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A review of the challenges and opportunities for water reuse in irrigation with a focus on its prospects in Tanzania

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Abstract: Water reuse is one of the potential ways to complement the existing portable water sources. Its adoption is becoming of interest due to water shortages in many parts of the world. Its implementation is supported by several benefits though it has challenges as well. This paper provides a review of practice of the water reuse for irrigation in the world and focuses on its potentiality in Tanzania with a highlight on the water supply and wastewater treatment situation in the country. The challenges that need to be addressed, the benefits expected and global wastewater treatment options, capital and operation costs as well as the cost benefit analysis have been pointed out. Some arguments to justify a shift to water reuse in irrigation has been given. Lastly, it has been shown that full implementation of water reuse will require among other things, proper defined policy and institutional framework, clear guidelines as well as more research and investment on wastewater treatment.

Keywords: irrigation; wastewater treatment; water reuse; Tanzania.

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1 Introduction

Waste water reuse is often used synonymously with the terms ‘wastewater recycling’ and ‘wastewater reclamation’ (McKenzie, 2005; Haering et al., 2009). Scientist has used the term water reuse to create a positive image to the public who does not understand the difference in quality between treated and untreated wastewater (McKenzie, 2005). The United States Environmental Protection Agency (US-EPA) defines wastewater reuse as, using wastewater or reclaimed water from one application for another application (McKenzie, 2005). Water reuse, can therefore be defined as the use of reclaimed water for a direct beneficial purpose. Reclaimed water, also known as recycled water, is water recovered from treatment plants that has been treated to standards that allow safe reuse (Haering et al., 2009). From these definitions it can generally be concluded that, water reuse is the sustainable use of effluent for beneficial purposes.

Water reuse is considered as one of the potential alternative to supplement the portable water sources (Carr et al., 2011a) and it can serve various purposes such as cooling, gardening, recreational, irrigation and impoundment (US Environmental Protection Agency, 2012). The choice as to what application should water be reused depends on many factors such as quality of treated wastewater, the water availability, human perceptions, existing laws and regulations. Due to the importance of water reuse, it is already practiced in several countries of the world. Countries or regions in which it is on the rise include the USA, Western Europe, Australia, Japan and Israel (Wade Miller, 2006). While in Israel water reuse and desalination have become the main source of water and about 65–70% of wastewater is used in agriculture after treatment (Friedler, 2001; Icekson-Tal et al., 2003) the practice is negligible in Kuwait (Abusam, 2008) and generally low in developing countries (Yang and Abbaspour, 2007). Literature indicates the presence many reuse projects in Japan (1,800) and USA (800), significant reuse projects in North and Latin America, Mediterranean and Middle East (Angelakis and Durham, 2008) and only some water reuse practices in China (Yang and Abbaspour, 2007) and Korea (Noh et al., 2004).

In developing African countries, water reuse has been reported in Tunisia, Morocco, Tanzania, Ghana, Sudan and Namibia (Kivaisi, 2001; Foeken et al., 2004; Amoah et al., 2007) where water is reused for vegetable irrigation and other short term crops. In most of these countries water reuse is predominantly to support urban agriculture but the practice is informal and less is documented about it. This paper provides a review of practice of the water reuse for irrigation in the world and focuses on its potentiality in Tanzania with a highlight on the water supply and wastewater treatment situation in the country.

Table 1 Water reuses practices and relevant drivers

	Country	*Reuse application reported*	*Drivers for reuse*	*Reference*
1	Israel	Unrestricted irrigation	Water scarcity Water resources management	Icekson-Tal et al. (2003) and Friedler et al. (2006)
2	Jordan	Irrigation	Water scarcity	Carr et al. (2011b)
3	Mediterranean Countries	Irrigation	Optimum utilisation of the resources, water scarcity	Petta et al. (2007)
4	China	Agricultural irrigation, urban lawn watering, industrial uses, recreational water amenities	Increasing water scarcity, increasing environmental awareness	Yang and Abbaspour (2007)
5	Czech Republic and other European countries	Agriculture, urban recreational, industrial	Integrated water management	Janosova et al. (2006)
7	Korea	Toilet flushing, landscape irrigation and/or process water	Increasing water stress	Noh et al. (2004)
8	African countries	Agricultural irrigation, aquaculture	Water stress, urban and peri urban agriculture	Bahri et al. (2008) and Qadir et al. (2010)

