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# Chapter 15

# Resource recovery from wastewater and the consumer point of view: social, cultural and economic aspects

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## 15.1 INTRODUCTION

Between now and 2030, the sourcing of water for human needs is expected to change as the pressure on natural freshwater resources becomes more intense. This pressure is likely to come primarily from agriculture, as increasing demands for higher protein diets and biofuels will require a significant increase in agricultural output, which can only be met through greater water use. This will accelerate the over-exploitation of our freshwater resources, including a 66% increase in non-renewable groundwater withdrawals which is likely to affect millions of people by 2030, and billions by the end of the century (GWI, 2010). Under these circumstances, there will be limited alternatives to water reuse and desalination, especially where long-distance transfer is not cost-competitive. As public agencies seek economically and socially acceptable solutions to cope with increasing water demands, matching waters of different qualities with appropriate uses and implementing helpful reuse incentives will become essential for achieving the related sustainable development goals (SDGs) 6.3, 7.2 and 12.5, which directly address resource recycling, recovery and reuse.

Recovering resources such as water, energy and nutrients from wastewater has been practiced for generations in many countries (GWI, 2010; Jimenez, 2005; Lazarova *et al.*, 2013; Otoo and Drechsel, 2018; Smit and Nasr, 1992). It is expected that resource recovery and reuse (RRR) will gain more momentum where resources for agricultural production are increasingly limited under progressing climate change, competition for clean water, energy, diminishing global nutrient reserves and increasing fertilizer prices; and especially in developing countries with lower purchasing power of individual households. Wastewater not only offers opportunities to reclaim water of different quality, but also energy, nutrients and organic matter with a high application potential in agriculture (Figure 15.1). This opportunity is especially important where soils are poor and the availability of alternative inputs are physically or economically constrained. There is great potential to close the nutrient loop and to create viable businesses that make best use of what wastewater can offer.

Consumer perceptions can however limit reuse among particular clients and reuse purposes or completely undermine the potential for resource recovery and anticipated reuse impact where the

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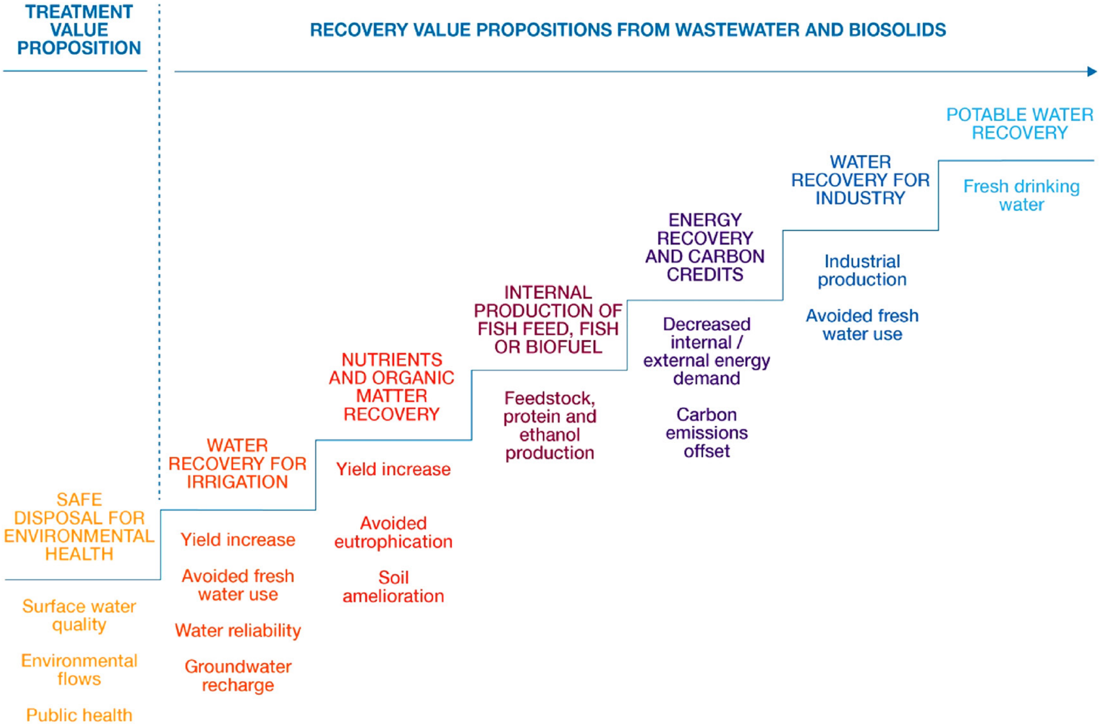

**Figure 15.1** Ladder of increasing value propositions related to wastewater treatment based on increasing investment in water quality and/or the reuse value chain (Source: Drechsel *et al.*, 2015).

reuse discussion steers public perceptions and hostility. Therefore, promoting reuse in any setting requires an assessment of public views, from risk awareness to the willingness to pay for reclaimed water, under consideration of alternative options consumers may have (Drechsel *et al.*, 2015; Fielding *et al.*, 2019; Ross *et al.*, 2014).

Historically, the earliest and most commonly accepted beneficial reuse of wastewater (and the valuable resources embedded in the wastewater matrix, e.g. ammonium and phosphate) is in agriculture and landscaping, although there are numerous reuse options in both fields with different risks and demands, as well as different degrees of planning (Otoo and Drechsel, 2018). These can range from designed reuse projects to farmers unconsciously using untreated but diluted wastewater. Reuse can also take place at different scales, from household-based greywater recycling to large-scale freshwater–wastewater swaps between rural and urban areas, or it can target indirect and direct (potable) reuse through blending with freshwater, groundwater recharge and/or high-end treatment, to name just a few of the existing water reuse business models (Drechsel and Hanjra 2018; Lazarova *et al.*, 2013). Globally, Namibia, the United States of America, Australia, and Israel are among the most successful countries in introducing water reuse. Scholars and public authorities in those countries have gained substantial experience in addressing public perceptions and attitudes toward the reuse of reclaimed water, be it for direct, indirect, potable and non-potable uses (Dishman *et al.*, 1989; Dolnicar and Schafer, 2009; Higgins *et al.*, 2002; Hurlimann and McKay, 2006; Hurlimann, 2009; USEPA, 2012; Woltersdorf *et al.*, 2016). In an ideal situation, public and private concerns and benefits can be aligned and concerns about real or perceived risks weighed against the benefits of using treated (reclaimed) water. However, this requires risk education and data to make informed decisions (Prouty *et al.*, 2018); two requirements which are unavailable in the context of many low-income countries. Given the many determinants of social acceptance and the need to improve wastewater management and use in many areas, a comprehensive but location specific approach, including educational, policy, and management strategies, is needed to support public acceptance (Keremane, 2007). For example, across nine international locations of Australia, Belgium, Canada, Israel, Japan, Jordan, Mexico, Norway and Los Angeles (Hurlimann and Dolnicar, 2016) water source preference varied. Desalinated water, a purified and scientifically treated source, was preferred over rainwater for close-to-person uses. However, rainwater was preferred to recycled water that was 'purified and scientifically tested', despite the increased health risks in untreated rainwater consumption. Also, the hypothetical willingness to use alternative water sources varies between locations, and perceptions are different across locations such that context specific intelligence and interventions are required.

Especially, discussions around the introduction of direct and indirect potable reuse have sparked public interest and demand research on social acceptance. However, also recreational or agricultural reuse requires stakeholder buy-in (Marks, 2004; Marks *et al.*, 2006; McKay and Hurlimann, 2003; Po *et al.*, 2004, 2005; USEPA, 2012; Wegner-Gwidt, 1991; WHO, 2006). Failure to gain public acceptance can result in program stalling or becoming unviable (Friedler and Lahav, 2006; Keremane, 2007; Wegner-Gwidt, 1991). Depending on the region and case, cultural, religious, educational and/or socio-economic factors can support or constrain the development of wastewater use in a given location (Po *et al.*, 2004). These social acceptance challenges pertain to both the introduction of new wastewater use schemes and also to improvements in existing situations where wastewater is already (often informally) used and the recovery of resources.

Despite these challenges, the discussion on resource recovery from wastewater has garnered significant momentum, especially in water scarce regions, and focuses on water reuse for both potable and non-potable purposes with more emphasis on safety than financial aspects. The discussion on nutrient recovery from wastewater is however one step behind and so far more determined by regulatory pressure or technical opportunities for cost savings than any actual market demand for recovering nutrients. With few exceptions the demand is more theoretical, embedded in the call for a more circular economy ideally turning conventional wastewater treatment plants into resource recovery centers (Wallis-Lage 2013), alongside treating wastewater to serve the imperative of protecting public health and ecosystems. Isolating nutrient recovery from the basic function of wastewater treatment for safeguarding public health and the environment, and from the value proposition of reclaiming water or energy, appears artificial. However, depending on the local context, market demand for certain recovered resources, such as water, fertilizers, or energy can be very different and treatment operators may opt for only the one option with the highest probability of returns or social benefit. So far, phosphorus (P) and nutrient (N) recovery from waste streams is expensive but new technologies which bypass the need for costly inputs in the precipitation of phosphate are emerging. From the business perspective, this could offer a financial breakthrough even if the P price will only slowly increase. Winkler *et al.* (2013) however stresses that so far the usage of struvite in agriculture has not been well accepted in the Netherlands and expects the same in other European countries despite full compliance with required standards.

While developed countries with extensive sewer systems require advanced technology to separate nutrients from the waste stream, the low chemical and metal contamination in household-based on-site treatment facilities, such as septic tanks and latrines, makes the resulting fecal sludge (septage) a valuable soil ameliorant. The dried and composted material can for example be pelletized or blended with particular nutrients to meet farmers' needs, as shown for example in South Africa and Ghana (Harrison and Wilson, 2012; Nikiema *et al.*, 2012). So far nutrient recovery from wastewater is more driven by the treatment sector and its challenges or caused by changing regulations than by market demand for alternative fertilizers.

Market demand for recovered energy from wastewater, on the other hand, is not hardly influenced by consumer perception and inherent barriers related to safety like treated wastewater use (Otoo and Drechsel, 2018). The majority of recovered energy from wastewater currently occurs from sewage-based systems, with limited examples of non-sewered (on-site) sanitation systems. In either case, the produced energy is typically used to meet internal energy (electricity) needs and any surplus sold to households/industries via national grids. The recovered energy does not possess product attributes such as color or taste or has it any potential direct or indirect health risk to consumers from use as recovered water and nutrients may have. From that perspective, this chapter focuses on key considerations and lessons learnt mostly in the domains of water and nutrient recovery from wastewater for agricultural and potable reuse; and also differentiates between nutrient recovery options commonly seen in sewered and non-sewered (on-site) sanitation system, looking at wastewater as well as fecal sludge and biosolids.

