

Sakurai, Katsuhiro; Mizunoya, Takeshi; Kobayashi, Shintaro; Higano, Yoshiro

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An Optimal Investment Policy to Control the Land-based Water Pollutant into the Sea of Japan

Katsuhiro Sakurai^{*}
Takeshi Mizunoya^{**}
Shintaro Kobayashi^{**}
Yoshiro Higano^{**}

Abstract In Asia, comprehensive problems like the climate change and global warming occur in recent years. Northeast Asia countries around the Sea of Japan area have to cooperate in economic and environmental policies. The Sea of Japan area consists of Japan, South Korea, China, and Far East Russia in Northeast Asia, and the countries have to join forces in order to control the ocean environment and attain the sustainable development in the regions. In this study, we try to evaluate an investment policy to reduce the land-based water pollutant from coastal area into the Sea of Japan by a system simulation approach. The system simulation model is formulated by an objective function, the structure of water pollutant inflow and the socio-economic system of the target countries and regions in coastal areas of the Sea of Japan. We present an optimal international investment for water environment taking account of economic situations and environmental influences of this area over a certain period of time through the dynamic simulation.

1. Introduction

The Sea of Japan area consists of some countries, which are Japan, South Korea, China, and Far East Russia in Northeast Asia. In connection with remarkable economic development of these local countries and regions, the corruption load substance which flows into the Sea of Japan has increased in recent years. Furthermore, since the Sea of Japan is the closed ocean area and has the deep basin to its surface area, it has weak structure against contamination. It is expected that the water pollution problem of the Sea of Japan will become more serious due to the above-mentioned factors in the near future. Though Northeast Asia countries around the Sea of Japan area have many differences in the national system one another, they should cooperate in environmental policies, respectively. We also have to present some execution programs of environmental policy options concretely. The countries and regions around the closed ocean have to cooperate with one another in order

^{*} Ocean Policy Research Foundation

^{**} University of Tsukuba

to improve the seawater environment and attain the sustainable development.

Although we have some activities of international cooperation to preserve the closed ocean area and improve the water quality, e.g. NOWPAP (Northwest Pacific Action Plan), it will be taken much more time to attain the ideal targets because of many problems in fact. It is very difficult to build the systems of environment monitoring, marine environment protection databases and information management for target ocean regions, and to assess and manage the water pollutant load by land-based activities in each area.

In this study, we build a system simulation model, which describes a structure of the land-based water pollutant inflow and a socio-economic system of the target countries and regions with an international investment policy for reduction of the pollutant emission from coastal area of the Sea of Japan. Next, we try to present an optimal investment policy to control the land-based water pollutant taking account of economic situations and environmental influences of this area over a certain period of time by dynamic simulation analysis.

2. Outline of regional activity “NOWPAP”

Now, the UNEP (United Nations Environment Programme) is promoting 14 local action plans all over the world. The NOWPAP is internationally promoted by the UNEP, which is one of the local sea action plans to preserve the ocean environment for the coastal countries and regions around the Sea of Japan. Four countries which are Japan, South Korea, China, and Russia adopted this plan in September 1994, and established seven concrete projects such as construction of the database about ocean environment, an environmental monitoring program, and local activity center for various fields related ocean and coastal environment. However, the efforts of these projects cannot bear fruit immediately, and will be taken more time.

In Table 1, it is the general feature of each region in the coastal area of the Sea of Japan.

Table 2 shows seven projects for comprehensive environmental policy measures by NOWPAP to improve the water environment of the Sea of Japan. It is shown the structure of an actual executive organization for NOWPAP by figure 1.