Source: Organised by the author

2 Drivers for water reuse

The drivers for water reuse may differ from one country to another depending on water situation and regulation in the respective country. Table 1 provides an example of some selected countries, the reuse application and the primary driver for water reuse. The general drivers for water reuse are also discussed below.

2.1 Urban agriculture

Urban agriculture is nearly practiced in all cities of the world by some residents as a means of subsistence (Bon et al., 2010). In Africa it is even more significant and important than other continents because of the social impact in providing source of livelihood (Bon et al., 2010). African cities where urban agriculture has been reported to be practiced include Dar es Salaam (Mlozi, 1997; Jacobi et al., 2000a, 2000b; Mougeot, 2005; Bon et al., 2009; Drechsel and Dongus, 2010; Prain and Lee-Smith, 2010), Yaounde (Bopda and Awono, 2010; Prain and Lee-Smith, 2010), Johannesburg and Cape Town (Rogerson, 1993), Kampala (Bryld, 2003; David et al., 2010; Nasinyama et al., 2010; Prain and Lee-Smith, 2010), Nairobi (Njenga et al., 2007; Prain and Lee-Smith, 2010; Gallaher et al., 2013), Kumasi (Afrane et al., 2004), Accra (Klinkenberg et al., 2008; Prain and Lee-Smith, 2010), Khartoum (Drechsel and Dongus, 2010), Lusaka (Bon et al., 2009) and Maputo (Bon et al., 2009). Most of these cities are located in water scarce zones where the available water supplies cannot meet the water demand for various purposes including irrigation. Cities and other urban areas have a great potential for generation of large amount of wastewater, this could be treated and be used to support urban agriculture instead of being disposed to the environment.

2.2 Water scarcity/stress

Different parts of the world including the Western USA (National Research Council, 2005), Northern Africa (Rijsberman, 2006), China (Yang et al., 2003; Ringler et al., 2010), Southern Africa (Ali, 1999), Brazil (de Araújo et al., 2004) do face water scarcity. The projections indicate that water scarcity will increase in the future due to population increase, climate change among other factors (Rijsberman, 2006; OCHA, 2010). Moreover, currently, some social problems related to water scarcity such as water conflicts have been reported in some areas (Ali, 1999; de Araújo et al., 2004). These problems are more anticipated with increasing water scarcity calling for sustainable use of the available water resources. Water reuse practice offers a potential alternative to counteract water scarcity therefore has to be given more emphasis.

2.3 Food production crisis

Water supply for agriculture which uses relatively large amount of water than the other needs is critical for future global food security (Hanjra and Qureshi, 2010). Treated effluent can be used as a source of water for food production if the challenges associated with its use are well addressed. The global water demand is increasing and the water resources are declining putting the agricultural food production at stake and calling for new alternative sources of water (Rosegrant et al., 2002). Already water shortages has impacted the food production in some areas of the world such as Australia (Ejaz-Qureshi et al., 2013) and the impact is expected to increase with increasing water scarcity and increased competition among multiple uses.

2.4 Urban population increase and urbanisation

The world is undergoing a rapid urban growth and it is estimated that about more than half of the world population will be living in towns and cities by 2030 (UNFPA, 2007). The population growth rate is more on the rise in developing countries including Africa such that it is posing a big challenge in supplying the necessary resources such as water, because of the high pressure on water supplies (Bahri et al., 2008). The growth has a consequence of increase in the urban water demand and wastewater generation calling for alternative sources for water supply and proper management of wastewater. Wastewater treatment and reuse can link between the increased water demand and the increased in wastewater generation by providing of reusable effluent to supplement the available water sources.