In view of wastewater reuse markets, particularly agricultural reuse, two contrasting situations are common (Drechsel *et al.*, 2015), the one where reuse has to be marketed and the one where it is already taking place but safety options have to be marketed:

- Marketing wastewater use and its recovered resources (nutrients): An example of this refers to irrigation schemes that are planned and formally designed to use treated wastewater as a source of water. These are common in many water-scarce regions of middle- and high-income countries, where wastewater is promoted as an economic good. Wastewater is treated before being released to irrigation schemes and there are usually strict regulations guiding its use. Additionally, we can consider the case where: (a) wastewater is treated for the recovery of nutrients from sewered (e.g. phosphorus recovery) and non-sewered systems for use as an agricultural input (soil amendment); (b) treated wastewater as a medium for aquaculture; and (c) production of aquatic plants, such as algae and duckweed that grow naturally as a part of pond and lagoon treatment systems and can absorb significant amounts of nutrients and be harvested for a variety of purposes, including biofuels, or a source of protein for animal/fish feeds, and so on. (Otoo and Drechsel, 2018).
- Marketing safety: This category pertains mostly to low- or middle-income countries with limited treatment capacity, in which untreated or partially treated wastewater is polluting water bodies which are used by smallholders for irrigating crops in high market demand. The wastewater may be used either in diluted or raw form, largely due to the lack of freshwater alternatives and, where diluted, often unconsciously. In this situation, the cultural and social challenge is not the 'introduction of reuse' but to support a 'transition to safe reuse'.

While the increase of planned wastewater use receives significant policy attention through the Sustainable Development Goal 6 (SDG 6 – Ensure availability and sustainable management of water and sanitation for all), the already ongoing, but usually unsafe reuse for agricultural irrigation covers an area approximately 30 times larger than previously reported (Thebo *et al.*, 2017). Due to the significant scale of water pollution in many low-income countries, and limited capacity to monitor water quality, banning the unsafe practices is difficult to enforce as the examples of, for instance, Ghana (Drechsel and Keraita, 2014), India and Pakistan (Otoo and Drechsel, 2018) showed. In these situations, the use of polluted water remains often in a state of 'laissez-faire', without the ability of authorities to enforce restrictions or assistance to reduce potential risks (Drechsel *et al.*, 2006). Introducing risk reduction efforts would have to rely on occupational safety measures, crop restrictions, safer irrigation practices, and good post-harvest handling, following for example the WHO (2006) multi-barrier approach. In this situation, the conventional 'technical responsibility' of treatment plants to safeguard public health becomes a social responsibility task involving various stakeholders along the food chain. Thus, the challenge of 'formalizing' informal wastewater, by introducing pathogen barriers, is as much a cultural and social challenge as the introduction of reuse itself. Drawing from practical cases of project failure or success, this chapter presents a number of factors that commonly influence the introduction or improvement of wastewater use for potable and non-potable purposes, as well for nutrient and organic matter recovery. This chapter draws from Drechsel *et al.* (2015) and Otoo *et al.* (2015).

## 15.2 LEARNING OBJECTIVES

At the completion of this chapter you should be able to:

- Describe circumstances and understand the key factors steering public acceptance or resistance vis-à-vis wastewater reuse for potable and non-potable purposes, and for nutrient and organic matter recovery.
- Understand why stakeholder participation in planning reuse is important.
- Explain the financial consideration of agricultural producers which may favor or disfavor the acceptance of wastewater or related recovered resources.
- Understand gender roles and responsibilities, influences of culture and religion in the context of wastewater use for potable and non-potable purposes, and recovered resources (nutrient and organic matter recovery).
- Understand that besides finding acceptance for reuse, another challenge (at area-wide or larger scales) is to find acceptance for safety practices by those who have no choice but to use wastewater, or to trade or consume wastewater-grown crops, even if they are unwashed or uncooked.
- Explain options to support behavior change, like education, awareness creation, incentives, social marketing and regulations.
- Give examples of situations where cultural, political or economic reasons steered the acceptance or disapproval of reuse.
- Describe pertinent research gaps such as gender analysis vis-à-vis water reuse. There is a need for a systematic way of assessing the different impacts of actions and results on both genders. This form of analysis asks the ‘who’ questions – Who does what? Who has access and control over water? Who makes the decisions? Who benefits from (better) reuse implementation? Who is burdened? Many of these are questions relating to power dynamics, social roles and responsibilities and relationships (Arafa *et al.*, 2007).

## 15.3 FACTORS INFLUENCING ACCEPTANCE OF RESOURCES RECOVERY FROM WASTEWATER

Many studies show that across the spectrum of reuse purposes, the acceptance of wastewater as a valuable resource is influenced by many factors, ranging from expressions of disgust to calculated costs and benefits, issues of choice, trust and knowledge, attitudes toward the environment, and socio-demographic factors. These reviews also showed that water and resource scarcity itself is a good but not sufficient driver of public acceptance (Po *et al.*, 2004; USEPA, 2012). The most recent detailed literature review of common factors influencing social acceptance of (waste) water reuse was provided by Fielding *et al.* (2019). Common cross-cutting results were that

- the acceptance of recycled water decreases with increasing human contact;
- greater knowledge is related to greater acceptance of recycled water;
- health risk perceptions are consistently and negatively associated with acceptance.

While these observations appear relevant in many planned wastewater schemes, they cannot be taken for granted, and can be very different where wastewater use is already taking place, although unplanned. Depending on the context, there are a number of key factors which can play an important role, such as knowledge and risk awareness, the availability of alternative water sources, the financial implications for those directly concerned, and the need to progress in mutual agreement for the benefit of all concerned. These and other factors will be discussed in the following two sections on: (a) introducing potable and non-potable reuse; and (b) promoting safety within existing agricultural reuse operations, using examples from developed and developing countries.

## 15.4 ACCEPTANCE OF TREATED WASTEWATER FOR POTABLE AND NON-POTABLE PURPOSES

### 15.4.1 Knowledge, perceptions, and acceptability

Non-potable reuse, or in a wider sense, reuse without human contact, in general has higher acceptance than reuse with human contact. More than 45 studies assessing the level of acceptance of wastewater use, irrespective of the measure of acceptance used, show the same pattern – acceptance of recycled wastewater drops with increasing human contact, that is, lower acceptance for more personal uses. Most participants found wastewater irrigation acceptable for public parks or home garden irrigation, while only very few would accept it for drinking. Indirect contact, like via food irrigation ranges in between the extremes (Figure 15.2). The reasons can vary depending on a range of factors, such as the education and risk awareness, the degree of water scarcity or availability of alternative water sources, economic considerations, involvement in decision making, and experience with treated wastewater. Some of these factors will be looked at in more detail.

### *15.4.1.1 Knowledge and direct exposure*

Higher levels of education are positively associated with acceptance of wastewater use. Several authors have investigated the association of socio-demographic descriptors with the acceptance of treated wastewater. The two factors that have been frequently found to be associated with the acceptance levels are the education/knowledge of the individuals expressing their opinion, and as mentioned the personal proximity or involvement in the planned reuse. In Kuwait or Greece, for example, the willingness to accept or pay for reuse increased with educational attainment (Alhumoud and Madzikanda, 2010). Positive perceptions towards reuse are usually directly the inverse of the level of physical contact with the reclaimed water (Hamilton *et al.*, 2007; Po *et al.*, 2005). For example, despite significant technical advances, potable use is usually rejected due to personal health concerns or at least avoided as long as there are alternatives (Dolnicar and Saunders, 2006; Higgins *et al.*, 2002). Wastewater use in agriculture generally is preferred to potable use, while more distant uses, such as landscape irrigation, are the most preferred (Figure 15.3). A similar perspective has been reported for Kuwait, Israel, UK, USA and Australia (Alhumoud and Madzikanda, 2010; Friedler *et al.*, 2006; Hartley, 2006; Po *et al.*, 2004; USEPA, 2012). Only two studies, in Turkey (Buyukkamaci and Alkan, 2013) and Beijing, China (Chen *et al.*, 2015) reported a negative relationship between education and support for wastewater use, which denotes a risk information-deficit. Education alone may not be a primary factor but it is correlated with other factors in influencing public acceptance of wastewater use. In peri-urban Bengaluru, India, the majority (67%) of households in apartments and gated communities appeared willing to accept and buy reclaimed wastewater for toilet flushing and landscaping, considering recycled wastewater as cost effective compared to other sources. Yet some (20%) were concerned about hygiene and others (33%) lacked trust. The main factors influencing the decision to use reclaimed wastewater in this case were: lack of trust in the public agency, health risks, quality standards and performance, psychological ('yuk') factor, affordability to buy better quality water, and alternative water availability (Ravishankar *et al.*, 2018).

### *15.4.1.2 Availability of alternative water sources*

New reuse schemes face greater initial public resistance where freshwater or groundwater supplies are still available. Even when advanced processes are used to treat wastewater and known health risks are well managed, negative public perception can prevent well-planned projects from moving forward. The case of Singapore is such an example where the produced NEWater is technically ultra-safe but the public remains hesitant to accept it, even for indirect potable use. As a result, only a small portion (2.5% in 2011) of NEWater has been injected into Singapore's freshwater reservoirs (Lim and Seah, 2012) during dry periods. Also bottled NEWater remains more a curiosum at water conferences than a marketable product, given many competing and affordable water brands are not derived from wastewater. Thus, today most of the reclaimed NEWater is used for industrial and air-con cooling purposes.

