Chapter 6
Policy and Institutional Determinants of Wastewater Use in Agriculture

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Abstract We describe policies, interventions, and institutions pertaining to wastewater use in agriculture, with particular emphasis on low and middle income countries. Designing policies and implementing interventions are challenging in such countries, where most of the wastewater used for irrigation is untreated and much of the use is informal and unintentional. Farmers, communities, and consumers are at risk from harmful constituents in the untreated wastewater, yet each group also obtains important benefits. There are no simple or easily affordable policy choices regarding the use of untreated wastewater in developing countries, particularly where the institutional support for wastewater collection, treatment, and reuse also is not yet well developed. In many countries, the responsibilities for wastewater management are shared among several ministries or agencies, and there is too little coordination regarding policies and programs pertaining to wastewater. Legislation alone is not sufficient in motivating or enabling greater use of wastewater in agriculture. Guidelines or regulations regarding specific water quality criteria, monitoring programs, and enforcement plans also are needed to provide farmers and consumers with the information and assurances needed to engender widespread support for wastewater irrigation.

Keywords Wastewater policies · Institutions · Legislation · Regulations · Costs

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6.1 The Rationale

Many farmers in developing countries use untreated wastewater for irrigation, often because it is the only source of water available. Many small-scale farmers obtain irrigation water from streams or ditches that are polluted with effluent from a nearby city, industry, or housing development. Polluted waterways are common in many developing countries, as wastewater treatment is not yet widely practiced. The average estimated rates of wastewater treatment are just 8 % in low-income countries and 28 % in lower-middle-income countries (Sato et al. 2013).

Most farmers irrigating with untreated wastewater likely would prefer higher quality water, but in most cases they have no alternative source. There can be agronomic value in the nitrogen and phosphorus in the untreated wastewater, but there are also pathogens and chemicals that threaten the health of farmers, food vendors, and consumers. Irrigating with untreated wastewater is risky business in developing countries, yet it generates household income for families with limited livelihood alternatives. Many farmers irrigating with untreated wastewater likely would vote to continue using the wastewater, even if they understood the risks, in the absence of an alternative, higher quality source.

In a sense, farmers using untreated wastewater provide a public service by removing effluent from polluted streams and applying it to soils, thus reducing the pollutant load in downstream locations. However, wastewater irrigation also generates risk for farm communities and consumers of farm products. Polluted canals and ditches, and wastewater-irrigated fields create hazards in which children and other residents are exposed to harmful pathogens and chemicals (Grangier et al. 2012). Consumers of farm produce also are at risk of illness when they handle and ingest contaminated vegetables, particularly when the food is eaten raw or prepared with inadequate care toward reducing contamination risk.

In this chapter, we describe the important roles of policies and institutions in motivating and assuring the safe use of wastewater in agriculture, with particular emphasis on low and middle income countries. The policy issues in higher income countries are somewhat straightforward and mature, as public agencies have largely determined appropriate water quality criteria and implemented treatment protocols to support wastewater use in irrigation. Future issues will include refining those standards and protocols and evaluating the costs and benefits of alternative levels of wastewater treatment and use in agriculture and other activities. There will also be discussions of who should pay for wastewater treatment and who should have priority in receiving limited supplies of treated wastewater. Those issues involve costs, returns, and the allocation of economic rents, but they generally do not involve decisions that can support or destroy livelihood opportunities, either intentionally, or as the unintended consequences of seemingly beneficial policy choices.

Policy issues are more challenging in developing countries, where most of the wastewater used for irrigation is untreated and much of the use is informal and unintentional (Wichelns and Drechsel 2011). In addition, institutional arrangements are

unclear and few specialists are trained to manage wastewater collection and treatment. Farmers, communities, and consumers are at risk from harmful constituents in the untreated wastewater, yet each group also obtains important benefits (Scheierling et al. 2011). Farmers generate financial returns that enhance their livelihoods and improve the economic status of farm communities. Consumers gain nutritional value by having affordable access to locally grown fresh vegetables (Weldesilassie et al. 2011). The public, more generally, benefits also when farmers divert effluent for use in irrigation, rather than allowing it to continue flowing downstream.

Public funding for treating all wastewater will not be available in many regions within the foreseeable future. Lacking the treatment alternative, public agencies must identify measures that will reduce the risks of using untreated wastewater, while maintaining the benefits that accrue to farmers, consumers, and the larger community (Drechsel and Seidu 2011). The best policies and programs will address both farm-level and societal concerns regarding the costs and benefits of wastewater irrigation. Farmers will seek assurances that they can maintain their access to wastewater for irrigation, while consumers will need assurances that the crops irrigated with wastewater are safe to consume. Crafting policies that address both sets of concerns will be challenging in some settings. Yet the potential rewards of implementing successful risk reduction measures that will enable the safe and profitable use of wastewater in agriculture are substantial.

6.2 A Conceptual Framework

From a policy perspective, the use of wastewater in agriculture provides opportunities and challenges that require public intervention. In one sense wastewater is an effluent requiring treatment or disposal, subject to regulations that protect public health. In the absence of regulations, private generators of wastewater would have little incentive to reduce volume or to manage the flow of wastewater beyond their property line. Because wastewater generation is a negative externality in most settings, regulations and incentives are needed to minimize the potential harm from wastewater in the environment.

Wastewater management has public good characteristics in that once it is provided, many members of society benefit. At the same time, it is difficult to exclude individuals from enjoying the benefits of a cleaner, healthier environment once the decision has been made to collect and treat all wastewater in a community. The non-rival nature of the benefits and the difficulty of exclusion provide the basis for managing wastewater treatment within the public sector.

The public goods perspective is appropriate when viewing wastewater as an effluent requiring treatment or disposal. However, when viewing wastewater as a resource, there are notable private benefits for which individuals will be willing to invest time, effort, and funding to enhance their opportunities. The private goods perspective pertains to both treated and untreated wastewater. Several water agencies in Australia, Israel, and the United States sell treated wastewater (directly or

through an aquifer recharge program) to farmers and golf course owners who obtain private benefits through irrigation (Mills et al. 2004; van Roon 2007). Often there is a price differential between treated wastewater and fresh water, thus providing a financial incentive for irrigators to select the treated wastewater (Hurlimann and McKay 2007).