3 Benefits of water reuse for irrigation

Water reuse is considered beneficial for several reasons including the reduced wastewater discharges to the environment (Chen and Wang, 2009), maintaining the downstream water quality and reducing the demand on fresh water resources (Janosova et al., 2006). It may also lead to reduced river and aquifer water abstraction (Winpenny et al., 2010). When the water bodies are not loaded with organic loading, the dissolved oxygen remains enough to support the life of biological organisms, it leaves the beaches unpolluted hence provide better recreational environment and improved aesthetics.

Another benefit is the ability to serve as alternative to supplement the existing available water sources (Kretschmer et al., 2000; Angelakis et al., 2003; McKenzie, 2005; Janosova et al., 2006; Bdour et al., 2009; Haering et al., 2009; Deniz et al., 2010; Cirelli et al., 2012) where treated wastewater can be reused for various purposes. As water availability is becoming a constraint for food production (Haddadin, 2001; Yang et al., 2003; Ringler et al., 2010), water reuse can also help in supplementing the agricultural water demand.

If treated effluent from wastewater is used for irrigation purposes it can supply nutrients that can be recycled to soil (Kretschmer et al., 2000; McKenzie, 2005; World Health Organisation, 2006b; Alobaidy et al., 2010; Winpenny et al., 2010; Carr et al., 2011a, 2011b) hence reduce the cost for buying fertiliser. For example literature indicates that at an irrigation rate of 1.5 m/year, treated municipal wastewater can supply up to 225 kg of nitrogen and 45 kg of phosphorus per hectare per year (Bdour et al., 2009). Therefore water reuse can offset of the cost incurred on buying artificial fertilisers (Bdour et al., 2009) at the same time protecting the environment from nutrient loading hence avoid eutrophication.

4 Challenges of water reuse for irrigation

While treated wastewater can be reused for various purposes, its use for agricultural purposes is faced with several challenges. The challenges include the health risks when used for irrigating crops (World Health Organisation, 2006b; Bahri et al., 2008; Alobaidy et al., 2010; Qadir et al., 2010) as most of the conventional treatment technologies do not completely remove the pathogens and chemical constituents such as heavy metals present in wastewater. Presence of pathogens can cause some serious health effects (Alobaidy et al., 2010) to the people who come into contact or use the crops irrigated with such water. The effect can arise through consumers being exposed to pathogens, organic and inorganic trace elements (Qadir et al., 2010) and from the post harvest contaminations (Amoah et al., 2007).

The presence of nutrients in wastewater is an incentive. But some studies indicates that the levels of nutrients can be higher than needed by the crops especially when inadequately treated wastewater is used (Husain and Ahmed, 1997; Carr et al., 2011b), hence this is considered as another challenge. A real example of this phenomenon has been observed on field in Tanzania where some paddy irrigated with partially treated wastewater would seem to grow very well vegetatively yielding less or no rice. Achieving balanced agronomical nutrient requirements for specific irrigated crops becomes of importance in this case and more research is called in this aspect.

Lack of legislation on reuse and lack of a properly defined institutional framework that would govern water reuse for irrigation purposes is another challenge (Angelakis et al., 2003; McKenzie, 2005). Despite the presence of international guidelines such as the World Health Organisation (WHO) guideline on reuse for agriculture that would simply provide the basis for development of national guidelines, many countries do not have their own guidelines except few. Lack of legislation and their appropriate regulations causes water reuse receive less attention than it would have been in their presence.

The other challenge is the negative perception and poor acceptability of water reuse by the community members that can lead to difficulty in its implementation (Angelakis et al., 2003). Experience shows that even when projects are technically sound and all of the relevant health protection measures have been taken, project on water reuse for irrigation can fail if it does not account adequately for public perception (World Health Organisation, 2006a). This is because the public will not accept to consume the crops irrigated using treated effluent. Therefore it is very essential to address this challenge before embarking on full implementation of water reuse project. Reported cases on poor water reuse acceptability include in country such as Bangladesh (Mojid et al., 2010), Saudi Arabia (Husain and Ahmed, 1997) and Korea (Noh et al., 2004) and on positive water reuse acceptability in countries such as USA (Marks et al., 2003; Hartley, 2006) and Australia (Marks et al., 2003). Research on perception and acceptability of water reuse products need to be done for each community and develop some strategies for raising awareness on the benefits of water reuse.

