WATER AND WASTEWATER REUSE

An Environmentally Sound Approach for Sustainable Urban Water Management

UNEP

GEC

In collaboration with:

Ministry of Land, Infrastructure and Transport of Japan (MLIT)
Public Works Research Institute of Japan (PWRI)
Osaka Municipal Government
Infrastructure Development Institute of Japan (IDI)

UNITED NATIONS ENVIRONMENT PROGRAMME

DIVISION OF TECHNOLOGY, INDUSTRY AND ECONOMICS - INTERNATIONAL ENVIRONMENTAL TECHNOLOGY CENTRE

Osaka Office
2-110 Ryokuchi koen, Tsurumi-ku,
Osaka 538-0036 Japan
Tel: +81-6-6915-4581
Fax: +81-6-6915-0304

Shiga Office
1091 Oroshimo-cho, Kusatsu City,
Shiga 525-0001 Japan
Tel: +81-77-568-4581
Fax: +81-77-568-4587

Email:ietc@unep.or.jp
URL: http://www.unep.or.jp/

Environmentally Sound Technologies (ESTs) encompass technologies that have the potential for significantly improved environmental performance relative to other technologies. Broadly speaking, these technologies protect the environment, are less polluting, use resources in a sustainable manner, recycle more of their wastes and products, and handle all residual wastes in a more environmentally acceptable way than the technologies for which they are substitutes. The adoption and use of ESTs carefully considers both human resource development and local capacity building.

Information on ESTs is not always available in a form that can be easily understood by decision-makers and those without technical expertise. To encourage greater understanding about ESTs and their benefits, this booklet has been prepared using a minimum of technical jargon. We hope that you find the information in this booklet both interesting and useful.

ACKNOWLEDGEMENT

The development of this publication was guided by an expert panel convened by GEC, in coordination with UNEP/DTIE/IETC. We sincerely acknowledge the contributions of the following members of the Advisory Committee as well as reviewers.

ADVISORY COMMITTEE:

Dr. Takashi Asano
Professor Emeritus, Department of Civil & Environmental Engineering,
University of California at Davis

Dr. Hiroaki Tanaka
Leader of Water Quality Team, Water Environment Research Group,
Public Works Research Institute*

Mr. Yutaka Suzuki
Leader of Recycling Research Team, Material and Geotechnical Engineering Research Group,
Public Works Research Institute

Mr. Makoto Matsubara
Deputy Director, Sewerage Planning Division, Sewerage and Wastewater Management Department
City and Regional Development Bureau,
Ministry of Land, Infrastructure and Transportation

Mr. Mitsuhide Kusumoto
Manager, Machinery Department, Sewerage Division, Environment and Sewerage Bureau,
Osaka Municipal Government

Mr. Hayato Sasai
Deputy Director, 2nd Research Department,
Infrastructure Development Institute*

Reviewers:
Prof. Dr. Takashi Asano
Professor Emeritus, Department of Civil & Environmental Engineering
University of California at Davis

Dr. Blanca Elena Jiménez Cisneros
Chair of the International Water Association's Water Reuse Specialist Group
Instituto Ingeniera, UNAM, Mexico City

Authors:
Dr. Chizuru Aoki and Dr. Mushtaq Ahmed Memon
Programme Officer, UNEP-IETC

Mr. Hiroyuki Mabuchi
Deputy Manager, Project Division, GEC*
(* The titles above are those at the time of writing.)