Farmers in developing countries also obtain private benefits, but the distribution of wastewater among them is much less formal and the wastewater generally has not been treated. An estimated 80 % of the sewage generated in developing countries is discharged untreated into the environment, and half the population is exposed to polluted water sources (UNESCO 2003; Drechsel and Evans 2010). Many farmers acquire untreated wastewater when they divert irrigation water from a stream or ditch that carries effluent from a nearby city or from households in an urban, peri-urban, or rural area. Water diversions and the use of wastewater in such settings generate private benefits for the farmers. The public gains also as the farmers remove the low-quality water from streams and ditches. However, the primary motivation for farmers is to boost their productivity and increase their net returns. By doing so, they risk the health of their families through exposure to untreated wastewater and they create situations in which consumers also are at risk of eating harmful produce. Public policies are needed to reduce these risks and to optimize the management of wastewater from the public's perspective.

6.3 Policy Challenges in Low and Middle Income Countries

Policy issues pertaining to wastewater irrigation in developing countries are notably challenging, in part, because much of the wastewater irrigation takes place in decentralized, informal settings in which individual farmers gain access to wastewater simply by diverting polluted water from a stream or ditch. Property rights to the water are not defined and there is no communal agency or water user association that coordinates irrigation activities. Millions of individual farmers will be reluctant to stop diverting polluted water for use in irrigation, given that their livelihoods depend on the sale of irrigated farm produce. In addition, financial resources are limited in developing countries and there are many competing demands on public funds. Thus, it is unlikely that large gains will be made in treating wastewater in the near future.

Public officials in developing countries must determine how to minimize the risks to farmers and consumers, while not destroying or severely diminishing the livelihoods of those farmers who currently irrigate with wastewater. This will not be easily achieved. Public officials will be mindful of the benefits that farmers provide by diverting and using polluted water for irrigation. If not for that activity, larger volumes of wastewater would continue flowing downstream in many watercourses, creating greater risk for downstream residents and causing environmental harm over a larger area. Farmers who irrigate with wastewater generate one set of risks for their families and consumers, while reducing another set of risks to residents downstream.

In summary, farmers generate both private and public benefits when they divert polluted water from streams and ditches to irrigate crops in urban areas. Public officials in developing countries must determine how to sustain these beneficial aspects of wastewater irrigation and the livelihoods of farm families, while minimizing risks to those same families and the consumers of their produce.

6.4 Interventions Include Treatment and Non-treatment Alternatives

The interventions available to public officials for reducing the risks associated with wastewater irrigation in developing countries, while sustaining livelihood benefits, might be placed in four categories:

1. Improve and extend centralized wastewater treatment
2. Improve and extend de-centralized wastewater treatment
3. Regulate (with enforcement) the use of untreated wastewater in agriculture
4. Complement existing wastewater use patterns with risk reduction interventions to protect farm families, communities, and consumers

The first category is likely the most costly and the least likely to be implemented along a reasonable timeline. There might be affordable opportunities in some settings within developing countries, in which new, large-scale wastewater treatment plants can be constructed to improve the quality of water available for agriculture. Yet it seems that if such opportunities were affordable, if they compared favorably with alternative public investments, and if an affordable source of finance were available, then such efforts would already be underway. It is difficult to imagine that the pace of investments in large, centralized wastewater treatment plants will be sufficient to improve water quality for many of the farmers who currently use wastewater for irrigation in developing countries.

Some developing countries are beginning to invest in wastewater collection, treatment, and reuse systems. For example, in the Mezquital Valley, Mexico where about 90,000 ha are irrigated largely with untreated wastewater, the government has invested in wastewater treatment. Initiated in 2010 on the basis of a build-operate-transfer contract, a large wastewater treatment plant is under construction, and is expected to be completed in 2015 (see also Chap. 9 of this book).

The second category includes interventions that should be more affordable than building large, centralized wastewater treatment plants. The goal within this category is to identify opportunities for enhancing irrigation water quality at an appropriate scale and within a meaningful distance from the point of wastewater use. Small-scale wastewater treatment plants might be designed with the expressed purpose of making higher quality water available for irrigation. The construction costs and operating criteria for such plants might be different—and less expensive—than those pertaining to centralized wastewater treatment plants that discharge water intended for uses outside agriculture (van Lier and Huibers 2010). For example, it

is important to remove solids, salts, and pathogens from water intended for use in irrigation, but farmers can accommodate higher nutrient levels than wastewater users in municipal and industrial settings.

The third category likely will be challenging in many developing country settings, given the decentralized, informal nature of wastewater use and the strong dependency of farm households on wastewater. Regulations will be politically unpopular and enforcement will be difficult to achieve. In Syria, for example, the government disallows the irrigation of vegetables with wastewater, but compliance with the restriction is not complete. Syrian officials resort to destroying vegetable crops irrigated with wastewater when they find such situations. As a result, less than 7% of the area irrigated with wastewater near the city of Aleppo is in vegetable production (Qadir et al. 2010). The opportunity costs involved in planting and cultivating crops, only to have them destroyed by the government, can be substantial for farm households with limited sources of income.

The financial burden of treating wastewater in developing countries and the challenge of regulating wastewater use by farmers will remain substantial for the foreseeable future. Hence, many farmers will continue using wastewater and their workers and families will remain at risk of infection while applying irrigation water. Consumers will remain susceptible to sickness caused by handling and consuming the irrigated produce. Given this near-term outlook, public agencies in developing countries should seek opportunities to reduce the risks of infection and sickness by intervening at selected stages of the process that includes wastewater generation, capture, irrigation, crop production, harvest and handling, and food preparation and consumption. Thus we focus on the fourth category of policy options—reducing risk to farm households, communities, and consumers.