In developing countries, the lack of comprehensive wastewater treatment system to support water reuse stands as another challenge. In Tanzania for example majority of the residents use onsite sanitation systems (Bahri et al., 2008) and the wastewater collected from the few individuals who use offsite sanitation systems is either partially or fully treated to meet discharge requirements only (Kivaisi, 2001). Therefore in this situation it becomes better to think of household level small systems for treatment and reuse apart from the centralised systems.

5 Wastewater treatment practices and design aspects

Wastewater treatment for reuse purposes is one of the topics that need attention in terms of research (Chung et al., 2008). Normally the conventional wastewater treatment technologies are usually meant to primarily protect public health, prevent environmental pollution (Johnson, 2006) but when considering reuse, treatment will in addition consider provision of suitable effluent for irrigation. Research on how the available treatment options can be modifies or integrated to meet the irrigation requirements is important to be undertaken.

Currently, wastewater treatment coverage is low globally and varies among countries depending on technology availability and funding. It is higher in developed countries and low in developing ones. For example, in the USA almost all of wastewater generated gets treated (Hermanowicz et al., 2001) while for developing countries, treatment is relatively low and only a portion of the collected wastewater collected is treated (Yang and Abbaspour, 2007). The overall global situation as depicted by United Nations Environmental Program (UNEP) shows that about 90% of the wastewater, flows untreated into rivers, lakes and highly reproductive coastal zones (Corcoran et al., 2010). This suggests that some more efforts to create incentives for wastewater treatment and reuse need to be sought so as the benefits associated with can be won.

However, there are few cases in different parts of the world whereby wastewater treatment for irrigation purposes using various treatment techniques has been undertaken. The advanced oxidation processes (Chung et al., 2008), activated sludge (Deniz et al., 2010), extended aeration process (Deniz et al., 2010), constructed wetlands (Kivaisi, 2001; Ghermandi et al., 2007) and waste stabilisation ponds (WSPs) (Vélez et al., 2002) are some of the technologies that have already been investigated. Moreover, some few cases have employed a combination of treatment methods. For example the combination of membrane filtration, simplified treatments, constructed wetlands and storage reservoirs and its suitability in obtaining effluent suitable for agriculture purposes has been investigated in Italy (Lopez et al., 2006) and the system recorded the average removal efficiencies and the irrigation with the effluent resulted in yield increase of olive of 50%. A combination of dual-sand, microfiltration, reverse osmosis and electrodyalis is reversal looking on the suitability of the system to produce effluent for irrigation purposes was also employed in Spain (Deniz et al., 2010). This system was good in removal of organics. The last example is a WSP combined with a constructed wetland that was employed in Greece and gave results in compliance with the US-EPA guideline for water reuse only for some parameters (Tsalkatidou et al., 2009).

Focusing on Tanzania, the most widely used conventional wastewater treatment is the WSP (Mbwele et al., 2004). However, currently there are some ongoing researches integrating this technology with constructed wetland. The constructed wetland systems enables further polishing of the effluent (Njau and Lugali, 2009) and has several advantages over the other treatment options making it currently receive some attention (Balkema et al., 2010). The advantages include the fact that it can be easily constructed, operated and maintained and that can be able to handle variable wastewater loadings (Kivaisi, 2001; Massoud et al., 2009; Balkema et al., 2010; Zhang et al., 2010). But also that it has proven to remove a number of pollutants including pathogens especially the fecal coli form (Balkema et al., 2010), BOD (Kouki et al., 2009; Stefanakis and Tsihrintzis, 2009), nitrogen (Molle et al., 2008; Sim et al., 2008) and phosphorus (Braskerud, 2002). With the emerging need to reuse water for irrigation the combination might be the best but research need to be done to provide evidence for this. The extensive research on emerging technologies for wastewater treatment and reuse such as membrane technology and its economical viability need to be done. Table 2 provides an overview of the treatment technologies for water reuse reviewed and their overall performances.