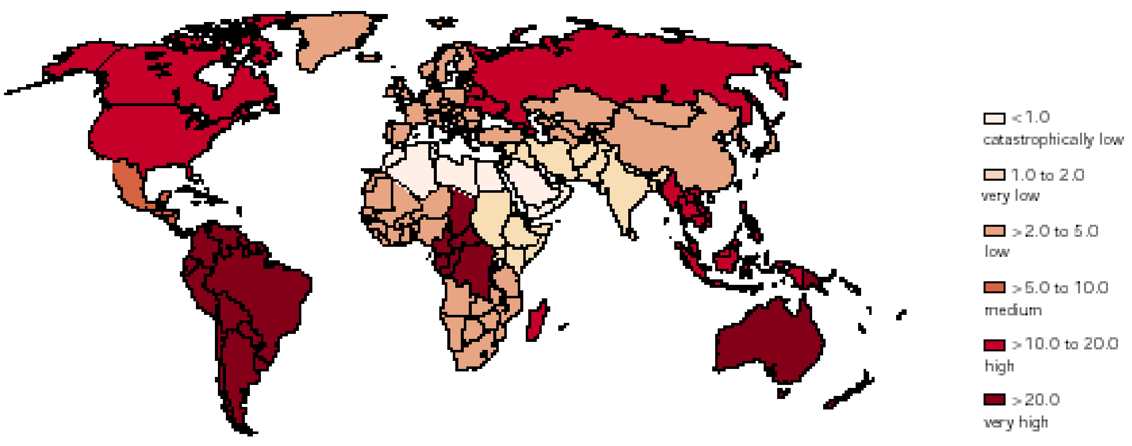
TABLE OF CONTENTS

1. Introduction

Water-related problems are increasingly recognized as one of the most immediate and serious environmental threats to humankind. Water use has more than tripled globally since 1950, and one out of every six persons does not have regular access to safe drinking water. Lack of access to a safe water supply and sanitation affects the health of 1.2 billion people annually (WHO and UNICEF, 2000). The latest Global Environment Outlook of the United Nations Environmental Programme (UNEP) reports that about one third of the world's populations currently live in countries suffering from moderate-to-high water stress, where water consumption is more than 10% of renewable freshwater resources. As Figure 1 shows, many countries in Africa and Asia have very low or catastrophically low water availability (UNEP, 2002a).

These problems may be attributed to many factors. Inadequate water management is accelerating the depletion of surface water and groundwater resources. Water quality has been degraded by domestic and industrial pollution sources as well as non-point sources. In some places, water is withdrawn from the water resources, which become polluted owing to a lack of sanitation infrastructure and services. Over-pumping of groundwater has also compounded water quality degradation caused by salts, pesticides, naturally occurring arsenic, and other pollutants. In urban areas, demand for water has been increasing steadily, owing to population growth, industrial development, and expansion of irrigated peri-urban agriculture. Population growth in urban areas is of particular concern for developing countries. Population growth is expected to occur in developing nations, as developed regions are projected to see their population decrease by 6% over the next 50 years. Meanwhile, the rural population is expected to stabilize at around 3.2 billion (from 2.97 billion today), indicating that the growing population will settle in urban areas (WHO and UNICEF, 2000). Many parts of the world are facing changes in climatic conditions, such as rainfall patterns, flood cycles, and droughts, which affect the water cycle.

Figure 1: Water availability in 2000 (Measured in terms of 1000m^3 per capita/year)



(UNEP, 2002a)

Faced with these challenges, there is an urgent need to improve the efficiency of water consumption, and to augment the existing sources of water with more sustainable alternatives. Numerous approaches, modern and traditional, exist throughout the world for efficiency improvements and augmentation. Among such approaches, wastewater reuse has become increasingly important in water resource management for both environmental and economic reasons. Wastewater reuse has a long history of applications, primarily in agriculture, and additional areas of applications, including industrial, household, and urban, are becoming more prevalent. Of them all, wastewater reuse for agriculture still represents the large reuse volume, and this is expected to increase further, particularly in developing countries (UNEP, 2002a). With such an increase in applications, there is a concurrent recognition that water resource management and proper water cycle maintenance requires up-to-date knowledge about basic practices, benefits and potential risks, capacity building of practitioners and planners, and appropriate policy frameworks to protect human health and the environment.