6.5 Interventions Should Focus on Reducing Risk

Conventional wastewater treatment might be viewed as the ultimate risk reduction measure when considering the use of wastewater in irrigation (Keraita et al. 2010a). Establishing and enforcing water quality standards, in conjunction with a wastewater treatment program, can be effective in removing potentially harmful constituents. However, the cost of treating wastewater and enforcing water quality standards will exceed affordability in many developing countries. Recognizing this challenge, the World Health Organization recommends shifting the policy focus from reliance on wastewater treatment and water quality standards, to establishing health-based targets that might be achieved by implementing a range of risk reducing interventions (WHO 2006a; Keraita et al. 2010a).

The World Health Organization (WHO 2006b) describes three sets of health protection measures pertaining to the three groups most susceptible to health impacts of wastewater irrigation: (1) farmers and their families, (2) agricultural communities, and (3) consumers of farm products. We consider each group in turn.

6.5.1 Farmers and Their Families

When delivering irrigation water or working in fields irrigated with wastewater, farmers, family members, and other farm workers can be exposed to microbial pathogens including viruses, bacteria, helminths (nematodes and tapeworms), and protozoa (Toze 2006). Wastewater also can contain endocrine disrupting chemicals, pharmaceutically active compounds, and residuals of personal care products (Ternes et al. 2007; Lapen et al. 2008; Siemens et al. 2008; Topp et al. 2008). Exposure to wastewater can result in skin irritation and diseases related to pathogens in human waste products. The World Health Organization (WHO 2006b) recommends considering the following measures when designing interventions to protect farmers and their families:

1. Treating wastewater
2. Supporting the use of personal protective equipment
3. Providing access to safe drinking water and sanitation on farms
4. Promoting good health and hygiene practices
5. Providing chemotherapy[1] and immunization
6. Controlling disease vectors and intermediate hosts
7. Reducing contact with disease vectors

One or more of these measures would be helpful in breaking or disrupting the pathway of contamination from wastewater to farm family members and farm workers. However, success will be determined by how effectively the benefits of these measures are communicated to farmers, and how aggressively farm workers adopt them. The farm-level cost of any measure also will be a key determinant of its successful adoption.

6.5.2 Agricultural Communities

In a sense, many residents of agricultural communities are susceptible to the same type of risks as farmers and their families, particularly if they utilize water in irrigation canals or ditches, or they have access to farm fields. In many irrigated areas, community residents use water from irrigation canals or ditches for cleaning clothes, washing livestock, and watering kitchen gardens (Meinzen-Dick and van der Hoek 2001). Young children often swim or play in irrigation ditches, while some residents rely on irrigation canals as a source of household drinking water (Senzanje et al. 2008). The lack of knowledge regarding the potential health risks in many rural and peri-urban settings, and the scarcity of fresh water supplies, create situations in which many residents are at substantial risk. The World Health Organization (WHO 2006b) recommends the following measures to protect members of agricultural communities:

[1] The term refers in this context to the use of, for example, deworming tablets, i.e. chemical treatment of infections.

1. Treating wastewater
2. Restricting access to irrigated fields and canals and ditches
3. Providing safe recreational water, particularly for adolescents
4. Providing safe drinking water and sanitation facilities to communities
5. Promoting good health and hygiene practices
6. Providing chemotherapy and immunization
7. Controlling disease vectors and intermediate hosts
8. Reducing contact with disease vectors

Several of these measures are similar to those recommended to protect farm families and farm workers, given the similarity in exposure opportunities on farms and in the larger community. Many of the challenges involved in implementing the measures and encouraging sustainable adoption also would be similar.

6.5.3 Consumers of Farm Products

In many settings, in the absence of policy intervention, consumers might be the least informed group regarding the potential health risks due to wastewater irrigation. They might be unaware that farmers using wastewater have produced some of the fruits and vegetables for sale in local markets. They might also be unaware that some of the farm produce carries harmful pathogens and chemicals, or that cooking the produce might reduce the likelihood of damage from infectious pathogens. Given these considerations, the World Health Organization (WHO 2006b) recommends the following measures to reduce the risk to consumers:

1. Treating wastewater
2. Restricting the crops that are irrigated with wastewater
3. Promoting irrigation practices that minimize contamination of plants
4. Implementing withholding periods that allow pathogens to die between the last irrigation and harvest
5. Promoting hygienic practices at food markets and during food preparation
6. Promoting good health and hygiene practices
7. Promoting produce washing, disinfection, and cooking
8. Providing chemotherapy and immunization.

Although enforcement will be difficult, public agencies might consider disallowing wastewater irrigation of vegetables and other crops that consumers often eat without cooking. Leafy vegetables, such as lettuce and spinach, are particularly prone to accumulating pathogens on edible portions of the plant when wastewater is applied directly over the plants and when irrigators splash contaminated soil particles on the leaves (Keraita et al. 2010b). Modifying the spouts of watering cans will reduce contamination by reducing the splashing of soil particles (Keraita et al. 2010b). Drip irrigation on the soil surface or below ground will minimize contamination (Capra and Scicolone 2007), but many poor farmers will not have the funds to invest in such systems.

Withholding periods between the date of last irrigation and harvest are sensible approaches, as well, but monitoring and enforcement might be problematic in areas where wastewater irrigation is prevalent. Some farmers report that irrigating lettuce on the morning of the day of harvest freshens the crop and enhances its appearance in local markets (Keraita et al. 2010b). Encouraging farmers to change such practices will be challenging, particularly given the perishable nature of leafy vegetable crops. Farmers generally want to obtain the highest price possible and to sell their produce quickly, before its appearance and quality begin to fade.

Public efforts to improve hygienic practices and food preparation at homes and in the marketplace also will be challenging. In areas where small-scale farmers sell produce to small-scale vendors who re-sell the produce in a restaurant or fast-food outlet, individuals have little incentive to assume the extra cost of enhanced food treatment. This situation in which information is limited and asymmetric, can be described also an externality involving producers and consumers. The benefits of a cleaner, safer food supply accrue to consumers and communities, rather than to the farmers and food shop owners who will incur higher costs if they implement improved production, washing, and handling practices. Public policy is needed to ensure that farmers and vendors internalize the external costs of their activities.

