Domestic Water Reuse Situation in the Context of Middle-income Countries: A Case Analysis

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Abstract

This paper presents the results of an analysis of domestic water reuse (WR) in middle-income countries, using Thailand as a case study. The analysis covers drivers and constraints of WR development, as well as current practices and opportunities for WR, based on both primary data through field survey and secondary data from the literature. The significant similarities and differences between middle- and high-income countries are then discussed, while the case demonstrates specific characteristics of the WR situation. More case studies of middle-income countries can contribute to further understanding and improved WR applications for sustainable water management to meet the challenges of a rapidly growing demand and a decreasing supply.

Keywords

Domestic Water Reuse; Environmental Awareness; Middle-income Countries; Sustainable Water Management

Introduction

Planned water reuse (WR) is considered an appropriate water management strategy and also a sustainable alternative for water management, as confirmed by Daigger [2009], Kazmi and Furumai [2005], and UNEP and GEC [2005]. It is also a growing practice in many regions of the world, as shown by the examples of WR implementation in TABLE 1. The TABLE also shows that WR practices in middle-income countries are still very limited compared to those in high-income countries. Furthermore, as shown in TABLE 2, in some middle- and high-income countries, not only the water supply and demand but also economic and social factors have influenced WR applications. The high-income countries reuse treated wastewater mainly due to social awareness. The middle-income countries have also innovated in WR, although their water conditions were the same or more critical than those of the high-income countries. In addition, the scientific literature on WR in middle-income countries is quite limited.

In Thailand, as a middle-income country, major budget allocations have been mainly for economic development, including the supply of water for several economic activities including agriculture, industry, tourism, etc. It is expected to be a water-stressed country by 2025. In 2005, the country also experienced a serious water shortage. Accordingly, Thailand has tended to rapidly progress its WR development due to the water crisis. In addition, the WR from domestic wastewater seems to be necessary not only for economic reasons but also for environmental and social issues. These are different from the WR of the industrial sector, which was implemented mainly based on clear economic benefits.

Based on limited available information and possible unique characteristics of WR practices in middle-income countries, this paper therefore aims to analyze domestic water reuse situation in that context, based on the case of Thailand. The scope of WR in this paper is planned reuse of treated domestic wastewater for non-potable applications, e.g., landscape irrigation, toilet flushing, and environmental recreation. Subsequently, findings in the case study are discussed, in terms of the current state of WR, and drivers and constraints to WR development. Furthermore, the discussion of WR in Thailand compares its practices with those of other countries. These are intended to show opportunities and recommendations on improved viability and sustainability.
Asano and Levine [1998] stated that advances in the effectiveness and reliability of wastewater treatment technologies have improved the capacity to produce reclaimed wastewater that can serve as a supplemental water source in addition to meeting water quality protection and pollution abatement requirements. Therefore, WR is easier to implement and more readily accepted by the public in high-income countries with a high technical capacity than that in middle-income countries. Although the concept of WR sounds plausible in middle-income countries, implementation seems to be limited because of many barriers, for example, unclear costs and benefits of implementation and lack of government support. As a case study of middle-income countries, Thailand is a rapidly developing country, and some areas face water crises in dry seasons. Wastewater in urban areas seems to have a high potential for WR for non-potable uses, such as agricultural irrigation and landscape irrigation. Economic, environment, social, and technical aspects are of concern in both drivers and constraints. These can be used to create appropriate strategies for the sustainability of WR implementation.

