Turning Brown Water into Green Produce:

Wastewater reuse in 22 Nicaraguan cities

May 2012

wsp water and sanitation program

The Water and Sanitation Program is a multidonor partnership administered by the World Bank to support poor people in obtaining affordable, safe, and sustainable access to water and sanitation services.

THE WORLD BANK

Turning Brown Water into Green Produce:
Wastewater reuse in 22 Nicaraguan cities

Author
Blanca Jiménez, Senior Researcher, Nacional Autonomus University of Mexico; and Consultant, Water and Sanitation Program

Content contributors
Nelson Medina, Coordinator for Nicaragua, Water and Sanitation Program
Francisco Carranza, Water and Sanitation Specialist, Water and Sanitation Program

Field Research
Jose Angel Mejía, Water and Sanitation Specialist

Graphic Design
Shinny Montes

First Edition: May, 2012
Press run: 500 copies
Printing: GMC Digital S.A.C.
Lima, Peru

This report has been produced by the Water and Sanitation Program

Reprinted from Journal of Water Reuse and Desalination, Volume 1, Issue number 1, Pages 185 - 201; with permission from the copyright holders, IWA Publishing.

www.wsp.org
wsplac@worldbank.org

Contents

I. Introduction

On a global scale, agriculture accounts for 70% of total water use; in different regions use ranges from 45% in developed countries to 81% in developing ones (Earth Trends, 2010). This high demand is the cause of the high rate of water reuse in irrigation. Moreover, agricultural reuse is increasing worldwide, not only due to water scarcity but also because of competition among users and advantages to farmers. Agricultural reuse is mostly unplanned, using non-treated or partially treated wastewater (Jiménez & Asano 2008) (for an explanation of planned and unplanned use, see below). It is estimated that at least 7% of the world's irrigated land in 50 countries is irrigated using non-treated or partially treated wastewater (WHO 2006), and in some cities up to 80% of the vegetables consumed locally are produced in this way (Ensink et al. 2004). The area of unplanned water reuse has increased six-fold in 20 years (Jiménez et al. 2010). It is estimated that 6–8 times greater land area is irrigated with non-treated or partially treated wastewater than with treated wastewater (Jiménez & Asano 2008). Wastewater reuse often occurs near cities, as these combine both the ready production of a large amount of wastewater with high demand for fresh food. This explains why four out of five cities in developing countries are reusing water, often polluted, for agricultural production (Raschid-Sally & Jayakody 2008).

The reuse of water is important in developing countries as they are often located in arid or semi-arid areas. They are home to three-quarters of the world's irrigated area and very dependent on agriculture to feed their populations and increase income. In addition, agriculture is responsible for up to 80% of export earnings (Jiménez et al. 2010). However, in the literature, there is no comprehensive global inventory of the extent and characteristics of reuse practices (such information does not exist even for planned reuse in developed countries). Figures are difficult to obtain as farmers fear rejection of their produce as a result of public perception of water reuse. The need to collect more and better information to improve reuse practices and provide proper policy frameworks has motivated this study. The objectives were, firstly, to identify the characteristics of agricultural reuse practices in a water-rich developing country (Nicaragua) and, secondly, to begin to understand the perception of reuse among different groups of stakeholders in low-income regions.

II. Background

Agricultural reuse may occur in a planned or an unplanned way. It is referred to as planned when it is part of a project in which wastewater is reused under controlled conditions – notably meeting standards – with the aim of protecting health, the environment and agricultural production. It is referred to as unplanned when it is used without considering control procedures or assessing whether the quality of the reused water meets criteria or standards. Agricultural water reuse may be referred to as direct when the effluent of a wastewater treatment plant (WWTP) is used to irrigate without previously diluting it with water from another source, or indirect if the effluent is discharged to a surface water body from which water is extracted for irrigation. The indirect reuse of water for irrigation is more likely to occur in wetter climates, and is significantly more frequent than direct reuse (Keraita et al. 2008).

In industrialized countries, water reuse is part of a strategy to tackle water scarcity, protect water bodies and reduce wastewater treatment costs (Asano 2006). In contrast, in developing countries, reuse is frequently a spontaneous response to a shortage of water and a means to increase income. It is generally practised with poor quality water and even with raw wastewater (Jiménez 2006). It is linked to lack of water and is very common in areas with rainfall below 900 mm (Raschid-Sally & Jayakody 2008). The use of untreated or partially treated wastewater is not necessarily linked to the economic income of a country or to sanitation coverage. It is practised by countries with up to 7,800 USD per capita gross domestic product (GDP) and 91% sanitation coverage. Political will seems to be an important element in the implementation of planned reuse of wastewater, as countries with only 4,300 USD per capita GDP but with 87% sanitation coverage practice it (Jiménez et al. 2010).