Table 2 Overview of the treatment technologies for water reuse

	Treatment technology	*Area implemented*	*Nature of wastewater*	*Major processes and/or modification*	*Overall removal efficiencies or performance*	*Reference*
1	Advanced oxidation methods	Korea	Livestock farming	Oxidation, coagulation, ozonation	Mean efficiency in terms of BOD and SS removal up to 98.7% (BOD from 2,900 mg/L to 50.2 mg/L, SS from 2,300 mg/l to 30.4 mg/L)	Chung et al. (2008)
2	Membrane filtration	Italy	Municipal	Filtration and storage	Achieved the Italian limits (COD = 100 mg/L, BOD = 20 mg/L, TSS = 10 mg/L, TN = 35 mg/L, e.coli = 50 CFU/100 mL) for agricultural reuse	Lopez et al. (2006) and Barbagallo et al. (2013)
3	Waste stabilisation ponds	Argentina	Municipal	Oxidation and facultative ponds	Not provided	Vélez et al. (2002)
		Colombia	Municipal	Naturally aerobic and anaerobic	Satisfactory removal efficiencies. Able to remove four log units of e.coli, one log unit of Streptococcus spp. and 100% of helminth eggs	Madera et al. (2002)
		Zimbabwe	Municipal	Duckweed-based ponds	Significant reductions to within permissible limits of parameters such as nitrates, pH, , iron, conductivity, total dissolved solids and total suspended solids	Dalu and Ndamba (2003)
		Ghana	Municipal	Naturally aerobic and anaerobic	SS, BOD and COD removals of about 84% (86.3 mg/L to 14.2 mg/L,) 77 (55.8 mg/L to 12.8 mg/L) and 71 (176 mg/L to 51.9 mg/L), respectively	Hodgson (2007)

Source: Compiled by author from indicated sources

Table 2 Overview of the treatment technologies for water reuse (continued)

Treatment technology	*Area implemented*	*Nature of wastewater*	*Major processes and/or modification*	*Overall removal efficiencies or performance*	*Reference*
4 Constructed wetland system	Italy	Municipal	Horizontal subsurface flow	Recorded removal efficiencies of 85% (from 78 mg/L to 10 mg/L), 65% (from 48 mg/L to 12 mg/L), 75% (from 78 mg/L to 18 mg/L) and 42% (from 24 mg/L to 17 mg/L) for TSS BOD, COD and TN respectively.	Lopez et al. (2006)
	China	Municipal	Artificial aerated constructed wetland system	Better for aerated system than the conventional one	Zhang et al. (2010)
	Tanzania	Municipal	Horizontal subsurface flow	45% nitrogen for *phragmites australis* and 44% nitrogen removal for *typha latifolia* (from 1.465 $gN/m^2.d$ to 0.642 $gN/m^2.d$)	Senzia et al. (2003)

Source: Compiled by author from indicated sources

The designs aspects of wastewater treatment plants for reuse purpose does not vary much from the general design aspects of the conventional treatment systems. However, the emphasis may differ in some aspects. For example whereas the design for conventional treatment system looks at minimisation of levels of nutrients, dissolved organics, pathogens and toxic chemical substances in the effluent to meet the environmental standards, the design for treatment for reuse will look focus on retention of nutrients for re-use in agriculture while still minimising the rest. This may require selection and combination of different technologies that are good for the removal of some of the contaminants while poor for the others. Some good examples are that WSPs are good for the removal of particulate solids, dissolved organics, while they are generally poor for nutrient removal and require large surface areas (Hodgson, 2007; Mara, 2008). Subsurface flow constructed wetlands are good in the removal of dissolved organics but relatively poor in the removal of nutrients (Kivaisi, 2001). Therefore, combination of treatment systems can take advantages of each type providing optimal outputs for reuse in irrigation.