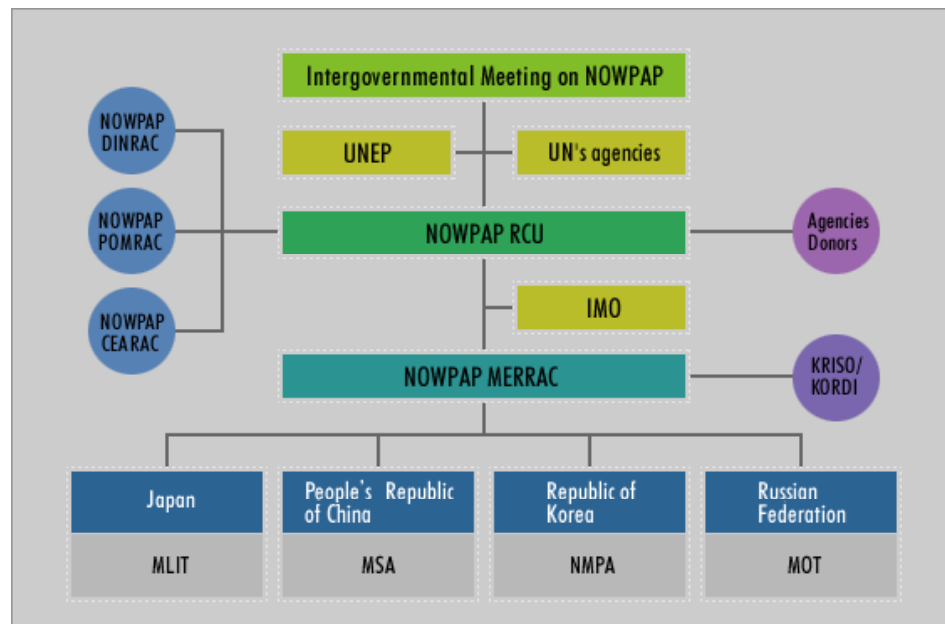
Table 1 Comparison of each region in the Sea of Japan area

| Region | Area (10,000 sq. km) | Population (10,000) | GNP (100 million dollars) |
|-------------------------------------|-------------------------|------------------------|------------------------------|
| Three ministries of China northeast | 79 | 10,364 | 830 |
| Far East Russia | 622 | 742 | 213 |
| Japan | 38 | 12,586 | 45,993 |
| South Korea | 10 | 4,555 | 5,202 |

| | | | |
|---|---------------|----------------|---------------|
| North Korea | 12 | 2,168 | 214 |
| Total | 761 | 30,415 | 52,452 |
| World (The ratio occupied in the world) | 13,560 (5.6%) | 576,800 (5.3%) | 286,549 (18%) |

Table 2 NOWPAP projects

| | |
|---------|--|
| NOWPAP1 | Development of Marine Environment Protection Database and Information Management System for Target Ocean Regions |
| NOWPAP2 | Study into Laws Related to Marine Environment Protection in Related Nations |
| NOWPAP3 | Production of Environment Monitoring Program for Target Ocean Regions |
| NOWPAP4 | Regional Cooperation on Ocean Pollution (action in case of oil pollution incidents, etc.) |
| NOWPAP5 | Designation of Regional Activity Centers to Become Centers of Activity in Respective Areas |
| NOWPAP6 | Public Awareness Raising on the Marine, Coastal and Associated Freshwater Environment |
| NOWPAP7 | Assessment and Management of Land-based Activities |



Note:

DINRAC: Data and Information Network Regional Activity Centre (established in People's Republic of China)

POMRAC: Pollution Monitoring Regional Activity Centre (established in Russian Federation)

CEARAC: Special Monitoring and Coastal Environmental Assessment Regional Activity Centre (established in Japan)

MLIT: Ministry of Land, Infrastructure and Transport, Japan
MSA: Maritime Safety Administration, People's Republic of China
NMPA: National Maritime Police Agency, Republic of Korea
MOT: Ministry of Transport, Russian Federation

Figure 1 Organization of NOWPAP activity

3. Purpose

First, we clarify the structure of land-based water pollutant emission from coastal area of the Sea of Japan and economic situation of target regions.

Secondly, we build a dynamic simulation model linked water pollutant load flowing into the Sea of Japan and socio-economic activities around the Sea of Japan area.

Lastly, we try to present an optimal international investment policy for water pollutant reduction to control emission of land-based water pollutant from human activity from coastal area of the Sea of Japan by dynamic simulation analysis. Simulation results will be contributed to decision-making for improvement of water environment and social economic policy in the coastal area of the Sea of Japan.

4. The Model

4.1 Study area

In this study, we focus on the Sea of Japan (or the Japan Sea), which is a sea area located along the northeastern part of the Asian continent. It is separated from the North Pacific Ocean by the Japanese Archipelago and Sakhalin. Figure 2 shows the location of the Sea of Japan and the surrounding countries and regions.



Figure 2 Map of the Sea of Japan

4.2 The framework of the model

Figure 3 shows the framework of our simulation model, which are linked socio-economic activities with water environment of the Sea of Japan and international investment among the countries of the area.

We build the ecosystem model with consideration to the transportation structure of the contaminant in the ring Sea of Japan area, mainly consider the seawater quality and environment as maximum restrictions and aim at the purpose of maximizing the sum of the GDP of all regions. Our simulation model of the water pollution management policy in the Sea of Japan includes an international development assistance policy, and we can analyze the optimal allocation of each country budget.

