沙漠研究 **19**-1, 291- 294　(2009)
Journal of Arid Land Studies

"Desert Technology IX "
Refereed Paper

A Proposal of a New Supply System of Fresh Water for Afforestation of the Desert in the Middle East

N. SAHO[1], S. YOSHIZAKI[2], A. MOCHIZUKI[3]

Abstract: Many countries that import energy resources, such as crude oil and liquefied natural gas, from the Middle East have a lot of domestic wastewater, most of which is discharged into rivers and the ocean after being purified by a high-class treatment. Meanwhile many Middle Eastern oil-producing countries that export energy resources have vast deserts and a large demand for the fresh water needed for irrigation. Meanwhile, large crude oil carriers and LNG tankers that are used to transport energy resources need to load and discharge a large amount of ballast water to safely voyage across the ocean. However, that ballast water pollutes oceans on a global scale by diffusing foreign aquatic microbes. This paper suggest a new system in which large tankers load highly purified recycled water as ballast water, voyage to Middle East, and discharge it for use in irrigating the desert there. Thus the system will provide a solution to some of the environmental issues that these oceanic ships cause and contribute to preserving the global environment.

Keywords: Afforestation, Ballast water, Fresh water

1. Introduction

In the oil producing country of the United Arab Emirates (UAE), desert is being afforested in order to improve the living environment and protect farmland from sand and wind (Allison, 1964; Yoshizaki, 1992). The afforested area has been expanding since 1970 and reached 200,000 hectares in total in 1991 (Al-Asam, 1992). Due to most of the irrigation for afforestation relies on groundwater, the groundwater level has lowered and salinization is in progress because of excess pumping to catch up with the expansion of the plantation. In order to maintain afforest, a new water source must be secured in the near future.

Meanwhile, a wary eye has turned to the ballast water drained from ocean ships that causes serious oceanic pollution because of worldwide diffusion of foreign organisms (Fukuyo, 2000). In February 2004, the International Maritime Organization (IMO) adopted the international treaty on ballast water (International Conference on Ballast Water Management for Ships, 2004). Once this treaty goes into effect in 2009, the amount of residual microorganisms in the ballast water from ships will be strictly regulated.

Many countries importing crude oil from the Middle East have the water resource which is not exploited effectively. Most of the produced water by a high-class treatment (hereafter "recycled water") from domestic wastewater is discharged into rivers, lakes, or the ocean. This recycled water contains a large amount of nitrogen and phosphorus which becomes a cause of eutrophication and it is one of the reasons which are not reused.

This paper proposes a water cycle system that contributes to preserving the global environment by

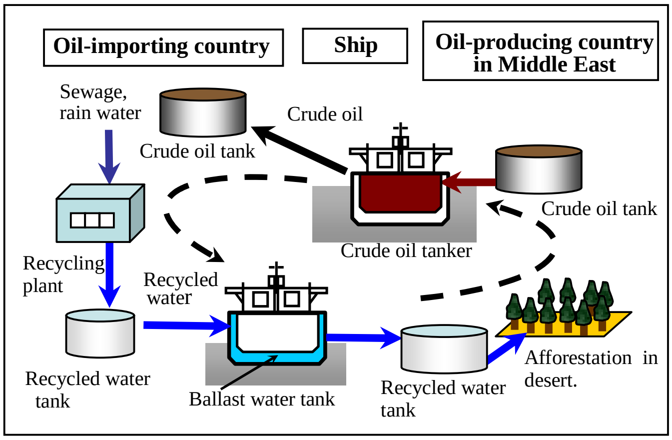

Fig. 1. Flow of new circulation system with recycled water.

[1] Mechanical Engineering Research Laboratory, Hitachi, Ltd. Ibaraki, Japan
[2] Faculty of Environmental and Information Studies, Musashi Institute of Technology, Japan
[3] Research and Development Group, Hitachi Plant Technologies, Ltd. Tokyo, Japan

Table 1. Comparison of quality of recycled water and river/lake water in Japan.

Type of water	SS (mg/L)	BOD (O_2mg/L)	COD (O_2mg/L)	T-N (mg/L)	T-P (mg/L)	Coli. (MPN/mL)
Recycled	2	3.6	7.3	6.9	0.5	2
River	10.0	1.4	3.1	2.6	0.10	31
Lake	25	4.0	8.2	1.9	0.15	74

SS: suspended solid, cfu: colony forming unit, BOD: biological oxygen demand, T-N: total nitrogen, COD: chemical oxygen demand, T-P: total phosphorus, Coli.: Coliform

providing a solution to the problems of two different regions linked by maritime trade. In this system, as seen in **Figure 1**, a tanker has separate tanks for ballast water and oil. In an oil importing country, the oil is unloaded, and then recycled water is loaded from storage tanks near the port of call.

The tanker returns to an oil producing country in the Middle East and unloads the recycled water before loading crude oil. The unloaded recycled water is stored in tanks near the port for use in irrigation. The tanker is filled with crude oil and voyages to an oil importing country.

