Agricultural Water Management 130 (2013) 1–13

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Review

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

Toshio Sato[a], Manzoor Qadir[b,c,d,*], Sadahiro Yamamoto[e], Tsuneyoshi Endo[e], Ahmad Zahoor[a,f]

[a] United Graduate School of Agricultural Science, Tottori University, 4-101, Koyamacho-minami, Tottori, Japan
[b] United Nation University Institute for Water, Environment and Health, 175 Longwood Road South, Hamilton, L8P 0A1 Ontario, Canada
[c] International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5466, Aleppo, Syria
[d] International Water Management Institute (IWMI), P.O. Box 2075, Colombo, Sri Lanka
[e] Faculty of Agriculture, Tottori University, 4-101, Koyamacho-minami, Tottori, Japan
[f] Department of Agriculture, Haripur Campus, Hazara University, Haripur, Pakistan

ARTICLE INFO

*Article history:*
Received 6 July 2012
Received in revised form 5 August 2013
Accepted 7 August 2013
Available online 1 September 2013

*Keywords:*
Water quality
Urban agriculture
Water scarcity
Water recycling
Water reuse

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.



**Contents**



* Corresponding author at: United Nation University Institute for Water, Environment and Health, 175 Longwood Road South, Hamilton, L8P 0A1 Ontario, Canada. Tel.: +1 905 667 5511; fax: +1 905 667 5510.
*E-mail address:* Manzoor.Qadir@unu.edu (M. Qadir).

0378-3774/$ – see front matter 
http://dx.doi.org/10.1016/j.agwat.2013.08.007

## 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 wastewater[1] production, treatment and use; (2) reporting the volumes of wastewater generation, treatment[2] 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; MNRERF, 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; Lekhooana, 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 $km^3$/year) from the year 1993, while World Bank, 2012; WRDLWB (2012) provides more recent information on wastewater treatment in Japan (14.65 $km^3$/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 $km^3$/year as the current estimated volume of wastewater generation in Nepal, and UNMIK (2003) reports 167,000 $m^3$/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'.

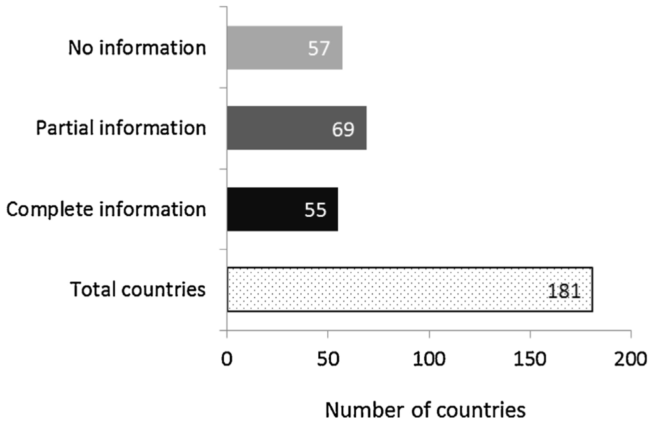


**Fig. 1.** The availability of complete, partial, or no data on wastewater production, treatment, and use. Complete refers to data on all aspects (wastewater production, treatment, and use), while partial refers to data on one or two aspects of wastewater. The data on wastewater production, treatment, 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 $km^3$/year), treatment (3.16 $km^3$/year), and use (0.368 $km^3$/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 $km^3$/year), treatment (4.570 $km^3$/year), and use (0.501 $km^3$/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 $km^3$/year) is smaller than the volume of treated wastewater used (0.117 $km^3$/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 possible that different criteria are used by different organizations in defining wastewater in the same country.

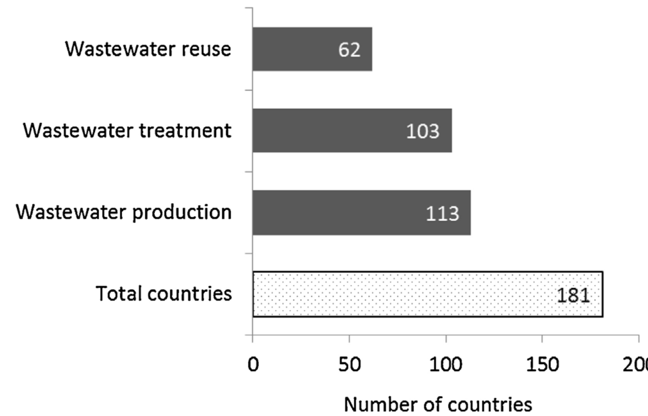


**Fig. 2.** Availability of data regarding each aspect of wastewater production, treatment, and use at the country level.

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.

