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## Water Balance and Energy Consumption in Man-made Island

Y. Nishimura, student member, Osaka University  
K. Muraoka, member, Osaka University

## 1. Introduction

There are many large reclaimed lands constructed and under constructing in Tokyo Bay and Osaka Bay. These areas have unique water balance and energy consumption because many kinds of urban infrastructure are arranged systematically there. In this study the water balance at present and in the future, and the energy consumption in the man-made islands in Kobe City are estimated to investigate the characteristics of reclaimed lands. In addition, the possibility of sewage heat reuse in this area is discussed in order to realize the desirable energy use in a new island city.

## 2. Outline of the Man-made Islands

Figure 1 shows the location of two man-made islands in Kobe City. Port Island has an area of 4.36 km<sup>2</sup> and a population of about 17,000, while Rokko Island has 5.8 km<sup>2</sup> and 5,000. The construction of the urban infrastructure in Rokko Island is progressing still now. These islands are built to deal with a lot of things in trade, so about 60 % of the land is occupied by harbor facilities. However, green area among the residual land is arranged in harmony with residential area. The separate sewer system is adopted and there is a sewage treatment plant in Port Island. In this area, ecosystem that is desired for future cities is also taken into account to a certain extent such as generating the electricity from the incinerator at the disposal plant and recycling the treated sewage water. In order to magnify Port Island to the open sea, 3.9 km<sup>2</sup> of new reclamation is in progress at present.

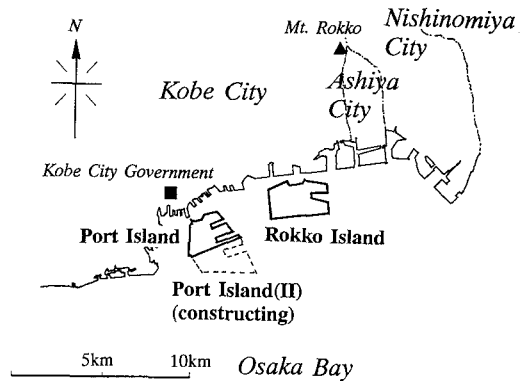


Fig. 1. Location of man-made islands

## 3. Water Balance

The hydrological elements of the islands are grouped into two systems.<sup>1)</sup> The first is the outer system that includes natural elements. The second is the inner system that represents artificial ones. Figure 2 shows the water balance in the islands at present and Fig. 3 shows the one in the future. These figures result;

- 1) The quantity of infiltration is only as much as about 20 % of the runoff component that is the sum of surface runoff and infiltration because the impervious area spreads around the harbor district and occupies 80 % of the whole area. The result shows that the water balance in the islands is quite different from that in natural land.
- 2) The total quantity of the supplied service water in the future will amount to about 2.5 times of that at present. Therefore it seems that recycling the treated sewage water is getting more necessary.

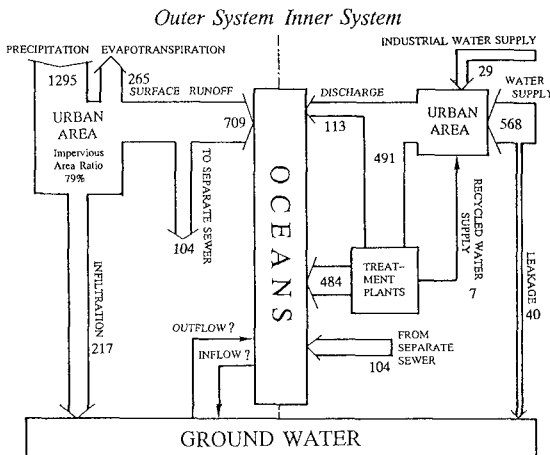


Fig. 2. Annual water balance in man-made islands in 1990 (unit: mm/year)

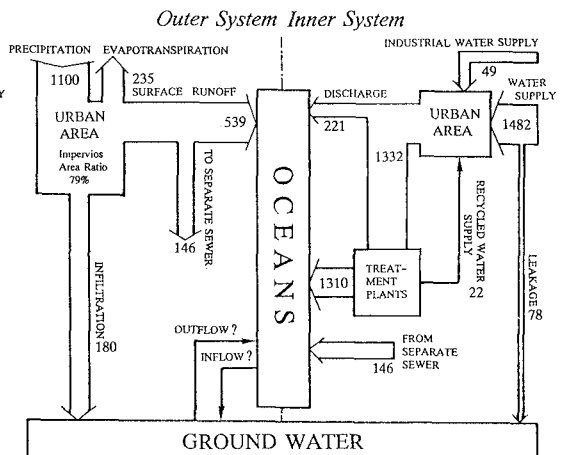
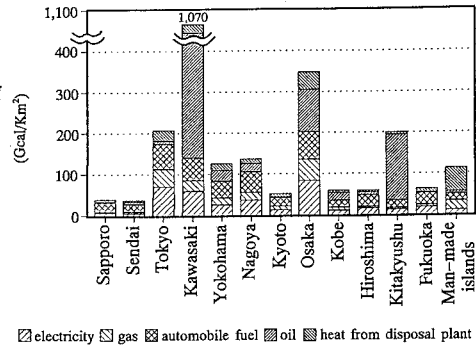