6.6 Examples of Public Policies

Helpful examples of public policies regarding wastewater use in irrigation are found in the Middle East and North Africa, and other regions where farmers have been using treated and untreated wastewater for many years. In some countries, such as Egypt, the volume of municipal wastewater exceeds the treatment capacity, and large volumes of untreated wastewater enter agricultural drains (Abdel-Dayem et al. 2007). The government attempts to manage the blending of treated and untreated wastewater with agricultural drainage water, and the use of blended water by farmers, but success is limited by the scale of the problem and the strong demand for supplemental water supplies in the Nile Delta. Irrigation with treated wastewater will increase over time, with the expansion of wastewater treatment capacity.

The Palestinian Ministry of Agriculture, which regulates the use of treated wastewater on the West Bank, requires color coding of pipelines carrying fresh water and wastewater, and the posting of lands irrigated with treated wastewater (Mizyed 2013). In addition, farmers irrigating with treated wastewater are required to wear protective clothing, although it is not clear if the monitoring and enforcement of the clothing regulation is effective. The extent of wastewater treatment and use in agriculture on the West Bank is limited partly by the lack of funding for treatment facilities and also by limited public acceptance of wastewater irrigation (McNeill et al. 2009).

Several countries in the region, including Algeria, Cyprus, and Tunisia, do not allow the irrigation of vegetables with treated wastewater. Cyprus also disallows the irrigation of ornamental plants destined for sale in international markets (Angelakis et al.1999). Wastewater policies are well developed in Cyprus and Tunisia, where

the governments actively support and regulate wastewater treatment and use. In Cyprus, the government pays for large portions of the cost of water treatment plants in cities and villages, while also paying for the distribution of wastewater to farmers (Bazza 2003). Tunisia requires that industries comply with wastewater discharge standards designed to support reuse on farms, golf courses, and landscapes, and also for aquifer recharge (Bazza 2003). Saudi Arabia plans to use all of its treated wastewater, primarily in agriculture. The city of Muscat in Oman has installed an extensive drip irrigation system for irrigating landscapes with treated municipal wastewater (Bakir 2001).

Several autonomous provinces in Spain have developed legal prescriptions or recommendations regarding wastewater use in agriculture (Angelakis et al. 2003). Wastewater accounts for an estimated 41 % of the irrigation water used on Spanish golf courses (Rodriguez Diaz et al. 2007). Much of the agricultural use of wastewater in Spain occurs along its arid Mediterranean coast and on nearby islands (Pedrero et al. 2010).

In Italy, legislators have acknowledged the potential value of treated wastewater use in irrigation, yet the implementing regulations are not sufficiently accommodative to promote widespread use of wastewater by farmers (Cirelli et al. 2012). In particular, there are many water quality parameters to be considered (54) and there is no allowance made for the impacts of alternative methods of irrigation on the likelihood of harm when applying wastewater. The same regulations apply to farmers using furrow irrigation and to those using sprinklers or drip systems. Yet the likelihood of contaminating vegetables is much smaller with drip irrigation, as less wastewater comes in contact with the plants. The government of Botswana has encouraged greater use of wastewater in irrigation and mining, in part, by ending its policy of providing fresh water supplies at subsidized prices (Swatuk and Rahm 2004). Botswana also is considering how to account for wastewater volumes within its national water accounting framework (Arntzen and Setlhogile 2007).

The city of Beijing, China uses a combination of administrative orders and financial incentives to motivate greater use of wastewater, as part of its strategy to accommodate increasing water demands. Households and industries in Beijing can purchase treated wastewater for 1 RMB per m^3 ($ 0.16), which is much lower than the prices of 4.0 RMB per m^3 for conventional water for household use and 6.2 per m^3 for industrial use (Chang and Ma 2012). Farmers can purchase treated wastewater for 0.05 RMB per m^3 ($ 0.008), which is less than the cost of pumping groundwater in agricultural areas of the city. Since 2003, the proportion of treated wastewater in Beijing's water deliveries has increased from 5.7 to 19.3 % (Chang and Ma 2012).

Beijing's progressive development of wastewater use has been motivated, in part, by a management directive issued by the city in 2009. The directive addresses the sectoral allocation of wastewater and calls for constructing safe distribution channels, as stated in four key points (Chang and Ma 2012):

1. Treated wastewater will be integrated into the city's water allocation system, and will be blended with surface water and groundwater.

2. Treated wastewater will be used primarily in industry and agriculture, and also for landscaping and to supplement lakes and rivers.
3. Wastewater suppliers and users will be guided by contracts they sign for the purchase and delivery of treated wastewater.
4. The delivery channels for wastewater must be constructed to ensure that water quality is maintained.

Not all efforts to implement wastewater treatment and management are successful as the program in Beijing. In the city of Hermosillo, Mexico, farmers lacking access to freshwater supplies continue to irrigate with untreated wastewater, despite several attempts by the city to fund and construct a water treatment plant (Scott and Pineda Pablos 2011). Absent that investment, much of the city's wastewater is discharged into irrigation canals managed by an irrigation district, which charges farmers a fee for the wastewater they divert. The farmers are pleased to have any source of irrigation water, although their production options are constrained to fodder crops, due to uncertainties regarding health effects and the possible deterioration in soil quality, over time.

Also in Mexico, farmers irrigating crops near the city of Durango have increased their production of corn, alfalfa, and oats by using treated wastewater during periods of drought (Heinz et al. 2011). In addition to achieving a 30 % increase in output, the farmers have reduced their fertilizer use by about 50 %. The city benefits, as well, from the reduced demand pressure on its limited groundwater supply.

Public officials in countries with little experience in regulating the use of wastewater in irrigation can gain value by reviewing the examples presented here and by considering ways to engage producers and consumers in active discussion of wastewater issues. As in many regulatory settings, the prospect of new rules and procedures regarding wastewater irrigation and food preparation will be viewed initially as a cost-increasing outcome that will harm the financial performance of individual farmers and food vendors. Hence the rational strategy from an individual's perspective, involves a combination of maintaining a low profile and quietly lobbying against the adoption of any new programs. Yet, in aggregate, net social welfare is decreased if the sum of damages from using wastewater in irrigation exceeds the sum of the benefits.