### Table 1: Example of WR Applications in High- and Middle-income Countries

<table>
<thead>
<tr>
<th>Categories of WR applications</th>
<th>Examples</th>
</tr>
</thead>
</table>
| **Agricultural irrigation**   | • Crop irrigation  
• Commercial nurseries     | • Israel  
• Tunisia  
• Vietnam |
| **Landscape irrigation**      | • Parks, schoolyards  
• Freeway medians  
• Golf courses  
• Cemeteries  
• Greenbelts  
• Residential     | • U.S. (Landscape irrigation, Australia)  
• Japan  
• Thailand (WR from hotels for golf course irrigation in Pattaya)  
• India (Irrigation in a small garden in Nagpur)  
• China |
| **Industrial applications**   | • Cooling water  
• Boiler make-up water  
• Industrial process water, e.g., in power plants, iron and steel production, and carpet dyeing | • Korea (Industrial wastewater reuse for industrial process in POSTECH Steel Company in Pohang)  
• Thailand (Industrial wastewater reuse for industrial process in the sugar industry) |
| **Groundwater recharge**      | • Groundwater replenishment  
• Salt water intrusion control  
• Control or prevent ground subsidence | • U.S. (Groundwater recharge program in Los Angeles and in northern Virginia) |
| **Recreational/Environmental use** | • Lakes and ponds  
• Marsh enhancement  
• Wetland enhancement and restoration  
• Stream-flow augmentation  
• Fisheries  
• Snow making  
• U.S. (Pond maintained with reclaimed wastewater in Los Angeles)  
• Italy |
| **Non-potable urban applications** | • Fire protection  
• Toilet flushing  
• Air conditioning  
• Commercial uses, e.g., vehicle washing, laundry  
• Construction water  
• Spain (On-site water reuse within commercial and residential buildings, grey water used for toilet flushing in municipality of San Cugat del Valles)  
• Japan (Toilet flushing in Tokyo) |
| **Potable reuse** | • Blending in water supply reservoir  
• Pipe to pipe water supply  
• U.S. (Discharge of highly treated municipal wastewater into the water supply source in Virginia)  
• Singapore (NEWater) |

### Table 2: Water Availability and WR Level in Selected Countries

<table>
<thead>
<tr>
<th>High-income countries</th>
<th>Middle-income countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>38,080</td>
</tr>
<tr>
<td>U.S.</td>
<td>43,770</td>
</tr>
<tr>
<td>Australia</td>
<td>3,760</td>
</tr>
</tbody>
</table>

Note: TARWR means total actual renewable water resource; n.a. means data not available; low income is USD 995 or less; middle income is USD 996 to 12,195; and high income is USD 12,196 or more.

This study is descriptive and exploratory using a mixed method and both primary and secondary data. Primary data were collected from field surveys and key informant interviews to explore drivers and constraints for WR implementation in middle-income countries through the case of Thailand. The interviews and questionnaire surveys were conducted with 36 key informants related to WR projects involving local government officials (10 persons), central governmental officials (12 persons), and WR developers (14 persons). The results of drivers and constraints from the key informant interviews were used to create the questionnaire survey. The questions used a 5-rating scale, while statistical methods including correlation analysis were used to analyze the survey results. Spearman’s rank correlation is a non-parametric measure, provides a distribution free test of independence between two variables. The Spearman’s rank correlation coefficient will always be between +1 and -1, and can be used to summarize the strength and direction (positive “+” or negative “-”) of a relationship. However, in addition to these drivers, there are also constraints to WR development, including institutional fragmentation, inadequate financing, lack of public information, or high WR quality standard due to concern on negative health impacts, which may differ considerably from those in high-income countries.

Review of Water Reuse Applications in Middle-income Countries

The need for alternative water resources, coupled with increasingly stringent water quality discharge requirements, is the driving forces for developing WR strategies in the world today [U.S. EPA, 2004]. Most significant WR activities are in arid and high-income countries (TABLE 1), even in countries that are not typically considered to have problems with water scarcity, such as Australia, Germany, Japan, and Singapore. Direct non-potable WR is currently the dominant mode for supplementing public water supplies – for irrigation, cooling water, river flow augmentation, etc. In addition, innovative technologies and standards for WR implementation have been developed to control WR quality and to monitor potential negative effects in high-income countries.

In middle-income countries, reusing treated wastewater has been expected to at least partly solve water shortages. This includes addressing water conflicts, especially between urban and rural areas due to rapid economic development and urbanization with significantly increasing water demand. Current WR applications are primarily focused at industry, for example, in Brazil and China [U.S. EPA, 2004], to control pollution. Unplanned use of inadequately treated wastewater also often occurs, particularly for irrigation, due to inadequate management of planning and regulations, as noted by Fu et al. [2007]. As shown by the growing development of sewerage collection and wastewater treatment facilities, reuse of treated domestic wastewater has been recognized as a way to cope with water demand, particularly in urban areas. However, in addition to these drivers, there are also constraints to WR development, including institutional fragmentation, inadequate financing, lack of public information, or high WR quality standard due to concern on negative health impacts, which may differ considerably from those in high-income countries.

