

Review

Global, regional, and country level need for data on wastewater generation, treatment, and use



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ABSTRACT

Irrigation with wastewater supports agricultural production and the livelihoods of millions of smallholder farmers in many parts of the world. Considering the importance of better wastewater management at the local and national levels, there is a need for updated national data on wastewater generation, treatment, and use, which would also assist in regional and global wastewater assessments. While searching data and literature in published or electronic forms for 181 countries, we find that only 55 countries have data available on all three aspects of wastewater – generation, treatment, and use. The number of countries with one or two aspects of wastewater generation, treatment, and use is 69, while there is no information available from 57 countries. Of the available information, only 37% of the data could be categorized as recent (reported during 2008–2012). The available data suggest that high-income countries on average treat 70% of the generated wastewater, followed by upper-middle-income countries (38%), lower-middle-income countries (28%), and low-income countries, where only 8% of the wastewater generated is treated. The availability of current information on wastewater generation, treatment, and use is crucially important for policy makers, researchers, and practitioners, as well as public institutions, to develop national and local action plans aiming at safe and productive use of wastewater in agriculture, aquaculture, and agroforestry systems. The country level information aggregated at the regional and global levels would help in identifying the gaps in pertinent data availability and assessing the potential of wastewater in food, feed, and fish production at different scales.

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1. Introduction

Freshwater resources and population densities are unevenly distributed worldwide. As a result, water demands already exceed supplies in regions with more than 40% of the world's population (Bennett, 2000). Limited access to freshwater already impacts the lifestyle and development opportunities in water scarce areas (Qadir et al., 2007a). By the year 2025, as much as 60% of the global population may suffer physical water scarcity (Pimentel et al., 1999; Rijsberman, 2006).

With about 70% of the world's freshwater currently used for irrigation, agriculture remains the largest user of water. In some countries, irrigation accounts for more than 95% of the developed water supply (FAO-AQUASTAT, 2012). The competition for freshwater allocation already exists among municipal, industrial, and agricultural sectors, particularly in water scarce areas. As a result, agriculture has been yielding its share gradually to non-agricultural uses (Rosegrant and Ringler, 2000; Qadir and Oster, 2004; Qadir et al., 2010a). As the use of freshwater for non-agricultural activities generates wastewater, the volume of wastewater has been increasing, commensurate with rapidly growing population, urbanization, improved living conditions, and economic development (Lazarova and Bahri, 2005; Asano et al., 2007).

The combination of less freshwater allocation to agriculture, more freshwater allocation to non-agricultural sectors, and increasing volumes of urban wastewater, is expected to continue and intensify, particularly in water scarce countries. Therefore, agriculture in these countries will increasingly rely on alternative water resources, such as wastewater generated by non-agricultural activities in urban and peri-urban areas. Most small-scale farmers in urban and peri-urban areas of water scarce countries already depend on wastewater to irrigate a range of crops, often as they have no alternative sources of reliable irrigation water (Raschid-Sally and Jayakody, 2008; Drechsel et al., 2010).

Despite the importance of wastewater irrigation in supporting the livelihoods of millions of smallholder farmers, as described in several studies highlighting the significance of wastewater use in agriculture (Qadir et al., 2007b; Jiménez and Asano, 2008a,b; Drechsel et al., 2010), information regarding the quantity of wastewater generated, treated, and used at national scale is unavailable, limited, or outdated in numerous cases. Yet information describing current levels of wastewater generation, treatment, and use is crucially important for policy makers, researchers, and practitioners, as well as public institutions, to develop national action plans aiming at wastewater treatment and productive use of wastewater in agriculture, aquaculture, and agroforestry systems for environment conservation and health protection. Country level information aggregated at the regional and global levels also is needed to identify the gaps in pertinent data availability and assess the potential of wastewater in food, feed, and fish production at the regional and global scales.

Considering this lack of information, we compile the available data on these aspects of wastewater. Our goals include: (1) identifying potential sources of data for wastewater¹ production, treatment and use; (2) reporting the volumes of wastewater generation,

treatment² and use based on country-specific data, where available; (3) summarizing country-specific information and describing wastewater production, treatment and use at regional and global scales; and (4) identifying gaps in pertinent data availability.

2. Sources of wastewater data and data reporting

We use the following published and web-based online sources to compile data describing the volumes of wastewater generation, treatment, and use at the country level: Food and Agriculture Organization of the United Nations (FAO, 2011; http://www.fao.org/nr/water/infores_databases_wastewater.html; FAO-AQUASTAT, 2012; <http://www.fao.org/nr/water/aquastat/main/index.stm>); European Commission supported Eurostat (<http://epp.eurostat.ec.europa.eu/portal/page/portal/environment/data/database>); United Nations (UN, 2000); United States Environmental Protection Agency (USEPA, 2004, 2012); country level database (NIWP, 2010; CSBL, 2011; CROSTAT, 2012; CSO, 2012; FIE, 2012; NBSRM, 2012; National Statistics Institute, Spain, 2012; SCSU, 2012; Statistics Netherlands, 2012; TURKSTAT, 2012); and published material (Solley et al., 1998; PEDCAR, 2001; Shrivastava and Swarup, 2001; UNECE, 2001, 2009; Basandorj, 2002; UNMIK, 2003; UNDESA-DSD, 2004; AQUAREC, 2006; Nyachhyon, 2006; Jiménez and Asano, 2008a; Kamal et al., 2008; MNRREF, 2009; PMDFEU, 2009; ABS, 2010; Environment Canada, 2010; MONSTAT, 2010; Van Rooijen et al., 2010; NSCRB, 2011; RMSSO, 2011; Aziz and Aws, 2012; Deras, 2012; FOSFBH, 2012; Gomez et al., 2012; Gyampo, 2012; Joysury et al., 2012; Kaur et al., 2012; Kayiizzi et al., 2012; Lekhoana, 2012; Marka, 2012; MENZ, 2012; MEPPRC, 2012; Moyo, 2012; Murtaza, 2012; Navarrete and Viches, 2012; NSSRA, 2012; Pérez and Montás, 2012; Saloua, 2012; SORS, 2012; SORSi, 2012; Souare et al., 2012; Tajrishy, 2012; Ulimat, 2012; World Bank, 2012; WRDLWB, 2012).

We use the FAO database as a starting point to arrange the country-specific data on wastewater generation, treatment, and use. We use data from other sources, as available, to fill gaps in the FAO database. We have updated some values in the FAO database, using more recent or more accurate data from reports produced by national institutions and ministries, and statistics offices. For example, in the case of Japan, FAO-AQUASTAT (2012) refers to wastewater treatment data (11.37 km³/year) from the year 1993, while World Bank, 2012; WRDLWB (2012) provides more recent information on wastewater treatment in Japan (14.65 km³/year), based on data from 2009.

In some cases, publications refer to 'current estimation' for specific data on wastewater. In such cases, we consider the reporting year for the data to be the year when the publication was produced. For example, Nyachhyon (2006) mentions 0.351 km³/year as the current estimated volume of wastewater generation in Nepal, and UNMIK (2003) reports 167,000 m³/year as a recent estimate of raw sewage production in Kosovo. In these cases, we consider 2006 and 2003 to be the reporting years for wastewater generation in Nepal and Kosovo, respectively.