Perhaps the key to starting policy discussions is to demonstrate the potential gains in aggregate net benefits. Farmers, food vendors, and consumers can gain value together as they work with public officials to develop safe practices in crop production and food preparation. Individual farmers and food vendors will not be disadvantaged if everyone agrees to adopt safe practices, and if consumers are willing to pay higher prices in return for safety assurances. Details regarding policy parameters, and effective monitoring and enforcement programs can be developed over time, once all parties appreciate the potential gains in net benefits made possible through the safe and efficient use of wastewater in agriculture and the preparation of healthful food products.

6.7 Policies and Interventions Differ, But the Goals Are Similar

Policies and interventions regarding the use of wastewater in irrigation are quite different in developed and developing countries. In developed countries, most municipal and industrial wastewater is treated, and thus most of the wastewater used in agriculture is treated. Protective guidelines regarding the quality of wastewater used for irrigation have been in place for many years. Interventions in developed countries pertain largely to financial and economic considerations regarding the improvement and expansion of wastewater treatment facilities. Public officials and water management agencies motivate greater use of wastewater by providing financial incentives and increasing public awareness of the safety and benefits of using treated wastewater on farms, golf courses and urban landscapes.

Public officials in developing countries also consider financial and economic questions regarding investments in wastewater treatment and use. However, in many countries, the pace of such investments will not be sufficient to meet demand, or remains uncoordinated. For instance, national water policy framework and reuse guidelines in India denote the need for wastewater use but with little progress towards specific treatment standards, types of reuse, operation and maintanace issues, and tariff structures for various reuses. Many reuse projects led by various states and cities across India operate in isolation and locally, often with a delink to national policy and programs.

Much of the wastewater generated in cities and rural areas will remain untreated for many years. As a result, farmers will continue to use untreated wastewater for irrigation, and their use will be largely unintentional and informal. Public officials must therefore implement risk reduction programs that protect farm families, communities, food vendors, and consumers from the potentially harmful effects of exposure to the pathogens and chemicals in untreated wastewater.

Public investments and interventions in developing countries will reflect a range of activities along a pathway that includes wastewater generation, irrigation water capture and use, crop production and harvest, food preparation, and consumption. Public officials can implement risk-reducing guidelines and programs at each stage along the wastewater exposure pathway. For example, public officials can support improvements in wastewater treatment at the point of generation, when funds for such improvements are available. Officials also can call for changes in household and industrial production practices that would reduce the loads of harmful constituents in wastewater, thus reducing concentrations of those constituents in the irrigation water diverted from streams and ditches by farmers.

At the farm level, public agencies can provide technical assistance regarding water diversion and irrigation methods that would reduce potential exposure of farm workers to harmful pathogens and chemicals. Technical assistance regarding irrigation methods that reduce contamination of leafy vegetables and other produce consumed without cooking is essential for reducing risks to food vendors and consumers. Although difficult to enforce, regulations that establish a minimum time period between the dates of last irrigation and harvest would be helpful in reducing the risk of contamination from agricultural products.

Public officials in developing countries might also consider implementing certification programs for "consumer safe" farm produce, particularly in markets where local farmers sell their irrigated vegetables. Public agencies can begin such programs, with support from farmers and food vendors, but eventually market forces must arise to sustain them. Consumers must find value in certified produce and they must be willing to pay a small premium that compensates farmers and vendors for their costs in providing the safer produce. Educational and marketing campaigns can be helpful in boosting demand for safe produce among consumers. Box 6.1 presents examples of key policy and institutional drivers of uptake of water reuse in selected counteries.

Box 6.1: Policy and Institutional Factors Driving Wastewater Use in Selected Countries

Global: The World Health Organization guidelines shift the policy focus from reliance on wastewater treatment and water quality standards, to establishing health-based targets that might be achieved by implementing a range of risk reducing interventions (WHO 2006a; WHO 2006b; Keraita et al. 2010a).

Australia: Water scarcity driven policy change is a defining feature of Australian society. Australia launched an extensive program to encourage the use of treated wastewater in agriculture and other sectors, including heavy manufacturing and water intensive industrial customers, such as power plants. This involved policy actions at national and state levels, resulting in National Guidelines for Water Recycling and Reuse (ARMCANZ-ANZECC 2000 2000) for the protection of public and environmental health and community amenities (Hanjra et al. 2012). Many entities now purchase recycled water from water providers. The new policy framework enables third party access to wastewater for recycled water projects. Increasing investments in infrastructure and research have aimed at a broadening the scope of reuse options. National policy has set a target of 30% of Australia's wastewater being recycled by 2015 (Marsden Jacob Associates 2012).

Israel: Israel implemented a substantial wastewater use program in irrigation in the 1970s, and today almost all crops are safely irrigated with wastewater. Israel uses about 70% of its sewage in rrigation, and national water policy describes wastewater as an important asset (Kislev 2011). Key factors that led to the wider uptake of wastewater irrigation include (Lawhon and Schwartz 2006; Dreizin 2007; Kislev 2011):

- State water security concerns
- The National Policy on Sustainable Agriculture and Rural Development, which includes wastewater irrigation
- Collaboration between the Ministry of Agriculture and the Ministry of Environment
- Development of regulations and reuse guidelines through the Inter- Ministerial Committee

- Research and development on reuse, and its uptake into national policy
- The transfer of knowledge from research to farmers, via the government extension service
- Requiring farmers to obtain permits for irrigation with effluent
- Linking environmental and economic sustainability with establishing standards for wastewater use
- Regulating private investments in wastewater use and providing incentives for investments in technology, infrastructure and partnerships.

Singapore: So far Singapore only meets its water needs through water imports from Malaysia. During the past 20 years, policy makers have reduced reliance on outside sources in part by incorporating the best available technology in water supply and wastewater treatment. The Public Utilities Board, which serves as the single entity for managing water supply and wastewater treatment, initiated the NEWater Program, in which municipal wastewater is treated to achieve drinking water standards. Although most NEWater is used for non-potable purposes, it will meet 40 % of Singapore's total water demand by 2020. The Public Utilities Board has adopted a full metering policy, introduced proper accounting of water, and implemented measures to prevent illegal water taps. The success in Singapore is due to strong government support and effective public education and communication (Lim and Seah 2013).