In Latin America the total estimated area irrigated with non-treated or partially treated wastewater is 500,000 ha. In Asia, in China alone, around 4 million hectares is at least seasonally irrigated with non or partially treated wastewater due to the lack of sanitation (Yang & Abbaspour 2007). In Pakistan and Vietnam, respectively, 30,600 and 7,000 ha are irrigated this way. In Vietnam, wastewater from Hanoi and other cities along the Red River Delta is pumped into irrigation channels at certain times of the year to supplement irrigation water (Trang et al. 2007). In Lebanon and Palestine, most of the wastewater collected by sewerage is discharged into nearby rivers from which it is extracted to be used for irrigation (Post 2006). In Turkey, wastewater is discharged into rivers and used for irrigation. Along the Mediterranean coastline, in Spain, Italy and Portugal, wastewater, usually but not always treated, is discharged into rivers that almost run dry in summer and is used for irrigation (Juanico & Salgot 2008).

Among the different physical, economic, social and managerial drivers that trigger agricultural water reuse, there are two that are considered by most authors as dominant: water scarcity and the advantages gained by farmers linked to the increase in yields and hence to income and food security (Qadir et al. 2007). In regions where rainfall varies markedly, leading in fact to only two seasons (wet and dry), the constant production of wastewater allows crops to be sown all year round. In addition the reliability of this supply makes it possible for farmers to select crops with higher profitability. Wastewater contains macro- and micronutrients that increase yields and save on chemical fertilizers or simply make them accessible and affordable to poor farmers. Reducing the use of chemical fertilizers not only represents advantages to farmers but also reduces side effects such as soil acidification and saves on the consumption of energy for their production and transport. All these advantages are reflected in an increase in farmers' income. However, few studies have evaluated all these impacts. Despite the previously mentioned advantages, there are also risks associated mainly with public health (Toze 2006). Risks are increased if wastewater is less thoroughly treated and become significant if reuse is unplanned. With regard to human health, there are two types of pollutants that are the origin of such risks: human pathogens and toxic chemical compounds. Risks from the first are, by far, the most important. To assess and control pathogens WHO (2006) recommends two types of indicators: faecal coliforms and helminth eggs. Diseases originate through complex pathways affecting not only a crop's consumers, but also farm workers, and populations living close to agricultural fields. Moreover, health risks can be introduced not only as a result of wastewater reuse but also through food handling, commercialization and even preparation. WHO (2006) recommends that in order to effectively control the associated diseases it is important to manage all risks along the production chain.

The social perception of agricultural water reuse varies from one community to another. Understanding public perception and the determinants of acceptance of water reuse are now recognized as one of the main ingredients of success for reuse projects (Anderson et al. 2008). Societies with high incomes and no previous experience of water reuse frequently oppose it due to the potential impacts on health and the environment, odour problems, its tendency to devalue property and changes to water and soil uses. The situation is completely different in poor areas lacking in job opportunities, where water reuse represents the only possibility of improving living standards by increasing income and ensuring food supplies. Nevertheless there are almost no studies assessing public perception in developing countries.