¹ Wastewater definition varies from country to country and there are different versions of the definition in scientific literature. We consider 'domestic, commercial, and industrial effluents, storm water, and other urban run-off' as wastewater.

² Wastewater treatment has various levels, i.e. primary, secondary, and tertiary. Several developing countries are unable to achieve the satisfactory levels of treatment found in most developed countries. We consider treated wastewater to be 'wastewater receiving any physical or chemical treatment process'.

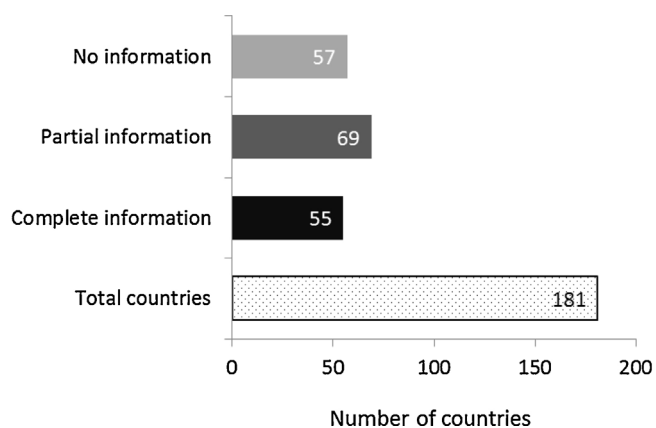


Fig. 1. The availability of complete, partial, or no data on wastewater production, treatment, and use. Complete refers to data on all aspects (wastewater production, treatment, and use), while partial refers to data on one or two aspects of wastewater. The data on wastewater production, treatment, and use for several countries are not from the same source and reporting year.

For some countries, there are many sources and years of data availability. In such cases, we evaluate data from all sources and years, and we report the most recent and consistent values. For example, the most recent data for Spain from FAO (FAO-AQUASTAT, 2012) for wastewater generation ($2.96 \text{ km}^3/\text{year}$), treatment ($3.16 \text{ km}^3/\text{year}$), and use ($0.368 \text{ km}^3/\text{year}$) pertain to 2008, 2004, and 2007, respectively. In this case, the volume of wastewater treated is greater than the volume of wastewater generated, although the data for wastewater treated are from 2004 and wastewater generated from 2008. To address such data issues, we examine other data sources. In the case of Spain, we use data available from the National Statistics Institute, Spain (2012). We use the data for all aspects of wastewater for 2007; i.e. wastewater generation ($5.204 \text{ km}^3/\text{year}$), treatment ($4.570 \text{ km}^3/\text{year}$), and use ($0.501 \text{ km}^3/\text{year}$).

3. Wastewater generation, treatment, and use at global scale

Upon examining data for 181 countries, we conclude that only 55 countries (30.4%) have data available on all three aspects of wastewater – production, treatment, and use (Fig. 1). In several cases, even the datasets from these 55 countries are not recent, and thus they may not provide correct estimates of the current situation. In many regions, wastewater volumes have been increasing with rapidly growing populations, urbanization, improved living conditions, and economic development. In addition, the data on wastewater production, treatment, and use for several countries are not from the same source and reporting year.

The number of countries with partial information (one or two aspects, i.e. wastewater production, treatment, or use) is 69, which accounts for 38.1% of the total number of countries. There are 57 countries (31.5%) for which no information is available on any aspect of wastewater production, treatment, or use.

Although 55 countries have data describing all three aspects of wastewater, in some cases there are discrepancies due to data reporting on wastewater generation, treatment, and use from different years. For example, the volume of wastewater treated in Chile ($0.048 \text{ km}^3/\text{year}$) is smaller than the volume of treated wastewater used ($0.117 \text{ km}^3/\text{year}$) in the country. This may be due to different reporting years, as the volume of treated wastewater is for 2001 and volume of treated wastewater used is for 2008. In addition, the volume of wastewater reported as used in 2008 may have included the volume of wastewater used in untreated form. It is also

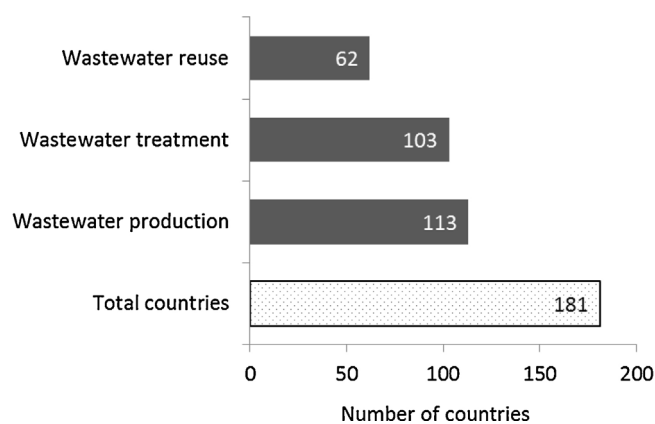


Fig. 2. Availability of data regarding each aspect of wastewater production, treatment, and use at the country level.

possible that different criteria are used by different organizations in defining wastewater in the same country.

We find that 113 countries have data available on wastewater production, 103 countries on wastewater treatment, and only 62 countries on wastewater use (Fig. 2). Thus the data on wastewater use is limited and accounts for only 34% of the countries for which the study was undertaken. This under-reporting might be related to the fear of economic repercussions in agricultural trade. That is, some governments might be reluctant to acknowledge the use of wastewater for irrigation, given international concerns regarding food safety and phyto-sanitary measures (Qadir et al., 2010a). For example, Jordan's export market was impacted in 1991 when countries in the region restricted imports of fruits and vegetables irrigated with inadequately treated wastewater (McCornick et al., 2004). Jordan had to implement an aggressive campaign to rehabilitate and improve wastewater treatment plants and introduced enforceable standards to protect the health of farmers and consumers. The Jordanian government continues to focus on this sensitive situation, given the importance of regional and international trade. The impacts of wastewater use can be indirect and wide-ranging.

Only 37% of the data describing one of the wastewater aspects could be categorized as recent, or reported within the last five years (2008–2012). The data from most countries (54%) pertain to 1998 to 2007, while 9% of the data pertain to the years before 1997 (Fig. 3). These trends reveal that even when data are available, many values are old and may not reflect current volumes of wastewater generation, treatment, and use. This is particularly relevant in developing countries, where wastewater volumes have increased substantially in recent years, due to rural-urban migration. The volumes of wastewater used might also have increased substantially, particularly in water scarce countries.

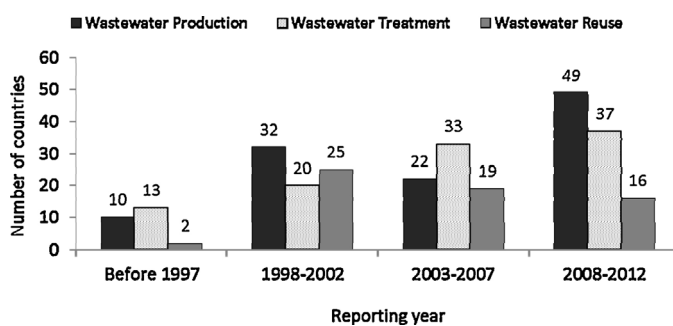


Fig. 3. Timeline for data availability on wastewater production, treatment, and use in selected countries.