Ghana: Wastewater use is not high on the political agenda in Ghana, even though some areas of the country experience a long dry season, and many urban centers are challenged to provide a continuous water supply. Within the sanitation sector, priority is given to increasing wastewater collection and treatment capacity, rather than increasing wastewater use. However, the National Environmental Sanitation Strategy and Action Plan supports the principles of waste reduction, recovery, use, and recycling. The political motivation for addressing wastewater use is the need to safeguard public health. The National Irrigation Policy, Strategies and Regulatory Measures of 2011 encourage research on safe irrigation practices in urban and peri-urban agriculture and support of best practices for the safe use of marginal quality water, in accordance with the WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater in Agriculture.

USA: Many American cities implement best practices in wastewater use. The US Environmental Protection Agency Guidelines for Reuse (revised in 2012), and state specific standards support wastewater use. Increasing water scarcity and the rising costs of providing water supply and environmental regulations motivate states and cities to implement wastewater use. Four states—Arizona, California, Florida, and Texas account for 90 % of all wastewater use. About 30 states have adopted grey water regulations that vary however in their comprehensiveness (Sheikh 2010).

6.8 Institutional Aspects of Wastewater Use in Agriculture

Many authors have examined wastewater use at different scales and many also have described methods and guidelines for promoting the safe use of wastewater (Ensink and van der Hoek 2009; Keraita et al. 2010a; Qadir et al. 2010; Abdulai et al. 2011). By contrast, there is limited information available regarding institutional aspects of wastewater use in agriculture, particularly in lower-middle-income and low-income countries, where respectively only 28 and 8 % of the wastewater generated is treated (Sato et al. 2013).

A recent assessment of the institutional aspects of wastewater management, undertaken in a UN-Water project addressing capacity assessment and development, examined the safe use of wastewater in agriculture (Raschid-Sally and Jayakody 2008). The project included an inception workshop and five regional workshops, involving representatives from 51 countries in Asia, Africa, Latin America, and the Caribbean. Feedback was collected in the form of responses to questionnaires and workshop discussions. This feedback from the country representatives was given in their personal capacity and views, and provided the basis for an assessment of the institutional aspects of wastewater management.

The representatives report a variety of institutional arrangements regarding the responsibility for wastewater management at the national or central government level. In India, wastewater management is the responsibility of the Ministry of the Environment and Forests, while in Iran, the Ministry of Energy has the responsibility. In Iraq and China, wastewater management falls within the Ministry of Agriculture, while in Jordan, the Ministry of Water and Irrigation is responsible. In some countries, several ministries share responsibility for wastewater management. For example, in Thailand, the Ministries of Industry (industrial wastewater), Interior (community wastewater), Natural Resources and Environment (water quality of natural water resources), and Public Health (human excreta collection, transportation and treatment) share the responsibility. In many countries, the ministry responsible for wastewater management and sanitation is not the ministry responsible for irrigation.

Similar diversity in wastewater management is observed at the municipal level, where a many institutions are responsible for wastewater collection, treatment, use, and disposal. None of the representatives reports excellent inter-ministerial or inter-institutional collaboration in wastewater management. Only 10 countries report adequate collaboration (20 %), 20 countries report inadequate collaboration (40 %) and 18 countries report average collaboration (36 %). Three countries report no inter-ministerial collaboration in managing wastewater.

There is also a lack of coordination between national agencies and local institutions for wastewater management, institutional arrangements are not sufficiently clear, and there are overlapping responsibilities across institutions. As a result, there are bureaucratic limitations in wastewater management at different scales. In terms of rating governments' commitment and budget allocation to wastewater management, a trend similar to inter-ministerial collaboration was reported by the

participants of the capacity development workshops. Only 7 countries reported adequate commitment and budget allocation for wastewater management (14%). Twenty-two countries reported an inadequate level (44%) and 18 countries reported an average level (36%). Four countries reported very little budget allocation for wastewater management. In cases in which wastewater treatment is not the primary objective of the responsible authority, the transaction costs of implementing programs can be substantial. In Ghana, for example, the Ministry of Defense manages its own treatment plants, while the Ministry of Health manages the treatment plants in hospitals, and the Ministry of Education manages their plants in universities.

Only seven countries report that farmers in peri-urban areas pay a local institution or organization for the wastewater they use for irrigation. In Tunisia, farmers pay for the volume of irrigation water required, the area to be irrigated, and the number of hours corresponding to the contract, at a rate of TND 0.02–0.03 per m^3 (US$ 0.012 to US$ 0.018 per m^3 in 2013). In some areas of South Africa, such as in eThekwini Metropolitan Municipality, the cost of wastewater is much lower than the cost of potable water. As drinking water often is subsidized, it is difficult to achieve substantial cost recovery for water reuse where wastewater is sold at a very low price.

In some areas of India, treatment is not available or sought for much of the collected wastewater, and it is sold to nearby farmers by the respective Water and Sewerage Board. In areas that lack alternative sources of water, such as Vadodara in Gujarat, one of the most lucrative income-generating activities for the lower social classes is the sale of wastewater and the renting of pumps for lifting wastewater. In Jordan, farmers sign contracts for wastewater with the Water Authority of Jordan, usually at 20 fils per m^3 (US$ 0.028 per m^3 in 2013). In Pakistan, wastewater is auctioned, and the highest bidder in turn sells the water to small farmers on an hourly basis. In Mexico, wastewater irrigators in the Mezquital Valley pay US$ 0.80 per ha.

There are only nine countries where farmer associations or water user associations collaborate with local institutions for wastewater delivery. In the Tula Irrigation District (District 03, Mezquital Valley, in Mexico), there are several farmer associations that have been operating since the 1990s. These associations develop irrigation plans, ensure water distribution, and conduct assessments of farm-level fertilizer and pesticide use, to improve crop yields. In South Africa, there is a private network of local communities for wastewater use in the eThekwini Metropolitan Municipality area. In addition, there are farmer groups in Mauritius that collaborate with the Wastewater Management Authority regarding the amount and quality of wastewater delivered. In general, however, there is a divide between the agriculture and sanitation sectors, and a lack of collaboration between farmer associations or water user associations and institutions responsible for wastewater management.