III. Methodology

Study sites

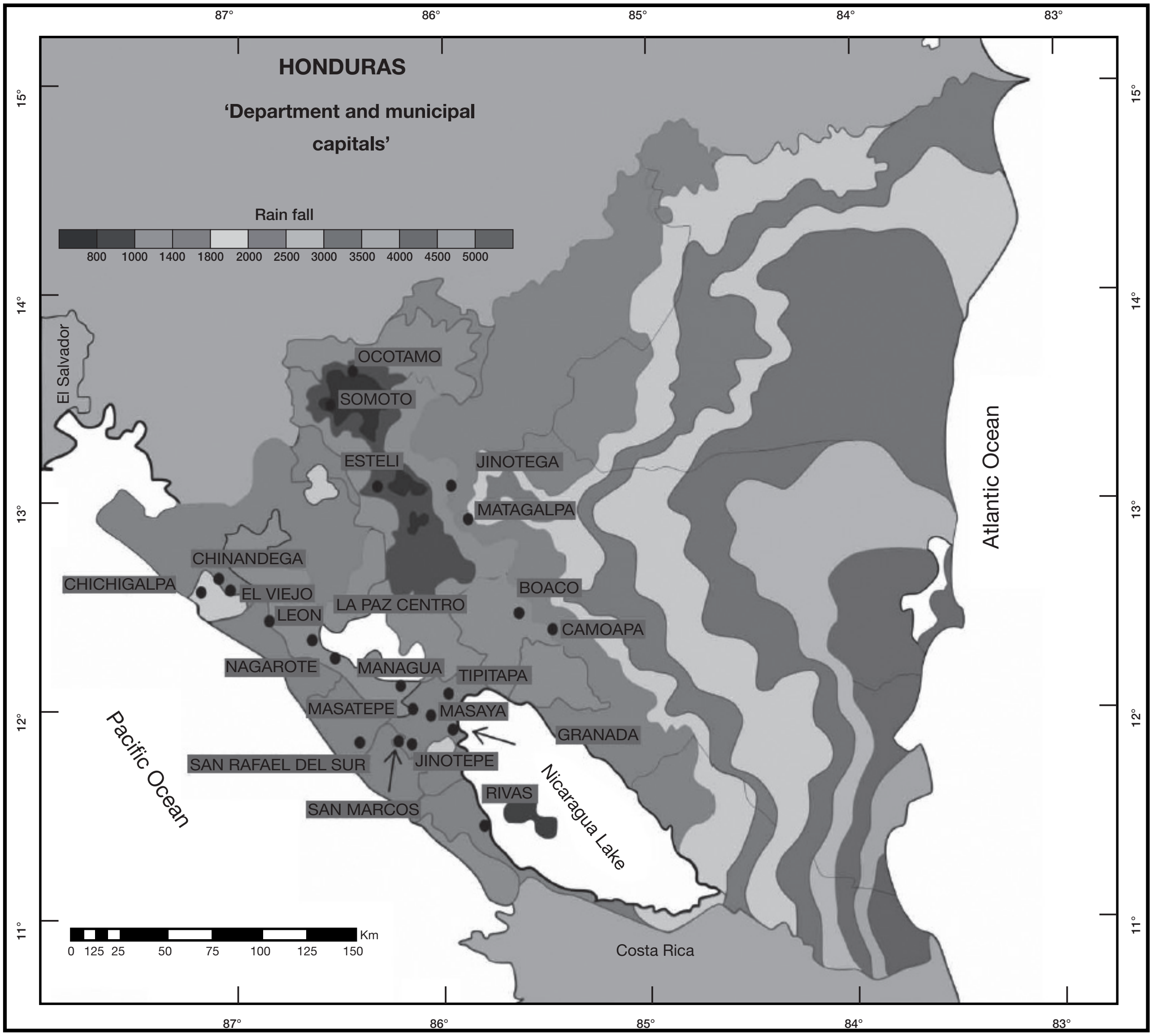
Nicaragua is situated in Central America. It has an area of 131,000 km2 and 5.071 million inhabitants, 62% living in urban areas (Gutiérrez-Nájera 2005). Water availability is around 35,000 m3/capita • yr, i.e. nearly eight times the global mean water availability. Annual rainfall is 2,391 mm but varies from 1,850 mm to less than 800 mm in the Pacific Basin and is over 2,000 mm in the Atlantic Basin (Figure 1). In addition, rainfall varies markedly throughout the year with a dry period between December and April. Despite this distribution of water, most of the population, agriculture and industrial activities are located on the Pacific Basin. Nicaragua is divided into 17 administrative departments, 13 of which are located on the Pacific Basin. At a national level, water is used for agriculture and cattle raising activities (83%), and in municipalities (3%) and industry (14%). Agriculture represents 20–26% of the GDP and, according to the Ministry of Agriculture, profits could be significantly increased by using irrigation. The Pacific region has the best soils for agriculture but the lack of water and irrigation limits productivity. In 2002 the total irrigated area was only around 94,000 ha, i.e. 8% of the agricultural land, with the potential to be increased by at least 30%. The main agricultural products are grains, vegetables, fruits, forage, Musaceae (such as banana) and sugar cane. Reusing water in the Pacific region would be of interest as the cost of extracting water from the subsoil represents 20–33% of production costs and water could be used to irrigate coffee, beans, sugar cane, rice, corn, peanuts, sesame, tobacco and sorghum (MAGFOR 2008).