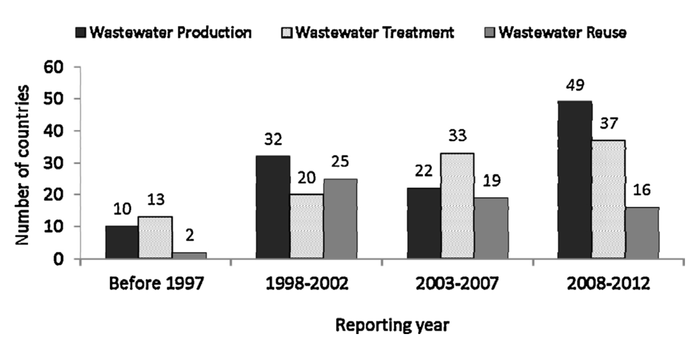


**Fig. 3.** Timeline for data availability on wastewater production, treatment, and use in selected countries.

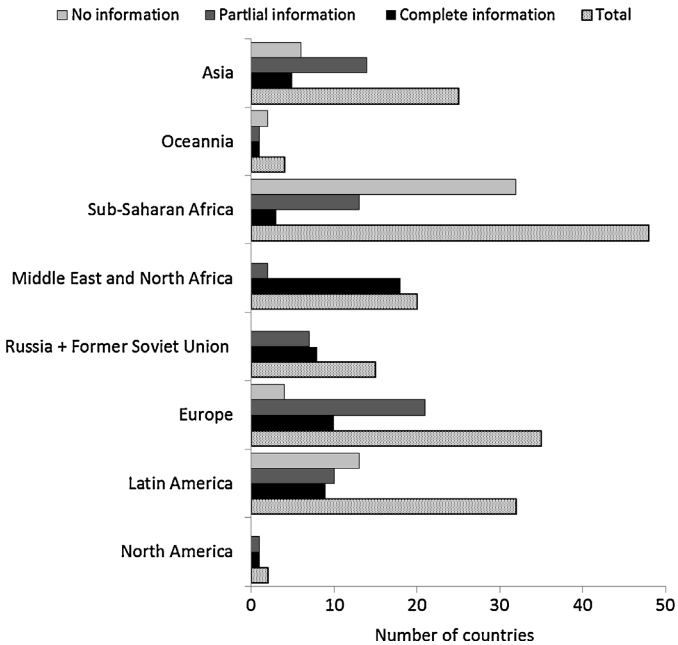


**Fig. 4.** The availability of complete, partial, or no data on wastewater production, treatment, and use. Complete refers to data on all aspects (wastewater production, treatment, and use) and partial refers to data on one or two aspects of wastewater. The data on wastewater production, treatment, 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 $km^3$, of which 61 $km^3$ 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 $km^3$, 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 $km^3$/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