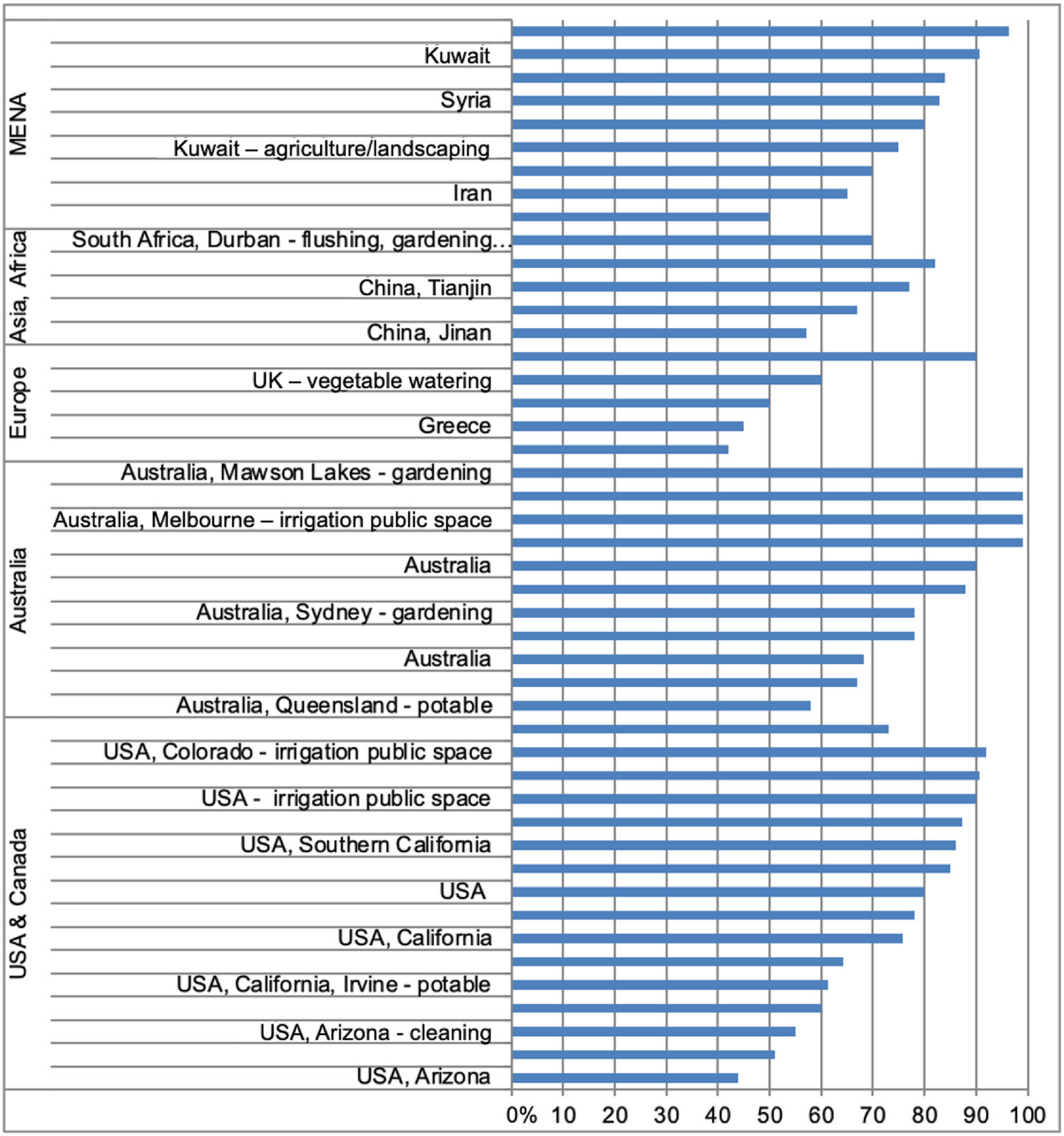

**Figure 15.2** Acceptance of recycled wastewater for irrigated agriculture (or specified uses) (Source: Authors, based on a literature review).

In Windhoek, Namibia, which lacks affordable water alternatives, up to 35% of the city's wastewater is treated and blended with other potable sources to increase the drinking water supply. The success of Windhoek is supported by the fact that since the wastewater use program began in 1968, no health problems have been reported (Lahnsteiner *et al.*, 2012). The Windhoek example shows that water scarcity is an important factor in support of wastewater treatment for reuse; and that safe reuse is possible.

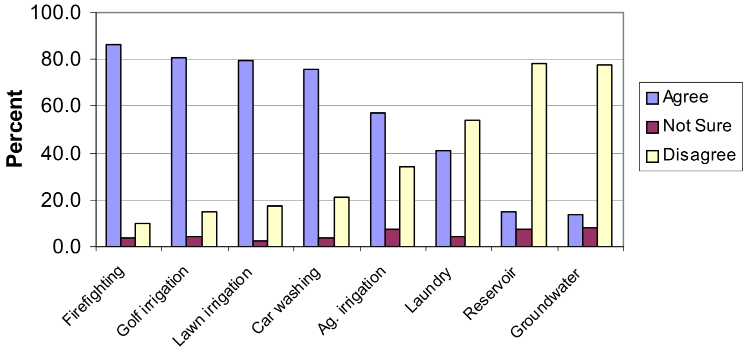

**Figure 15.3** Attitudes towards wastewater use options, as expressed by 303 participants in a telephone survey in southeast United States (Source: Robinson *et al.*, 2005).

An alternative freshwater source is a crucial disincentive to the adoption of reuse, as it was reported for example for Jordan, Spain, and Tunisia (Ben Brahim and Duckstein, 2011; Molinos-Senante *et al.*, 2010; Otoo and Drechsel, 2018). In Tunisia, for example, although farmers were charged less for reclaimed water than for conventional freshwater, demand for reclaimed water remained modest, especially where farmers had access to shallow groundwater which was free, except its pumping costs. Moreover, water salinity may increase through wastewater treatment making reclaimed water less preferred than untreated wastewater or groundwater (Drechsel and Hanjra, 2018). A general recommendation in the Tunisia case was that to promote water reuse, groundwater access has to be regulated.

#### *15.4.1.3 Public awareness and marketing challenges*

In the case of wastewater irrigation, crop acceptance by the consumer remains the most critical criterion. Assuming the source of the crop is known to the consumer, his/her decision to buy or not to buy a crop produced with reclaimed water is determined by public views, knowledge and perceptions. To identify the actual consumer and to understand consumer's views, crop marketing channels need to be analyzed before assessing the perceptions (Abu-Madi *et al.*, 2008; Amoah *et al.*, 2007). In many countries, with planned reuse schemes and much more in those where informal wastewater irrigation is common reality, the existing marketing system does not differentiate between different farms or water sources, and wastewater irrigated crops are on offer together with freshwater irrigated crops. This may give an advantage to farmers using wastewater, but obviously not to consumers who can be at risk and, depending on their risk awareness, will prefer dedicated marketing channels to compare and decide. However, unless consumers clearly articulate their preference there will not be much advantage for traders to separate and display produce according to its source (Keraita and Drechsel, 2015). Dedicated marketing channels for crops produced with treated wastewater can also be a success if well branded, like in Botswana's Glen Valley, where horticultural incubators are supported with modern technologies and improved farming practices growing high value, high (off-season) demand, and high yielding crops (cherry tomatoes) in a controlled greenhouse environment with treated wastewater. Without such 'high tech' branding, reclaimed water will have a negative association which implies financial risks to farmers. The situation becomes even more challenging in view of export markets. In Northern Africa, for example, where farmers try to enter the European market, they are very reticent about using treated wastewater (Abu-Madi *et al.*, 2008; Choukr-Allah, 2013).

#### *15.4.1.4 Public involvement, trust and buy-in*

A general consensus across many reuse cases is that to achieve general acceptance of planned wastewater use schemes, especially in a social environment with the power to influence the implementation process, it is important to ensure active public involvement from the planning phase to full implementation (USEPA, 2012; WHO, 2006). Public involvement begins with early contact with potential users, and can involve the forming of an advisory committee, and public workshops on reasons, benefits and risks of reuse. The exchange of information between authorities and public representatives should ensure that concerns from perceived health or environmental impacts to lower property values have been shared and addressed (Crook *et al.*, 1992; Helmer and Hespanhol, 1997). The dialogue should build on mutual trust to provide the right climate for negotiation and conflict resolution. Timing may be an important factor. Gaining public acceptance is easier once water scarcity is affecting the public and the need to conserve high quality water sources for domestic purposes is established. In a sense, the use of wastewater becomes a solution to a problem, rather than a problem (Fawell *et al.*, 2005). In Durban, South Africa, for example, 60–70% of the surveyed consumers not only favored reuse to save water, but also the next step of dual piping systems at home (Bakare *et al.*, 2016). However, good timing alone is not a guarantee of success, as the Toowoomba example shows (Box 15.1). It will also require a sensitive approach to avoid a (e.g. politically driven) polarization of stakeholders in favor and against reuse.

### Box 15.1 Public opposition to re-use

Toowoomba city in Queensland State of Australia is an often-cited case illustrating the strength of public opinion regarding wastewater use. A plan to turn wastewater into drinking water failed in Toowoomba at a referendum in 2006, although water scarcity in the community was severe, to the point that water use for gardening was completely prohibited in the 'Garden City'. With no major river nearby, the community water supply had to be pumped uphill. During several years of drought, the 140 000 residents of Toowoomba and surrounding areas endured tough water restrictions. Local officials considered that the city had no choice but to treat and use parts of its wastewater for drinking water, and given the water crisis, they expected the program would be acceptable. However, the proposal was met with fierce opposition from the community. In 2006, the residents of Toowoomba voted strongly against treating and using 25% of the city's wastewater. They relied instead on water piped from Brisbane's Wivenhoe Dam, at a cost to ratepayers of nearly $100 million more than the reuse program would have cost.

The Toowoomba proposal was an indirect wastewater use program, in which highly treated wastewater would be passed through an environmental buffer before being treated again, as part of the drinking water system. The public poll was accompanied by two dynamic campaigns building on the 'yuck' and 'fear' factors on one side, and social and financial arguments on the other. In the end, 62% of those polled opposed the project (Hurlimann and Dolnicar, 2010).

Source: Drechsel *et al.* (2015), modified.

Results from Australia indicate that actual exposure (see above) and practical experience can positively influence trust building in water authorities and community acceptance of reclaimed water, indicating also the importance of demonstration projects (Hurlimann, 2008). Dolnicar and Saunders (2006) propose reuse pilots in high-status communities first, positively influencing acceptance rates also in lower status communities.

Jordan has succeeded in informing and convincing its population about the importance of wastewater use in agriculture, by implementing an active educational campaign with strong community outreach (EMWATER, 2004). The program component included the distribution of newsletters, guidebooks, coverage of water issues in newspapers and on television and radio, websites, public educational places, and the education of land-use decision makers. Additionally, educational materials were distributed in schools, universities, and libraries (Al-Momani, 2011). However, in many low-income countries, authorities may have limited capacity to deliver on policies and enforce regulations. In such settings, local monitoring and oversight can be insufficient, and public mistrust can be fundamental (Dare and Mohtar, 2018).

In some cases, like for example Jordan, Tunisia or Kuwait, also religious concerns (Box 15.2) about water reuse were expressed in farm and household surveys (Abu-Madi *et al.*, 2008; Alhumoud and Madzikanda, 2010) while Wilson and Pfaff (2008) did not find any fundamental religious objections comparing feedback from different faith groups in South Africa.