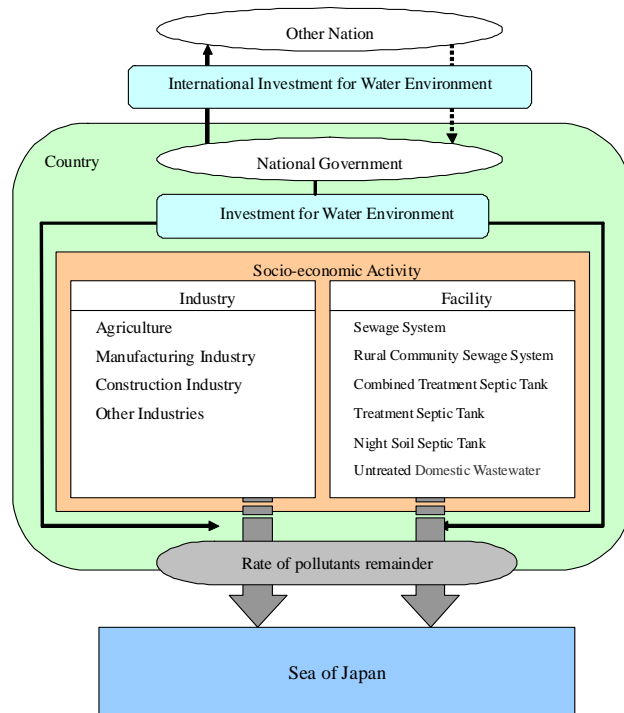


Figure 3 Framework of the model

As shown in Table 3, the pollutant index measured in this study is only COD (Chemical Oxygen Demand), because it is too difficult to get other pollutant data depending on areas.

Table 4 shows the classification of the target area, which is distinguished by administrative districts like prefectures in each country.

First, based on past data, we can guess the total amount of contaminant discharge and its coefficient of the region. Secondly, we build the multi-area and multi-section regional economic model in the ring Sea of Japan area. The socio-economic model describes the

social and economic activities in each region and how the pollutant is originated by production, household wastewater, and other industries. Table 5 and Table 6 show the categories of industries and classification of household wastewater disposal system in each area. In Table 5, “Others” emits no water pollutants.

Table 3 Target pollutant

| Index | Pollutant |
|-------|------------------------------|
| 1 | COD (Chemical Oxygen Demand) |

Table 4 Classification of the study area

| Country | Index | Prefecture | Area (10 ⁴ km ²) | Population (1,000) (1995) | GRP(billion dollars) (1995) |
|----------------|-------|---------------------------------|--|---------------------------------|-----------------------------------|
| Japan | 1 | Hokkaido | 7.8 | 5,719 | 208.9 |
| | 2 | Aomori, Akita, Yamagata | 3.1 | 4,000 | 129.5 |
| | 3 | Niigata, Nagano, Toyama | 3 | 5,820 | 229.1 |
| | 4 | Ishikawa, Fukui, Gifu | 1.9 | 4,108 | 155.8 |
| | 5 | Kyoto, Hyogo | 1.3 | 7,960 | 318.6 |
| | 6 | Yamaguchi, Shimane, Tottori | 1.6 | 2,957 | 105.6 |
| | 7 | Fukuoka, Saga, Nagasaki | 1.1 | 7,345 | 260.1 |
| | | (Others) | (18) | (87,660) | (3,729.8) |
| South Korea | 8 | Kangwon-do, Gyeongsangbuk-do | 3.6 | 4,308 | 4.4 |
| | 9 | Busan, Gyeongsangnam-do | 1.1 | 7,843 | 8.7 |
| China | 10 | Ji Lin | 18.7 | 25,920 | 13.5 |
| | 11 | Heilongjiang | 45.5 | 37,010 | 24.1 |
| Russia | 12 | Khabarovsk Krai | 82.4 | *1,608 | 4.3 |
| | 13 | Primorsky Krai | 16.6 | *2,287 | 3.5 |
| | 14 | Sakhalinskaya Oblast | 8.7 | *699 | 1.7 |

Table 5 Classification of industry

| Index | Industry |
|-------|-------------------------------------|
| 1 | Agriculture |
| 2 | Manufacturing Industry |
| 3 | Construction Industry |
| 4 | Communication and Transportation |
| 5 | Commerce and Services |
| 6 | Others |