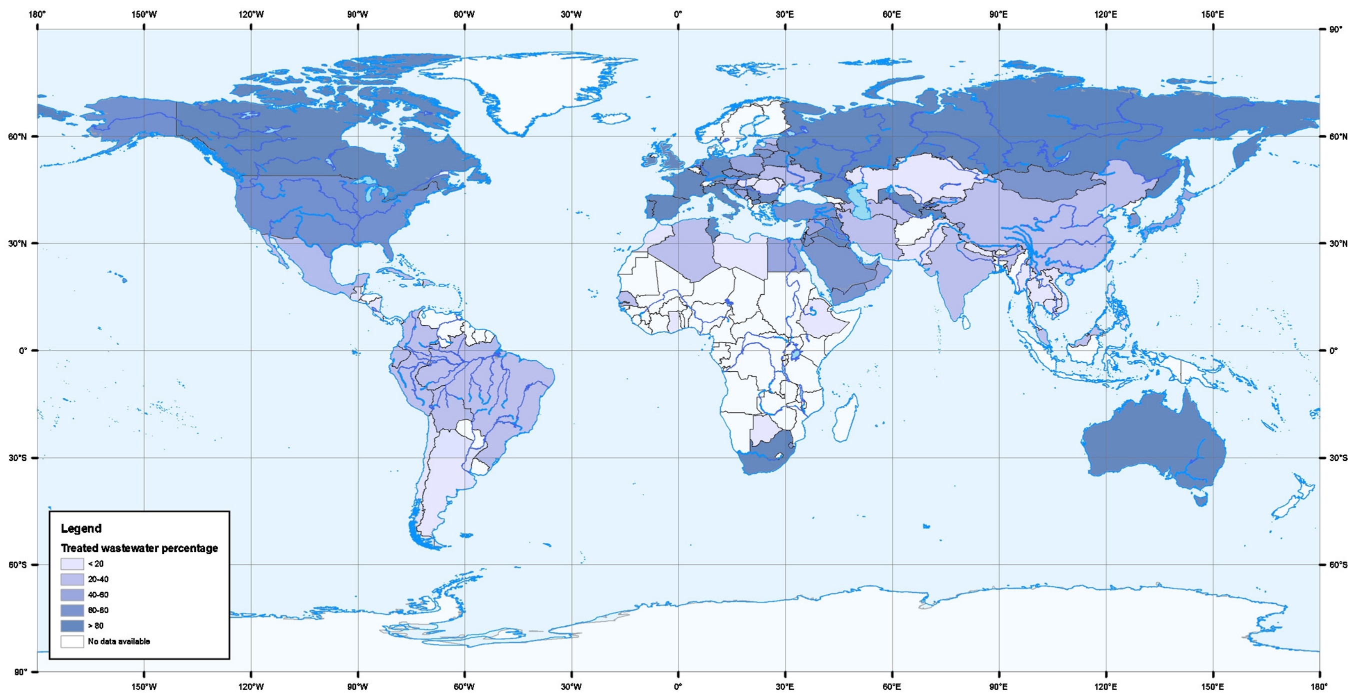


**Fig. 5.** The ratio of treated wastewater to total generated wastewater (expressed as a proportion) in selected countries.
Based on data from FAO-AQUASTAT (2012), EUROSTAT (2012); and references given in Tables 1–8.

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[*] | 2008 | 0.117[*,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 km$^3$/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 km$^3$/year, of which 51% (11.4 km$^3$/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 (RMSSO, 2011).
[m] It may include cooling water. Water abstract for industrial cooling is 3.327 $km^3$ 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 (MNRERF, 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[*] | 2006 | 0.058[*] | 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 $km^3$ 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 counties (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 (Funamiu et al., 2008). In 2009, 0.2 $km^3$ 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.

## Acknowledgments

The first author gratefully acknowledges the Global COE Program 'Global Center of Excellence for Dryland Science' of Japan for the financial support to undertake data collection and preparation of this manuscript. We appreciate very much the helpful comments of two anonymous reviewers, whose contributions have greatly enhanced the quality of our discussion.

## References

Anderson, J., Bradley, J., Radcliffe, J., 2008. Water reuse in Australia and New Zealand. In: Jiménez, B., Asano, T. (Eds.), Water Reuse: An International Survey of Current Practice, Issues and Needs. IWA, London, pp. 105–121.
Angelakis, A.N., Bontoux, L., 2001. Wastewater reclamation and reuse in European countries. Water Policy 3, 47–59.
AQUAREC, 2006. Integrated concepts for reuse of upgraded wastewater: Report on integrated water reuse concepts. AQUAREC. EVK1-CT-2002-00130, Deliverable D19. RWTH Aachen University, Aachen.
Asano, T., Burton, F.L., Leverenz, H., Tsuchihashi, R., Tchobanoglous, G., 2007. Water Reuse: Issues, Technologies, and Applications. McGraw-Hill Professional, New York.
Australian Bureau of Statistics (ABS), 2010. Water Account Australia 2008–2009. http://www.ausstats.abs.gov.au/ausstats/subscriber.nsf/0/D2335EFFE939C9BCCA2577E700158B1C/$File/46100_2008-09.pdf (accessed 07.10.11).
Aziz, A.M., Aws, A., 2012. Wastewater production, treatment and use in Iraq: Country report , Presented at the Second Regional Workshop of the Project 'Safe Use of Wastewater in Agriculture', 16–18 May 2012, New Delhi http://www.ais.unwater.org/ais/mod/page/view.php?id=62 (accessed 21.12.12).
Basandorj, D., 2002. Water Resource Management in Mongolia. In: the National Seminar on Water Quality Improvement, Ulaanbaatar, 12–13 June. Cited by: Dore, G., Nagpal, T., 2006. Urban Transition in Mongolia: Pursuing Sustainability in a Unique Environment. Environment: Science and Policy for Sustainable Development 48, 10–24.
Bennett, A.J., 2000. Environmental consequences of increasing production: some current perspectives. Agriculture, Ecosystems & Environment 82 (1–3), 89–95.
Bixio, D., De heyder, B., Cikurel, H., Muston, M., Miska, V., Joksimovic, D., Schäfer, A.I., Ravazzini, A., Aharoni, A., Savic, D., Thoeye, C., 2005. Municipal wastewater reclamation: where do we stand? An overview of treatment technology and management practice. Water Science and Technology: Water Supply 15, 77–85.
Bixio, D., Thoeye, C., De Koning, J., Joksimovic, D., Savic, D., Wintgens, T., Melin, T., 2006. Wastewater reuse in Europe. Desalination 187, 89–101.
Bryck, J., Prasad, R., Lindley, T., Davis, S., Carpenter, G., 2008. National database of water reuse facilities summary report. Water Reuse Foundation, Alexandria, Virginia.
Central Statistical Bureau of Latvia (CSBL), 2011. Database: Environmental Protection. http://www.csb.gov.lv/ (accessed 21.09.11).
Cornish, G.A., Kielen, N.C., 2008. Wastewater irrigation – hazard or lifeline? Empirical results from Nairobi, Kenya and Kumasi, Ghana. In: Scott, C.A., Faruqui, N.I., Raschid-Sally, L. (Eds.), Wastewater Use in Irrigated Agriculture Confronting the Livelihood and Environmental Realties. CABI-IWMI-IDRC, Wallingford, UK, pp. 69–79.
CROSTAT, 2012. Public sewage system, 2011. http://www.dzs.hr/default_e.htm (accessed 21.12.12).
Czech Statistical Office (CSO), 2012. Water Supply, Sewerage and Watercourses in 2010. http://www.czso.cz/csu/2012edicniplan.nsf/engpubl/2003-12-eng_r_2012 (accessed 21.12.12).
Danso, G., Drechsel, P., Wiafe-Antwi, T., Gyiele, L., 2002. Income of farming systems around Kumasi. Urban Agriculture Magazine 7, 5–6.
Deras, M.A.R., 2012. Wastewater production, treatment and use in El Salvador , Presented at the Forth Regional Workshop of the Project 'Safe Use of Wastewater in Agriculture', 11–13 December 2012, Lima http://www.ais.unwater.org/ais/pluginfile.php/378/mod_page/content/127/EL_SALVADOR.pdf (accessed 21.12.12; in Spanish).
Drechsel, P., Scott, C.A., Raschid-Sally, L., Redwood, M., Bahri, A., 2010. Wastewater Irrigation and Health: Assessing and Mitigating Risk in Low-Income Countries , Earthscan-International Development Research Centre (IDRC)-International Water Management Institute (IWMI).
Ensink, J.H.J., Mahmood, T., Van der Hoek, W., Raschid-Sally, L., Amerasinghe, F.P., 2004. A nation-wide assessment of wastewater use in Pakistan: an obscure activity or a vitally important one? Water Policy 6, 1–10.
Environment Canada, 2010. 2010 Municipal Water Use Report: Municipal Water Use, 2006 Statistics. Environment Canada, Gatineau.
Esteban, R.I., Ortega, E., Batanero, G., Quintas, L., 2010. Water reuse in Spain: data overview and costs estimation of suitable treatment trains. Desalination 263, 1–10.
EUROSTAT, 2012. Generation and discharge of wastewater. http://epp.eurostat.ec.europa.eu/portal/page/portal/environment/data/database (accessed 21.12.12).
Exall, K., Jiménez, B., Marsalek, J., Schaefer, K., 2008. Water reuse in the United States and Canada. In: Jiménez, B., Asano, T. (Eds.), Water Reuse: An International Survey of Current Practice, Issues and Needs. IWA, London, pp. 68–104.
Food and Agriculture Organization of the United Nations (FAO), 2003. Review of World Water resources By Country. Water report 23. FAO, Rome.
FAO, 2005. Irrigation in Africa in figures: AQUASTAT Survey – 2005. Water report 29. FAO, Rome.
FAO, 2010. Current world fertilizer trends and outlook to 2014. FAO, Rome.
FAO, 2011. The wastewater database. http://www.fao.org/nr/water/infores_databases_wastewater.html (accessed 21.09.11).
FAOSTAT, 2012a. Resource STAT. http://faostat.fao.org/site/405/default.aspx (accessed 21.12.12).