The subjects of wastewater management and use do not appear in the standard course offerings of many primary or secondary schools. Most countries have yet to introduce the importance of water quality and wastewater management in their standard curriculum. However, in recent years, several universities have added new courses on wastewater management and use.

6.9 Summing Up

The policies and interventions we describe pertain largely to near-term strategies for minimizing the risk of negative health effects, while also enabling farmers to gain the potential benefits of using untreated and partially treated wastewater in agriculture. This approach is appropriate for countries that presently cannot afford to build, operate, and maintain a full complement of modern wastewater treatment facilities. Over time, as the demand for water in agriculture and other uses continues to increase, public officials in all countries should endeavor to provide wastewater treatment that matches end uses, including the irrigation of crops, landscapes, and golf courses. In developing countries, it will be necessary also to ensure that small-scale farmers retain access to a reliable source of irrigation water when the untreated and commingled wastewater they once relied on becomes unavailable, with the expansion of wastewater treatment programs.

Institutional arrangements regarding wastewater collection and reuse are unclear in many countries. In some countries, the responsibility for wastewater management is divided among several ministries or departments, rather than placed within a single agency. This can increase the transaction costs of managing wastewater effectively and delay the pace with which improvements are implemented. In addition, the annual budgets of many countries are not sufficient to support the collection, treatment, and reuse of all wastewater in an environmentally acceptable manner.

In most countries of Asia, Africa, Latin America, and the Caribbean, supportive institutional arrangements are needed to facilitate wastewater collection, treatment, and reuse. These arrangements must be implemented at several levels and may include some of the following components: relevant policies facilitating water recycling and reuse at the local and national scales; strategic campaigns regarding water quality protection and wastewater treatment and productive reuse; and institutional collaboration such as private sector participation. A flexible policy framework, implemented with effective institutional support across sectors, can be helpful in addressing rapid demographic changes and protecting public health and the environment. To champion the concept of a ‘Circular Economy’ where recycling is taken seriously, the right combination of smart policies, effective institutional linkages, and wise financial planning will enable cities, provinces, and countries to achieve the potential private and public benefits made possible by collecting, treating, and using wastewater and its byproducts in agriculture and other sectors.

Take Home Messages

- Limited information is available regarding institutional aspects of wastewater use in agriculture, particularly in lower- and low-income countries.
- Information is limited also regarding the trajectory toward comprehensive regulatory frameworks in high-income countries.

- Future policy issues include refining wastewater use guidelines and protocols, and continually evaluating the costs and benefits for pro-development policy.
- In addition, policy interventions should focus on reducing risks by motivating safer practices by those who use wastewater, consume wastewater irrigated crops and get in contact with parks or landscapes irrigated with wastewater.
- Smart policies, effective institutions, and financial instruments are needed to enhance the public and private benefits of wastewater use programs.

References

Abdel-Dayem S, Abdel-Gawad S, Fahmy H (2007) Drainage in Egypt: a story of determination, continuity, and success. Irrig Drain 56 (Suppl. 1):S101–S111

Abdulai A, Owusu V, Bakang JA (2011) Adoption of safer irrigation technologies and cropping patterns: evidence from Southern Ghana. Ecol Econ 70:1415–1423

Angelakis AN, Marecos do Monte MHF, Bontoux L, Asano T (1999) The status of wastewater reuse practice in the Mediterranean Basin: need for guidelines. Water Res 33:2201–2217

Angelakis AN, Bontoux L, Lazarova V (2003) Challenges and prospectives for water recycling and reuse in EU countries. Water Sci Tech: Water Supply 3(4):59–68

ARMCANZ-ANZECC (2000) Guidelines for sewerage systems—use of reclaimed water. Agriculture and Resource Management Council of Australia and New Zealand and the Australian and New Zealand Environment and Conservation Council, 2000

Arntzen JW, Setlhogile T (2007) Mainstreaming wastewater through water accounting: the example of Botswana. Phys Chem Earth 32(15–18):1221–1230

Bakir HA (2001) Sustainable wastewater management for small communities in the Middle East and North Africa. J Environ Manage 61:319–328

Bazza M (2003) Wastewater recycling and reuse in the near East region: experience and issues. Water Sci Tech Water Supply 3(4):33–50

Capra A, Scicolone B (2007) Recycling of poor quality urban wastewater by drip irrigation systems. J Cleaner Produc 15:1529–1534

Chang D, Ma Z (2012) Wastewater reclamation and reuse in Beijing: influence factors and policy implications. Desalination 297:72–78

Cirelli GL, Consoli S, Licciardello F, Aiello R, Giuffrida F, Leonardi C (2012) Treated municipal wastewater reuse in vegetable production. Agric Water Manage 104:163–170

Drechsel P, Evans AEV (2010) Wastewater use in irrigated agriculture. Irrig Drain Sys 24:1–3

Drechsel P, Seidu R (2011) Cost-effectiveness of options for reducing health risks in areas where food crops are irrigated with treated or untreated wastewater. Water Int 36:535–548

Dreizin Y (2007) Wastewater reuse—risk assessment: the Israeli case study, Water Commission, Israel

Ensink JHJ, van der Hoek W (2009) Implementation of the WHO guidelines for the safe use of wastewater in Pakistan: balancing risks and benefits. J Water Health 7(3):464–468

Grangier C, Qadir M, Singh M (2012) Health implications for children in wastewater-irrigated peri-urban Aleppo, Syria. Water Qual Expo Health 4:187–195

Hanjra MA, Blackwell J, Carr G, Zhang F, Jackson TM (2012) Wastewater irrigation and environmental health: implications for water governance and public policy. Int J Hyg Environ Health 215(3):255–269

Heinz I, Salgot M, Mateo-Sagasta Davila J (2011) Evaluating the costs and benefits of water reuse and exchange projects involving cities and farmers. Water Int 36:455–466

Hurlimann A, McKay J (2007) Urban Australians using recycled water for domestic non-potable use—an evaluation of the attributes price, saltiness, colour and odour using conjoint analysis. J Environ Manage 83:93–104