Table 6 Classification of household wastewater disposal system (1,000 person, 1995)

| Index | Treatment Facility | Japan | South Korea | China | Russia |
|-------|--------------------------------|--------|-------------|--------|--------|
| 1 | Sewage System | 24,819 | 4,637 | 12,598 | 689 |
| 2 | Rural Community Sewage System | 1,115 | 0 | 0 | 0 |
| 3 | Combined Treatment Septic Tank | 3,231 | 0 | 0 | 0 |
| 4 | Treatment Septic Tank | 8,496 | 0 | 0 | 0 |
| 5 | Night Soil Septic Tank | 248 | 0 | 0 | 0 |
| 6 | Untreated Domestic Wastewater | 0 | 6,403 | 50,332 | 3,905 |
| Total | | 37,909 | 11,040 | 62,930 | 4,594 |

5. Simulation Model

5.1 Total Amount of pollutant flowing into the Sea of Japan

The total amount of pollutant (COD) into the Sea of Japan is shown by eq. (1).

$$Q(t) = \sum_{j=1}^{14} q_j(t) \quad (1)$$

$Q(t)$: Total amount of pollutant flowing into the Sea of Japan

$q_j(t)$: Pollutant flowing into the Sea of Japan from zone j

5.2 Amount of pollutant from each zone

The amount of pollutant emission from each zone consists of household and industry sector, and it can be reduced by investment for water pollution control.

$$q_j(t) = f_1^j E \cdot z_j^u(t) + f_2^j [Px_j(t) - Rk_j^A(t)] \quad (2)$$

f_1^j : Rate of remainder pollutants from household wastewater disposal system in zone j

f_2^j : Rate of remainder pollutants from industries in zone j

E : Coefficient of pollutant from household wastewater disposal system

z_j^u : Population using each household waste water disposal system in zone j

P : Coefficient of pollutant from industries

$x_j(t)$: Industrial production vector in zone j

R : Abatement coefficient of investment

$k_j^A(t)$: Capital accumulation of abatement for industry emission in zone j

($u=1$: Sewage system, $u=2$: Rural community sewage system, $u=3$: Combined treatment septic tank, $u=4$: Treatment septic tank, $u=5$: Night soil septic tank, $u=6$: Untreated domestic wastewater)

5.3 Capital accumulation of abatement

The capital accumulation of abatement for industries in each zone is as follows:

$$k_j^A(t+1) = k_j^A(t) + i_j^A(t) - \delta_j^A \cdot k_j^A(t) \quad (3)$$

$k_j^A(t+1)$: Capital accumulation of abatement for industries in zone j in term of t+1

$i_j^A(t)$: Investment of abatement for industries

δ_j^A : Depreciation rate

5.4 Investment for abatement of water pollutant

$$i_j^C(t) = i_j^A(t) + i_j^S(t) \quad (4)$$

$$i_j^S(t) = \sum_{u=1}^6 i_j^u(t) \quad (5)$$

$i_j^C(t)$: Total investment for abatement of water pollutant

$i_j^S(t)$: Investment for household wastewater disposal system

$i_j^u(t)$: Investment for construction of abatement facilities

5.5 Population

Population in each zone is as follows:

$$z_j(t+1) = z_j(t) + \Delta z_j(t) \quad (6)$$

$$\Delta z_j(t) = \lambda_j z_j(t) \quad (7)$$

$z_j(t)$: Total population in zone j

$\Delta z_j(t)$: Change of population in zone j

λ_j : Rate of population change in zone j

5.6 User population of each household wastewater disposal system

User population of each household wastewater disposal system is as follows:

$$z_j(t) = \sum_{u=1}^6 z_j^u(t) \quad (8)$$

$$z_j^u(t+1) = z_j^u(t) + \Delta z_j^u(t) \quad (9)$$

$$\Delta z_j^u(t) = \Gamma_j^u i_j^u(t) \quad (10)$$

Γ_j^u : Parameter

In case of $u=3$, the change of combined treatment septic tank is defined as follows:

$$z_j^3(t+1) = z_j^3(t) + \Delta z_j^3(t) \quad (11)$$

$$\Delta z_j^3(t) = \frac{i_j^3}{\Phi} \quad (12)$$

Φ : Setting cost for combined treatment septic tank per person

5.7 Flow conditions of production market

5.7.1 Japan side ($j \leq 7$)

$$x_j(t) \geq Ax_j(t) + c_j(t) + Di_j^c(t) + i_j^p(t) + y_j(t) + EX_j(t) - IM_j(t) \quad (13)$$