Field inspections and surveys

The methodology, adapted to conditions in developing countries, basically consisted of: (a) performing field inspections; (b) carrying out a study on the perception of governmental institutions, farmers and water utilities; (c) complementing the information with bibliographic research; and (d) validating the data obtained from all sources through two workshops with the main stakeholders. For the field survey, the 32 WWTPs serving the main cities of the Pacific region were investigated. The total volume of wastewater treated was 66.6 Mm3/year. Seventeen of the wastewater treatment plants were stabilization ponds, while the remainder used Imhoff or septic tanks and anaerobic filters, biofilters or UASB (up-flow anaerobic sludge blanket). These facilities were provided to remove biodegradable organic matter but not nutrients. Of the 32 WWTPs, 24, corresponding to 22 cities, were selected as they are located close to agricultural fields (Figure 1). Fifteen use stabilization ponds, and the rest use septic or Imhoff tanks, one of which is complemented with down-flow anaerobic filters. The data on the influent and effluent quality for the years 2009 and 2010 was provided by ENACAL (NicaraguanWater Utility for Water Supply and Sanitation), the main public water utility serving all the cities; the data presented here concerns only those plants for which the effluent was reused. During site visits the effluent of each WWTP was followed up to a distance of 2 km from the point of discharge. This was sometimes a challenging task as in Nicaragua the vegetation tends to be extremely dense and the terrain uneven.

Questionnaires were prepared in advance, and reviewed by an engineer with local experience to ensure the suitability of the language used and the pertinence of the questions in a local context. They included six sections: (a) general knowledge of wastewater reuse for irrigation; (b) perception of reuse; (c) drivers to reuse wastewater; (d) the legal and institutional framework; (e) economic aspects; and (f) the criteria to reuse wastewater for irrigation. Not all of the questions were the same for the different targeted groups. For the governmental group, 10 institutions were considered from the Ministry of the Environment and Natural Resources, the Ministry of Health, the Ministry of Agriculture and Forestry, the public water utility at the central level and different national research and academic institutions. Water utilities considered in the survey were all from ENACAL and questionnaires were answered at the regional or local level (WWTP operators). With regard to farmers, in total 35 were interviewed from those encountered in the fields who were being irrigated during visits and agreed to collaborate. In addition, prior to the surveys, personal interviews with the governmental institutions and one workshop were held to discuss aspects of water reuse relevant to the country. Following the surveys, another workshop was held to present and validate the results and to discuss methods to control reuse. The study was performed during 2009 and 2010; the field surveys were performed and the questionnaires administered in April and May 2010.

FIGURE 1: RAINFALL IN NICARAGUA AND LOCATION OF THE WASTEWATER TREATMENT PLANTS INVESTIGATED IN THIS STUDY



IV. Results and discussion

Characterization of the practice

Extent

Of the 22 effluents studied, 13 were reused on different pieces of land. It was not feasible to determine the total extent of the irrigated area and types of crops for all of these sites, as access to some of the fields was simply prohibited; therefore the results presented here concern only sites for which data was obtainable. In particular, private fields cultivating tobacco and sugar cane which were the largest, were not accessible, thus the actual area under irrigation is much greater than that reported in this paper. In total, 247.25 ha were irrigated with partially treated wastewater. This represents a 55% increase compared to the estimated area in 2002, when 160 ha were irrigated with reused water (Table 1), 60% of which used 52 L/s of untreated wastewater (CEPIS 2002). Considering the wastewater treated in plants, the irrigated area could easily be in the range 357–400 ha. Although the same departments were not considered in both surveys (there were 12 in 2002 and 11 in 2010) comparisons can be made. Water was not resused in Nueva Segovia in either 2002 or 2010. In four departments reuse decreased from 114 ha to only 1.2 ha, becoming almost negligible. The reason for this decrease was either the construction of a WWTP disposing of the effluent to sites where it was no longer accessible to farmers, the lack of procedures to formally reuse water or the surveillance of government institutions to ensure water was not reused. In seven departments reuse increased by 6.8 times, from 36 to 246 ha. In these departments, irrigation with non-treated wastewater was common in the past. In 2002 reuse occurred in 10 departments mostly with untreated wastewater, while in 2010 reuse occurred in 9 departments with treated wastewater, thanks to the introduction of WWTPs. In addition, at two sites farmers were also reclaiming the treated sludge to improve soil fertility. It was not possible to obtain reliable figures for individual flow rates. The total flow produced in all WWTPs but three, reusing their effluents, was 22,981 m3/d or 265 L/s.

