disease is also caused by cadmium pollution.

Cadmium discharged from a plant upstream of the Jintsu River in Toyama prefecture was bio-concentrated and absorbed into the human body.

There is also a problem of pollution in lakes and marsh and the sea due to the organic tin compound used for coating the undersides of ships and to prevent grime from accumulating on the fishing nets. This compound has been used to prevent crustacea (barnacles) from attaching themselves to the undersides of large tankers, as they reduce the ship's speed and increase its fuel consumption, and also to prevent oxygen deficiency caused by seaweed attaching itself to fishing nets in fixed nets and farms. Naturally, there is concern about the effect on the health of man, who is at the top of the food chain, due to bio-concentration and seafood pollution from these chemicals. The use of organic tin compounds is currently strictly regulated in Japan, due to its difficulty to degrade, high accumulation, and its chronic toxicity, also worldwide restrictions are necessary in the near future.

(3) Polycyclic Aromatic Hydrocarbons (PAH)

There are many polycyclic aromatic hydrocarbons (PAH) produced by the imperfect combustion of oil and coal, and within automobile exhaust fumes. Many of them are contained in coal tar extracted from coal, and they can be found in drinking water if used to paint the insides of water pipes. A variety of PAHs are detected in airborne particles (air pollutants). These PAHs fall to the ground and become dissolved in the groundwater and other water sources with the rain, and then finally appear in drinking water or are converted to mutant substance and trihalomethane by chlorination.

(4) Water Pollution caused by PCBs

PCBs, which are known to be the cause of the Kanemi Rice Oil Food poisoning, have been used in paints, printing ink solvents, insulation oil for transformers and condensers, as well as a thermal medium. This is a substance that has certain effects on living organisms, such as pigmentation and liver failure, it is difficult to degrade and becomes highly concentrated, resulting in its permanent presence in the environment. Thus, PCBs that were used in industry have polluted the rivers, lakes and marsh and sea, and have become concentrated in the food chain of aquatic organisms and finally entered the human body, so it has been detected both in the human body and mother's milk. Although manufacturing of PCBs has been prohibited since 1972 in Japan, it is still being detected in the environment.

(5) Water Pollution caused by Dioxin

Dioxin, which is reputed to be one of the most toxic substances on earth, has been found in fish and deposits on the sea floor. Dioxin is a by-product of herbicides and settles in the environment where it is also difficult to degrade and becomes highly concentrated in organisms, remaining in the liver or fat of bodies for a long time, where even minute amounts are highly carcinogenic or teratogenic.

It has become clear that it is generated in the pulp bleaching process of paper mills, and its discharge from scavenger facilities or office and domestic incinerators has recently been recognized as a problem.

It is obvious that dioxin is created if vinyl chloride products and plastics are burnt at temperatures of 500~600°C and is discharged in the smoke and ash. Dioxin discharged into the atmosphere pollutes the groundwater, as well as polluting foods, such as dairy/meat, marine and agricultural products, and is also absorbed into the human body through drinking water. This has become a worldwide problem, and it is regulated in some countries. It is possible to reduce the amount of dioxin in the environment by reducing the amount of waste that is incinerated, and recycling it instead, or increasing the incineration temperature to 850°C.

2) Pollution Due to Domestic Sewage

(1) Pollution caused by kitchen waste and excreta

Domestic sewage has different characteristics to industrial sewage. There is much organic matter included in sewage from cooking, washing, bathing and excretions. It is discharged into rivers and lakes and marsh, after being purified in the sewage works in areas where the drainage have well-diffused. However, domestic sewage is directly discharged in areas where the drainage have not well-diffused. It is said that 60% or more of river pollution is due to domestic sewage. Discharging excreta directly into the water source makes the pollution worse, and also significantly degrades the self-purification of medium and small sized rivers in urban areas, which may lead to infectious diseases. As for the biochemical oxygen demand (BOD), which is used as an index for organically related river pollution, of domestically discharged sewage, 42% of the total BOD value is from the kitchen, 26% is excreta, 22% is from bathing, and 10% is from washing.

It was reported that the BOD load volume of the domestic sewage discharged per day in Japan was 935mg/l on the average (1973). Purification of domestic sewage must be actively undertaken, because the quality of river water in which fish can survive is a BOD of 5mg/l.

(2) Water Pollution caused by Phosphorus/Nitrogen and Eutrophication.