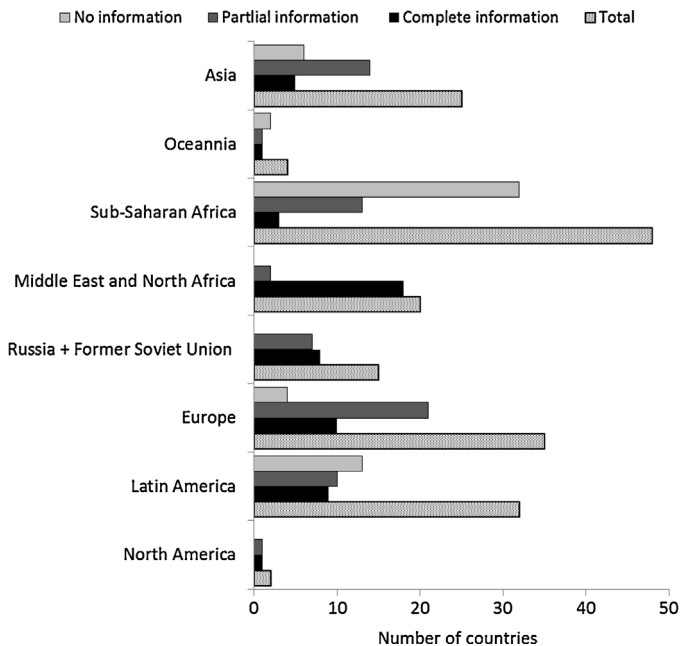


Fig. 4. The availability of complete, partial, or no data on wastewater production, treatment, and use. Complete refers to data on all aspects (wastewater production, treatment, and use) and partial refers to data on one or two aspects of wastewater. The data on wastewater production, treatment, and use for several countries are not from the same source and reporting year.

Wastewater is being used for irrigation on an estimated 4.5 million ha worldwide (Jiménez and Asano, 2008b). Other estimates suggest that about 200 million farmers irrigate with treated and untreated wastewater, on an estimated 20 million ha (Hussain et al., 2001; Scott et al., 2004; Raschid-Sally and Jayakody, 2008). With large variation, these estimates suggest that wastewater accounts for about 1.5–6.6% of the global irrigated area of 301 million ha. Although these estimates have been reported in several publications and scientific presentations, there is no comprehensive study that reveals the basis or verifies the number of farmers using wastewater, or the area under wastewater irrigation at the global scale.

4. Wastewater generation, treatment, and use at region and country scales

We use the modified FAO regional classification of countries in developing regional estimates of wastewater use (FAO, 2003). In particular, we consider North America (U.S. and Canada); Latin America (Mexico, Central America and Caribbean, and South America regions); Europe (Western and Central Europe and Eastern Europe excluding the former Soviet Union countries); the Russian Federation and independent states from the former Soviet Union; Middle East and North Africa (Near East and North Africa); Sub-Saharan Africa (African countries except North African countries); Oceania (Australia, New Zealand, and Pacific Islands); and Asia (Southern and Eastern Asia and Afghanistan).

We consider two countries in North America, 32 in Latin America, 35 in Europe, 15 in the Russian Federation and independent states from the former Soviet Union, 20 in the Middle East and North Africa, 48 in Sub-Saharan Africa, 4 in Oceania, and 25 in Asia. Fig. 4 summarizes the number of countries in different regions with regard to the availability of complete, partial, or no data on wastewater generation, treatment, and use.

Fig. 5 depicts the proportions of wastewater receiving treatment, by country. Using the World Bank, 2012; World Bank (2012)

classification of countries for economic categories (low-income, lower-middle-income, upper-middle-income, and high-income), we find that high-income countries on average treat 70% of the generated wastewater, followed by upper-middle-income countries (38%), lower-middle-income countries (28%), and low-income countries where only 8% of the wastewater generated is treated.

4.1. North America

The estimated volume of wastewater generated in North America each year is about 85 km³, of which 61 km³ are treated (Table 1). The large volumes of generated and treated wastewater are likely due to the highly developed economies and the use of higher volumes of freshwater in industrial and domestic sectors. The annual use of treated wastewater accounts for 2.3 km³, which is only 3.8% of the wastewater treated in the region. Thus, while about 75% of the wastewater generated in North America is treated, only a small portion is used.

While the data describing wastewater generation and treatment are available in Canada, the data on wastewater use are not available. However, there are several projects implemented on an experimental basis with a focus on decentralized and centralized wastewater use (Exall et al., 2008), suggesting use of wastewater in Canada at pilot scale. In the United States, California and Florida use notable amounts of reclaimed water in agriculture. An estimated 46% of California's annual reclaimed water use takes place in agriculture. In Florida, the proportion is 44% (Bryck et al., 2008). Increasingly stressed water resources motivate wastewater use in Arizona, California and Texas, while limited groundwater motivates water recycling and reuse in Florida (USEPA, 2012). California has adopted both a 'Recycled Water Policy' and 'Water Recycling Criteria' to promote the use of recycled water in agriculture (SWRCB, 2009; USEPA, 2012).

Jiménez and Asano (2008a) report that 15,000 ha are irrigated with treated wastewater in the United States. Most of the water reuse projects are located in arid and semi-arid areas, yet projects on wastewater use are increasingly implemented in humid areas due to rapid growth and urbanization (Exall et al., 2008). Estimates of wastewater use in the northeastern United States range from 0.011 to 0.014 km³/year. Municipalities use wastewater for landscape irrigation and to augment stressed potable water supplies (USEPA, 2012). According to Asano et al. (2007) and USEPA (2004), other factors that encourage wastewater use in the region are stringent water and wastewater standards (Water Pollution Act and Clean Water Act), the increased cost of mobilizing new water resources due to rapid increases in urbanization, and environmental considerations.

4.2. Latin America

Complete information on wastewater generation, treatment, and use is available from only 9 of 32 countries: Argentina, Bolivia, Brazil, Chile, Dominican Republic, Guatemala, Mexico, Nicaragua, and Peru (Table 2). Even this information is relatively old as the data pertain largely to 1996–2002. Ten countries have partial data available: Antigua and Barbuda, Belize, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, Panama, Paraguay, and Venezuela.

Only about 20% of generated wastewater undergoes treatment in the Latin American countries for which pertinent data are available, in part because many Latin American countries do not have well developed wastewater collection and treatment systems (UN, 2012). In 8 of 15 Latin American countries, less than half the population is connected to wastewater collection and treatment systems (UN, 2012). Although the population using improved sanitation facilities in the region is 81% in urban and 57% in rural areas, more than 140 million residents do not have