Overview of Water and Wastewater Management in Thailand

In Thailand, agricultural, domestic and industrial water consumption rates are around 51,786, 2,739 and 2,777 million cubic meters per year, respectively. With increase of water demand, Thailand is expected to be a water-stressed country by 2025. Furthermore, in some years when the dry season is unusually prolonged, agricultural activities suffer losses and the population lack an adequate supply for consumption and other domestic uses. More serious problems often occur from water conflicts between rural and urban needs and among industrial, municipal, and agricultural uses. There are many approaches to solving the water shortage problem, but those used have been limited to engineering approaches. Thailand has also planned to import water from neighbouring countries such as Cambodia, Myanmar, and Lao PDR. This approach may lead to future unsustainability of water in the country and the region.

Wastewater management in the country has been primarily in municipal areas and the industrial sector. Typical wastewater management in rural areas is discharging untreated wastewater directly onto land or into a nearby stream. In the municipal areas, there were about 86 central wastewater treatment plants (CWWTPs) operating throughout the country in 2006, generating about 2 million cu.m per day [Water Quality Management Bureau, 2006] or about 14.3% of total domestic wastewater. The national plan has a
target of full control over domestic wastewater within the next 30 years. The central wastewater facilities have been mainly funded by the central government. After construction is finished, the facilities are normally transferred to local governments, with limited or no wastewater charges. Consequently, the costs of operating and maintaining the facilities are the responsibility of the local governments. According to the National Policy and Plan for Environmental Quality Promotion and Conservation, B.E. 2540-2599 (A.D. 1999-2016), only five municipalities in Thailand have applied the Polluter Pays Principle (PPP) for wastewater charges.

**Current Situation of Water Reuse**

Traditionally, WR in Thailand has not been formalized, for instance, using wastewater from laundry for landscape irrigation in households, or unplanned reuse of effluent/wastewater in a river as it flows downstream. However, more attention has been given to WR and its volume has increased due to water shortages, for example in 2003-2004, especially in the industrial sector in the Eastern region. Presently the country does not have any regulations, standards, or official guidelines directly related to WR. There have only been campaigns and indirect reinforcement [Sanguanduan and Nittivattananon, 2011]. According to interviews of key informants (2008), most implemented WR projects were concerned with negative effects, particularly human health in relation to WHO’s WR standards for agricultural and aquaculture uses. To develop WR for other purposes outside agricultural uses, the U.S. EPA guidelines [2004] were considered.

Based on the review of available information, WR activities in Thailand have been mostly limited to industries with their own wastewater treatment plants (WWTPs), for WR within industrial areas such as landscape irrigation and industrial processes. The WR in industrial sectors have been implemented due to both direct economic benefits, e.g. water saving and reducing of wastewater treatment fee, and indirect economic benefits, e.g. avoid water shortage problem.

WR is not used extensively in urban areas due to limited central wastewater treatment facilities. However, in large cities with WWTPs (such as Bangkok, Pattaya, and Phuket), WR has been considered to improve efficient water use. These also cover the business sector (such as hotels and apartments) with their own WWTPs. Furthermore, WR has also been used to mitigate the effects of development projects, such as large buildings and housing projects, on wastewater.

Treated domestic wastewater in Thailand is mainly reused for non-potable purposes. Based on the official document reviews, field surveys, and key informant interviews in this study, current WR practices of domestic sectors can be summarized in TABLE 3, in terms of sources of effluent, WR applications, and examples. However, the current WR amount is estimated to be less than 1% of total effluent, and it seems that WR has moved forward more in the industrial sector than in the domestic sector. Some respondents stated that this is due to clear economic benefits from WR implementation in the industrial sector and tangible strategies supported by the central government, for instance, provision of subsidies for cleaner technology development.

This is different from WR practices in other countries, such as Spain [Iglesias Esteban and Ortega de Miguel, 2008] and Jordan [Ammary, 2007], where the major WR application is for irrigation including agricultural and landscape irrigation. This is because those countries are in arid zone in which WR provides an essential water source for agricultural production with a high technological capacity to ensure no adverse environmental or health effects.