In cities and regions of developed countries, where wastewater collection and treatment have been the common practice, wastewater reuse is practised with proper attention to sanitation, public health and environmental protection. The situation is different in many developing countries owing to the lack of appropriate capacity and resources to enforce strict wastewater treatment standards for its reuse. Wastewater reuse for irrigation is quite common in many places; therefore, the poor quality of wastewater may pose substantial health risks for the farmers as well as consumers of those agricultural products. The World Health Organization (WHO) has been working to draw up and update the guidelines for wastewater reuse in agriculture.

With this background, this booklet was prepared to introduce the basic concepts of water and wastewater reuse, and applications of Environmentally Sound Technologies (ESTs) for enabling reuse. In particular, the booklet addresses the following questions, illustrated with case studies from both developed and developing countries:

- What are the benefits of implementing water and wastewater reuse initiatives?
- Which cases and approaches of wastewater reuse result in efficient and successful management of resources?

Furthermore, the booklet aims to illustrate that sustainable water management is relevant for regions with abundant water resources as well as for those with limited water resources.

2. Wastewater Reuse as Environmentally Sound Technologies ESTs

Wastewater reuse, when appropriately applied, is considered as an example of EST applications. ESTs are defined in Chapter 34 of Agenda 21 as technologies that:

- Protect the environment;
- Are less polluting;
- Use all resources in a more sustainable manner;
- Recycle more of their wastes and products; and
- Handle residual wastes in a more acceptable manner than the technologies for which they are substitutes.

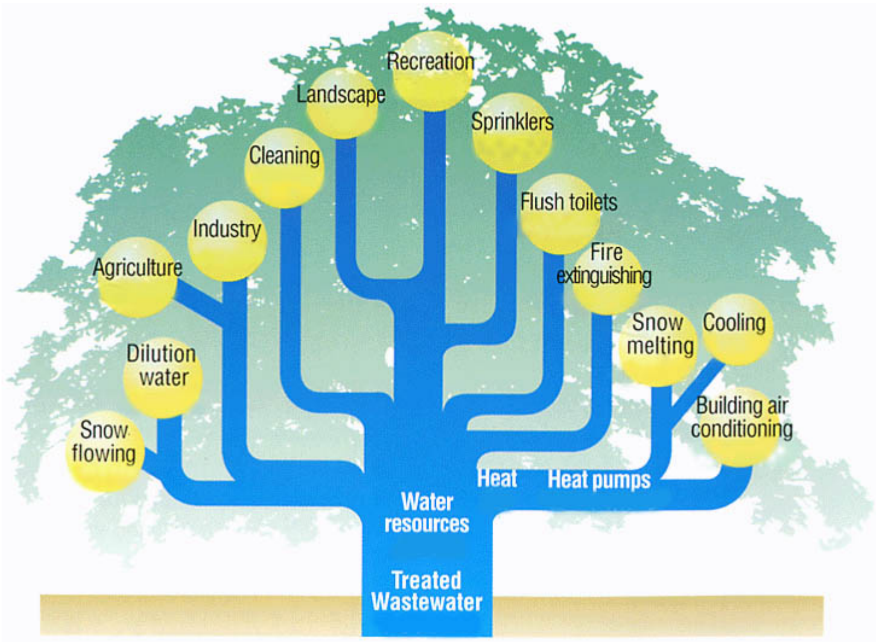
The use of ESTs plays a key role in facilitating freshwater protection and integrated water resource development and management, as recognized in Chapter 18 of Agenda 21. Wastewater reuse applications cover a wide range, including industrial, residential, recreational, and environmental enhancement purposes, as shown in Figure 2.

Water and wastewater reuse has various benefits. First, recycled wastewater can serve as a more dependable water source, containing useful substances for some applications. For example, the quantity and quality of available wastewater may be more consistent compared to freshwater, as droughts and other climatic conditions tend to have a less pronounced effect on wastewater generation. With adequate treatment, wastewater can meet specific needs and purposes, such as toilet flushing, cooling water, and other applications. The reuse of treated wastewater is particularly attractive in arid climates, areas facing demand growth and those under water stress conditions. Some wastewater streams also contain useful materials, such as organic carbon and nutrients like nitrogen and phosphorous. The use of nutrient-rich water for agriculture and landscaping may lead to a reduction or elimination of fertilizer applications.