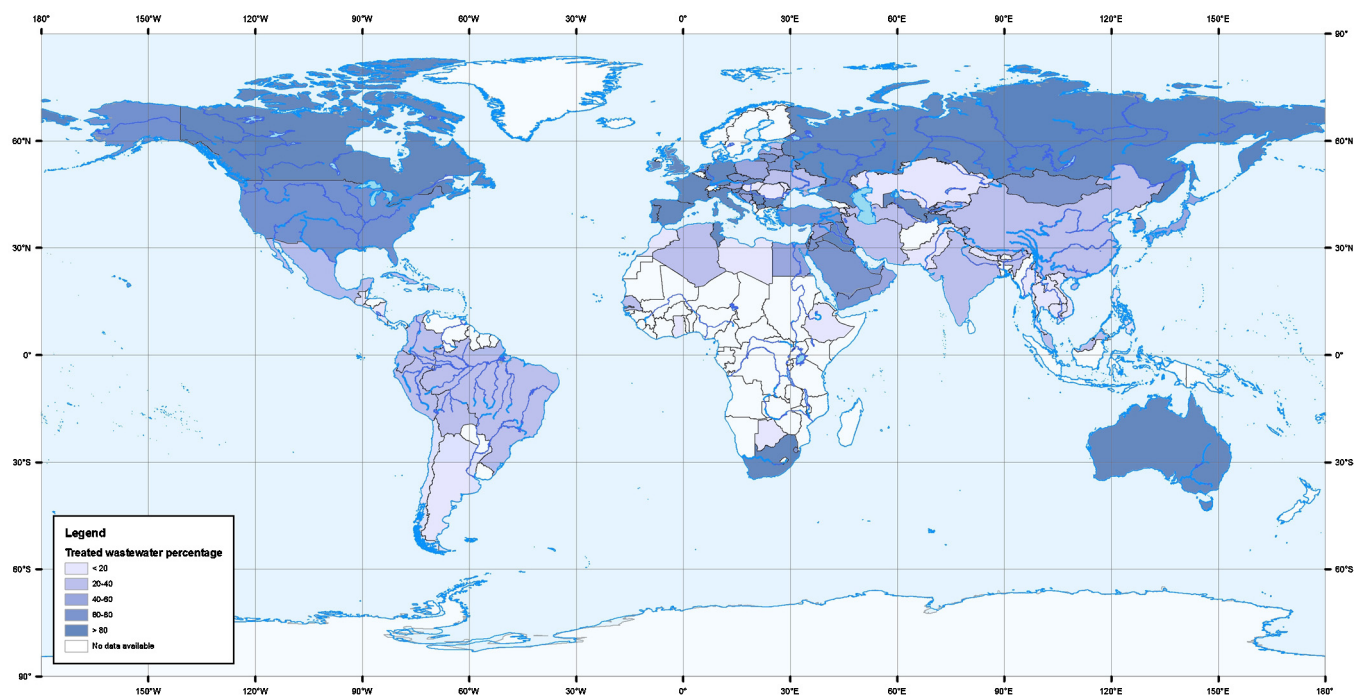


Fig. 5. The ratio of treated wastewater to total generated wastewater (expressed as a proportion) in selected countries. Based on data from [FAO-AQUASTAT \(2012\)](#), [EUROSTAT \(2012\)](#); and references given in [Tables 1–8](#).

improved sanitation facilities ([WHO-UNICEF, 2012](#)). Furthermore, rapid urbanization without sanitation facilities has caused major downstream pollution problems in this region ([García, 2006](#)). The urban population is projected to further increase by 130% in 2025 and by 166% in 2050 ([FAOSTAT, 2012b](#)), thus placing additional pressure on governments to provide improved sanitation facilities and to manage urban wastewater to protect health and the environment.

In Mexico an estimated 70,000 and 190,000 ha are irrigated with treated and untreated wastewater, respectively. In Peru an estimated 1350 and 9346 ha are irrigated with treated and untreated wastewater. In Argentina and Chile the areas irrigated with treated wastewater are similar or larger than the areas irrigated with untreated wastewater ([Jiménez and Asano, 2008a](#)). In Chile, untreated wastewater was used directly for agricultural purposes until 1992. With widespread occurrence of cholera in Latin America, the direct use of untreated wastewater was restricted in the country. The 1991 cholera epidemic in Chile made it necessary to revisit the approach of using untreated wastewater for food production in that country ([Westcot, 1997](#)). The government undertook an emergency program to eliminate health risks by improving irrigation and drinking water quality, modifying irrigation methods, and motivating changes in consumer behavior. The program succeeded in curbing the spread of both typhoid and cholera, with the development of a 1998 sanitation plan for treating all wastewater generated in Santiago ([USEPA, 2012](#)).

Water scarcity is not the main driver of wastewater use in most of Latin America. Rather, farmers engage in wastewater use because it provides a low-cost source of plant nutrients ([Jiménez, 2008](#)). Wastewater use in the region is particularly important, given that the shortages in supply of phosphate (P_2O_5) and potash (K_2O) fertilizers are projected to increase to 3.5 and 4.1 million tons by 2014 ([FAO, 2010](#)).

4.3. Europe

Complete information on wastewater generation, treatment, and use is available for only 10 countries in Europe – Cyprus, France, Germany, Italy, Malta, Netherland, Poland, Portugal, Spain, and United Kingdom ([Table 3](#)). Most of this information pertains to the last 10 years. Partial data are available for almost two-thirds of Europe, including Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Denmark, Greece, Hungary, Ireland, Luxembourg, Kosovo, Monaco, Montenegro, Republic of Macedonia, Romania, Serbia, Slovakia, Slovenia, Sweden, and Switzerland. No data are available for Albania, Finland, Iceland, and Norway.

Most of the wastewater generated in Europe (71%) undergoes treatment, due partly to the high public awareness regarding health and environment protection, technological advancement for wastewater treatment methods, and investments by most governments in wastewater treatment systems ([OECD, 2008](#); [UN, 2012](#)). In addition, the legal and regulatory framework for water

Table 1
Wastewater generated, treated and used in North America.

Country	Wastewater generated		Wastewater treated		Treated wastewater used	
	Reporting year	Volume (km^3 /year)	Reporting year	Volume (km^3 /year)	Reporting year	Volume (km^3 /year)
Canada	2006	5.395 ^a	2006	4.477 ^a	–	NA
United States of America	1995	79.573 ^b	1995	56.642 ^b	2002	2.345 ^c

NA refers to data not available.

^a [Environment Canada \(2010\)](#).

^b [Solley et al. \(1998\)](#).

^c [USEPA \(2004\)](#).

Table 2
Wastewater generated, treated, and used in Latin America.

Country	Wastewater generated		Wastewater treated		Treated wastewater used	
	Reporting year	Volume (km ³ /year)	Reporting year	Volume (km ³ /year)	Reporting year	Volume (km ³ /year)
Antigua and Barbuda	–	NA	1990	0.0002	–	NA
Argentina	1997	3.530	2000	0.104	2000	0.091
Belize	1994	0.002	–	NA	–	NA
Bolivia	2001	0.135 ^a	1992	0.034	2008	0.016 ^b
Brazil	1996	2.567	1996	0.885	2008	0.009 ^b
Chile	2011	1.516 ^c	2001	0.048 ^d	2008	0.117 ^{e,b}
Colombia	2010	2.395 ^d	2010	0.597 ^d	–	NA
Costa Rica	2000	0.086 ^e	2000	0.005	–	NA
Cuba	1994	0.502	1994	0.109	–	NA
Dominican Republic	2011	0.427 ^f	2000	0.131	2000	0.019
Ecuador	1999	0.631 ^e	1999	0.158	–	NA
El Salvador	2010	0.097 ^g	2010	0.001 ^g	–	NA
Guatemala	1998	0.365	1994	0.006	2008	0.0005 ^a
Mexico	2002	13.340	2005	3.110	2000	0.280
Nicaragua	1996	0.067	2000	0.007	2000	0.001
Panama	1998	0.394	–	NA	–	NA
Paraguay	2000	0.009 ^e	–	NA	–	NA
Peru	2012	0.786 ^h	2012	0.275 ^h	2000	0.019
Venezuela	1996	2.903	–	NA	–	NA

Except as otherwise noted, the data are from [FAO-AQUASTAT \(2012\)](#). No data are available on wastewater production, treatment, or use from the following countries: Barbados, Dominica, Grenada, Guyana, Haiti, Honduras, Jamaica, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, and Uruguay. NA refers to data not available.