Keraita B, Drechsel P, Konradsen F (2010a) Up and down the sanitation ladder: harmonizing the treatment and multiple-barrier perspectives on risk reduction in wastewater irrigated agriculture. Irrig Drain Sys 24:24–35

Keraita B, Konradsen F, Drechsel P (2010b) Farm-based measures for reducing microbiological health risks for consumers from informal wastewater-irrigated agriculture. In: Drechsel P, Scott CA, Raschid-Sally L, Redwood M, Bahri A (eds) Wastewater irrigation and health: assessing and mitigating risk in low-income countries. Earthscan, London, pp 188–207

Kislev Y (2011) The water economy of Israel, TAUBC centre for social policy studies in Israel, policy program paper No 2011.15, Jerusalem, Israel

Lapen DR, Topp E, Metcalfe CD, Li H, Edwards M, Gottschall N, Bolton P, Curnoe W, Payne M, Beck A (2008) Pharmaceutical and personal care products in tile drainage following land application of municipal biosolids. Sci Total Environ 399:50–65

Lawhon P, Schwartz M (2006) Linking environmental and economic sustainability in establishing standards for wastewater re-use in Israel. Water Sci Technol 53:203–212

Lim, M-H, Seah H (2013) NEWater: a key element of Singapore's water sustainability. In: Lazarova V et al (eds) milestones in water reuse. The best success stories. IWA Publishing, London, pp 53–62

Marsden Jacob Associates Australia (2012) Progress against the national target of 30 % of Australia's wastewater being recycled by 2015, Report prepared for the department of sustainability, environment, water, population and communities (DSEWPaC), Canberra, Australia

McNeill LS, Almasri MN, Mizyed N (2009) A sustainable approach for reusing treated wastewater in agricultural irrigation in the West Bank—Palestine. Desalination 248:315–321

Meinzen-Dick R, van der Hoek W (2001) Multiple uses of water in irrigated areas. Irrig Drain Sys 15:93–98

Mills RA, Karajeh F, Hultquist RH (2004) California's task force evaluation of issues confronting water reuse. Water Sci Technol 50:301–308

Mizyed NR (2013) Challenges to treated wastewater reuse in arid and semi-arid areas. Environ Sci Policy 25:186–195

Pedrero F, Kalavrouziotis I, Alarcón JJ, Koukoulakis P, Asano T (2010) Use of treated municipal wastewater in irrigated agriculture—review of practices in Spain and Greece. Agric Water Manage 97:1233–1241

Qadir M, Wichelns D, Raschid-Sally L, McCornick PG, Drechsel P, Bahri A, Minhas PS (2010) The challenges of wastewater irrigation in developing countries. Agric Water Manage 97:561–568

Raschid-Sally L, Jayakody P (2008) Drivers and characteristics of wastewater agriculture in developing countries: results from a global assessment. IWMI Research Report 127, International Water Management Institute, Colombo, Sri Lanka, 35 p

Rodriguez Diaz JA, Knox JW, Weatherhead EK (2007) Competing demands for irrigation water: golf and agriculture in Spain. Irrig Drain 56:541–549

Sato T, Qadir M, Yamamoto S, Endo T, Zahoor A (2013) Global, regional, and country level need for data on wastewater generation, treatment, and reuse. Agric Water Manage 130:1–13

Scheierling SM, Bartone CR, Mara DD, Drechsel P (2011) Towards an agenda for improving wastewater use in agriculture. Water Int 36:420–440

Scott CA, Pineda Pablos N (2011) Innovating resource regimes: water, wastewater, and the institutional dynamics of urban hydraulic reach in northwest Mexico. Geoforum 42:439–450

Senzanje A, Boelee E, Rusere S (2008) Multiple use of water and water productivity of communal small dams in the Limpopo Basin, Zimbabwe. Irrig Drain Sys 22:225–237

Sheikh B (2010) White Paper on Graywater, Prepared for the WateReuse Association, Water Environment Federation, and American Water Works Association, pp 1–51

Siemens J, Huschek G, Siebe C, Kaupenjohann M (2008) Concentrations and mobility of human pharmaceuticals in the world's largest wastewater irrigation system, Mexico City-Mezquital Valley. Water Res 42:2124–2134

Swatuk LA, Rahm D (2004) Integrating policy, disintegrating practice: water resources management in Botswana. Phys Chem Earth 29:1357–1364

Ternes TA, Bonerz M, Herrmann N, Teiser B, Andersen HR (2007) Irrigation of wastewater in Braunschweig, Germany: an option to remove pharmaceuticals and musk fragrances. Chemosphere 66:894–904

Topp E, Monteiro SC, Beck A, Coelho BB, Boxall ABA, Duenk PW, Kleywegt S, Lapen DR, Payne M, Sabourin L, Li H, Metcalfe CD (2008) Pharmaceutical and personal care products in tile drainage following land application of municipal biosolids. Sci Total Environ 396:52–59

Toze S (2006) Water reuse and health risks—real vs. perceived. Desalination 187:41–51

UNESCO (2003) Water for people, water for life. UN world water development report. Paris: United Nations Educational, Scientific, and Cultural Organization (UNESCO) Publishing

van Lier JB, Huibers FP (2010) From unplanned to planned agricultural use: making an asset out of wastewater. Irrig Drainage Sys 24:143–152

van Roon M (2007) Water localization and reclamation: steps towards low impact urban design and development. J Environ Manage 83:437–447

Weldesilassie AB, Amerasinghe P, Danso G (2011) Assessing the empirical challenges of evaluating the benefits and risks of irrigating with wastewater. Water Int 36:441–454

Wichelns D, Drechsel P (2011) Meeting the challenge of wastewater irrigation: economics, finance, business opportunities and methodological constraints. Water Int 36:415–419

World Health Organization (WHO) (2006a) Guidelines for the safe use of wastewater, excreta and greywater. vol 1: policy and regulatory aspects. World Health Organization,Geneva

World Health Organization (WHO) (2006b) Guidelines for the safe use of wastewater, excreta and greywater. vol 2: wastewater use in agriculture. World Health Organization,Geneva