FAOSTAT, 2012b. Pop STAT. http://faostat.fao.org/site/550/default.aspx#ancor (accessed 21.12.12).

FAO-AQUASTAT, 2012. Global information system on water and agriculture. http://www.fao.org/nr/water/aquastat/main/index.stm (accessed 21.12.12).

Faruqui, N.I., Niang, S., Redwood, M., 2004. Untreated wastewater use in market gardens: a case study of Dakar, Senegal. In: Scott, C.A., Faruqui, N.I., Raschid-Sally, L. (Eds.), Wastewater Use in Irrigated Agriculture Confronting the Livelihood and Environmental Realties. CABI-IWMI-IDRC, Wallingford, UK, pp. 113–125.

Federation Office of Statistics, Federation of Bosnia and Herzegovina (FOSFBH), 2012. Statistical Yearbook 2012. FOSFBH, Sarajevo.

French Institute for the Environment (FIE), 2012. EA30: Sewage treatment: treatment and sludge (water and sanitation survey). http://www.stats.environnement.developpement-durable.gouv.fr/Eider/series.do# (accessed 21.12.12; in French).

Funamiu, N., Onitsuka, T., Hatori, S., 2008. Water reuse in Japan. In: Jiménez, B., Asano, T. (Eds.), Water Reuse: An International Survey of Current Practice, Issues and Needs. IWA, London, pp. 373–386.

García, L.E., 2006. Water Quality Issues in Latin America. In: Biswas, A.K., Braga, B., Tortajada, C., Rodriguez, D.J. (Eds.), Water Quality Management in the America. Springer, Berlin, pp. 1–15.

Gomez, M.J.L., Campos, S.M., Olarte, B.C., 2012. Wastewater production, treatment and use in Colombia , Presented at the Forth Regional Workshop of the Project 'Safe Use of Wastewater in Agriculture', 11–13 December 2012, Lima http://www.ais.unwater.org/ais/pluginfile.php/378/mod_page/content/127/COLOMBIA.pdf (accessed 21.12.12; in Spanish).