^a Selected main cities of Bolivia ([Marka, 2012](#)).

^b [Jiménez and Asano \(2008a\)](#).

^c Domestic wastewater ([Navarrete and Viches, 2012](#)).

^d [Gomez et al. \(2012\)](#).

^e Values refer to domestic wastewater only ([FAO, 2011](#)).

^f National district and Santo Domingo Province ([Pérez and Montás, 2012](#)).

^g Metropolitan areas of San Salvador ([Deras, 2012](#)).

^h Domestic wastewater only ([Tong, 2012](#)).

^{*} Greater volume of treated wastewater use than volume of treated wastewater may be due to respective data from different reporting years; volume of treated wastewater reported from 2001 and volume of treated wastewater used reported from 2008.

and wastewater management plays a crucial role in supporting wastewater treatment in the region.

Wastewater use in Europe differs somewhat by geography. In southern Europe reclaimed wastewater is used predominantly for agricultural irrigation (44% of the wastewater projects) and urban or environmental applications (37% of the projects). In northern Europe, wastewater is used primarily for environmental applications (51% of the projects) and industry, which accounts for 33% of the projects ([Bixio et al., 2006](#)). In terms of multiple uses of wastewater in country-specific situations, 71% of wastewater volume in Spain is used for irrigation, 17% for environmental applications, 7% for recreation, 4% for urban reuse, and 0.3% for industrial purposes ([Esteban et al., 2010](#)). Agriculture is major water-use sector in Spain, where irrigation accounts for 68% of water withdrawals ([FAO-AQUASTAT, 2012](#)). In Portugal, the area irrigated with treated wastewater ranges between 35,000 and 100,000 ha, depending on the storage retention time for wastewater ([Angelakis and Bontoux, 2001](#)). In Cyprus, 38,200 ha are irrigated with treated wastewater. The primary use of wastewater in Italy also is for irrigation, which covers 28,285 ha ([Jiménez and Asano, 2008a](#)).

4.4. Russian Federation and Independent States from the Soviet Union

Complete information on wastewater generation, treatment, and use is available for 8 countries – Armenia, Azerbaijan, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Turkmenistan, and Uzbekistan ([Table 4](#)). Partial data are available for other countries – Belarus, Estonia, Georgia, Republic of Moldova, Russian Federation, Tajikistan, and Ukraine.

The volume of wastewater treated in the Russian Federation is about 14 km³/year ([UNDESA-DSD, 2004](#)). Nearly 28% of this is treated in accordance with established regulations, while the

remainder is emitted in inadequately treated form into water bodies. The major factors for low efficiency of wastewater treatment plants are insufficient management (60% of the treatment plants are overloaded) and old facilities (38% have been in operation for about 30 years and need rehabilitation). Poor water and wastewater management, and outdated wastewater treatment systems, have contributed to severe water pollution in Ukraine ([WB, 1999](#)), Georgia ([UNECE, 2003](#)), and in areas surrounding the Caspian Sea ([Stolberg et al., 2006](#)). Financial support and resource allocation are needed for proper management and updating of wastewater collection and treatment facilities in the region.

4.5. Middle East and North Africa

The estimated volume of wastewater generated in the Middle East and North Africa (MENA) region is 22.3 km³/year, of which 51% (11.4 km³/year) is treated ([Table 5](#)). With the exception of Algeria and Iraq, complete information on wastewater generation, treatment, and use is available from all countries in the region.

The efficiency of wastewater treatment in the MENA region is highly variable and many treatment plants have design limitations to treat a mixture of domestic and industrial wastewater, which is usually the most prevalent form of wastewater reaching the treatment plants. In addition, the wastewater treatment plants do not have the capacity to accommodate the large volumes of wastewater resulting from increasing urban populations. In some treatment plants, the retention times for wastewater treatment have become too short to be effective ([Qadir et al., 2010b](#)).

Treated wastewater use is essential in the water scarce MENA region. Currently, 51% of treated wastewater is used for irrigation. Some countries in the region are planning to increase the use of treated wastewater. For example, Saudi Arabia intends to increase

Table 3
Wastewater generated, treated, and used in Europe.

Country	Wastewater generated		Wastewater treated		Treated wastewater used	
	Reporting year	Volume (km ³ /year)	Reporting year	Volume (km ³ /year)	Reporting year	Volume (km ³ /year)
Austria	2009	2.352 ^a	2006	1.061 ^a	–	NA
Belgium	2003	1.114 ^a	–	NA	2000	0.003 ^b
Bosnia and Herzegovina	2011	0.065 ^c	2009	0.003 ^c	–	NA
Bulgaria	2009	0.462 ^a	2007	0.387 ^a	–	NA
Croatia	2011	0.343 ^d	2011	0.267 ^d	–	NA
Cyprus	2005	0.022 [†]	2007	0.245 [†]	2008	0.007
Czech Republic	2009	1.248 ^a	2010	0.871 ^e	–	NA
Denmark	–	NA	1998	0.802 ^a	–	NA
France	2004	7.910 ^f	2004	6.654 ^f	2004	0.411 ^a
Germany	2007	6.172 ^a	2007	5.213 ^a	2000	0.042 ^b
Greece	–	NA	2007	0.566	2000	0.023 ^b
Hungary	2004	4.162 ^a	2006	0.414 ^a	–	NA
Ireland	–	NA	2007	0.290	–	NA
Italy	2007	3.926	2007	3.902	2000	0.233 ^b
Kosovo	2003	0.0002 ^g	–	NA	–	NA
Luxemburg	2003	0.090	2008	0.040	–	NA
Malta	2009	0.020	2003	0.003	2000	0.002 ^b
Monaco	2009	0.008 ^h	2009	0.006 ^h	–	NA
Montenegro	2009	0.066 ⁱ	2009	0.015 ⁱ	–	NA
Netherlands	1991	1.651 [†]	2009	1.818 ^{†,j}	2000	0.008 ^b
Poland	2009	2.198 ^a	2007	1.174 ^a	2000	0.003 ^b
Portugal	2009	0.577 ^k	2009	0.561 ^k	2000	0.001 ^b
Republic of Macedonia	2010	0.020 ^l	2010	0.020 ^l	–	NA
Romania	2009	5.120 ^a	2007	0.811 ^a	–	NA
Serbia	2011	3.499 ^m	2011	0.189 ⁿ	–	NA
Slovakia	2007	0.580 ^a	1998	0.484 ^a	–	NA
Slovenia	2010	0.173 ^o	2010	0.146 ^o	–	NA
Spain	2007	5.204 ^p	2007	4.570 ^p	2007	0.487 ^p
Sweden	–	NA	2006	0.539 ^a	–	NA
Switzerland	2005	1.441 ^a	–	NA	–	NA
United Kingdom	2002	4.019	2008	3.806	2008	0.164

Except as otherwise noted, the data are from [FAO-AQUASTAT \(2012\)](#). No data are available on wastewater production, treatment, or use from the following countries: Albania, Finland, Iceland, and Norway. NA refers to data not available.