### Box 15.2 Religious concerns

In 1978, the Council of Leading Islamic Scholars (CLIS) in Saudi Arabia stated that treated wastewater can be used if its treatment included advanced technical procedures that remove impurities with regard to taste, color and smell (Faruqui *et al.*, 2001). According to Farooq and Ansari (1983), there are three ways in which impure water may be transformed into pure water:

- self-purification of the water (e.g., removal of the impurities by sedimentation);
- addition of pure water in sufficient quantity to dilute the impurities; and
- removal of the impurities by the passage of time or physical effects (e.g., sunlight and wind).

It is notable that the first and third of these transformations are essentially similar to those achieved by wastewater treatment processes.

Framing water reuse messages can strongly influence acceptance or resistance to reuse (Menegaki *et al.*, 2009; Wester *et al.*, 2016). Care must be taken that the use of negative language and images does not stigmatize wastewater use. Negative branding, especially by some media, including such headlines as ‘Toilet to Tap’ or ‘Recycled Sewage’ prevents unbiased thinking and can generate fear, stigma, and disgust (Macpherson and Slovic, 2012). Also, technical terms may not be convincing, as learned in a study in the United States (Figure 15.4).

While inadequate and negative terminology can impede clear communication, positive images and terms that enhance knowledge and understanding of water and wastewater can enhance the likelihood of success (Macpherson and Slovic, 2012). Box 15.3 presents commonly used terminology in wastewater (re)use literature.

### Box 15.3 Commonly used terminology in water reuse and social acceptance modelling studies

Wastewater use: reclaimed water, reclaimed wastewater, water reuse, renovated water, treated wastewater, water recycling, recycled water, NEWater.

*Side note: technically speaking there is “water* ***reuse****” or “wastewater* ***use****”, although in normal language as well as scientific papers this difference is commonly ignored.*

Social acceptance: health risk perceptions, level of support or opposition, willingness to use, willingness to pay, likelihood of use, happiness to use, feeling comfortable to use, positive attitude, satisfaction, level of assurance or trust.

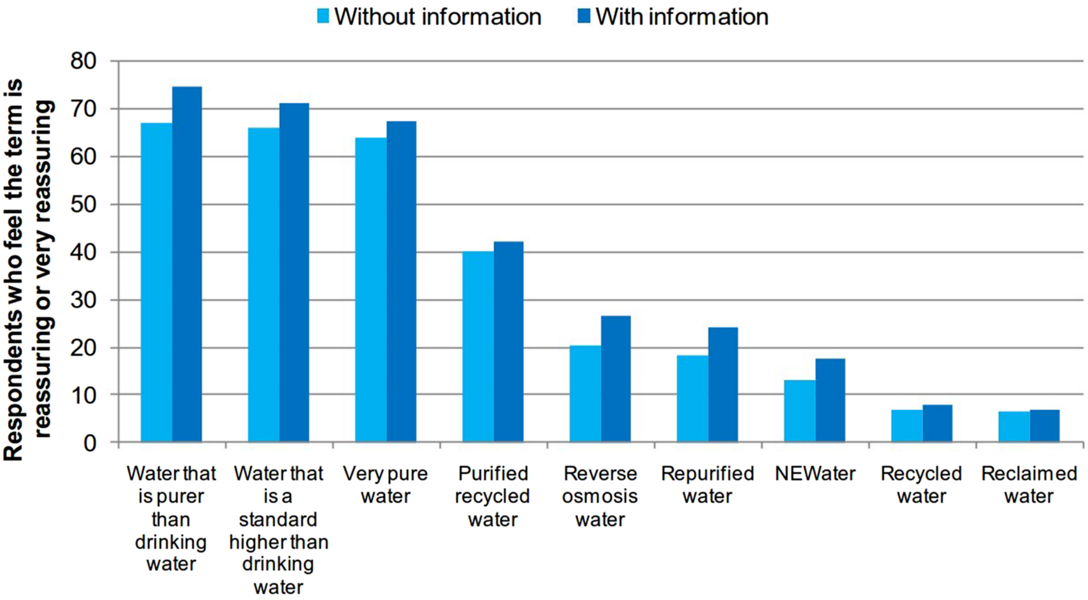

**Figure 15.4** Water reclamation terms in order of declining public reassurance (USEPA 2012, based on data from the Water Reuse Association www.watereuse.org/product/07-03).

### 15.4.2 Accepting safety interventions for untreated or diluted wastewater use in agriculture

Highly polluted, informal wastewater use by farmers, be it raw or diluted, is far more common than planned reuse (Thebo *et al.*, 2017). Unfortunately, many countries with low treatment capacity also miss the capacity to monitor water quality for effective restrictions. The resulting situation is a widespread use of untreated or partially treated wastewater, either directly or indirectly from receiving streams, putting farmers and consumers at risk (Scott *et al.*, 2010). WHO (2006) recommends as an interim measure the adoption of safety interventions on- and off-farm to reduce health risks. These recommended practices (safer irrigation systems, produce washing or cooking, etc.) require behavior change. The adoption of these practices will largely depend on: (i) personal health risk awareness, which inter-links with educational standards, cultural and social factors; (ii) financial benefits and cost of changing current practices; and (iii) perceived water quality which may not correspond with a scientific assessment:

#### *15.4.2.1 Risk awareness*

In many low-income countries, pathogen-related risks are commonplace and many poor households face numerous risk factors daily. The risks include missing freshwater access, limited (cooling) capacity to keep food and water safe, inadequate or missing sanitation facilities, poor hygiene, and so on. In such a setting, food safety hazards (like vegetables irrigated with polluted water), which would concern consumers in developed countries, usually do not get special attention or a priority claim on the households' financial resources as experienced in a more developed environment (Whittington *et al.*, 2013). Thus, the normal living environment in large parts of Africa is characterized by several notable health hazards, such that the health risks of producing or consuming vegetables irrigated with unsafe water is usually not a primary concern of farmers, traders, or consumers, and also only one of many challenges authorities are facing.

However, not only consumers, but also farmers rank wastewater exposure commonly more like an occupational burden, which the achieved benefits from crop sales offset (see next section), and other farming practices (pest control, water carrying, weeding, etc.) as a more important health burden. In addition, whenever health risks are identified, farmers link them more to off-farm activities such as sanitation and drinking water than to farm based activities (Chaudhuri, 2008; Keraita and Drechsel, 2015; Kilelu, 2004; Ouedraogo, 2002; Weldesilassie *et al.*, 2010). Thus, there are often no significant differences in risk perception between farmers using safe and unsafe water from an outsider perspective (Gbewonyo, 2007; Gerstl, 2001), even when risk assessments predict or confirm likely health impacts (Niang, 2002; Seidu *et al.*, 2008).

Educational efforts trying to link wastewater exposure to health risk face social and scientific challenges. A limited risk awareness applies in particular to the most common situation in which wastewater is diluted (indirect use), compared to the use of raw sewage or where chemical contamination is visually evident (Binns *et al.*, 2003). The invisibility of pathogens and the lack of connection made between symptoms of potential illnesses and exposure show the need for mutually agreed on risk indicators (Box 15.4) and their use for building risk awareness.

### Box 15.4 The challenge of visualizing invisible risks

Clarifying farmers and consumers' risks is normally the base for introducing health risk mitigation measures. A significant challenge for the introduction of safety options for wastewater use is getting farmers and traders to understand health risks stemming from 'invisible' contamination, such as from parasites or chemicals in water, soil and crops, and their possible transmission to consumers. Especially where farm households do not consume the (exotic) vegetables they produce, only occupational exposure problems, such as skin rashes, appear to be suitable indicators. However, the common measures to avoid skin contact, for example through the use of rubber boots, will not protect the consumer.

Studies in West Africa of traders and consumers show a generally low risk perception which is limited to visible quality characteristics, such as the produced/product's color, size and cleanliness (Acheampong *et al.*, 2012; Drechsel and Keraita, 2014; Hope *et al.*, 2008; Keraita and Drechsel, 2015). Thus it is important to also identify other risk indicators to increase awareness (Knudsen *et al.*, 2008). In Kano, Nigeria, for example, severe chemical contamination from tanneries resulted in different water colors that were well known and distinguished by local farmers in terms of possible risks (Binns *et al.*, 2003). In participatory trials with consumers and farmers, the use of UV fluorescent reactive gel (www.glitterbug.com) received positive feedback as a way to visualize potential germs (Amoah *et al.*, 2009). However, where risks remain invisible and hard to comprehend, behavior change can also be achieved without 'education' but through association of a wrong practice, for example with disgust (yuck factor), which was a successful trigger in Ghana's hand wash campaign (Scott *et al.*, 2007).

Source: Keraita *et al.* (2008), modified.

#### *15.4.2.2 Financial benefits*

Water access can have significant financial benefits for farmers, especially where it allows off-season (i.e. dry season) production of cash crops. Based on limited risk awareness or unenforced restrictions, water quality is usually a less important consideration. Studies show that farmers in West and East Africa, Southeast Asia and the MENA region generally are concerned about the quality of their irrigation water, mostly for crop growth, yet they consider the potential gains from irrigating with wastewater to be greater than any possible personal risks (Hanjra *et al.*, 2015). The common lack of safer (and at least equally beneficial) alternatives makes the use of polluted water an accepted, hardly avoidable professional trade-off (Abu-Madi *et al.*, 2008; Gbewonyo, 2007; Gerstl, 2001; Keraita *et al.*, 2008; Kilelu, 2004; Knudsen *et al.*, 2008).

A challenge related to some of the recommended safer irrigation practices, such as wastewater treatment, drip irrigation, or cessation of water application, is that these practices do not only reduce microbial contamination, but can also reduce crop yields (and income) if they are not well adapted to local conditions (Amoah *et al.*, 2011). For example, (i) drip kits with too wide inner-tube spacing in Ghana reduced plant density and yields; (ii) cessation of watering a few days before harvest made the vegetables appear dry and unattractive for traders; (iii) and wastewater treatment in ponds in Pakistan increased the salinity content of the water making it unsuitable for crops. Participatory research is required in such situations to understand farmers' constraints and adjust the technology to farmer's particular crops and farming conditions.