Gyampo, M.A., 2012. Wastewater production, treatment, and use in Ghana , Presented at the Third Regional Workshop of the Project 'Safe Use of Wastewater in Agriculture', 26–28 September 2012, Johannesburg http://www.ais.unwater.org/ais/mod/page/view.php?id=61 (accessed 21.12.12).

Hussain, I., Raschid, L., Hanjra, M.A., Marikar, F., van der Hoek, W., 2001. A Framework for Analyzing Socioeconomic, Health and Environmental Impacts of Wastewater Use in Agriculture in Developing Countries. Working Paper 26, International Water Management Institute, Colombo.

Jiménez, B., 2008. Water reuse in Latin America and the Caribbean. In: Jiménez, B., Asano, T. (Eds.), Water Reuse: An International Survey of Current Practice, Issues and Needs. IWA, London, pp. 177–195.

Jiménez, B., Asano, T., 2008a. Water Reuse: An International Survey of Current Practice, Issues and Needs. IWA, London.

Jiménez, B., Asano, T., 2008b. Water reclamation and reuse around the world. In: Jiménez, B., Asano, T. (Eds.), Water Reuse: An International Survey of Current Practice, Issues and Needs. IWA, London, pp. 3–26.

Joysury, R., Abeeluck, D., Hauzaree, R., 2012. Wastewater production, treatment, and use in Mauritius , Presented at the Third Regional Workshop of the Project 'Safe Use of Wastewater in Agriculture', 26–28 September 2012, Johannesburg http://www.ais.unwater.org/ais/mod/page/view.php?id=61 (accessed 21.12.12).

Kamal, A.S.M., Goyer, K., Koottatep, T., Amin, A.T.M.N., 2008. Domestic wastewater management in South and Southeast Asia: the potential benefits of a decentralized approach. Urban Water Journal 5, 345–354.

Kaur, R., Wani, S.P., Singh, A.K., Lal, K., 2012. Wastewater production, treatment and use in India , Presented at the Second Regional Workshop of the Project 'Safe Use of Wastewater in Agriculture', 16–18 May 2012, New Delhi http://www.ais.unwater.org/ais/mod/page/view.php?id=61 (accessed 21.12.12).

Kayiizzi, R.K., Tomusange, T.M., Paskwale, K.A., Lal, K., 2012. Wastewater production, treatment, and use in Uganda , Presented at the Third Regional Workshop of the Project 'Safe Use of Wastewater in Agriculture', 26–28 September 2012, Johannesburg http://www.ais.unwater.org/ais/mod/page/view.php?id=61 (accessed 21.12.12).

Keraita, B., Drechsel, P., Huibers, F., Raschid-Sally, L., 2002. Wastewater use in informal irrigation in urban and peril-urban areas of Kumasi, Ghana. Urban Agriculture Magazine 8, 11–13.

Lazarova, V., Bahri, A., 2005. Water Reuse for Irrigation: Agriculture, Landscapes, and Turf Grass. CRC Press, Boca Raton, FL.

Lekhooana, L., 2012. Wastewater production, treatment, and use in Lesotho , Presented at the Third Regional Workshop of the Project 'Safe Use of Wastewater in Agriculture', 26–28 September 2012, Johannesburg http://www.ais.unwater.org/ais/mod/page/view.php?id=61 (accessed 21.12.12).

Marka, L., 2012. Wastewater production, treatment and use in Bolivia , Presented at the Forth Regional Workshop of the Project 'Safe Use of Wastewater in Agriculture', 11–13 December 2012, Lima http://www.ais.unwater.org/ais/mod/page/view.php?id=171 (accessed 21.12.12; in Spanish).

McCornick, P.G., Hijazi, A., Sheikh, B., 2004. From wastewater reuse to water reclamation: progression of water reuse standards in Jordan. In: Scott, C.A., Faruqui, N.I., Raschid-Sally, L. (Eds.), Wastewater Use in Irrigated Agriculture. CABI Publishing, UK.

Ministry for the Environment, New Zealand (MENZ), 2003. Sustainable Wastewater Management: A Handbook for Smaller Communities. MENZ, Wellington, pp. 156.

MENZ, 2012. Wastewater. http://www.mfe.govt.nz/issues/waste/wastewater/index.html (accessed 21.12.12).

Ministry of Environment Protection, the People's Republic of China (MEPPRC), 2012. Report on the state of the environment in China 2010. http://english.mep.gov.cn/standards_reports/soe/soe2010/ (accessed 21.12.12).

Ministry of Natural Resources and Ecology of the Russian Federation (MNRERF), 2009. The status and use on water resources Russian Federation in 2008: state report. http://www.mnr.gov.ru/upload/iblock/7ea/4490_gosdoklad_po_vodn._resursam_za_2008_g.pdf?spetial=Y (accessed 21.12.12; in Russian).

Moyo, L.G., 2012. Wastewater production, treatment, and use in Namibia, Presented at the Third Regional Workshop of the Project 'Safe Use of Wastewater in Agriculture', 26–28 September 2012, Johannesburg http://www.ais.unwater.org/ais/mod/page/view.php?id=61 (accessed 21.12.12).