^a EUROSTAT (2012).

^b AQUAREC (2006).

^c FOSFBH (2012).

^d CROSTAT (2012).

^e CSO (2012).

^f FIE (2012).

^g UNMIK (2003).

^h PMDFEU (2009).

ⁱ MONSTAT (2010).

^j Statistics Netherlands (2012).

^k Continent area only (NIWP, 2010).

^l Values refer to industrial wastewater (RMSO, 2011).

^m It may include cooling water. Water abstract for industrial cooling is 3.327 km³ by the year of 2011 (SORS, 2012).

ⁿ SORS (2012).

^o SORSi (2012).

^p National Statistics Institute, Spain (2012).

[†] Greater volume of treated wastewater than volume of wastewater generated may be due to respective data from different reporting years. In case of Cyprus, volume of treated wastewater reported from 2007 and volume of wastewater generated reported from 2005. In case of the Netherlands, volume of treated wastewater reported from 2009 and volume of wastewater generated reported from 1991.

wastewater use to 65% by 2016 (USEPA, 2012). Israel already uses 70% of the wastewater generated in the domestic sector.

High-income countries in the region use treated wastewater for agricultural and landscape irrigation. In Kuwait, the use of treated wastewater for landscape irrigation is increasing in urban areas. However, the primary use of treated wastewater is agricultural irrigation (4,470 ha), representing 25% of the irrigated area in the country (USEPA, 2004). Only vegetables that are eaten after cooking (potatoes and cauliflower), industrial crops, forage crops (alfalfa and barely), and highway landscapes may be irrigated with treated wastewater in Kuwait. In the United Arab Emirates, 16,950 ha are irrigated with treated wastewater (Jiménez and Asano, 2008a), of which 15,000 ha are in urban forests, public gardens, trees, shrubs, and grasses along roadways (USEPA, 2004). In Israel, the area irrigated with treated wastewater varies between 28,000 and 65,000 ha (Jiménez and Asano, 2008b). Wastewater use represents

about 10% of the Israeli national water supply and almost 20% of the water supply for irrigation (USEPA, 2004). According to FAO (2005), an estimated 217,527 ha in Egypt are irrigated with treated wastewater. In Syria, 9,000 ha are irrigated with treated wastewater, while 40,000 ha are irrigated with untreated wastewater (Jiménez and Asano, 2008a). In Morocco, about 8000 ha are irrigated with untreated or insufficiently treated wastewater (USEPA, 2004). Data describing the use of treated wastewater for irrigation in Morocco are not available, although irrigation with treated wastewater has been reported in the literature (Jiménez and Asano, 2008a).

4.6. Sub Saharan Africa

Among 48 Sub-Saharan African countries, complete information on wastewater generation, treatment, and use is available from only 3 countries – Senegal, Seychelles and South Africa (Table 6).

Table 4
Wastewater generated, treated, and used in the Russian Federation and independent states from the former Soviet Union.

Country	Wastewater generated		Wastewater treated		Treated wastewater used	
	Reporting year	Volume (km ³ /year)	Reporting year	Volume (km ³ /year)	Reporting year	Volume (km ³ /year)
Armenia	2011	0.750 ^a	2011	0.115 ^a	2006	0.0001
Azerbaijan	2005	0.659	2005	0.161	2005	0.161
Belarus	2010	0.990 ^b	2010	0.676 ^b	–	NA
Estonia	2009	0.379 ^c	2007	0.104 ^c	–	NA
Georgia	–	NA	2005	0.009	–	NA
Kazakhstan	1993	1.833	1993	0.274	2000	0.274
Kyrgyzstan	2006	0.701 ^d	2006	0.148 ^d	2000	0.0001
Latvia	2009	0.282 ^e	2009	0.128 ^e	2000	0.012
Lithuania	2009	0.263 ^c	2007	0.161 ^c	1995	0.005
Republic of Moldova	2011	0.686 ^f	2011	0.122 ^f	–	NA
Russian Federation	2007	9.327 ^{*,g}	2002	14.000 ^{*,h}	–	NA
Tajikistan	2008	0.092	2008	0.089	–	NA
Turkmenistan	2010	1.275	2004	0.336	2004	0.336
Ukraine	2011	8.044 ⁱ	2011	1.763 ⁱ	–	NA
Uzbekistan	2001	2.200 ^j	2001	2.069 ^j	1994	0.205

Except as otherwise noted, the data are from [FAO-AQUASTAT \(2012\)](#). NA refers to data not available.

^a NSSRA (2012).

^b NSCRB (2011).

^c EUROSTAT (2012).

^d UNECE (2009).

^e CSBL (2011).

^f Figures are included as sewage, mine and underground drainage waters ([NBSRM, 2012](#)).

^g Value refers to estimated volume of wastewater generated from some activities ([MNREF, 2009](#)).

^h UNDESA-DSD (2004).

ⁱ SCSU (2012).

^j Values refer to industrial wastewater which may include cooling water ([UNECE, 2001](#)).

* Greater volume of treated wastewater than volume of wastewater generated may be due to different criteria used by different organizations in defining wastewater and different reporting years.

Even this information is old, as the data from Seychelles and South Africa pertain to 2000 to 2003. The countries with partial data available are Botswana, Burkina Faso, Cote d'Ivoire, Djibouti, Eritrea, Ethiopia, Ghana, Lesotho, Mauritania, Mauritius, Namibia, Swaziland and Uganda. No data are available from the remaining 32 countries in the region.

Most wastewater goes untreated in sub-Saharan Africa, where water pollution triggers the spread of waterborne diseases such as diarrhea and cholera ([WHO, 2007, 2008](#)). In most cases, the wastewater used for in agriculture is polluted. For example, untreated wastewater is used for irrigation in the peri-urban zones around Kumasi in Ghana ([Keraita et al., 2002](#)), Dakar in Senegal ([Faruqui et al., 2004](#)), Nairobi in Kenya ([Cornish and Kielen, 2004](#)) and Bul-

Table 5
Wastewater generated, treated, and used in Middle East and North Africa (MENA).

Country	Wastewater generated		Wastewater treated		Treated wastewater used	
	Reporting year	Volume (km ³ /year)	Reporting year	Volume (km ³ /year)	Reporting year	Volume (km ³ /year)
Algeria	2010	0.730	2010	0.150	–	NA
Bahrain	2010	0.084	2005	0.062	2005	0.016
Egypt	2011	8.500	2011	4.800	2011	0.700
Iran	2010	3.548 ^a	2010	0.821 ^a	2010	0.328
Iraq	2012	0.580 ^b	2012	0.580 ^b	–	NA
Israel	2007	0.500	2007	0.450	2004	0.262
Jordan	2008	0.180	2011	0.115 ^c	2012	0.108 ^c
Kuwait	2008	0.254	2005	0.250	2002	0.078
Lebanon	2003	0.310	2006	0.004	2005	0.002
Libya	1999	0.546	1999	0.040	2000	0.040
Morocco	2010	0.700	2010	0.124	2008	0.070
Oman	2000	0.090	2006	0.037	2006	0.037
Palestinian Territories	2001	0.071 ^d	2001	0.030 ^d	1998	0.010
Qatar	2005	0.055 ^e	2006	0.058 ^e	2005	0.043
Saudi Arabia	2000	0.730	2002	0.548	2006	0.166
Syria	2002	1.364	2002	0.550	2003	0.550
Tunisia	2010	0.246	2010	0.226 ^e	2001	0.021
Turkey	2010	3.582 ^f	2010	2.719 ^f	2006	1.000
United Arab Emirates	1995	0.500	2006	0.289	2005	0.248
Yemen	2000	0.074	1999	0.046	2000	0.006

Except as otherwise noted, the data are from [FAO-AQUASTAT \(2012\)](#). NA refers to data not available.