Health risk reduction measures will be adopted more easily if they appeal to farmers' priority challenges. For example, drip kits reduce pathogen exposure for farmers and crops, and they also enable farmers to save labor which is a high priority burden (Keraita *et al.,* 2010). In Ghana, Keraita *et al.* (2008) concluded that cost/labor savings and market incentives are the main factors which would motivate farmers to adopt best practices in the long term. However, marketing channels or an institutional framework to promote safer vegetable production and marketing are missing. To build such value chains, gender related work distribution will have to be addressed. In Ghana, for example, the marketing of most exotic vegetables is only done by women, while vegetable farming is mostly the domain of men (Drechsel *et al.,* 2013). These gender roles prevent farmers from direct marketing and result in 'safe' vegetables usually becoming mixed with unsafe vegetables in markets.

In general, the net beneficiaries of safe vegetables are the urban consumers, who may pay more for safe produce and dedicated marketing channels (Ngigi *et al.,* 2011). So far only specialist markets for more wealthy population groups show interest to pay for safety (Acheampong *et al.,* 2012; Lagerkvist *et al.,* 2013). A challenge will be how to make safe produce accessible for the most vulnerable, who have the lowest ability to pay a premium.

#### *15.4.2.3 Water preferences*

While consumers will generally prefer freshwater over (treated) wastewater, farmers' preferences can be the opposite where missing restrictions allow them to choose. In contrast to the planned introduction of reuse, where the availability of freshwater can be a strong disincentive for accepting reclaimed water, farmer preference can be very different in informal irrigation, especially if the driver of choice is income and not personal safety. Where wastewater is highly concentrated, farmers are often also aware of its fertilizer value (Van der Hoek *et al.*, 2002). There are many cases described where farmers actively seek the wastewater, and preferably untreated wastewater. In Pakistan, for example, treated wastewater did not find the same acceptance among farmers than untreated wastewater given its increase in salinity in treatment ponds (Ensink *et al.*, 2004). In Mexico, farmers protested against treatment to maintain the fertilizer value of the water (Scott *et al.,* 2000; Silva-Ochoa and Scott, 2004). In Bangladesh, farmers appeared to be well aware of actual and possible risks but still preferred wastewater for its fertilizer value or due to lack of alternative or equally (year round) reliable water sources (Mojid *et al.,* 2010), also supported from Morogoro, Tanzania (Mayilla *et al.,* 2017). A rather indifferent view was observed when reuse was indirect from streams carrying diluted wastewater. In this situation, the nutrient value of wastewater can be negligible (Erni *et al.,* 2010) while the year-round availability steers the added wastewater value. In the Mezquital Valley, Mexico, the possibility of irrigating with wastewater instead of (only) rainwater caused land rents to increase many times as the additional water enabled three crops to be harvested per year instead of one (Jimenez, 2005). Only where wastewater use is actively regulated, like in Tunisia, does its use become unattractive (Dare *et al.,* 2017).

#### *15.4.2.4 Facilitating the adoption of safer behavior*

Where authorities lack capacity to implement and monitor safety regulations, education as well as economic and/or social incentives can help to enhance food safety along the value chain. Behavior change is a particular challenge where wastewater is the only water source, and safety measures are required to facilitate a transition from informal to formal use (Prouty *et al.*, 2018). Such safety measures can be introduced from 'farm to fork', as described for example by Amoah *et al*. (2011) and WHO (2006). Where risk awareness is low and not easy to develop, research is needed to determine how best to motivate and trigger adoption of risk mitigation measures. Gender specific roles can be an important factor in this context (see below). Measures to support behavior change can include economic or social (marketing) incentives, such as access to credit, labelling/branding, dedicated marketing chains, tax exemptions, and institutional support, like the provision of extension services, awards, or tenure security, but also restrictive regulations if they can be enforced (Drechsel and Karg, 2013). Labeling of food products in a reliable manner that reveals safe or unsafe irrigation methods will be needed to support a market response to changing consumer behavior.

In many cases increased education and risk awareness will not be sufficient to motivate the desired changes in behavior. Economic incentives may be helpful in motivating wastewater farmers who are usually engaged in cash crop production, while consumers may respond better to social marketing which aims to respond to inner desires, fears and motivations (Dishman *et al.*, 1989; Scott *et al.*, 2007). Successes with social marketing have been reported from promoting latrine use and hand washing (Box 15.5). Where regulations and monitoring are weak, media publicity can encourage farmers to adopt safety practices including safer water sources, in the same way that negative media exposure can harm business activity (Drechsel and Keraita, 2014).

### Box 15.5 Social-marketing studies in the West African context

'Health in your hands' refers to a marketing approach applied in a nationwide hand-washing campaign in Ghana, involving the use of professional marketing techniques facilitated through a private–public partnership to promote 'socially useful products' (in this case, hand washing with soap) through generation of demand. The underlying research revealed two main drivers for hand washing with soap: disgust of dirt (yuck factor) and caring for a child, whereas health (protection from disease) was a weak motivator. The communication campaign was thus designed to evoke the feeling of disgust without mentioning health or sickness. The campaign was fairly successful: soap use after toilet use increased by 13% and soap use before eating increased 41% (Scott *et al.*, 2007) and thus raised awareness.

'A wanted latrine is a used latrine': Many sanitation projects in developing countries have failed because they relied only on subsidized latrine construction and health education without generating demand. Thus the target community did not change established habits (like open defecation) and the latrines remained unused. In Benin, the social marketing approach was applied to improve sanitation. Research was conducted to determine what triggers people to invest in a latrine and to use it. Health benefits did not appear in the top ten triggers, whereas safety, dignity and social prestige were among the top five (Martinsen, 2008), and the social marketing approach was much more successful where local social actors such as school teachers led the campaign, like in Ethiopia (Crocker *et al.*, 2016).

## 15.5 ACCEPTANCE OF RECOVERED NUTRIENTS FROM WASTEWATER FROM SEWERED SYSTEMS

### 15.5.1 Biosolids recovery and use

The conventional view of wastewater as a public and environmental health concern still results in the linear model where large amounts of energy and chemicals are utilized to ensure that wastewater is effectively treated and/or transformed into products which meet stringent human health and environmental standards before they are released back to the environment (WRF, 2022). Where such treatment is in place, and contaminants are controlled, the beneficial uses of wastewater and sludge (biosolids) produced during the treatment process are well documented. There are various technology options to achieve Class A or Class B biosolids standards (USEPA, 2012). However, technical possibilities do not imply market demand and thus business opportunity. There are different constraints but also opportunities.

A common limitation for the biosolids market is the lack of regulatory and financial support needed to catalyze market demand for biosolids. However, in a context where landfills are filling up fast and sludge is being produced in ever greater quantities, growth in sustainable solutions for sludge treatment are on the horizon. With increasing competition for valuable landfill space and new government guidelines and compulsory policies emerging, many countries such as the UK, USA, Australia, South Africa, India, Japan and China are phasing out landfilling of sludge in favor of sludge dewatering and utilization, like land application, soil amelioration, energy and heat recovery, or the production of bricks and cement blocks (Box 15.6).

### Box 15.6 Sludge management in China

In China, government policies have set national goals of treating 70% of the sludge in large cities and 50% in small cities and significant investments have been committed in sewage sludge treatment. The Ministry of Environmental Protection, together with the Ministry of Housing and Urban-Rural Development and the Ministry of Science and Technology, published the "Policy on Sludge Treatment and Pollution Prevention Technology in Urban Wastewater Treatment Plants" which aims to regulate and promote beneficial sludge utilization practices, which can have a major potential to be exploited as a Clean Development Mechanism (CDM) project. These plans show government recognition that shifting from disposal to utilization is compatible with their idea of a circular economy and are a clear signal that sludge treatment and utilization can have a future in the environmental protection industry (GTZ 2009).

Although sewage sludge has been used in agriculture in many parts of the world, its acceptability varies significantly with different cultures and beliefs among agricultural producers. Even with strict guidelines in place, in some countries like Australia and the US, agricultural producers have significant reservation in using sewage sludge (Krogmann *et al.*, 2001; Murphy, 2018). For these agricultural producers, perceived risks related to heavy metal contamination (soil build-up, crop uptake), negative food purchasers and consumers' perception, odor complaints, and potential increase of contaminants in water supply outweigh the economic incentives (nitrogen and lime value of sewage sludge) and soil improvement benefits (addition of organic matter) (Krogmann *et al.*, 2001). Farmers' reluctance to use sewage sludge is with good reason given that in China for example, 80% of the produced sludge is still transferred to landfills because industrial contamination makes the sludge unsuitable for most reuse options. On the other hand, in places like Palestine, farmers are in favor of using sewage sludge from a certified fully functioning wastewater treatment plant (Rashid *et al.*, 2017). It is important to note that the majority of the farmers were however in favor of using it for growing fruit trees, rather than growing vegetables and other plants in a greenhouse. In the case of the latter, farmers' willingness to use treated sewage sludge increased on condition that: (i) consumers are willing to buy agricultural products fertilized by sludge; (ii) sludge meets the public health requirements; and (iii) sludge is available at low costs.

Not surprisingly, public perception is a major concern of agricultural producers given that their livelihoods depend on consumer satisfaction of their produce. This has been justified by studies about consumer preferences (Krogmann *et al.*, 2001; Murphy, 2018; Rashid *et al.*, 2017; Zimmerman *et al.*, 1991); although it is important to note that limited research has been conducted on consumer preferences about food crops grown on sewage sludge applied land. As with potable vs. non-potable wastewater reuse, reuse without human contact in general has higher acceptance than reuse with human contact, as corroborated by Zimmerman *et al.*'s (1991) findings that US households have a preference for land application of sewage sludge in parks and roadways compared to flowers and food chain crops. Food purchasers and consumers' reservations are noted to be driven by key risk perceptions related to biosolids regulations, treatment, and application. Surveyed respondents believed that the benefits derived from biosolids did not offset the perceived health and safety risks. Significant gender differences were observed, with females perceiving greater risks to health and safety from biosolids use than males.

Sewage sludge for agriculture use is unlikely to grow until farmers' diverse concerns about consumer perceptions, crop and land application are addressed. Even with existing regulations and guidelines governing land application practices of sewage sludge, it is still unclear whether farmers are not knowledgeable about the regulations or are simply not convinced that the regulations are protective enough. Innovative and practical communication strategies focusing on crop or land related issues are imperative to improve farmers' adoption of sewage sludge for agriculture. Community-specific outreach programs are critical to address public risk perceptions and those driven by gender differences.

Beyond negative consumer perceptions, another common problem with biosolids-as-fertilizers in developed countries relates to the level of nutrient, in particular nitrogen (N), even in dewatered biosolids, which is oftentimes too low to support a market price that permits an independent company to be profitable; and thus actually produce it for the market. Only a fraction (5–15%) of the available nitrogen in the wastewater can be recovered through phosphate (P) based precipitates. It is more likely that P recovery will drive the process. However, making a high value biosolids-fertilizer mix can also be a viable option today because of increasing tipping fees by municipally operated wastewater treatment plants to dispose of their biosolids, especially in medium to large municipalities.