6 Capital and operational costs for water reuse

Wastewater treatment and sanitation projects in general require significant level of funding in terms of the capital and operational costs. The most recurrent costs include the personnel, energy, chemicals and spare parts and repair costs. It has been revealed through experience that despite the fact that the capital costs can be high, the operational costs for most of the wastewater treatment employing natural mechanism are relatively lower (Baz et al., 2008). Also for water reuse beyond the treatment systems, the costs are relatively lower especially on the gravity systems. The recurrent costs in this case can be for monitoring water quality, record keeping, reporting and compliance to the regulations and laws. However these costs can be partially be recovered when tariffs for sanitation are introduced. Also for reuse in agriculture costs for fertiliser application are subsidised through use of treated effluent containing nutrients.

Table 3 The selected parameters of interest and the recommended limits or range for irrigation

S/N	*Issue of concern and the parameters associated with it*	*Recommended limit/range*
1	Salinity (affects crop water availability)	
	Conductivity	0–3 d S/m
	TDS	0–2,000 mg/L
2	Toxicity (affects the growth of sensitive crops)	
	Aluminium	5 mg/L
	Iron	5 Mg/L
	Cadmium	2 mg/L
	Boron	0–3 mg/L
	Sodium	3–9 mg/L
	Chloride	4–10 me/L
3	Other miscellaneous effects (affects the growth of the susceptible crops)	
	Nitrate-nitrogen	5–30 mg/L
	Bicarbonate	1.5–8.5 me/L
	pH	6.5–8.4

Source: World Health Organisation (2006b) and US Environmental Protection Agency (2012)

7 Quality of reused water and reuse treatment technologies

While water reuse for irrigation is currently of interest, quality of treated effluent is one of the key issues to consider. The use of poor quality effluent may cause serious public health problems, can affect the crops being irrigated or to damage the receiving environment. Due to this fact the guidelines providing limits of the important contaminants need to be prepared and adhered to. For example, the presence of pathogens, salts and heavy metals can significantly affect the suitability of such water for irrigation purposes (US Environmental Protection Agency, 2012). The sensitivity varies with different type of crops therefore it is better to understand the crop tolerance levels to specific contaminants. For example if the effluent contains high levels of dissolved salts, it can affect the plant water uptake; the presence of heavy metals can cause toxicity to irrigated crops. Table 3 shows the parameters of interest and the limits for use in irrigation.

Wastewater treatment to make effluent suitable for irrigation remains as one of the challenges. In order to treat the wastewater to quality acceptable for water reuse, it will requires a combination of at least a primary and secondary treatment techniques for non-food irrigation while for food crop irrigation it will require a primary, secondary, filtration and disinfection. For non-restricted irrigation, treatment may require some additional advanced techniques (US Environmental Protection Agency, 2012). The choice of the specific treatment technology in each category depends on the number of factors including the composition of the wastewater, the type of crop to be irrigated, the available technologies the economic viability and social aspects.

8 Cost benefit analysis of water reuse projects

The cost benefit analysis of water reuse project indicates that most of the reuse projects are economically viable. The cost of reuse projects are associated with the special treatment required, the measure required to protect health and the operational costs. The benefits from the reuse projects include the reduced fertiliser applications, environmental protection and the reduced water stress which serves as an alternative water source. For example on the analysis done for decentralised reuse systems in China, it showed significant economical advantage when the environmental benefits are considered (Chen and Wang, 2009). On another evaluation done in Spain it was concluded that when all the internal and external benefits are considered, the reuse project are economically viable (Molinos-Senante et al., 2011). Therefore with the water reuse in irrigation, it is expected that such projects can even become more viable because the nutrient present in treated effluent can be used as fertiliser and hence becomes an incentive.

9 Overall water and wastewater situation in Tanzania

In most of the cities and municipality of Tanzania, the available water supply capacity does not suffice the demand (Table 4). The urban population is rapidly increasing and the water supply expansion schemes do not tally with the increase. At the same time the sewerage coverage remains the lowest and is below 25% in most of the cities and municipalities with only one town reporting 45% coverage (Table 4). This tells that intentional intervention on the issue of sanitation is crucial.