Phosphorus nitrogen compounds within domestic sewage are discharged into lakes and marsh and bays, and a massive number of plankton and protozoa, which feed on it as a nutrient, are produced, and consume the oxygen dissolved in the water, which results in the death of many fish and shellfishes due to oxygen starvation. This is called eutrophication, and is also known as 'Red water' and 'Water bloom'. 45% of the phosphorus in lake water results from domestic sewage, while the remainder is from fertilizer in outlying fields.

On the other hand, eutrophication promotes an increase in microorganisms, which produce substances that cause moldy smells such as 2-methylisobolneol and diosumine.

Thus, the water becomes unsuitable for drinking. Advanced water purification technology combined with ozone processing and activated carbon have been introduced to remove the moldy smells. In order to prevent eutrophication caused by the direct discharge of phosphorus and nitrogen compounds, there is a plan to purify the drains. It is estimated that 680 billion would be needed to construct a facility to treat the phosphorus and nitrogen compounds contained in the treatment of 4.3 million m^3 of sewage per day from the drains within the wards of Tokyo, and another 170 ~ 250 million per day to maintain and manage these compounds. We must make efforts to reduce the amount of phosphorus and nitrogen compounds discharged within domestic sewage as much as possible in order to protect our future water resources, in developing countries as well as developed countries, in line with the increasing domestic sewage volume due to population increases and urbanization.

3) Water Pollution caused by Agricultural Chemicals

Agricultural chemicals are indispensable for increasing agricultural production. However, some of them are carcinogenic and exhibit chronic long-term toxicity.

DDT is a case in point, as is not degraded in the environment, becomes highly accumulated, and is also reportedly possibly carcinogenic to animals. Although this has not been used in Japan since 1971, it can still be detected in the environment.

Furthermore, a large quantity of herbicides, insecticides, and sterilization agents are spread out to maintain the condition of the greens on golf courses. There are 40 types, which include the same type as those used for fields. Those agricultural chemicals that are spread on fields and golf courses later cause pollution in rivers, lakes and marsh, and groundwater in the end. In particular, organic phosphorus pesticides, which are included in insecticides, obstruct the function of enzymes, such as cholinesterase, within the human body and act as a neurotoxins, and it is said that their toxicity is increased between a hundred-fold and a thousand-fold after the chlorination of drinking water. Restrictions need to be carried out concerning their use.

4) Water Pollution caused by Chlorination

It started in 1972 with the detection of chloroform in the lower reaches of the Rhine River in Holland. Carcinogenic substances contained in rivers have been treated as a problem since Mr. Harris reported in 1974 that the percentage of carcinogens amongst people living in New Orleans, America, was higher amongst those who had been drinking water from the Mississippi River than in those who had been drinking water from other sources.

Originally, chlorination was carried out to disinfect harmful microorganisms existing in drinking water and safe water supplies. However, it cannot be denied that the increasing amount of chlorine for water treatment due to pollution caused by organic matters within the original water has recently become worse.

It has been confirmed that the chlorine reacts with a small amount of the organic matters in the original water, such as humin and other substances that cause mold, to generate carcinogenic organic halogen compounds. These are known as trihalomethanes in general, and include such compounds as chloroform, tribromomethane, dichlorobromomethane, and chlorodibromomethane.

Humin exists in rotting matter in the soil and in domestic sewage, such as excrete-treatment and sewage-treatment water. Mold smell is caused by 2-methylisobolneol and diosumine as mentioned before. Trihalomethane production increases as the water temperature rises, and as the time spent in contact with chlorine gets longer.

Trihalomethane can be removed using advanced water purification treatment in combination with activated carbon and ozone treatment. However, essentially, we must reduce the amount of organically induced pollution of the original water as much as possible.

3. Conclusion

Mankind has spent thousands of years investigating causes of infectious water borne diseases.

However, the fact remains that there are many countries and regions that cannot yet supply safe and clean water, despite knowing that the supply of purified water is necessary.

Furthermore, water purification alone has become insufficient to cope with the increasing population and urbanization. In other words, water quality has become as an important issue as water quantity, and worldwide efforts are required, not limited to Japan.

In order to prevent water pollution caused by industrial sewage and various chemicals and organic materials, which are discharged domestically, we need to establish environmental standard items and values, and monitoring with action to prevent discharging sub-standard water into rivers, lakes and marsh and bays through concentrated processing or internal company processing is necessary. A recent problem is that some companies have moved their production bases to developing countries that have no standards for waste discharge, because the regulations in their own countries have become very strict. Consequently, the establishment and monitoring of international standards are necessary.

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