### 15.5.2 Phosphorus recovery and use

The currently dominant process to extract phosphorus (P) with market value from wastewater treatment streams is based on crystallization and precipitation of struvite (magnesium ammonium phosphate or MAP) (Duenas *et al.*, 2003; Rahman *et al.*, 2014). Struvite can have many uses with the most common as slow-release fertilizer or raw material for the fertilizer industry (Gaterell *et al.*, 2000). Given that the world's affordable mineable reserves of phosphorous are set to start running out in the coming decades and an expected increase of the price of high-quality rock phosphate, alternative high quality P sources, like struvite, will become more competitive than currently (Rahman *et al.*, 2014). A contemporary driver observed for example in USA, are anticipated changes to regulatory limits affecting effluent discharge permits. The result is that the number of treatment plants recovering phosphorus is continuously increasing and also the number of technologies offered for P recovery, especially in the Netherlands, Germany, Austria, Canada, and Japan.

Technology plays a significant role for P recovery as there are various options with very different costs and efficiencies. A wastewater treatment process offers several locations for phosphorus recovery.

Raw material options for phosphorus recovery processes include the sludge-free wastewater, the sludge liquid and the sludge itself, and the incinerated sludge ash, each with a different P concentration and recovery potential but also costs. Crystallization processes based on the liquid phase from sludge dewatering are so far cost and energy wise the commonly preferred option, while processes building on P recovery from sludge ash are slightly more expensive but have a significant more favorable P recovery capability. Options to recover P from sludge can extract similar amounts of P than those based on incineration, but the additional energy demand and costs makes them so far less attractive (Morf and Koch, 2009).

Limited information is available on the actual use of the recovered struvite from its registration as fertilizer under local law and how far the fertilizer sector is accepting the product at the scale of its production, or only for niche markets. So far the market value of the struvite is not a driver for phosphorus recovery and recycling (P-REX, 2013). In fact, the chemical reagents necessary for struvite production (in particular magnesium chloride) cost so far more than the market value of the produced phosphate fertilizer. However, savings in removing unwanted struvite and avoiding blocked pipes, reducing sewage sludge production and disposal, and sustainable development objectives make the innovation an appreciated and viable value proposition with payback periods of 3–7 years (Shu *et al.*, 2006).

In view of the market for recovered P, there can be a variety of challenges which differ from country to country and are still limiting the potential of P recovery despite its obvious benefits (Otoo and Drechsel, 2018). One in particular relates to the political and regulatory environment. The regulatory context in many countries still does not yet support ‘secondary’ phosphorus containing fertilizers and their producers as it is often classified as waste (P-REX, 2013). While stringent environmental regulations on the discharge of P effluents into water bodies are on the increase and provide an opportunity to promote recovery and reuse, and so do SDG 12.4 and 12.5, these regulations mostly favor P removal, but not yet recovery and reuse. In fact, in Europe, regulations on the reuse of waste derived resources, including urine and struvite, are often very restrictive (Winkler *et al.*, 2013). On the other hand, in many developing countries, regulations and standards may be lacking which can place resource recovery and reuse in a gray area where entrepreneurs may face few barriers, but quality control and legal security remain risk factors. However, with increasing attention to the SDGs and a circular economy the situation is changing, especially in Europe (Box 15.7).

Other limiting factors to the development of the phosphorus market include:

- In many countries a range of markets may not be accessible due to prohibitive legislations or missing legislation on the reuse of waste derived resources.
- The volumes of the recovered P are still too small compared with the market size, which increases the costs of entering the current mainstream value chain.
- Although many studies show that recovered P crystals are of high quality and are often less contaminated with metals and other micro-contaminants than natural rock phosphate, legislation and the fertilizer industry are hesitant to accept the product, be it for blending of other P sources or as stand-alone slowly-soluble fertilizer.
- More progressive legislation in support of a circular economy could help penetrate the conventional P market by demanding for a certain ratio of recovered to natural P; one example is that of the Indian Government which requires the fertilizer industry to co-sell bags of industrial fertilizer with a number of bags of waste-based compost.
- To avoid perception related risks, marketing strategies normally avoid any connection between the name of the P product and its source.
- With the never-ending generation of wastewater, also the supply of recovered P will be continuous irrespective of agricultural seasons. This will pose storage challenges unless multiple market segments next to seasonal crops are available (e.g. parks and gardens, forest or fruit plantations, year-round home gardens).

### Box 15.7 P-recovery regulations and obstacles in Europe

Switzerland was the first European country to make phosphorus recovery and recycling from sewage sludge and slaughterhouse waste obligatory. The new regulation entered into force on 1.1.2016 with a transition period of 10 years. Switzerland banned direct use of sewage sludge on land in 2006, so that the new regulation will lead to obligatory technical recovery and recycling in the form of inorganic P products. Swiss sludge and slaughterhouse waste together represent an annual flow of 9100 t of phosphorus. In Germany, a new sewage sludge ordinance (AbfKlärV) is expected to enter into force early in 2018, making phosphorus recovery obligatory for larger sewage works within 12 years (>100,000 p.e.) or 15 years (>50,000 p.e.), under certain conditions. P-recovery will thus be required for around 500 sewage plants, treating around two-thirds of German sewage. Following the legislative developments in Switzerland and Germany, Austria is now also opting for mandatory P recovery from municipal sewage sludge. The draft Federal Waste Plan 2017 (Bundes-Abfallwirtschaftsplan) includes a ban of direct land application or composting for sewage sludge generated at Wastewater Treatment Plants (WWTP) with capacities of 20,000 p.e. or above within a transition phase of 10 years. Alternatively, these WWTP will have to recover the P from sludge or its ash. This regulation will cover 90% of the P contained in the Austrian municipal wastewater. However, P recovery within a Circular Economy requires reuse. Until now, struvite recovered from wastewater is only authorized for use as a fertilizer for some producers in some countries (e.g. the Netherlands, Denmark and Japan), or only on a case-by-case (e.g. Ostara plant by plant) authorization. Even in a country like the Netherlands, approval as a fertilizer does not ensure end-of-waste status for struvite. End-of-waste criteria specify when a certain material ceases to be waste and obtains a status of a product (or a secondary raw material). This current lack of clarity and disparities even between EU Member States poses a significant obstacle, also to investments in the technology as long as it cannot necessarily be sold in another country because the resulting product cannot be sold as a fertilizer. The currently (2017) discussed new EU Fertilizers Regulation will enable recycled nutrient products to be sold in any Member State, when the new Regulation comes into force. Recognized products will also be granted de-facto end-of-waste status. Composts and digestates are already included in the proposed regulation text, but struvite is not. The EU's Joint Research Centre (JRC) has been mandated to make an impact assessment and (if this concludes positively) to propose criteria to add struvite, biochars and ash-based recycled nutrient products to the new Regulation annexes.

Source: http://phosphorusplatform.eu/

- It is a significant advantage if like in the Ostara case the cost of P recovery can be (more than) absorbed by savings in conventional P removal, as the price of rock-phosphate is still too low compared with the breakeven price of recovered P, pushing recovered P into premium or niche markets which are able to pay higher-than-average prices.

### 15.5.3 Wastewater-based aquaculture

Greater wastewater reuse can enhance social benefits, provided health and environmental risks can be managed appropriately. The majority of wastewater reuse for aquaculture in the world today occurs in Asia, where it is a traditional practice in countries such as Vietnam and China (Edward and Pullin, 1990). Many international organizations, such as the UNDP and World Bank, are promoting the adoption of an integrated system of wastewater treatment plants and aquaculture in developing countries (Edward, 2008). These systems have the potential to improve sanitation because they provide low treatment cost options to policy makers and have the opportunity to reduce nutrients and pathogens in wastewater.

In several cities in northern Vietnam, the use of wastewater in agriculture is the only means of treatment and fertilizes about 500 ha of fish ponds (Vo, 1996; WHO, 2006). From a public sector perspective, the sale of fish and aquatic plants represent opportunities to offset the costs of the wastewater treatment. This trend is supported by national estimates of Vietnam, which indicates that wastewater-based aquatic products have the potential to generate a revenue of approximately $5760 per ha per year for vegetable production and $7200 per ha per year for fish production, which is three times higher than that of rice production, a major local staple crop (Nguyen and Leung, 2009). The food security perspective of wastewater-based aquaculture cannot be ignored, especially in view of the limited availability of reliable fresh water sources for sustainable aquaculture production. Wastewater represents an important source of nutrients and water, which can be used to increase both fish and crop production (Bunting, 2007). Wastewater-based aquaculture accrues significant social benefits via employment generation, fish for households, service providers such as producers of fish fingerlings, and economic actors involved in fish transport and marketing.

While the potential benefits of wastewater use for aquaculture are multi-fold and significant, the market prospects are limited by social barriers and consumer perceptions. A key factor that threatens wastewater-based aquaculture is the perceived consumer health risks. The World Health Organization (WHO) has developed specific guidelines for the safe use of wastewater for aquaculture to ensure public health protection (WHO, 2006). The guidelines recognize the need for public health standards to be based on epidemiological rather than microbiological guidelines, as these guidelines are context specific (WHO, 2006). Many studies show that there is no strong evidence of health risks from the consumption of wastewater-raised fish (Edward, 2008). Supporting studies from India and Egypt (Easa *et al.*, 1995; Pal and Das Gupta, 1992) suggest that fish reared in treated wastewater-raised ponds have better microbiological quality than freshwater fish cultivated in water bodies and surface waters, which may have been unintentionally polluted. A study in Vietnam corroborates this notion, where there was no significant difference found in the number of presumptive thermos-tolerant coliforms in the gut content and muscle tissue of fish raised in wastewater-based ponds and non-wastewater-based ponds (Lan *et al.*, 2007). Fattal *et al.* (1992) and Edwards and Pullin (1988) reported similar findings.