<table>
<thead>
<tr>
<th>Sources of wastewater</th>
<th>Current WR applications</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>From large areas, typically from CWWTPs</td>
<td>- Landscape irrigation</td>
<td>- CWWTPs in Bangkok with reuse for landscape irrigation in the municipal area</td>
</tr>
<tr>
<td></td>
<td>- Toilet flushing</td>
<td>- CWWTPs in Pattaya City with reuse for landscape irrigation in the municipal area (less than 10% of total treated wastewater)</td>
</tr>
<tr>
<td>From small areas, e.g. from a number of buildings and reuse in their common area</td>
<td>- Landscape irrigation</td>
<td>- Hotels, e.g. in Pattaya City, Koh Samui, and Koh Phuket, with reuse for landscape irrigation in their areas</td>
</tr>
<tr>
<td></td>
<td>- Toilet flushing</td>
<td>- Department stores with reuse for landscape irrigation and toilet flushing in their areas</td>
</tr>
<tr>
<td>From individuals/ households, e.g. single building of household or apartment</td>
<td>- Landscape irrigation</td>
<td>- Private houses, with installed piping system for reuse of wastewater from laundry for landscape irrigation</td>
</tr>
</tbody>
</table>

Source: Analyzed from field survey and key informant interview (2008)
Analysis of Drivers and Constraints

There have been a number of previous studies concerning WR drivers and constraints, but they were conducted in high-income countries with high level of education, as presented in UNEP et al. [2004], Asano [2005], and U.S. EPA [2004]. Several driving forces can be identified in worldwide WR practices, including water shortages caused by very low amounts of rainfall in combination with high evaporation, such as in Australia, large freshwater demand from the population, such as in Japan, or environmental and economical considerations, such as in Germany and France [Chu et al., 2004]. Using the literature as a base, key drivers and constraints of WR development in Thailand were analyzed in this study through the key informant interviews and ranked by the questionnaire survey.

Drivers

Key WR drivers in Thailand are increased water shortages, policy instruments, economic incentives, and environmental awareness, which are presented and ranked in TABLE 4.

<table>
<thead>
<tr>
<th>Drivers</th>
<th>Rank (with % of total respondents)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st</td>
</tr>
<tr>
<td>Water shortages</td>
<td>86.11</td>
</tr>
<tr>
<td>Policy instruments</td>
<td>2.78</td>
</tr>
<tr>
<td>Economic incentives</td>
<td>0.00</td>
</tr>
<tr>
<td>Environmental awareness</td>
<td>11.11</td>
</tr>
</tbody>
</table>

Source: Analysis from a questionnaire survey (2008)

1) Water Shortages

Water shortages are clearly a key driving factor in places such as EU countries [Angelakis and Durham, 2008], Saudi Arabia [Al-A’ama and Nakhla, 1995], and China [Chu et al., 2004]. Water demand in Thailand is increasing significantly, especially in the domestic and industrial sectors, due to population and economic growth. Demand was predicted to increase by 27% from 2001 to 2021, with a predicted domestic water demand increase of about 6%. While the water demand is increasing, the water supply is likely decreasing due to reduced rainfall. Therefore, WR is proposed as an alternative water source to ensure sustainable water management.

2) Policy Instruments

Based on the interviews related to WR from CWWTPs, WR in Thailand is also attractive because the central government subsidizes CWWTP construction projects. The central government also provides possible incentives, such as relaxing wastewater fees for WR users, encouraging more private sector involvement in WR development. Hence, the policy instruments for WR are important drivers of WR development. Moreover, government attention to WR seems to be increasing, based on external factors such as the growing number of successful WR projects in other countries.

3) Economic Incentives

Economic incentives can come from both tangible and intangible benefits of reducing potential losses from drought and preventing wastewater pollution. This also includes increasing the price of tap water. Nowadays, the progressive rate for tap water is about 10.20-16.95 and 11.45-23.00 THB/cu.m for households and businesses, respectively. In some areas, the price of raw water use is about 6-8 THB/cu.m. Also, economic incentives for WR have been increased by applying a wastewater fee in some urban areas. Furthermore, wastewater treatment technology has become more efficient and cheaper, for example membrane technology. This development has reduced WR production costs, making it more economically viable for implementation, particularly for large water users.