Fig. 3. Annual water balance in man-made islands approximately in 2000 (unit: mm/year)

#### 4. Energy Consumption

The energy use of cities depends mainly on the consumption of electricity, gas, automobile fuel, oil and heat from disposal plants. Figure 4 shows the consumption in the man-made islands and twelve large cities in Japan. There are some notices as follows;

- 1) Compared with the twelve cities, the islands have a large amount of energy consumption of 100 Gcal/km<sup>2</sup> annually.
- 2) In the islands the heat from the disposal plant amounts to as much as half of the total energy consumption.
- 3) The sum of the consumption of electricity, gas and automobile fuel, which are defined as secondary energy consumption, reaches 20 Gcal/person and is also equivalent to the value of twelve cities.



□ electricity □ gas ▨ automobile fuel ▩ oil ■ heat from disposal plant

Fig. 4. Annual energy consumption in man-made islands and twelve cities in Japan in 1990

#### 5. Possibility of Sewage Heat Reuse

The recoverable sewage heat in Port Island is estimated. The reason is that the arrangement of the urban infrastructure has already finished and a sewage treatment plant has been established, too. The heat balance in the separate sewer system is formulated as follows<sup>2)</sup>;

$$Q_{sw} \times T_{sw} + E_q/C_w = Q_t \times T_t \quad (1)$$

where,  $Q_{sw}, T_{sw}$ : quantity of supplied service water and its temperature,  $E_q, C_w$ : exhausted heat into the sewage water and its heat capacity, and  $Q_t, T_t$ : quantity of treated sewage water and its temperature.

It is desirable to recover the heat from the sewage of which temperature has difference of more than 5°C from atmospheric one in terms of economical and efficient use of heat pump. The recoverable sewage heat is calculated by the following equation<sup>2)</sup>;

$$H = \{T_t - (At \pm 5^\circ\text{C})\} \times Q_t \times C_w \quad (2)$$

where,  $At$ : atmospheric temperature.

Figure 5 shows the exhausted heat into the sewage water and the recoverable one. Table 1 represents the energies of Port Island and other cities in Japan. These results are described as follows;

- 1) It is expected to recover 70 % of the exhausted heat in winter.
- 2) The exhausted heat into the sewage water per person in a day in Port Island is about 1.5 times of those in the other cities, and the recoverable heat amounts to as much as about 2.3 times.

These results shows that it is possible to adopt effective heat reuse systems in reclaimed lands. It is also available to link the heat from neighboring cities because reclaimed lands area mainly located near cities.

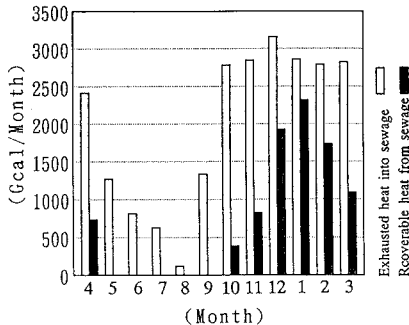


Fig. 5. Exhausted heat and recoverable heat in sewage water in Port Island in 1990

Table 1. Energies in Port Island and Other Cities in Japan

	23 District of Tokyo <sup>3)</sup>	Osaka City <sup>3)</sup>	Fukuoka City <sup>2)</sup>	Port Island
Population for sewer system ①(pers.)	7,387,200	2,557,210	850,900	22,386
Total energy consumption (Tcal)	124,800	74,800	20,400	922
Exhausted heat into sewage ②(Tcal)	7,700	2,400	788	24
Recoverable heat from sewage ③(Tcal)	—	580	200	9
②/①(Kcal/day/pers.)	2,856	2,571	2,537	3,785
③/①(Kcal/day/pers.)	—	621	644	1,428
③/②(%)	—	24.2	25.4	37.7

#### 6. Conclusions

The study shows that the water balance in the man-made islands are quite different from that of natural land because of their land use. The water recycle system will be more necessary according to the increase of quantity of the supplied service water. In addition, the results of the energy consumption leads that there is a large amount of energy consumption from the disposal plant and recoverable sewage heat in the islands. It will be important to consider water and heat reuse systems to discuss environment and development in urban coastal areas in the future.

#### References

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- 3)T. Seoka and K. Muraoka: Proc. of Annual JSCE Kansai Chapter Meeting No. II-6, 1992.