Even with the implementation of practices that satisfy health and hygiene guidelines, research shows mixed reviews on consumers' perception of wastewater-raised fish. In Ghana, for example, wastewater-raised tilapia is sold at prevailing market prices as those of freshwater systems (Murray *et al.*, 2011). Conversely, in Vietnam, although significant evidence indicates no increased human health risks from consumption of fish raised in wastewater reuse systems, concerns over toxin accumulation in edible fish has been found to significantly influence consumer demand (WHO, 2006). Mancy *et al.* (2000) found similar results in Egypt where consumers were reluctant to consume fish cultivated in wastewater although noted suitable for human consumption. This issue of food safety has been attributed to market failures related to imperfect information between households and producers with regard to product-specific attributes (Ortega *et al.*, 2011). Particularly for wastewater-raised fish, this issue also arises because of inadequate knowledge and awareness of the level of health risks associated with wastewater-raised fish, unclear policy development and regulation for fish marketing. There is limited information on the sources of water used to raise fish for the market. As a result, households' purchasing decisions are usually not based on improved fish safety and quality attributes. The assessment of fish safety attributes can restore households' confidence and provide the optimal attributes mix for potential investors to focus on for the promotion of wastewater-raised fish. If indeed consumers' purchasing decisions are influenced by source and product quality information, then understanding consumers' acceptance of fish reared in treated wastewater is critical.

Several authors have investigated the association of socio-demographic descriptors with the acceptance of fish reared in treated wastewater. The three factors that have been frequently found to be associated with acceptance levels are the education/knowledge of the individuals expressing their opinion, income, and their perception of certification by a trusted government agency. Higher levels of education are positively associated with acceptance of fish reared in treated wastewater.

Fewer studies have included informational attributes such as third-party certification. Fish safety issues often arise from lack of trust between producers and consumers with respect to product-specific attributes. Such market failures are remediable with quality certification measures using a trustworthy and independent party to test the product for its quality. Third-party certification can serve as a quality assurance indicator, which may influence household purchasing decisions (Danso *et al.*, 2017; Fonner and Sylvia, 2015; Ortega *et al.*, 2011). The existence of an independent certification can create a more competitive market to provide certified fish products and other businesses will be incentivized to pay the fees for certification, and compete to provide the given quality most effectively. Brand identity conveys a message of product quality, but this is often realized at the cost of high prices and limited supply.

Danso *et al.* (2017) found a positive correlation between consumers' willingness-to-pay (WTP) for certification of fish and information on the medium used to raise fish in Vietnam; with demand expected to increase if certification is done by a trusted government agency. This result indicates that there is a strong need for the Vietnamese government to provide adequate food safety and quality control as the households in this study preferred a government party to provide food safety certification. The results also suggest that quality assurance considerations and high incomes are factors that would increase the probability of higher expenditures on wastewater-raised fish. As the Vietnamese urban per capita income continues to rise rapidly, more people are expected to join the higher income class that is incentivized to pay a higher price for better information on food safety. This should serve as a catalyst for governmental agencies and the private sector to invest in quality control services for food safety and new wastewater-based aquaculture businesses as this approach may contribute to improve food and strengthened nutritional quality in Vietnam. While some households may be willing and able to pay for values they believe in, it must first be apparent that the market can deliver these values. Innovative marketing strategies including pricing and product promotion strategies will be required to facilitate market entry.

Beyond wastewater use for aquaculture, biological processes can be used for recovering nitrogen and phosphorus from wastewater, like through aquatic plants growing in treatment ponds, aquaculture, or wastewater irrigation. Aquatic plants, such as algae and duckweed that grow naturally as a part of pond and lagoon treatment systems, can absorb significant amounts of nutrients and be harvested for a variety of purposes, including biofuels, or a source of protein for animal/fish feeds, and so on. Ozengin and Elmaci (2007), for example, reported 83–87% total nitrogen removal and 70–85% total phosphorus removal for duckweed fed with municipal and industrial wastewater. In the US, most wastewater treatment ponds and lagoons are functionally high rate algae producers and in more recent years the systems have been explored for their potential to grow algae that can be used, for example, for biofuel production (Sturm and Lamer, 2011). Biological nutrient recovery via the production of fish food (duckweed) and/or fish has been tested successfully in different environments from Bangladesh to Peru with full cost recovery, not only of the additional costs but all operational costs of the pond-based treatment system (http://www.agriquatics.com/Case_Studies.html; Otoo and Drechsel, 2018). Although there is a potential significant market, this is a nascent sector and very limited research on end users' perceptions and the market has been conducted to date.

### 15.5.4 Wastewater from non-sewered systems (onsite sanitation systems) as a nutrient source

While developed countries with extensive sewer systems require advanced technology to separate nutrients from the waste stream, the low chemical and metal contamination in household based on-site treatment facilities, such as septic tanks and latrines, makes the resulting fecal sludge (septage) a valuable soil ameliorant. The dried and composted material can for example be pelletized or blended with particular nutrients to meet farmers' needs, as shown for example in South Africa and Ghana (Harrison and Wilson, 2012; Nikiema *et al.*, 2012). Fecal sludge (FS) is an abundant and valuable resource, similar to other organic manure such as farmyard manure which is used as a source of fuel and fertilizer. However, with diarrhea being the second top ranking contributor to the global burden of diseases

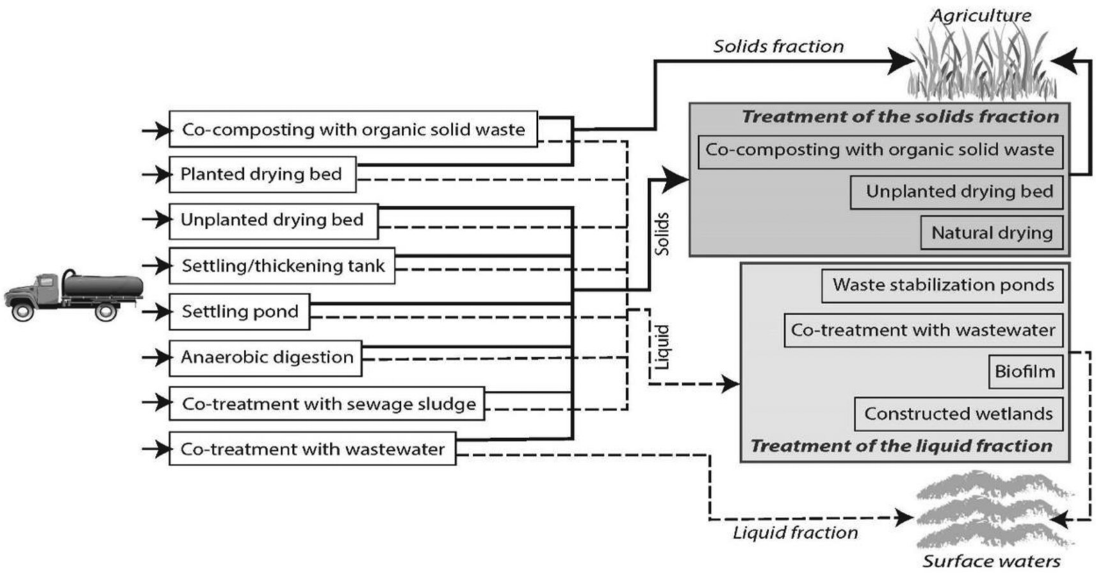

**Figure 15.5** Appropriate FS treatment options in developing countries with option for nutrient and water recovery (Source: Strauss (2006), modified).

and 88% of cases of diarrhea worldwide attributed to fecal matter contamination, the management and possible reuse of human waste containing fecal matter receives priority attention across the water supply, sanitation, food and health sectors (WHO, 2006). A controlled resource recovery approach can however reduce the negative impact of fecal matter on the environment and have a positive public health impact, by turning a potential threat into an asset for the production of nutritious food. For the reuse of nutrients captured in on-site sanitation systems, a number of nutrient recovery options exists (Figure 15.5) as described, for example, by Tilley *et al.* (2008).

In areas where fertilizer production is limited and/or their prices are high, smallholder farmers may resort to the use of raw FS for fodder, tree (crop) plantation or cereal production. For example, farmers in West Africa and South India are redirecting cesspit truck operators to their fields to obtain the nutrient rich manure. Research has shown that farmers have concerns with low product nutrient content, skin diseases from product use, labor requirements and general mistrust of information on product quality, and these may significantly affect the demand for compost products (Cofie *et al.*, 2006; Murray *et al.*, 2011; Viaene *et al.*, 2015). In many situations, farmers' willingness-to-pay is either too low or farmers prefer existing substitutes for soil inputs such as cow dung, poultry manure or even dried fecal sludge. A major drawback in mitigating farmers' reservation about potential health risks is the lack of regulations and negative perceptions of the authorities themselves concerning the use of fecal matter in food production. Crop restrictions and sufficient solar drying can minimize these risks (Keraita and Drechsel, 2015; Seidu *et al.*, 2008), even where no other regulations govern the process like, for example, in the septage program of Michigan's Department of Environmental Quality, USA, where septage application in agriculture is a well-regulated option.

Formalized use of processed fecal sludge for agricultural production is still novel (Otoo and Drechsel, 2018). Few opportunities to increase the accessibility and usability of value-added FS products in agriculture are emerging, with cases identified in Nigeria, Ghana and South Africa. Different entities have adopted innovative value-addition techniques such as fortification and enrichment of FS with nutrients to boost its safety quality and fertilizer value. For the latter, a nutrient source such as 'natural' like rock-phosphate or struvite/urine or industrial fertilizer can be added as an enrichment. Another option is pelletizing composted FS, resulting in an easy to handle, safe, high-value product. These commodity-value based approaches have shown significant potential in increasing farmers' demand as has product certification (Danso *et al.*, 2017; Otoo *et al.*, 2015). Farmers' incentive to pay for certification is indicative of their need of safety assurance from the use of a fecal sludge-based product. Similar to wastewater-based aquaculture, quality certification measures using a trustworthy and independent party to test the product for its quality will be essential in increasing farmer adoption.

## 15.6 GENDER ASPECTS OF WASTEWATER USE

Understanding gender differences is important for examining the social aspects and public responses to wastewater use, planned or unplanned, due to common gender differences in roles, risk exposure and perception (Gustafsod, 1998). Very limited research has been conducted on gender dimensions related to unplanned use of untreated wastewater in comparison to that of planned reuse of treated wastewater for agriculture. From that perspective, this section solely focuses on the latter.

On the general issue of accepting water reuse, most gender-sensitive studies either found no significant association between gender and acceptance of wastewater use or concluded a higher acceptance of wastewater use among men than women – for example, in USA, Australia, Greece, Iran, and Bahrain (Baghapour *et al.*, 2017; Bakopoulou *et al.*, 2010; Gibson and Burton, 2014; Haddad *et al.*, 2009; Madany *et al.*, 1992; Price *et al.*, 2012; Rock *et al.*, 2012; Rozin *et al.*, 2015; Tsagarakis *et al.*, 2007), while also the opposite has been observed, like in Italy (Saliba *et al.*, 2018) or Tanzania (Mayilla *et al.*, 2017). Around Addis Ababa, Ethiopia, positive perceptions towards water reuse were higher among male farmers, while female farmers appeared more aware towards problems of eating unwashed vegetables (Woldetsadik *et al.*, 2018). However, as the reasons behind observed patterns can vary, each situation ideally requires both qualitative and quantitative analysis (Gustafsod 1998).