4) Environmental Awareness

Based on the literature and the surveys, public acceptance of WR has been increased by environmental awareness of water shortages and environmental problems. More public education will also lead to increased public awareness of the environment, including the development of WR as also recommended by Urkiaga et al. [2006]. In addition, environmental awareness has been enhanced through human development and more understanding of climate change in Thailand. These drive the implementation of WR, particularly in industries and businesses that promote their products or services as being more environmental friendly. This implementation includes promoting WR as a part of international concepts/principles.

2 USD 1 is approximately THB (Thai Baht) 0.33.
such as sustainable development in the World Commission on Environmental and Development (WCED) in 1987; "ISO 14000 Series" by the International Organization for Standardization; green growth by UNESCAP; and the 3Rs concept that refers to the reduction of water at usage, the reuse of water, and the recycling of water.

According to TABLE 4, water shortages are the major driver for WR, which is consistent with the literature [Asano, 2005; Bixio et al., 2006]. Subsequently, policy instruments for WR and economic incentives are closely ranked, because the policy can also affect the economic incentives. Furthermore, the higher rank of the economic incentives as compared to the environmental awareness represents more significant constraint in middle-income countries on economic over environmental concerns.

Spearman’s rank correlation was used to determine the relationship between the drivers (TABLE 5). It was found that the water shortage problem has a significant negative correlation with the policy instrument and environmental awareness, with correlation coefficient values of -0.359 and 0.164, respectively. Subsequently, the economic incentive also has a significant negative correlation with the policy instrument and environmental awareness, with correlation coefficient values of -0.113 and -0.380, respectively. These results show that without the water shortage problem, WR could be made more attractive through government policies, economic incentives, and environmental awareness.

Some drivers of WR development in Thailand differ from those in EU countries. Angelakis [2008] states that WR is of vital importance to EU countries, because it: (a) increases the water resources available, (b) reduces eutrophication, and (c) can reduce cost and lower energy demand. The policy instruments for WR are included in the set of key drivers in Thailand, whereas the indirect benefits of WR, particularly on environmental prevention such as reduced eutrophication and lower energy demand, are less important. These confirm the different perspectives on WR between middle- and high-income countries. These results indicate that more efforts and approaches are required for promoting WR in middle-income countries, particularly from enforcement of government policies or regulations and from raising economic incentives or public environmental awareness.

| TABLE 5 SPEARMAN’S RANK CORRELATION BETWEEN THE DRIVERS IN WR IMPLEMENTATION |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
| Drivers                         | Water shortages | Policy instruments | Economic incentives | Environmental awareness |
| Correlation Coefficient         | 1.000           | -0.359*           | -0.067           | -0.164*          |
| Sig. (2-tailed)                 | -               | 0.000            | 0.188            | 0.001            |
| Correlation Coefficient         | -0.359*         | 1.000            | -0.113           | -0.027           |
| Sig. (2-tailed)                 | 0.000           | -                | 0.027            | 0.595            |
| Correlation Coefficient         | -0.067          | -0.113           | 1.000            | -0.380*          |
| Sig. (2-tailed)                 | 0.188           | 0.027            | -                | 0.000            |
| Correlation Coefficient         | -0.164*         | -0.027           | -0.380*          | 1.000            |
| Sig. (2-tailed)                 | 0.001           | 0.595            | 0.000            | -                |

* Correlation is significant at the 0.05 level (2-tailed).

**Constraints**

Not only have the drivers of WR development been addressed, but many constraints have also been identified, as shown in TABLE 6. These include (1) public acceptance of WR, (2) investment and operation and maintenance (O&M) costs, (3) adverse human health effects, (4) laws and regulations, and (5) efficiency and reliability of wastewater treatment systems.