Table 4 The overall water and wastewater treatment situation in major Tanzanian cities and town

City/municipal council	*Population (2012 census)*	*Water demand (m^3/d)*	*W/S capacity (m^3/day)*	*Estimated w/w gen.[a] (m^3/d)*	*% sewer cov.*	*Vol. of w/w treated (m^3/d)*	*Calculated N-content[b] (kg/d)*	*Calculated P-content[b] (kg/d)*	*Calculated K-content[b] (kg/d)*
Dodoma	410,956	55,800	26,690	21,352	13	4,600	230	46	138
Morogoro	315,816	40,755	22,500	18,000	3.3	816	40.8	8.16	24.48
Mwanza	706,453	65,000	64,536	51,629	8	1,680	84	16.8	50.8
Tanga	273,332	35,370	30,524	24,419	16	2,164	108.2	21.64	64.92
Dar es Salaam	4,364,541	532,689	245,011	196,008	13	24,960	1,248	249.6	748.8
Arusha	416,442	96,379	35,113	28,090	16.7	6,350	317.5	63.5	190.5
Moshi	466,737	27,383	22,953	18,362	45	5,000	250	50	150
Mbeya	375,289	39,267	42,000	31,413	10	4,500	225	45	135
Mtwara	228,003	12,400	5,664	4,531	0	0	0	0	0
Iringa	254,032	16,000	17,105	13,684	23	1,830	91.5	18.3	54.9
Total	7,811,601	921,043	512,096	407,488		51,900□	2,595	519	1,557.4

Notes: [a]Based on the estimation that approximately 80% of water used becomes wastewater,
[b]Based on the average typical nitrogen and phosphorus content in treated wastewater,
N = nitrogen,
P = phosphorus,
K = potassium,
w/w = wastewater,
W/S = water supply,
gen = generation,
cov = coverage

Source: Tchobanoglous et al. (2003) and extracts from budget speeches, urban water authority reports and national census report of 2012

Despite the fact that the treated wastewater is just a small fraction of the wastewater generated, already about 51,900 m^3 (Table 4) of wastewater is treated and be discharge to the environment every day. This wastewater would have provided approximately 2,595 kg, 519 kg and 1,557 kg of nitrogen, phosphorus and potassium respectively based on the typical average nutrient content values for treated wastewater (Tchobanoglous et al., 2003). This highlights that there is a potential for supporting urban agriculture if it is carefully considered and planned. Water reuse for urban agriculture therefore serves as an incentive for expansion of the wastewater treatment works in the country. However research on the optimal wastewater treatment for water reuse in the country need to be investigated before its full implementation.

8 Water reuse for irrigation in Tanzania

Water reuse for irrigation is now receiving much attention as it can improve food production. Tanzania is among the countries that do face drought conditions and the rain fed agriculture has become non-dependable due to unpredicted rainfall patterns (Sosovele et al., 2005; Lankford and Beale, 2007; United Republic of Tanzania, 2009; Dubbeling and Zeeuw, 2011), hence considering water reuse options for irrigation purposes is inevitable.

Currently there is no formal water reuse practice and community members do use both the treated and untreated sewage effluents for irrigation purposes and using poor quality water in some cases. The evidence for this can be seen in cities such as Dar es Saalaam, Morogoro, Mwanza, Arusha and Mbeya where production of various crops especially vegetables is done (Foeken et al., 2004; Kimwaga and Marwa, 2012). In Dare s Salaam for example, leafy vegetables (especially *amaranthus sp*) are produced over 650 hectares of open land and home gardens and do offers employment to about 4,000 people (Dongus, 2000; Jacobi et al., 2000b; Mwegoha et al., 2012). Another example is Arusha in Lemara ward where vegetables and other food crops are grown using wastewater (Kimwaga and Marwa, 2012). The practices are questionable in terms of the microbial quality and the public health risks to the consumers hence improvement of the practice is highly recommended.