This water cycle system offers many benefits: (1) Pollution of the ocean's biological environment is prevented by removing ballast seawater that contains various microorganisms inhabiting the seas of oil importing countries. (2) Ballast seawater will not need to be purified before dumping, which as a result reduces the cost of such water purification operations. (3)Using fresh water for ballast decreases corrosion on ballast tank walls and lessens the inclusion of sludge that may be pumped up together with seawater in a shallow sea. Additionally, this reduces maintenance costs of the tanks (such as periodical painting and cleaning deposits on the ship's bottom).

Table 1 lists the qualities of recycled water, river water, and lake water in Japan. The quality of recycled water (Northern Purification Center, 2004) was measured at the recycling plant near the port of call, and the listed values are yearly averages for 2003. The water quality value of the river is Tonegawa's annual average water quality (River Bureau, 2005). The water quality value of the lakes is Kasumigaura's annual average water quality (River Bureau, 2005). The quality of river and lake water running through urbanized areas is comparatively eutrophicated. The items that differ considerably in quality between recycled water and river/lake water are the values of total nitrogen (T-N), total phosphorus (T-P), and coliform bacillus. The T-N and T-P values are high in recycled water— specifically the concentration of T-P is three to five times higher than that of river/lake water. It is known that nitrogen and phosphorus are essential to grow plants, so their comparatively high concentration in the recycled water will not negatively affect the afforestation. Since recycled water is sterilized during treatment, it contains far less coliform bacillus compared with river/lake water. The values of BOD and COD of recycled water are nearly the same as river/lake water.

2. Methods

2.1. Standard form of afforestation in desert region.

The standard form of afforestation in the desert region in UAE (Yokota *et al.*, 1997) is shown in **Figure 2**. To protect the afforested area from feeding damage by camels, sheep, etc., it is surrounded by a fence of two meters or higher, inside of which trees are densely planted to form a belt for protection. Inside the belt, the main afforestation trees are planted at intervals of seven meters with an average density of 200 trees per hectare. As for standard irrigation, in the first year, 31.82×10^{-3} m^3 (seven gallons) of water are given to each tree a day, in the second year, 22.73×10^{-3} m^3 (10 gallons) of water are given to each tree every other day, and in the third and later years, 30.31×10^{-3} m^3 (20 gallons) of water are given every three days. The amount of irrigation water each time is averaged, but the frequency is adjusted by taking into consideration the water leaching below salty soil layers underground. For irrigation, water is dripped.

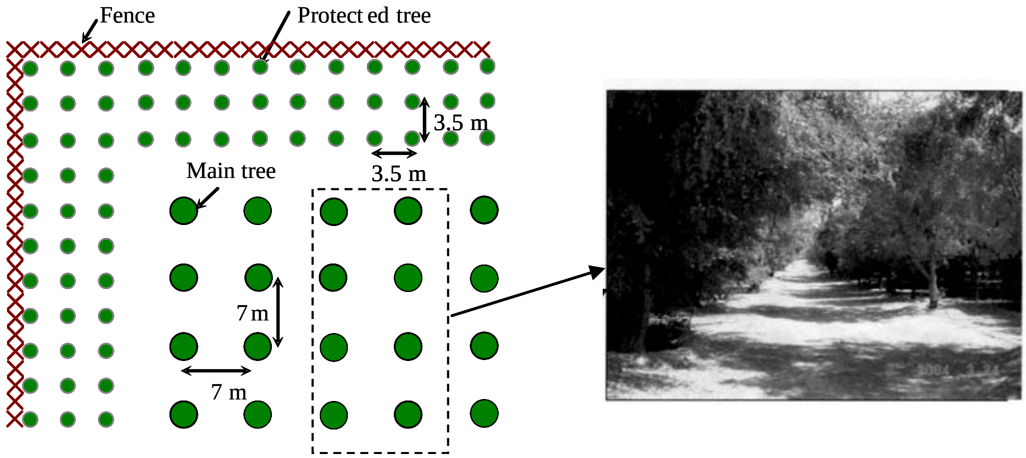

Fig. 2. Standard form of afforestation in desert regions in UAE and photograph of afforested area. Recycled water from urban households used for some of the water for irrigating these woods.

In the UAE, 85% of groundwater is used for agriculture and afforestation, and the remaining 15% is used for drinking water (Al-Afifi, 1993). Since the water necessary for irrigation is taken from underground, lowering water levels and salinizing the underground water are becoming serious issues. One way to secure water for afforestation is to use the recycle water. Mixing the treated water and the underground water is being attempted in order to dilute the salinized water for use in afforestation in UAE.

2.2. The amount of ballast water to the Middle East.

The amount of oil exported from the UAE and the all of the Middle East (Japan Petroleum Development Association and Japan National Oil Corporation, 2003), the estimated amount of recycled water which can be carried for irrigation by oceanic ships, and estimated plantable area which can be maintained by the imported recycled water are shown in **Table 2**. The potential amount of recycled water that can be carried from Japan to the UAE and the all of the Middle East is about 16,270,000 m^3 and 60,580,000 m^3 per year, respectively. Including all areas of the world, the figure becomes 309,380,000 m^3 per year.