| TABLE 6 RANK OF CONSTRAINTS ON WR |
|----------------------------------|-----------------|-----------------|-----------------|-----------------|
| Constraints                      | Rank (with % of total respondents) |
|                                  | 1st  | 2nd  | 3rd  | 4th  | 5th  |
| Public acceptance of WR          | 41.67| 22.22| 11.11| 19.44| 5.56 |
| Investment and O&M costs         | 27.78| 19.44| 19.44| 11.11| 22.22|
| Adverse effects on human health  | 13.89| 38.89| 8.33 | 11.11| 7.78 |
| Laws and regulations             | 5.56 | 8.33 | 38.89| 27.78| 19.44|
| Efficiency and reliability of wastewater treatment system | 8.33 | 11.11| 22.22| 30.56| 27.78|

Source: Analysis from a questionnaire survey (2008)
It is widely agreed that without public acceptance of wastewater recycling and reuse, it will be difficult for any municipalities to site, finance, construct, or operate WWTPs [Bdour, Hamdi, and Tarawneh, 2009]. The literature identifies negative perceptions among the public as key constraints to WR, included in Thailand. Although some surveys about WR feasibility, particularly on CWWTP feasibility, reported that WR has positive public acceptance, many developers are still unsure of WR actual implementation in terms of public concerns.

Implementing WR requires investing in new facilities, and operation and maintenance costs per unit of wastewater may also increase. Consequently, this is a constraint for WR developers and it may also lead to failure in recognizing the economic value of treated wastewater for reuse. From the key informant interviews, this constraint would result from insufficient scientific information about WR regarding costs and benefits.

Constraints due to adverse effects on human health and laws and regulations are related to the efficiency and reliability of the wastewater treatment system. Thailand does not have direct laws or regulations about WR quality to prevent possible negative effects of WR and to monitor wastewater treatment systems. Consequently, lack of efficiency and reliability of these systems will potentially result in lack of confidence regarding protection against adverse human health effects. According to the in-depth interviews, these constraints are related to a lack of technical staff to operate the wastewater treatment system and insufficient funding of wastewater treatment and WR utilities, particularly in the private sector. These constraints are directly linked to trust in wastewater treatment, and are root causes for lack of acceptance of WR by the public and also by the developers.

The main constraint to WR development is public acceptance, which is consistent with the literature. Next, investment and O&M costs are given priority over adverse effects on human health as developers’ concerns about the economic and technical issues of WR implementation. However, these should be optimized with effluent quality for WR application and to protect against adverse effects on human health. Furthermore, the efficiency and reliability of the wastewater treatment system is given the lowest priority regarding the level of technical capacity for wastewater treatment.

From the analysis of correlation among constraints (TABLE 7), the efficiency and reliability of a wastewater treatment system is negatively correlated with laws and regulations, public acceptance of WR, and investment and O&M costs, with coefficient values of -0.340, -0.285, and -0.206, respectively. Also, the investment and O&M costs have correlations with adverse human health effects, public acceptance of WR, the efficiency and reliability of the wastewater treatment system, and laws and regulations, with coefficient values of -0.336, -0.243, -0.206, and +0.105, respectively.

<table>
<thead>
<tr>
<th>Constraints</th>
<th>Correlation Coefficient</th>
<th>Sig. (2-tailed)</th>
<th>Correlation Coefficient</th>
<th>Sig. (2-tailed)</th>
<th>Correlation Coefficient</th>
<th>Sig. (2-tailed)</th>
<th>Correlation Coefficient</th>
<th>Sig. (2-tailed)</th>
<th>Correlation Coefficient</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public acceptance of WR</td>
<td>1.000</td>
<td>-</td>
<td>1.000</td>
<td>-</td>
<td>0.105</td>
<td>+0.336</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.335</td>
</tr>
<tr>
<td>Investment and O&amp;M costs</td>
<td>-0.243*</td>
<td>0.000</td>
<td>-0.336*</td>
<td>0.000</td>
<td>0.040</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.098</td>
</tr>
<tr>
<td>Adverse effects on human health</td>
<td>-0.098</td>
<td>0.000</td>
<td>-0.336*</td>
<td>1.000</td>
<td>-0.347*</td>
<td>0.049</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.040</td>
</tr>
<tr>
<td>Laws and regulations</td>
<td>0.010</td>
<td>0.105*</td>
<td>-0.347*</td>
<td>0.852</td>
<td>1.000</td>
<td>-0.340*</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>-0.206*</td>
</tr>
<tr>
<td>Efficiency and reliability</td>
<td>+0.285*</td>
<td>0.040</td>
<td>0.000</td>
<td>-0.206*</td>
<td>0.049</td>
<td>-0.340*</td>
<td>0.000</td>
<td>-0.206*</td>
<td>0.000</td>
<td>-0.206*</td>
</tr>
</tbody>
</table>

*Correlation is significant at the 0.01 level (2-tailed).