Murtaza, G., 2012. Wastewater production, treatment and use in Pakistan, Presented at the Second Regional Workshop of the Project 'Safe Use of Wastewater in Agriculture', 16–18 May 2012, New Delhi http://www.ais.unwater.org/ais/mod/page/view.php?id=62 (accessed 21.12.12).

Mutengu, S., Hoko, Z., Makoni, F.S., 2007. An assessment of the public health hazard potential of wastewater reuse for crop production. A case of Bulawayo city, Zimbabwe. Physics and Chemistry of the Earth 32, 1195–1203.

National Bureau of Statistics of the Republic of Moldova (NBSRM), 2012. Discharge of sewage, mine and underground drainage waters in natural water reservoirs (2004–2011). http://www.statistica.md/pageview.php?l=en&idc=324&id=2302 (accessed 21.12.12).

National Institute for Water, Portugal (NIWP), 2010. Portuguese acronym for National Inventory on Urban Water Supply and Sewerage Systems. Cited by: National Institute of Statistic (2010) Wastewater discharged (m3) by Geographic localization and Existence of treatment. http://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_indicadores&indOcorrCod=0001879&contexto=bd&selTab=tab2 (accessed 21.12.12).

National Statistics Institute, Spain, 2012. Survey on water supply and sewage. http://www.ine.es/welcoing.htm (accessed 21.12.12).

National Statistical Committee of the Republic of Belarus (NSCRB), 2011. Statistical Yearbook 2011. NSCRB, Minsk, Belarus.

National Statistical Service of the Republic of Armenia (NSSRA), 2012. Statistical Yearbook of Armenia 2012. NSSRA, Yerevan.

Navarrete, P., Viches, R., 2012. Wastewater production, treatment and use in Chile , Presented at the Forth Regional Workshop of the Project 'Safe Use of Wastewater in Agriculture', 11–13 December 2012, Lima http://www.ais.unwater.org/ais/mod/page/view.php?id=171 (accessed 21.12.12; in Spanish).

Nyachhyon, B.L., 2006. Service Enhancement and Development of Sanitary Sewage System in Urban and Semi-Urban Setting in Nepal, Policy Paper 23 , Prepared for Economic Policy Network, Ministry of Finance (MOF)/HMGN, ADB Nepal Resident Mission, pp. 86–94 (Cited by: Tuladhar, B., Shrestha, P., Shrestha, R., 2008. Decentralised wastewater management using constructed wetlands. In: Wicken, J., Verhagen, J., Sijbesma, C., Silva, C.D., Ryan, P. (eds.) 2008. Beyond construction: use by all. A collection of case studies from sanitation and hygiene promotion practitioners in South Asia. IRC, International Water and Sanitation Centre – WaterAid, Delft and London).

Organisation for Economic Co-operation and Development (OECD), 2008. OECD Environmental data: Compendium 2006–2008. http://www.oecd.org/dataoecd/22/55/41878136.pdf (accessed 21.12.12).

Palestinian Economic Council for Development and Reconstruction (PEDCAR), 2001. Water Sector Strategic Planning. Environmental Authority, Palestine (Cited by: Fatta, D., Salem, Z., Mountadar, M., Assobhei, O., Loizidou, M., 2004. Urban wastewater treatment and reclamation for agricultural irrigation: the situation in Morocco and Palestine. Environmentalist, 24, 227–236).

Pérez, A.L., Montás, L.A.R., 2012. Wastewater production, treatment and use in Dominican Republic , Presented at the Forth Regional Workshop of the Project 'Safe Use of Wastewater in Agriculture', 11–13 December 2012, Lima http://www.ais.unwater.org/ais/mod/page/view.php?id=171 (accessed 21.12.12; in Spanish).

Principality of Monaco, Department of Facilities of the Environment and Urban (PMDFEU), 2009. The environment in Principality of Monaco: data collection 2009. http://www.gouv.mc/content/download/7013/108142/file/LEnvironnement%20Recueil%20Donnees%202009-2.pdf (accessed 21.12.12; in French).

Pimentel, D., Bailey, O., Kim, P., Mullaney, E., Calabrese, J., Walman, L., Nelson, F., Yao, X., 1999. Will limits of the Earth's resources control human numbers? Environment, Development and Sustainability 1, 19–39.

Qadir, M., Oster, J.D., 2004. Crop and irrigation management strategies for saline-sodic soils and waters aimed at environmentally sustainable agriculture. Science of the Total Environment 323, 1–19.

Qadir, M., Sharma, B.R., Bruggeman, A., Choukr-Allah, R., Karajeh, F., 2007a. Non-conventional water resources and opportunities for water augmentation to achieve food security in water scarce countries. Agricultural Water Management 87, 2–22.

Qadir, M., Wichelns, D., Raschid-Sally, L., Minhas, P.S., Drechsel, P., Bahri, A., McCornick, P., 2007b. Agricultural use of marginal-quality water – opportunities and challenges. In: Molden, D. (Ed.), Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture. Earthscan, London, pp. 425–457.