A : Input coefficient matrix

$c_j(t)$: consumption vector in zone j

D : Input coefficient vector for investment of abatement

$i_j^p(t)$: Total production investment vector

$y_j(t)$: International investment vector for abatement received by zone j

$EX_j(t)$: export in zone j

$IM_j(t)$: import in zone j

5.7.2 Other countries ($j \geq 8$)

$$x_j(t) + y_j(t) \geq Ax_j(t) + c_j(t) + Di_j^c(t) + i_j^p(t) + EX_j(t) - IM_j(t) \quad (14)$$

International investment for abatement of water pollutant received by zone j is less than equal to the sum of total investment for abatement in each zone.

$$i_j^c(t) \geq y_j(t) \quad (15)$$

5.8 Production function

The amount of production is dependent on capital accumulation of production.

$$x_j(t) \leq \omega_j k_j^p(t) \quad (16)$$

ω_j : Proportion coefficient of production to capital stock

$k_j^p(t)$: Capital accumulation of industrial production

5.9 Capital accumulation

Capital accumulation of production in zone j is determined by production investment and consumption of fixed capital in each zone.

$$k_j^p(t+1) = k_j^p(t) + i_j^p(t) - \delta_j^p \cdot k_j^p(t) \quad (17)$$

δ_j^p : Depreciation rate

5.10 Restriction of consumption

Consumption in zone j is determined by population in each zone.

$$c_j(t) \leq k_j z_j(t) \quad (18)$$

k_j : Consumption coefficient vector

5.11 GRP (Regional GDP)

GRP in zone j is determined by the rate of added value and the amount of production in each zone.

$$GRP_j(t) = V_j x_j(t) \quad (19)$$

$GRP_j(t)$: Regional GDP in zone j

V_j : Vector of added value rate

5.12 Total GDP

Total amount of GDP is the sum of GRP that in each zone.

$$GDP(t) = \sum_{j=1}^{14} GRP_j(t) \quad (20)$$

$GDP(t)$: Gross domestic product in target area

5.13 International assistance investment for abatement of water pollutant

Total amount of international assistance investment for abatement of water pollutant is as

follows:

$$y_j^T(t) \leq \gamma GDP_j^T(t) \quad (21)$$

$y_j^T(t)$: Total international assistance investment for abatement of water pollutant in Japan

γ : Parameter

$GDP_j^T(t)$: Total GDP in Japan

5.14 Fund for assistance raised in Japan

The sum of investment for abatement of water pollutant in zone j is equal to total international assistance investment for abatement in Japan.

$$y_j^T(t) = \sum_{j=1}^{14} y_j(t) \quad (22)$$

5.15 Accumulated debt of each zone

The accumulated debt of each zone is taken as total of the debt in each zone in each term, and accumulated debt in each zone in term t carries out to less than the fixed ratio of the t term GDP in each zone.

$$DB_j(t) = \sum_{t=1}^t y_j(t) \quad (23)$$

$$DB_j(t) \leq \sigma_j GRP_j(t) \quad (24)$$

$DB_j(t)$: Accumulated debt in zone j

σ : Rate of debt

5.16 Objective function

The objective function is the sum of water pollutant (COD) flowing into the Sea of Japan from all zones, and minimizing it in the last term with restriction of the GDP.

$$\min Q(t) \quad (25)$$

$$\text{subject to } GDP(t) \geq GDP^*(t) \quad (26)$$

$$Q(t+1) \leq Q(t) \quad (27)$$

$GDP^*(t)$: Constraint value of GDP

6. Simulation

6.1 Simulation cases

We establish the simulation cases shown as Table 7, and the running period is set from 1995 to 2007 in the calculation because it is based on scientific data in 1995. For example, Case00 is the basic case minimizing total amount of land-based water pollutant inflow from coastal

area of the Sea of Japan in term t=6 with restriction of 0% GDP growth rate.

In Table 8, it shows estimation results of the total emission and inflow of household and industry sector in each zone of the Sea of Japan area from scientific data in 1995 referring World bank[11] and Wada[10] through the simulation model. It is clear that the emission from household wastewater is higher than industry sector. It is higher emission from household in two zones of China comparing with others.

Table 9 shows total GDP of each zone in the Sea of Japan area in the first period.