Based on the relationship between the drivers and constraints (FIG. 1), an approach to influencing management measures through policy, economic, and persuasive instruments could enhance the WR level although without the experience of water shortage problems. Based on the figure, the priority measures can be related to policy instruments and economic incentives as the most common drivers, and investment and O&M costs and efficiency and reliability of a wastewater treatment system for the most common constraints.
Opportunities and possible strategies

With a focus on the reuse of treated domestic wastewater, urban or municipal areas have higher potential than rural areas where wastewater collection and treatment facilities are limited. From the review of wastewater management practices, the wastewater in rural areas of middle-income countries is typically discharged onto surface land or into streams without reuse or unplanned reuse. This is inconsistent with the opportunities in high-income countries, for example, in areas with low population densities, such as North America and Australia, as grey water reuse is common due to water scarcity, growing awareness about water conservation, and lack of centralized treatment facilities [Mandal et al., 2011].

In urban areas of middle-income countries through the case of Thailand, WR from large and small areas has been much more developed than that from individual systems. According to the comparison between building effluent quality standards and suggested WR quality levels in TABLE 8, large buildings, particularly Building Type A with CWWTPs, have higher potential than single households. The potential priority of WR application is for landscape irrigation, including in roadway medians and golf courses. Typically effluent from large and small areas is formally monitored, improving the safety and reliability of effluent quality. This is consistent with a previous study [Jia et al., 2002] which showed that, while small WR systems might be more flexible, large WR systems are safer, more reliable, and more easily accepted by the public.

TABLE 8 COMPARISON OF BUILDING EFFLUENT STANDARDS WITH SUGGESTED WR QUALITY LEVEL

<table>
<thead>
<tr>
<th>Building Type</th>
<th>pH</th>
<th>BOD (mg/l)</th>
<th>Suspended Solids (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Type A</td>
<td>5-9</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Building Type B</td>
<td>5-9</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>Building Type C</td>
<td>5-9</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>Building Type D</td>
<td>5-9</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Building Type E</td>
<td>5-9</td>
<td>200</td>
<td>60</td>
</tr>
<tr>
<td>CWWTP**</td>
<td>5.5-9.0</td>
<td>20</td>
<td>30</td>
</tr>
</tbody>
</table>

Suggested values of effluent quality for WR***

- Landscape irrigation: 6-9, 10, -
- Industrial application: 6-9, 30, 30
- Recreation/Environmental uses: 6-9, 10, -
- Toilet flushing: 6-9, 10, -
- Blending with raw water supply: 6-9, 10, -

Sources: "Notification of the Ministry of Natural Resources and Environment: Building Effluents Standards dated November 7, B.E. 2548 (2005), "Notification of the Ministry of Natural Resources and Environment: Central Wastewater Treatment Effluents Standards dated June 2, B.E. 2553 (2010), and "U.S. EPA [2004] sq.m; department stores with 5,000-25,000 sq.m; fresh food markets with 1,500-2,500 sq.m; restaurants with 500-2,500 sq.m; dormitories with 250 rooms or more; or massage parlors (or equivalent) with 5,000 sq.m or more.

Building Type C is defined as the following: condominiums with less than 100 units; hotels with less than 60 rooms; office buildings with 5,000-10,000 sq.m; fresh food markets with 1,000-1,500 sq.m; restaurants with 250-500 sq.m; dormitories with 50-250 rooms; or massage parlors (or equivalent) with 1,000-5,000 sq.m.

Building Type D is defined as the following: fresh food markets with 500-1,000 sq.m; restaurants with 100-250 sq.m; or dormitories with 10-50 rooms.