Qadir, M., Wichelns, D., Raschid-Sally, L., McCornick, P.G., Drechsel, P., Bahri, A., Minhas, P.S., 2010a. The challenges of wastewater irrigation in developing countries. Agricultural Water Management 97, 561–568.

Qadir, M., Bahri, A., Sato, T., Al-Karadsheh, E., 2010b. Wastewater production, treatment, and irrigation in Middle East and North Africa. Irrigation and Drainage Systems 24, 37–51.

Raschid-Sally, L., Doan, D.T., Abayawardana, S., 2004. National assessments on wastewater use in agriculture and an emerging typology: the Vietnam case study. In: Scott, C.A., Faruqui, N.I., Raschid-Sally, L. (Eds.), Wastewater Use in Irrigated Agriculture Confronting the Livelihood and Environmental Realties. CABI-IWMI-IDRC, Wallingford, UK, pp. 81–90.

Raschid-Sally, L., Jayakody, P., 2008. Drivers and Characteristics of Wastewater Agriculture in Developing Countries: Results from a Global Assessment. Research Report 127. International Water Management Institute, Colombo.

Republic of Macedonia, State Statistical Office (RMSSO), 2011. Environmental statistics, 2011. RMSSO, Skopje.

Rosegrant, M.W., Ringler, C., 2000. Impact on food security and rural development of transferring water out of agriculture. Water Policy 1, 567–586.

Rijsberman, F.R., 2006. Water scarcity: fact or fiction? Agricultural Water Management 80, 5–22.

Saloua, R., 2012. National Report: Tunisia , Presented at the First Regional Workshop of the Project 'Safe Use of Wastewater in Agriculture', 18–19 February 2012, Marrakech http://www.ais.unwater.org/ais/mod/page/view.php?id=59 (accessed 21.12.12; in French).

Scott, C.A., Faruqui, N.I., Raschid-Sally, L., 2004. Wastewater use in irrigation agriculture: management challenges in developing countries. In: Scott, C.A., Faruqui, N.I., Raschid-Sally, L. (Eds.), Wastewater Use in Irrigated Agriculture Confronting the Livelihood and Environmental Realties. CABI-IWMI-IDRC, Wallingford, UK, pp. 1–10.

Shrivastava, P., Swarup, A., 2001. Management of wastewater for environmental protection of freshwater resources: an approach for tropical countries both developing and undeveloped , International Conference on Freshwater, 3–7 December, Bonn (Cited by: Kamal, A.S.M., Goyer, K., Koottatep, T., Amin, A.T.M.N., 2008. Domestic wastewater management in South and Southeast Asia: the potential benefits of a decentralized approach. Urban Water Journal, 5, 345–354).

Solley, W.B., Pirce, R.R., Perlman, H.A., 1998. Estimated Use of Water in the United States in 1995. U.S. Geological Survey Circular, 1200. U. S. Geological Survey, Colorado.

Souare, M.M., Sambe, L., Mbaye, M., Balde, D., 2012. National Report: Senegal , Presented at the First Regional Workshop of the Project 'Safe Use of Wastewater in Agriculture', 18–19 February 2012, Marrakech http://www.ais.unwater.org/ais/mod/page/view.php?id=59 (accessed 21.12.12).

Statistics Netherlands, 2012. Urban waste water treatment per province and river basin district. http://statline.cbs.nl/StatWeb/publication/?DM=SLEN&PA=7477ENG&D1=24,42&D2=a,!1-16&D3=l&LA=EN&VW=T (accessed 21.12.12).

Statistical Office of Montenegro (MONSTAT), 2010. Statistical Year Book 2010. MONSTAT, Podgorica.

Statistical Office of the Republic of Serbia (SORS), 2012. Statistical Year Book 2010. SORS, Belgrade.

Statistical Office of the Republic of Slovenia (SORSi), 2012. Environment, energy, and transport in figures. http://www.stat.si/doc/pub/OET-ANG.pdf (accessed 21.12.12).

Stolberg, F., Borysova, O., Mitrofanov, I., Barannik, V., Eghtesadi, P., 2006. Global international water assessment: Caspian Sea, GIWA Regional assessment 23. http://www.unep.org/dewa/giwa/areas/reports/r23/giwa_regional_assessment_23.pdf (accessed 21.12.12).

Strauss, M., Blumenthal, U.J., 1990. Use of human wastes in agriculture and aquaculture: utilization practices and health perspectives , International Reference Centre for Waste Disposal (IRCWD) report No 08/90, IRCWD, Dübendorf.

State Water Resources Control Board (SWRCB), California, 2009. Recycled Water Policy. http://www.swrcb.ca.gov/water_issues/programs/water_recycling_policy (accessed 21.12.12).

Tajrishy, M., 2012. Wastewater production, treatment and use in Iran , Presented at the Second Regional Workshop of the Project 'Safe Use of Wastewater in Agriculture', 16–18 May 2012, New Delhi http://www.ais.unwater.org/ais/mod/page/view.php?id=62 (accessed 21.12.12).