Table 7 Simulation cases

| Case | Case00 | Case05 | Case10 | Case15 | Case20 | Case24 |
|-----------------|--------|--------|--------|--------|--------|--------|
| GDP growth rate | 0% | 5% | 10% | 15% | 20% | 24% |

Table 8 Estimate of total COD emission and inflow of each zone in the Sea of Japan area
(ton/year)

| Zone | Household wastewater | Industry wastewater | Total emission | Total inflow |
|--------------------------------|----------------------|---------------------|----------------|--------------|
| 1 | 5,882 | 6,209 | 12,092 | 8,732 |
| 2 | 13,048 | 3,849 | 16,897 | 11,430 |
| 3 | 18,694 | 6,812 | 25,506 | 17,414 |
| 4 | 13,635 | 4,632 | 18,267 | 12,432 |
| 5 | 12,021 | 9,472 | 21,493 | 15,271 |
| 6 | 8,971 | 3,140 | 12,111 | 8,254 |
| 7 | 12,316 | 7,732 | 20,047 | 14,067 |
| Total in Japan | 84,568 | 41,846 | 126,413 | 87,600 |
| 8 | 26,572 | 2,577 | 29,149 | 14,816 |
| 9 | 27,393 | 4,841 | 32,234 | 17,021 |
| Total in South Korea | 53,965 | 7,418 | 61,383 | 31,838 |
| 10 | 207,620 | 453 | 208,074 | 33,582 |
| 11 | 296,455 | 809 | 297,264 | 48,080 |
| Total in China | 504,075 | 1,262 | 505,337 | 81,662 |
| 12 | 13,660 | 498 | 14,158 | 5,862 |
| 13 | 19,425 | 602 | 20,028 | 8,252 |
| 14 | 6,970 | 269 | 7,240 | 3,004 |
| Total in Russia | 40,055 | 1,370 | 41,425 | 17,118 |
| Total in the Sea of Japan area | 682,662 | 51,895 | 734,560 | 218,217 |

Table 9 Estimate of total GDP of each zone in the ring Sea of Japan
(million dollars)

| Zone | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|------|---------|---------|---------|---------|---------|---------|---------|
| GRP | 208,860 | 129,458 | 229,126 | 155,803 | 318,599 | 105,606 | 260,052 |

| | | | | | | | |
|------------------------------------|--------|--------|--------|-----------|-------|-------|-------|
| Zone | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| GRP | 44,025 | 86,718 | 13,523 | 24,126 | 8,099 | 9,790 | 4,378 |
| Total GDP in the Sea of Japan area | | | | 1,598,163 | | | |

6.2 Simulation results

6.2.1 Objective value

Table 10 and Figure 4 show the changes of objective value (total COD inflow into the Sea of Japan) from 1997 to 2007, which are the solutions derived by optimization.

In Case24, it can be obtained the feasible solution, however, we can derive no feasible solution in case of 25% GDP growth rate.

Comparing Case00 and Case05, though objective value in the last period of Case00 is smaller than that of Case05, total amount of COD inflow in Case05 through the simulation period is smallest in all cases. It shows that economic activity has important role to invest for abatement of water pollutant.

Table 10 Change of objective value (total COD inflow into the Sea of Japan)

(ton/year)

| Year | Case00 | Case05 | Case10 | Case15 | Case20 | Case24 |
|---------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|
| 1997 | 218,217 | 218,217 | 218,217 | 215,632 | 218,217 | 218,217 |
| 1999 | 218,217 | 204,502 | 210,310 | 211,510 | 213,599 | 217,339 |
| 2001 | 218,217 | 204,502 | 210,310 | 209,575 | 213,599 | 217,339 |
| 2003 | 207,152 | 204,502 | 210,310 | 209,575 | 213,599 | 217,339 |
| 2005 | 201,798 | 203,545 | 206,212 | 209,575 | 213,599 | 217,339 |
| 2007 | 201,798 | 203,545 | 206,212 | 209,575 | 213,599 | 217,339 |
| Total | 1,265,399 | 1,238,812 | 1,261,570 | 1,265,440 | 1,286,212 | 1,304,913 |
| Average | 210,900 | 206,469 | 210,262 | 210,907 | 214,369 | 217,486 |
| Reduction rate in the last term | 7.5% | 6.7% | 5.5% | 2.8% | 2.1% | 0.4% |