Building Type E is defined as the following: restaurants with less than 100 sq.m.
As previously discussed, the potential to implement WR using treated domestic wastewater from CWWTPs and/or large wastewater treatment facilities is high. The key drivers and constraints (FIG. 1) can be systematically used to create possible strategies for promoting WR development. Considering environmental management measures (including economic, regulation, and moral suasive measures), key strategies for enhancing WR development in Thailand can be briefly discussed in the following:

**Regulatory Measures**

Regulatory measures, based on the driver of policy instruments and constraints on adverse effects to human health, laws and regulations, and the efficiency and reliability of wastewater treatment systems, include:

- Giving priority to WR in government policies. This can also cover measures to reduce water shortages.
- Establishing regulations or standards for WR quality. The literature notes that establishing WR quality standards is required at the beginning of WR development due to their contribution to minimizing negative effects and to more positive public acceptance. Adopting WR standards from high-income countries would be one way to initiate WR implementation.
- Setting administrative controls to monitor effluent quality. The municipality/city should adopt this strategy due to the policy on decentralization to local government authorities, while the producers should report their WR quality and their implementation plans to concerned agencies. Furthermore, the municipalities/cities with direct responsibility for both water and wastewater services and implementing a public/private partnership for wastewater would have a higher potential for WR implementation than other municipalities, considering this administrative issue.

**Economic Measures**

Economic measures, based on the driver of economic incentives and the constraints of public acceptance of WR, investment and O&M costs, and efficiency and reliability of wastewater treatment systems, cover:

- Providing economic incentives for WR implementation. Incentives such as savings on the cost of wastewater fees and subsidies for wastewater treatment and WR instruments could reduce the costs of investment and O&M of wastewater treatment, and increase the capacity by using the most effective technology. This would also increase public acceptance of WR.

**Moral Suasive Measures**

Moral suasive measures, based on the driver of environmental awareness and the constraints of public acceptance of WR, adverse health effects, and the efficiency and reliability of the wastewater treatment system, involve:

- Providing information on water/wastewater management and good WR practices. This could enhance the public acceptance and reliability of the wastewater treatment system, including better understanding of economic feasibility and environmental values of WR. Moreover, trust and confidence in the WR operator in some areas might need to improve before WR implementation. This issue is different from high-income countries with better quality of wastewater management.
- Building partnerships among stakeholders. A partnership between the producers and consumers, such as the municipalities and the hotel businesses, and between local governments and related central government departments, are required to improve the technical capacity of WR.
- Improving participation of the stakeholders in the WR system development. This includes raising public awareness of water problems and understanding of WR that would also increase public acceptance.

In addition, these measures have also pointed out the difference between high- and middle-income countries in terms of institutional and technical capacities. Technology transferred or developed from high-income countries would be required taking into account local conditions. For example, the costs of membrane technology, which is a typical wastewater treatment process for WR, should be considered.
Conclusions

Current knowledge of some similarities and differences between middle- and high-income countries has been partly included in the literature and also reviewed in this study. While non-potable reuse has been a common opportunity, the two groups of countries do not share the same drivers and constraints in applying WR. Using Thailand as a case for middle-income countries in this study, the results show the major drivers of domestic WR are water shortages, policy instruments, economic incentives, and environmental awareness. Furthermore, the constraints on WR in the domestic sector lie in the areas of public acceptance, investment and O&M costs, adverse effects on human health, laws and regulations, and the efficiency and reliability of wastewater treatment systems. Similarities between high- and middle-income countries on WR for the sustainability of the water supply are also noted. The difference is affordability, particularly regarding economic and technical issues.

The WR opportunities in Thailand should focus on non-potable use (such as landscape irrigation) in urban water with medium to large areas or population size, requiring policies to encourage WR development and to address some implementation issues through regulatory and incentive measures, including preventing negative effects while encouraging positive effects of WR applications. Hence, the government could be expected to play an important role in WR development.

This study has contributed to an increased understanding of the WR development situation in middle-income countries. It also identified key drivers and constraints as well as opportunities that can systematically lead to WR strategies corresponding to the particular country and local conditions. Nevertheless, as this study was conducted based on the case of Thailand with limitations of information on WR in other middle-income countries, further studies are recommended, including analysis of WR development in other middle- and lower-income countries to investigate the relevance of national and local economic conditions on WR development. Additional research is also required on WR quality for each of major applications, which can be based on monitoring and reporting systems of past and ongoing WR activities.

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