In many cultures, women carry the main responsibility for hygiene and health, also vis-à-vis greywater or wastewater use as reported for example from Jordan (Boufaroua *et al.*, 2013), Vietnam (Knudsen *et al.*, 2008) and Tunisia (Mahjoub, 2013). The strong connection between water use at a household level and women offers a significant potential for innovative training approaches to improve the social acceptance of safe water reuse as recently demonstrated in Jordan (Boufaroua *et al.*, 2013), as well as household livelihoods (Box 15.8). In Ghana, where households already use greywater to grow indigenous crops in backyards like sugarcane, banana/plantain, taro, sweet/wild basil, and dandelion, the major plant benefits identified were food (84% of respondents) and medicine (62% of respondents), both supporting household roles expected from women (Dwumfour-Asare *et al.*, 2018).

As shown in the example of Box 15.8, water reuse can also contribute to gender equality and shrink the income gap amid socially mediated gender roles. Perceived advantages and greater acceptance of greywater use by women than men were, for instance, reported in South Africa and India (Bakare *et al.*, 2016; Ravishankar *et al.*, 2018). Another example of gender specific responses is the acceptance and use of protective clothing to avoid health risks. In Vietnam, women were observed wearing protective gloves and boots with more consistency than men. The differences were attributed to the gender specific work separation on the farm, with men walking around the farms much more than women, where protective clothing constrained men's movements (Knudsen *et al.*, 2008). A lesson from gender analysis vis-à-vis water reuse is the need for a systematic way of assessing the different impacts of actions and results on both genders. This form of analysis asks the 'who' questions – Who does what? Who has access and control over water? Who makes the decisions? Who benefits from (better) reuse implementation? Who is burdened? Many of these are questions relating to power dynamics, social roles and responsibilities and relationships (Arafa *et al.*, 2007).

### Box 15.8 Greywater reuse supporting women

In Jordan, a pilot project implemented by IDRC in partnership with the Inter-Islamic Network on Water Resources Development and Management (INWRDAM) allowed the poor in Tufileh to reuse household greywater in home gardens. The women of the community used small revolving loans to implement simple greywater recovery systems and set-up gardens. Although women were not very prominent publicly, they are actually the ones who decided what went into the system. It is they who gauge the quantity of grease or soap that enters the system and women are the 'water managers' at the household level. Their active involvement was critical for ensuring that the system worked properly. The project allowed the community to offset food purchases and generate income by selling surplus production, earning an average of 10% of their present income. Had the households used municipal sources for this supplemental irrigation, on average, they would have used 15% more water and had 27% higher water bills. Moreover, the project helped community members gain valuable gardening, irrigation, and food preservation skills. Women reported feeling more independent and proud because of the income they generated, the skills that they gained and their enhanced ability to feed their families. It is worth mentioning here that an environmental impact assessment demonstrated that the quality of the treated greywater was adequate, and the negative impacts on soil and crops were negligible.

Source: Arafa *et al.* (2007).

## 15.7 CHAPTER SUMMARY

While water scarcity and material value support a discussion about reuse, decisive factors may be the level of direct exposure, availability of alternative water and material sources, education levels and perceptions of health risks, extent of public participation and buy-in, religious concerns, gender specific roles and responsibilities, and the means and messages used in knowledge sharing and communication. Overall, the acceptance of (safe) wastewater and residuals use varies with and within the development stage of the society, and can be a very dynamic process which makes social feasibility studies, close participation of target groups, and trust building essential components of successful reuse programs, independently of the technical advances and geographies.

The discussion on resource recovery from wastewater has particular momentum in water scarce regions and focuses on water reuse for both potable and non-potable purposes, with more emphasis on safety than financial aspects. The discussion on nutrient recovery from wastewater is however one step behind and so far more determined by regulatory pressure or technical opportunities for cost savings than any actual market demand for recovering nutrients and farmers' and food consumers' perceptions. With few exceptions the demand is more theoretical, embedded in the call for a more circular economy, ideally turning conventional wastewater treatment plants into resource recovery centers (Wallis-Lage, 2013), alongside treating wastewater to serve the imperative of protecting public health and ecosystems.

The documented experience on consumers' perceptions related to the social and cultural dimension of marketing water reuse and related recovered resources analyzed common factors challenging the acceptance of reuse, as well as of behavior change towards increased safety where reuse is already taking place, but without enforced guidelines. Decision making appears to be influenced by context-specific factors, for example consumers' knowledge about reuse, the level of risk awareness, direct or indirect contact or exposure, the availability of alternative water options, financial benefits, buy-in through participatory planning of reuse schemes and trust building. Responses can also differ by gender and may be influenced by religious beliefs. There are geographic differences in terms of education and risk awareness, but these do not guarantee that reuse is easier promoted and/or accepted in developed countries.

For potable reuse, individual and group perceptions related to risks and disgust and the possibility of alternatives appear to be the main decisive criteria for potential users of reclaimed water. Farmers' main arguments for or against changing their water source or behavior was usually related to economic arguments, like (domestic, export) market perceptions and regulations affecting sales and revenues or cost and benefits in general (saving on fertilizer, extra harvest, reliability of supply, etc.). As a result, wastewater may be rejected in one situation, favored in another, or only be accepted if not treated in a third (to preserve nutrient while keeping the salinity level low). Even where own health impacts were experienced by farmers, these were often perceived as an acceptable challenge, balanced by financial gains. A key lesson seems to be that acceptance of reclaimed water is hard to predict and requires a careful socio-economic analysis. In fact, technical perfection is an important input, but may not be the final decision-making factor as the example of Singapore showed. This implies that the introduction of water reuse, of behavior change towards increased safety, requires a strong integration of social science research and related strategic partners and stakeholders in the strongholds of engineering and epidemiology to address possible adoption barriers and opportunities. These concern in particular:

- public perceptions and group dynamics which can easily jeopardize any reuse project;
- educational levels which may be too low to understand risks and related responsibility; which can 'favor' reuse but may also prevent it based on beliefs and myths;
- the lack of economic or social incentives for changing practices.

Compared to the significant body of references on the introduction of water reuse and its social challenges, there is comparatively little information on strategies, achievements or failures along the trajectory from unplanned to planned reuse, or informal to formal, like in Peru, Mexico or several MENA countries where both systems co-exist. The reason for this lack of information may be that there are only a few countries, like Tunisia, which began combining wastewater treatment and reuse programs early in the 1980s, resulting in significant treatment for reuse efforts supported by well-enforced regulations (Bahri, 2009; ONAS, 2012). Most other success stories derive from well-resourced developed countries with own reuse regulations. These regulations are however seldom transferable to developing countries due to differences in institutional and technical capacities.

Locally adapted and applied regulations and reuse guidelines are essential to support reuse programs in the long term. The global WHO guidelines for potable water as well as water reuse in agriculture and aquaculture provide a flexible framework for local adaptation and are particularly strong in supporting the transition from informal to formal reuse even where treatment plants are not yet able to safeguard public health. They are building on the adoption of multiple barriers (safety options) along the contamination pathway from farm to fork, similar to the well accepted Hazard Analysis and Critical Control Points (HACCP) concept of the food industry. However, the guidelines fall short in explaining how the behavior change towards their adoption could be facilitated and sustained.

The WHO 2006 guidelines face limited acceptance, probably due to their loss of simplicity by moving away from irrigation water quality thresholds to more flexible, human exposure-based targets based on local risk assessments. The more recently published Sanitation Safety Planning Manual (WHO, 2015) and Guidelines on Sanitation and Health (WHO, 2018) are addressing this challenge to increase the adoption and sustainability of safe wastewater use.

## 15.8 EXERCISES

**Exercise 15.1:** How should a campaign to introduce water reuse at household level in the MENA region be designed?

**Exercise 15.2:** Could you describe why it is so challenging to change behavior of, for example, African farmers who use untreated wastewater due to the lack of safer alternative water sources?

**Exercise 15.3:** Select a country where farmers use wastewater for agricultural production. Determine which of these measures (economic or social (marketing) incentives, such as access to credit, labelling/ branding, dedicated marketing chains, tax exemptions, and institutional support, like the provision of extension services, awards, or tenure security) would be the best in supporting behavior change and justify why?

**Exercise 15.4:** Even with existing regulations, can you explain the reluctance of agricultural producers in using treated wastewater for irrigation?

**Exercise 15.5:** What regulations need to be changed to allow/incentivize biosolids land application?

**Exercise 15.6:** Where risk awareness is low and not easy to develop, how best can farmers be motivated to trigger adoption of risk mitigation measures?

**Exercise 15.7:** Select a country and assess the potential for wastewater-based aquaculture. Determine socio-economic factors that can support and/or limit consumer demand.

**Exercise 15.8:** Assess the current level of formal and informal use of septage in agriculture in your country. Evaluate the factors supporting and limiting its formal use.

## 15.9 DISCUSSION QUESTIONS

**Question 15.1:** Why is wastewater use in agriculture much more common than official statistics show, and what are the related health and behavior change challenges? Consider differences between treatment capacities in developed and developing countries; consider the time frame it may take to bring treatment capacities to a similar level. What should be done in the meantime for farmers facing polluted water without choice? Consider educational levels and what it takes to change behavior. Discuss options around regulations, incentives, social marketing, education and awareness creation.

**Question 15.2:** Which financial considerations can influence the acceptance of water reuse by farmers, as well as of common safety interventions (like drip irrigation)? Consider chemical water quality differences (nutrients, salinity) and how treatment, in particular pond-based systems, may influence those. Consider the profit from producing cash crops (like exotic vegetables) in the dry season. Consider market expectations and regulations. How do farmers see their own exposure to polluted water assuming they are aware of it?

**Question 15.3:** How can we promote water reuse for potable purposes? Although water savings and reuse are very important in drier climates, many consumers do not accept water reuse despite excellent technical progress and high educational levels, like in South Africa and Australia, or at best for purposes which avoid any direct contact, like landscape irrigation. What are the reasons? What can be done to address these obstacles and promote a broader and inclusive reuse agenda?

**Question 15.4:** What strategies can private entities engaged in the wastewater reuse market adopt or implement to improve market demand for the recovered resources? Select 2–3 recovered resources and develop and justify strategies to be implemented.

**Question 15.5:** What protection or assistance do farmers need to protect themselves from liability and assist with cleanup if contamination issues are found from a wastewater treatment plant's application?

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