Table 2. Amount of oil exported from Middle Eastern countries. Estimated amount of transportable recycled water and estimated tree plant area. Crude oil export volume data from 2002. Amount of recycled water assumed to be 35% of crude oil export weight and 0.8 of crude oil density.

Item	Exported crude oil (10^6m^3/year)	Recycled water (10^6m^3/year)	Estimated afforestation area (ha)
Japan and UAE	58.1	16.27	7,352
Japan and Middle East	216.37	60.58	27,381
World and Middle East	1140.63	309.38	144,342

3. Results and Discussion

3.1. Estimated afforestation area in a desert.

Estimated irrigating areas shown in Table 2, which can be maintained by the imported recycled water of 16,270,000 m^3, 60,580,000 m^3 and 309,380,000 m^3 per year, are a vast 7,352, 27,381 and 144,342 hectares, respectively. If salinized underground water is used for afforestation after being mixed with recycled water, the maintainable area will be further expanded. As a base of comparison, the annual amount of discharge recycled water from Northern Purification Center was 25,550,000 m^3. At the same time, the use of recycled water partly solves the problems of the lowering underground water levels and salt-coagulated soil.

From the viewpoint of global warming, afforesting deserts is currently attracting attention because it contributes to reducing the green house effect gas by sequestrating carbon dioxide from the atmosphere. In Middle Eastern countries, when oil is exported by tankers, recycled water can be imported on their return trips. In this water cycle system, water for irrigation is thus steadily secured for the long term.

3.2 Environmental preservation effect.

At the same time, oil importing countries benefit from exporting recycled water as ballast water because nitrogen and phosphorus that cause eutrophication at home can be transported and used abroad. Assuming the concentrations of nitrogen and phosphorus in recycled water are 6.9 mg/L and 0.5mg/L (the values in Table 1) respectively, the annual amount of nitrogen exported from Japan to UAE and the all of the Middle East will be 112 and 418 tons, and that of phosphorus will be 8 and 30 tons, respectively. The annual amount of nitrogen and phosphorus transported from the rest of the world to these countries will be 2,204 and 160 tons respectively, and all of these compounds will be consumed as nutrients for afforestation. From these data, it is clear that supplying such nitrogen and phosphorus to afforested areas prevents eutrophication in the water environments in oil importing countries as well as been helpful in maintaining the soundness of the recycled water-released environment.

4. Conclusions

The water cycle system (Saho *et al.*, 2005) in this report can prevent the contamination of the ocean’s biological environment, which is caused by ballast water discharged from tankers offshore oil producing countries. Recycled water used for the ballast water in tankers on return trips has the potential to irrigate 146,320 hectares of desert for afforestation in the Middle East. Oil importing countries will benefit by finding an environmentally safe use for the recycled water produced at their wastewater treatment facilities. This system can be applied not only to oil tankers but also LNG tankers, ore or coal carriers, and bulkers.

References

Al-Afifi M.A.R. (1993): UAE’s agriculture offers business and food security, *Agriculture and Equipment International*, **44**: 122-123.

Allison L.E. (1964): Salinity in relation to irrigation. *Advance in Agronomy*, **16**: 139-180.

Yoshizaki S. (1992): Desert Revegetation in the United Arab Emirates. *Japan Greenery Research and Development Center*, **19**: 15-20.

Al-Asam M.S. (1992): Country report for the United Arab Emirates, Symposium on the Greening of the G.C.C. Countries, Proccedings: 135-166,

Fukuyo Y. (2000): Increases of Frequency and Geographical Distribution of Harmful Plankton and Possible Responsible Mechanisms for the Increase. *NAVIGATION*, **145:** 13-18,

International Conference on Ballast Water Management for Ships (2004): *International Convention for the Control and Management of Ships’ Ballast Water and Sediments.* IMO, BWM/CONF/**36**: 22

Japan Petroleum Development Association and Japan National Oil Corporation (2003): *Oil Resource Development Data 2003*, 8-92.

Northern purification center (2004): *Outline of the Northern Purification Center -Wastewater Treatment Plant- 2003*. Mie Prefecture Sewage Works Public Corporation.

River Bureau (2005): *Water quality of TONEGAWA in 2003, Japanese River Water Quality Yearbook 2003*. Ministry of Land, Infrastructure and Transport:288.

River Bureau (2005): *Water quality of KASUMIDAURA in 2003: Japanese River Water Quality Yearbook 2003*. Ministry of Land Infrastructure and Transport: 574.

Saho N., Isogami H., Mizumori T., Mochizuki A., Imamura Y. (2005): *Freshwater Supply System*, IRAN Patent, Registration Number P31139.

Yokota H., Abe M., Shoji T., Kiriiwa Y., Ozawa K., Yoshizaki S., Oishi A. (1997): Effect of irrigation water salinity on the growth of trees for revegetation in the United Arab Emirates. *Proceeding of International Plant Nutrition Colloquium*, 415-416.