9 The Tanzania policy for water reuse in irrigation

There is no proper defined institutional arrangement and guidelines for water reuse in Tanzania except the international guidelines despite the fact that water reuse requires presence of clear policy regulatory and institutional framework for its implementation. One of the international guidelines that can serve the purpose when implementing water reuse projects is the WHO guidelines (World Health Organisation, 2006b, 2006a). The other guidelines that can be borrowed are Environmental Protection Agency guideline on water reuse (US Environmental Protection Agency, 2012) and the Australian Environmental guideline on use of effluent by irrigation (NSW, 2004).

The local policies and legislations speaks in a nutshell about the water reuse or wastewater treatment and reuse issue and some policy statements are fragmented in some national policies and acts as indicated in Table 5. Most of the statements provide statements in favour of irrigation but do not expose the issue of water reuse comprehensively. This raises a need for development of a water reuse policy.

Table 5 Policies and laws supporting water reuse considerations in Tanzania

S/N	*Policy or legislation*	*Statement supporting water reuse or irrigation*	*Reference*
1	Agricultural and Livestock Policy, 1997	• Irrigation systems should be developed as a strategy for Agricultural development	United Republic of Tanzania (1997a)
2	National Water Policy, 2002	• Promotes irrigated agriculture to protects against drought and ensures food security • Promotes wastewater recycling and desalination of seawater a means of increasing the availability of water resources. • Urban Water Supply and Sewerage entities shall cooperate with industries and other institutions in the research and development of least cost technologies for wastewater treatment and recycling	United Republic of Tanzania (2002)
3	National Environmental POLICY, 1997	• Sets an objective of promotion of the use of the environmentally sound technologies that protect the environments • Sets another objective to promote technology for efficient water use particularly for water and wastewater treatment and recycling.	United Republic of Tanzania (1997b)
4	Irrigation Policy, 2009	• Recognises the fact that dependency on rain-fed agriculture has led to low production and productivity, reliance of the country on irrigated agriculture is inevitable	United Republic of Tanzania (2009)
5	The water Utilization (Control and Regulation) Act, Cap-331	• Puts a fine to anyone who pollutes the water in any river stream or water course or in any body of surface water to such extent to be likely to injure directly or indirectly to public health.	United Republic of Tanzania (1992)
6	Environmental Management Act. 2004	• Gives mandate to the local government to ensure that sewage is properly treated before discharged to the water body or open land and in ensuring that there is compliance of the treatment works	United Republic of Tanzania (2004)

Source: Compiled by author

10 Future prospects of water reuse for irrigation in Tanzania

Water reuse for irrigation in Tanzania is a viable alternative as some opportunities for its implementation do exist. The current water stress on agriculture and the declining soil fertility can be compensated through the use of treated wastewater effluent for irrigation purposes. To arrive at this the optimal and feasible treatment options that ensure the public health is protected and some nutrients are retained should be developed. It is therefore important to study how the available treatment technologies can be modified or what other feasible technologies can be incorporated to suit this requirement.

Fully and successful implementation of water reuse depends on a number of issues including the political will and public acceptance of the crops irrigated with treated effluents. The current policies and the institutional framework do not strongly support water reuse therefore they need to be reviewed to accommodate it. Raising the awareness of the public and building capacity of the local expertise can influence water reuse adoption to its success.

11 Conclusions

Water reuse has many advantages as compared to the challenges facing its implementation. Tanzania and many other developing countries need to harness this opportunity for use in irrigation to improve food security. This is supported by the presence of urban agriculture, food production decline and water scarcity. However more investment in urban wastewater treatment is required for successful implementation. With employment of the feasible and optimal treatment options, it will be possible to use the water and nutrients contained in the treated effluent for agricultural production and address the existing problems of lack of water and poor soil productivity at the same time. To arrive at this point, research on the feasible and affordable treatment technologies should be done, strong policy to support water reuse should and the issue of public attitude on water reuse for irrigation should be addressed.

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