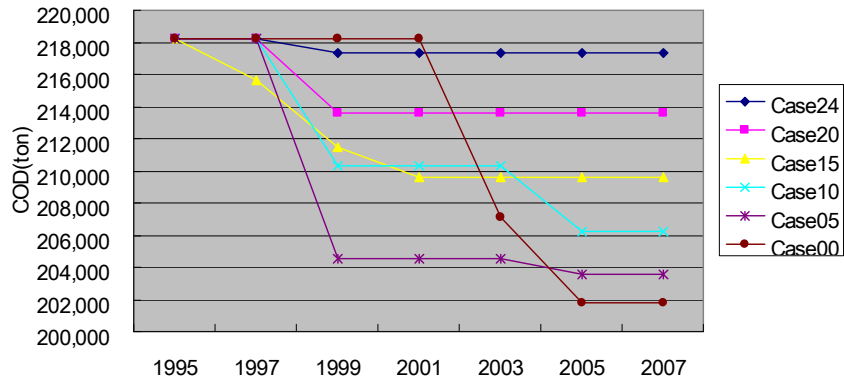


Figure 4 Change of total COD inflow into the Sea of Japan

6.2.2 GDP

Table 11 shows the change of total GDP in coastal area of the Sea of Japan. These GDP values are the restriction in the system simulation model, for instance, the GDP growth rate is 5% in each term in Case05. In this study, it is shown that the maximum growth rate is 24% in each term.

Table 11 Change of total GDP of the Sea of Japan area

(billion dollars)

| Year | Case00 | Case05 | Case10 | Case15 | Case20 | Case24 |
|---------|--------|--------|--------|--------|--------|--------|
| 1997 | 1,598 | 1,598 | 1,598 | 1,598 | 1,598 | 1,598 |
| 1999 | 1,598 | 1,678 | 1,758 | 1,838 | 1,918 | 1,982 |
| 2001 | 1,598 | 1,762 | 1,934 | 2,114 | 2,301 | 2,457 |
| 2003 | 1,598 | 1,850 | 2,127 | 2,431 | 2,762 | 3,047 |
| 2005 | 1,598 | 1,943 | 2,340 | 2,795 | 3,314 | 3,778 |
| 2007 | 1,598 | 2,040 | 2,574 | 3,214 | 3,977 | 4,685 |
| Total | 9,589 | 10,871 | 12,331 | 13,990 | 15,870 | 17,548 |
| Average | 1,598 | 1,812 | 2,055 | 2,332 | 2,645 | 2,925 |

6.2.3 International assistance investment for abatement of water pollutant

(1) Change of total international investment from Japan to other countries

In this study, we assume a policy of international assistance investment for abatement of water pollutant emission from industrial activity in coastal area of the Sea of Japan. Table 2 shows the change of total amount of international assistance investment for abatement from Japan to other three countries, which are South Korea, China, and Russia. In case of higher GDP growth rate, it is invested for abatement of water pollutant much more and in earlier term from Japan to other countries.

Table 12 International assistance investment for abatement from Japan to other countries

(million dollars)

| Year | Case00 | Case05 | Case10 | Case15 | Case20 | Case24 |
|-------|---------|---------|---------|---------|-----------|-----------|
| 1995 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1997 | 5,337 | 10,505 | 13,504 | 15,379 | 15,379 | 15,379 |
| 1999 | 2,413 | 4,198 | 4,763 | 5,312 | 5,312 | 5,312 |
| 2001 | 3,103 | 4,902 | 6,277 | 7,421 | 7,421 | 7,421 |
| 2003 | 8,594 | 12,367 | 16,028 | 18,763 | 18,763 | 18,763 |
| 2005 | 55,520 | 60,947 | 65,775 | 70,489 | 70,489 | 70,489 |
| 2007 | 407,775 | 525,036 | 680,707 | 875,883 | 886,578 | 1,366,129 |
| Total | 482,743 | 617,956 | 787,054 | 993,249 | 1,003,944 | 1,483,495 |

(2) Change of international assistance investment to South Korea, China, and Russia

Figure 5, 6, and 7 show the change of international assistance investment for abatement of water pollutant to South Korea, China, and Russia, respectively. In case of China, total amount of investment is almost same in every case. It shows that we have to abate COD emission from China as much as we can, because amount of water pollutant emission from China is very large as shown in Table 8.