^a Domestic wastewater only ([Tajrishy, 2012](#)).

^b Aziz and Aws (2012).

^c Ulimat (2012).

^d PEDCAR (2001).

^e Saloua (2012).

^f TURKSTAT (2012).

* Greater volume of treated wastewater than volume of wastewater generated may be due to respective data from different reporting years.

Table 6
Wastewater generated, treated, and used in Sub-Saharan Africa.

Country	Wastewater generated		Wastewater treated		Treated wastewater used	
	Reporting year	Volume (km ³ /year)	Reporting year	Volume (km ³ /year)	Reporting year	Volume (km ³ /year)
Botswana	2000	0.043	1999	0.008	–	NA
Burkina Faso	2000	0.001	–	NA	–	NA
Cote d'Ivoire	–	NA	1994	0.0001	–	NA
Djibouti	–	NA	–	NA	2000	0.0001
Eritrea	2000	0.018	–	NA	–	NA
Ethiopia	2009	0.049 ^a	–	NA	2009	0.009 ^a
Ghana	2006	0.280 ^b	2006	0.022 ^b	–	NA
Lesotho	2012	0.007 ^c	–	NA	–	NA
Mauritania	–	NA	1998	0.0007	2000	0.0007
Mauritius	–	NA	2012	0.039 ^d	2006	0.015 ^d
Namibia	2012	0.013 ^e	–	NA	2000	0.007
Senegal	2010	0.067 ^f	2010	0.015 ^g	2010	0.002 ^f
Seychelles	2003	0.009	2003	0.0009	2003	0.000006
South Africa	2000	3.200	2000	3.200	2008	0.030 ^h
Swaziland	2002	0.012	2002	0.009	–	NA
Uganda	2012	0.008 ⁱ	–	NA	–	NA

Except as otherwise noted, the data are from [FAO-AQUASTAT \(2012\)](#). No data are available on wastewater production, treatment, or use from the following countries: Angola, Benin, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Gambia, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mozambique, Niger, Nigeria, Rwanda, Sao Tome and Principe, Sierra Leone, Somalia, Sudan, Tanzania, Togo, Zambia, and Zimbabwe. NA refers to data not available.

^a Addis Ababa city, capital in Ethiopia ([Van Rooijen et al., 2010](#)).

^b Domestic wastewater generated in urban Ghana ([Gyampo, 2012](#)).

^c [Lekhooana \(2012\)](#).

^d [Joysury et al. \(2012\)](#).

^e Windhoek, capital in Namibia only ([Moyo, 2012](#)).

^f [Kayiizzi et al. \(2012\)](#).

^g Dakar only ([Souare et al., 2012](#)).

^h [Jiménez and Asano \(2008a\)](#).

ⁱ [Souare et al. \(2012\)](#).

awayo in Zimbabwe ([Mutengu et al., 2007](#)). In peri-urban Kumasi, about 11,900 ha are irrigated with untreated wastewater ([Keraita et al., 2002](#)). In urban and peri-urban areas of Ghana, vegetable farming using wastewater is reported to generate farm incomes ranging from US\$ 300 to US\$ 800 per year (depending on crop type and cropping intensity). Such incomes enable households to rise above the poverty line, which is US\$ 300 to US\$ 380 per year ([Danso et al., 2002](#)).

Although sub-Saharan Africa accounts for 14% of the global arable land and the area planted in permanent crops, fertilizer use is very limited in the region, resulting in low productivity ([FAOSTAT, 2012a](#)). For example, the estimated annual use of nitrogen is 1.3 million tons (1.3% of global nitrogen use), while the estimates for phosphorus and potassium are 0.56 million tons (1.5%), and 0.36 million tons (1.9%), respectively. These low levels of fertilizer use are supplemented partly with the nutrients contained in the wastewater used for irrigation. However, given the inherent uncertainty regarding wastewater quality and nutrient content, it is not possible for farmers to optimize the use of nutrients, particularly when using untreated wastewater.

4.7. Oceania

Complete information on all three aspects of wastewater is available only from Australia ([Table 7](#)). The volume of treated wastewater is available for New Zealand, but the information on the volume of wastewater generated and treated wastewater used is not available. No information regarding wastewater is available from Fiji and the Solomon Islands.

About 45% of the 450 wastewater use projects in Oceania are in agriculture ([Bixio et al., 2005](#)). In Australia, an estimated 0.35 km³ of treated wastewater are used annually. This volume accounts for 19% of the wastewater treated in the country and about 4% of the total water supply ([ABS, 2010](#)). Agriculture is the major sector benefiting from wastewater use in Australia, where about 20,000 ha

are irrigated with treated wastewater ([USEPA, 2004](#)). Wastewater use in Australia is more common in inland, rural areas, where rainfall is limited and agricultural demands for irrigation water are notable ([Anderson et al., 2008](#)). In New Zealand, wastewater is used to irrigate golf courses and for industrial applications, but the volumes involved likely are small ([Anderson et al. \(2008\)](#)). Wastewater use in small coastal settlements and towns, and in scattered, low-density rural settlements is supported by an awareness of the need to manage natural resources wisely ([MENZ, 2003](#)).

4.8. Asia

Information on all three aspects of wastewater is available from only 5 countries – China, India, Japan, Republic of Korea, and Vietnam ([Table 8](#)). Partial data are available for 14 countries, including Bangladesh, Bhutan, Cambodia, Laos, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, and Thailand.

Only about 32% of the wastewater generated in Asia is treated, due largely to the lack of treatment facilities in several countries ([WEPA-IGES, 2012](#)). The most common constraint in Asia is the lack of financial resources, followed by the lack of well-defined policies and the shortage of qualified personnel in the field of wastewater management ([UN, 2000](#)).

Japan has adopted a comprehensive strategy for treated wastewater use ([Funami et al., 2008](#)). In 2009, 0.2 km³ of treated wastewater were used in the country. More than half was used for environmental purposes, such as landscape irrigation (27% of treated wastewater), recreation (2%), and river maintenance (29%) ([World Bank, 2012](#); [WRDLWB, 2012](#)). Wastewater use in agriculture and industry is not substantial, accounting only for 7% and 1% of the treated wastewater, respectively. In addition, more than 3% of the treated wastewater is used for toilet-flushing ([World Bank, 2012](#); [WRDLWB, 2012](#)). Japan's wastewater use strategy is somewhat unique, as it is focused on meeting urban water needs,

Table 7
Wastewater generated, treated, and used in Oceania.

Country	Wastewater generated		Wastewater treated		Treated wastewater used	
	Reporting year	Volume (km ³ /year)	Reporting year	Volume (km ³ /year)	Reporting year	Volume (km ³ /year)
Australia	2008	2.094 ^a	2008	1.779 ^a	2008	0.348 ^a
New Zealand	–	NA	2012	0.548 ^b	–	NA

No data are available on wastewater production, treatment, or use from Fiji and the Solomon Islands. NA refers to data not available.