The State Committee of Statistics of Ukraine (SCSU), 2012. Main indicators on the water resources use and protection. http://www.ukrstat.gov.ua/ (accessed 21.12.12).

Tong, B.C., 2012. Wastewater production, treatment and use in Peru, Presented at the Forth Regional Workshop of the Project 'Safe Use of Wastewater in Agriculture', 11–13 December, Lima. http://www.ais.unwater.org/ais/mod/page/view.php?id=171 (accessed 21.12.12, in Spanish).

TURKSTAT, 2012. Environment statistics; Municipal Wastewater Statics. http://www.turkstat.gov.tr/Start.do;jsessionid=hkLSRRjHdxhhKXPhMZLTwYG0w6SRJ5HLT2bGZdlpB0L0khfYB9tY!-1381182142 (accessed 21.12.12).

Ulimat, A.A., 2012. Wastewater production, treatment and use in Jordan , Presented at the Second Regional Workshop of the Project 'Safe Use of Wastewater in Agriculture', 16–18 May 2012, New Delhi http://www.ais.unwater.org/ais/mod/page/view.php?id=62 (accessed 21.12.12).

United Nations (UN), 2000. Wastewater management policies and practices in Asia and the Pacific , Water Resources Series No 79, UNESCAP, Bangkok.

UN, 2012. Population connected to wastewater collecting system. http://unstats.un.org/unsd/environment/wastewater.htm (accessed 21.12.12).

UN Department of Economic and Social Affairs, Division for Sustainable Development (UNDESA-DSD), 2004. Sanitation Country Profile: Russian Federation. http://www.un.org/esa/agenda21/natlinfo/countr/russia/RussiaSanitation04f.pdf (accessed 21.12.12).

UN Economic Commission for Europe (UNECE), 2001. Environmental Performance Reviews: Uzbekistan. UN Publication, New York and Geneva.

UNECE, 2003. Environmental Performance Reviews: Georgia. UN Publication, New York and Geneva.

UNECE, 2009. Environmental Performance Reviews: Kyrgyzstan Second Review. UN Publication, New York and Geneva.

UN Interim Administration Mission in Kosovo (UNMIK), 2003. Kosovo: State of the Environment Report. http://enrin.grida.no/htmls/kosovo/Kosovo_SOE_part1.pdf (accessed 21.12.12).

United State Environmental Protection Agency (USEPA), 2004. Guidelines for Water Reuse. EPA/625/R-04/108, USEPA, Washington, DC.

USEPA, 2012. 2012 Guidelines for Water Reuse. USEPA, Cincinnati, OH: National Risk Management Research Laboratory. USAID (EPA/600/R-12/618), Washington, DC.

van der Hoek, W., 2004. A framework for a global assessment of the extent of wastewater irrigation: the need for a common wastewater typology. In: Scott, C.A., Faruqui, N.I., Raschid-Sally, L. (Eds.), Wastewater Use in Irrigated Agriculture Confronting the Livelihood and Environmental Realties. CABI-IWMI-IDRC, Wallingford, UK, pp. 11–24.

Van Rooijen, D.J., Biggs, T.W., Smout, I., Drechsel, P., 2010. Urban growth, wastewater production and use in irrigated agriculture: a comparative study of Accra, Addis Ababa and Hyderabad. Irrigation and Drainage Systems 24, 53–64.

Water Environment Partnership in Asia (WEPA), Institute for Global Environmental Strategies Ministry of the Environment, Japan (IGES), 2012. WEPA Outlook on water environmental management in Asia 2012. http://www.wepa-db.net/pdf/1203outlook/01.pdf (accessed 21.12.12).

Water Resource Department of Land and Water Bureau (WRDLWB), Ministry of Land, Infrastructure, Transport and Tourism, Japan, 2012. Water Resources in Japan, 2012. http://www.mlit.go.jp/tochimizushigen/mizsei/hakusyo/index5.html (accessed 21.12.12; in Japanese).

World Bank (WB), 1999. Ukraine: Restoring Growth with Equity: A Participatory Country Economic Memorandum. WB, Washington, DC.

WB, 2012. The World Bank data; GNI per capita, Atlas method (current US$). http://data.worldbank.org/indicator/NY.GDP.PCAP.CD (accessed 21.12.12).

Westcot, D.W., 1997. Quality Control of Wastewater for Irrigated Crop Production. Water Reports 10. FAO, Rome, pp. 86.

World Health Organization (WHO), 2007. Diarrhea: Why Children are still Dying and What can be Done. WHO, Geneva.

WHO, 2008. The Global Burden of Disease: 2004 Update. WHO, Geneva.

WHO, United Nations Children's Fund (UNICEF), 2012. Joint Monitoring Programme (JMP) for water supply and sanitation. http://www.wssinfo.org/data-estimates/table/ (accessed 21.12.12).