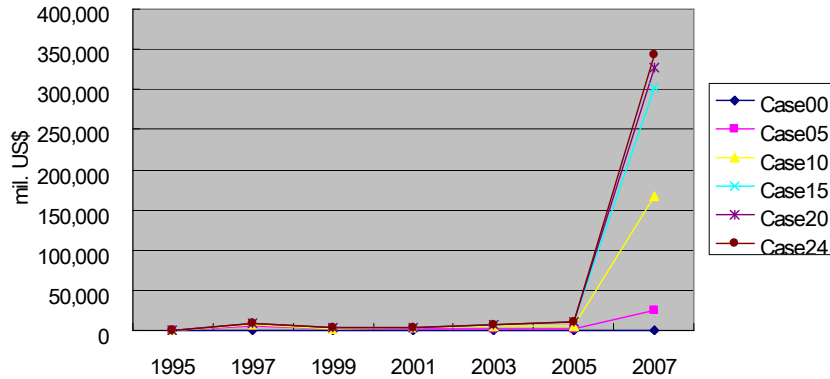


Figure 5 Change of international investment to South Korea

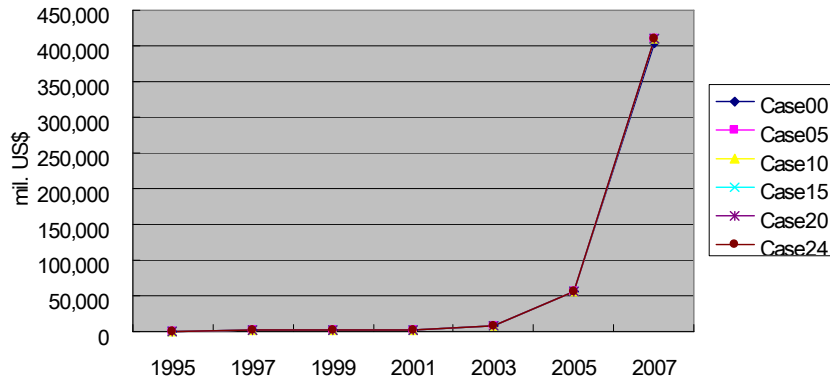


Figure 6 Change of international investment to China

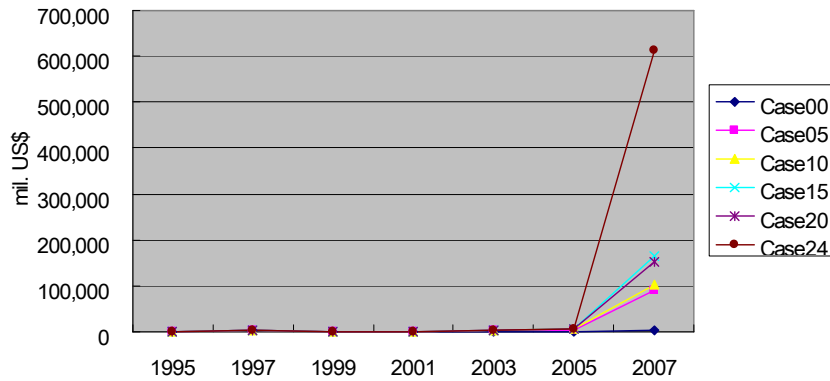


Figure 7 Change of international investment to Russia

7. Conclusion

In this study, we can obtain the feasible solution, which is 7.5% maximum reduction rate of COD inflow in the last term with 0% GDP growth rate in coastal area of the Sea of Japan in Case00. However, Case05 is the best solution from viewpoint of average amount of COD emission and economic development of target area (See Figure 8). It is clear that minimizing environmental impact with sacrifice of economic growth is not always the best solution by simulation result. It is also important for abatement of water pollutant to invest for environmental policy and to promote technologies by industrial and economic development. Furthermore, countries and regions around the Sea of Japan area have to cooperate to manage an international ocean in various fields such as water environment, industrial technology and so on, from integrated ocean management perspective.

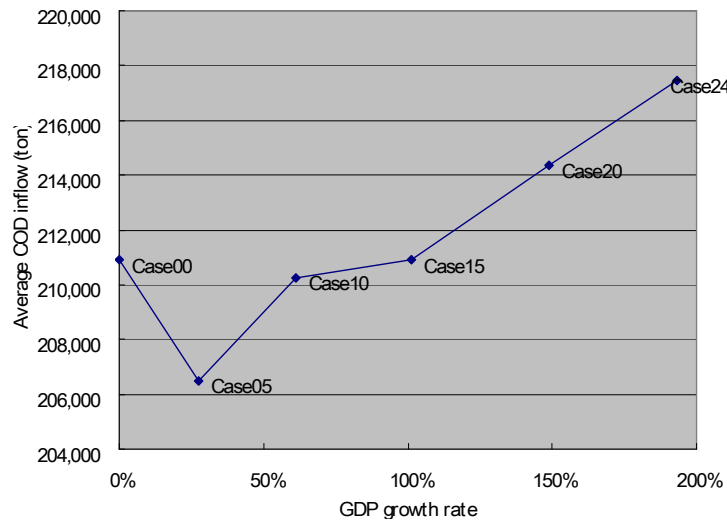


Figure 8 GDP growth rate and average COD inflow

8. Further development

We have to analyze other pollutant indices for water and air environment. And then, it is necessary to collect more precise and new scientific data of our target area. It has to be set more long-run period in the simulation as much as possible.

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