^a ABS (2010).

^b Domestic wastewater in New Zealand (MENZ, 2012).

Table 8
Wastewater generated, treated, and used in Asia.

Country	Wastewater generated		Wastewater treated		Treated wastewater used	
	Reporting year	Volume (km ³ /year)	Reporting year	Volume (km ³ /year)	Reporting year	Volume (km ³ /year)
Bangladesh	2000	0.725 ^a	–	NA	–	NA
Bhutan	2000	0.004 ^a	–	NA	–	NA
Cambodia	2000	1.184 ^b	1994	0.0002	–	NA
China	2009	58.920 ^c	2006	17.890	2005	13.390
India	2012	13.999 ^d	2012	4.302 ^d	2000	0.450 ^e
Japan	2009	27.000 ^f	2009	14.650 ^f	2009	0.204 ^f
Laos	2000	0.546 ^b	–	NA	–	NA
Malaysia	2000	1.403 ^a	1995	0.398	–	NA
Maldives	2000	0.004 ^a	–	NA	–	NA
Mongolia	2002	0.126 ^g	2002	0.083 ^g	–	NA
Myanmar	2000	0.017 ^a	–	NA	–	NA
Nepal	2006	0.135 ^h	2006	0.006 ^h	–	NA
Pakistan	2011	6.849 ⁱ	2011	0.548 ^j	–	NA
Philippines	2000	7.500 ^k	1993	0.010	–	NA
Republic of Korea	2000	6.895 ^a	1996	4.180	2008	0.157 ^l
Singapore	2000	0.470 ^a	–	NA	2008	0.027 ^l
Sri Lanka	2000	0.950 ^a	–	NA	–	NA
Thailand	2008	5.293	1995	0.035	–	NA
Viet Nam	2003	1.100	2009	0.070	2003	0.175

Except as otherwise noted, the data are from FAO-AQUASTAT (2012). No data are available on wastewater production, treatment, or use from the following countries: Afghanistan, Brunei, Democratic People's Republic of Korea, Indonesia, Papua New Guinea, and Timor-Leste. NA refers to data not available.

^a UN (2000).

^b Values refer to domestic wastewater estimated considering daily per capita water consumption (230 L) and total population in the respected countries in 2000 (Kamal et al., 2008).

^c MEPPRC (2012).

^d Kaur et al. (2012).

^e Shrivastava and Swarup (2001).

^f World Bank, 2012; WRDLWB (2012).

^g Basandorj (2002).

^h Nyachhyon (2006).

ⁱ Murtaza (2012).

^j Calculated based on the estimates that about 8% of the wastewater generated in Pakistan undergoes treatment (Murtaza, 2012).

^k Values refer to domestic wastewater only (UN, 2000).

^l Jiménez and Asano (2008a).

rather than providing water primarily for agricultural uses (USEPA, 2004).

An estimated 1.3 million ha are irrigated with wastewater in China, while an estimated 9500 ha are irrigated with untreated wastewater in Vietnam (Jiménez and Asano, 2008a). At least 2% of the agricultural land around most Vietnamese cities is irrigated with wastewater, and much of that land is planted in rice (Raschid-Sally et al., 2004). An estimated 32,500 ha are irrigated with wastewater in Pakistan (Ensink et al., 2004). Most of the wastewater is untreated, and yet there are no clear regulations in Pakistan regarding which crops may be irrigated with wastewater (van der Hoek, 2004). Direct use of untreated wastewater is also common in India, where in 1985, an estimated 73,000 ha were irrigated with (Strauss and Blumenthal, 1990). Since then, wastewater volumes and wastewater use for irrigation have increased substantially (USEPA, 2004). An estimated 40,000 ha are irrigated with water from the Musi River, which carries large volumes of untreated wastewater (van der Hoek, 2004).

The increasing demand for plant nutrients in Asia provides an incentive for farmers and public officials to develop safe methods

for distributing and managing wastewater for use in agriculture. Projections suggest that the potash supply in East Asia will be much smaller than demand by 2014 (FAO, 2010). The projected supply-demand gaps pertaining to plant nutrients are wider in South Asia, where fertilizer use is rapidly increasing. The projected annual nutrient deficits for South Asia include 4.3 million tons for nitrogen, 7.4 million tons for phosphorus, and 5.1 million tons for potash (FAO, 2010). These gaps in fertilizer demand and supply can be partly offset with nutrients in wastewater. However, substantial work is need by scientists and policy analysts in designing effective technical solutions and establishing appropriate institutional and regulatory mechanisms.

5. Conclusions

Wastewater treatment and use in the humid regions of developed countries, such as the eastern part of North America, northern Europe, and Japan are motivated by stringent effluent discharge regulations and public preferences regarding environmental quality. The increasing competition between industrial and domestic

sectors for limited freshwater resources also motivated investment in wastewater treatment and use. Treated wastewater is also used for irrigation, but this end use is not substantial in humid areas. The situation is different in the arid and semi-arid areas of developed countries, such as western North America, Australia, and southern Europe, where treated wastewater is used primarily for irrigation, given the increasing competition for water between agriculture and other sectors.

In developing countries, wastewater treatment is limited, as investments in treatment facilities have not kept pace with persistent increases in population and the consequent increases in wastewater volume in many countries. Thus, much of the wastewater generated is not treated, and much of the untreated wastewater is used for irrigation by small-scale farmers with little ability to optimize the volume or quality of the wastewater they receive. Many farmers in water scarce developing countries irrigate with wastewater because: (1) it is the only water source available for irrigation throughout the year, (2) wastewater irrigation reduces the need for purchasing fertilizer, (3) wastewater irrigation involves less energy cost if the alternative clean water source is deep groundwater, or (4) wastewater enables farmers in peri-urban areas to produce high-value vegetables for sale in local markets.

Irrigation with treated wastewater likely will expand in developed countries, particularly in arid and semi-arid areas, where competition for freshwater supplies will continue to increase. Technical solutions and public policies generally are adequate in developed countries to accommodate increases in the treatment and use of wastewater. The same is not true for many developing countries, where treatment facilities already are inadequate, and much of the wastewater used by farmers is not treated.

It is likely that the demand for wastewater as a source of irrigation will increase in arid and semi-arid areas of developing countries at a faster pace than the development of technical solutions and institutions that might ensure the safe distribution and management of wastewater. Thus, the key technical and policy questions in developing countries include those pertaining to better methods for handling untreated wastewater on farms and in farm communities, better recommendations regarding the crops and cultural practices most suitable for settings in which wastewater is the primary source of irrigation, and better methods for protecting farm workers and consumers from the potentially harmful pathogens and chemicals in wastewater.

Technical and policy efforts to improve wastewater treatment, distribution, and management will benefit from better data collection on the part of national and provincial offices regarding wastewater generation, treatment, and use. We have described the current state-of-the-art regarding such data by reviewing the information available in many developing and developed countries. Our goal has been partly to inform those working in the field of wastewater management and partly to encourage public officials and technical specialists to enhance existing programs and implement new efforts to improve data collection and reporting. The issues regarding wastewater generation, treatment, and use will intensify in future, with increasing water scarcity and economic growth. Better data will enable the research and policy community to enhance understanding and craft effective solutions that will benefit millions of producers and consumers, worldwide.

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