The second benefit of wastewater reuse is that it leads to reduced water consumption and treatment needs, with associated cost savings. In many applications, reusing wastewater is less costly than using freshwater, with savings stemming from more efficient water consumption and a reduced volume of additional wastewater treatment, as well as associated compliance cost savings. The infrastructure requirements for advanced water and wastewater treatment may also be reduced. For instance, many areas with adequate water resources and a growing urban population have experienced increased water consumption, both on a per capita and total basis. Meeting such a growing demand often requires the additional development of large-scale water resources and associated infrastructure. By meeting some of the water demand through wastewater reuse and efficiency improvement, additional infrastructure requirements and the resulting financial and environmental impacts can be reduced or, in some cases, eliminated altogether.

Finally, by reusing treated wastewater for these applications, more freshwater can be allocated for uses that require higher quality, such as for drinking, thereby contributing to more sustainable resource utilization. Wastewater reuse can thus be considered as an appropriate application of ESTs as shown in Figure 2.

Figure 2: Tree of water resources recycling



(MLIT, 2001)

Wastewater can be recycled within the same industrial process or for another application such as in agricultural irrigation, with or without treatment to meet specific quality requirements. It can also be used for cascading use, which refers to a practice of using water in sequence for different applications. If the quality is not suitable for direct cascading use, wastewater can be reclaimed with adequate treatment, or used after dilution with clean water or other higher quality wastewater.

Raw wastewater reuse is an important practice in several countries, especially for agriculture, with about 20% of the world population's food being produced through this practice. However, this practice also has its risks and benefits, which should be critically analysed before taking the decision to either use the raw wastewater directly or use the wastewater after treatment. This aspect should be analysed with reference to local conditions and requirements as wastewater quality and water use is different in individual countries and regions. In some, industrial or municipal uses are the predominant ones, while in others agriculture is the predominant use. WW reuse will normally follow the main use of a local region, i.e. where industry is important, WWR will also be important for industry.

Therefore, in order to optimize water use and cost reduction potential, it is beneficial to analyse both the quality and the quantity of source wastewater against potential reuse applications and water quality requirements. Appropriate technology and its availability should also be taken into consideration. Moreover, it is important not only for new wastewater reuse techniques but also to control/improve existing practices.

Life cycle cost (LCC) analysis is useful in evaluating conditions under which water reuse ESTs can be cost effective and in comparing cost performances of different technologies. The LCC approach covers the cost of a product over its entire lifespan, from the cradle to grave, including design, production, installation, operations, maintenance, repair, and disposal (UNEP, 1996). Box 1 shows an example of an LCC analysis of wastewater reuse options in office buildings in Tokyo, Japan. The results show that if the reclaimed water volume is more than $100m^3$ per day, wastewater reuse options are more cost effective compared to the conventional freshwater and sewage treatment option. There are examples (for example from Latin America) that shows that agricultural water reuse projects with properly treated wastewater have a benefit-cost ratio from 1.2–2.2, depending on the types of crop and types of treatment involved (Yamagata *et al*., 2003).

Box 1: Lifecycle Cost of Wastewater Reuse
An LCC analysis was conducted to compare options for wastewater reuse with a conventional freshwater and sewage treatment option in office buildings in Tokyo, Japan. The cost for a conventional non-reuse option was calculated based on an infrastructure cost with a repayment schedule of 15 years and an annual interest rate of 6%, as well as on its operating and maintenance costs. Figure 3 shows that if the volume of reclaimed water exceeds $100m^3$/day, reuse options cost less than a conventional non-reuse option (Yamagata *et al*., 2003).

Figure 3: Life cycle cost comparison of wastewater reuse options