TABLE 1: WATER REUSE IN NICARAGUA IN 2002 AND 2010

Department	Ha		Wastewater Treatment		Crops	
	2002	2010	2002	2010	2002	2010
Not reusing wastewater						
Nueva Segovia	0	0	--	--	--	--
Decrease in reuse						
Carazo	57	0.5	Yes	Yes	Varied	Pumpkin (*Ayote*)
			No			Bananas
Managua	27	0	No	---	ND	-----
Leon	20	0.7	Yes	Yes	ND	Forage grass
Masaya	10	0	Yes	Yes	Forestry	-----
Increase in reuse						
Rivas	9	74.2	Yes	Yes	Pines	Papaya
						Banana
						Cassava
Estelí	0	70	Yes	Yes	ND	Tobacco
Granada	9	46.2	Yes	Yes	Varied	Sugar cane
						Forage grass
						Bananas
Jinotega	3	16.45	No	Yes	Varied	Tomato
						Onion Cauliflower Celery
						Forage grass
Matagalpa	14	20.3	No	Yes	ND	Squash
						Forage grass
						Maize
						Pumpkin (*Ayote*)
						Oranges
						Onion
						Rice
Chinandenga	1	10.5	Yes	Yes	ND	Sugar cane
Somoto (Madriz)	0	8.4	--	Yes	---	Green pepper
						Maize
						Avocado
Not studied in 2010						
Boaco	10	ND	No	NS	Forestry	--
Total	160	247.25				

ND: No data.

Irrigation practices and crops

Most of the irrigation took place near the WWTPs, sometimes even taking the effluent directly from the point of discharge, next to the fence and before dilution with river water. For those farmers taking reused water from rivers, the degree of dilution varied considerably, depending on the size of the WWTP and the river flow. Some farmers used small tanks to store the water, or installed dykes to take water from rivers. Pipelines, pumping systems, channels and storage tanks were built and operated by farmers. Irrigation methods consisted mostly of flood and furrow methods, but at one site sprinkler irrigation was used. At 85% of the sites, the aquifer level was deeper than 10 m below ground level. Almost all farmers (90%) used the effluents all year round.

There was a wide variety of irrigated crops. In terms of area, the most important were banana (50%), forage grass (25%) and maize (8.5%), but sugar cane, tomatoes, green peppers, cauliflower, papaya, rice, pumpkin, cassava, avocado, oranges and celery were also cultivated, over a total area of between 0.25 and 7 ha for each crop. Vegetables were grown in small plots for family consumption. Agricultural drainage returned to rivers (94%) or passed directly to wetlands (6%). In general, farmers were well aware of the risks of using wastewater and to control these, it seems they have voluntarily selected (in some cases compelled by water utilities) low-risk crops. Produce was sold in the local cities or markets (50%), in supermarkets (8%) or at other sites (45%), including food industries and exporters. From these first points of sale, produce was distributed by very complex pathways to different sites that could not be tracked. This illustrated the difficulties that must be faced if barriers to control risks are to be implemented along the commercialization chain for all types of crops, including those irrigated with reused water. Instead, it seems that it would be more feasible to develop best management practices for all persons involved in the commercialization chain.

Farmers' socio-economic profile

The land size for all farmers ranged from <10 ha to 600 ha; 66% of the data was available for pieces of land ≤ 20 ha and 82% ≤ 50 ha. In Nicaragua, a small farmer is defined as one cultivating an area of around 3–10 ha. The size of land over which water was reused varied between 2 and 200 ha, and frequently reused water was applied to only part of the pieces of land. Nearly 49% of the surveyed farmers were owners, with an income of between 93 and 563 USD per month (at the time of the survey 1 USD ¼ 22.35 córdobas); 67% of the farmers had an income of only 93–164 USD per month. Eighty-five per cent of the farmers interviewed had attended primary, secondary or technical bachelor school.

The rest had either not attended school or simply did not reply. Independently of reusing or not reusing water, it is important to provide safe working conditions in agricultural fields. Of the all the farmers surveyed (reusing or not reusing water), only 57% had access to water from a pipeline or protected well, while the remainder had no access at all or were able to extract it from a non-protected well. With regard to sanitation, 77% had latrines, 20% flushing toilets and 3% had no access to toilets at all.

Treated wastewater quality

Forty-six percent of the reused water came from stabilization ponds and 64% from septic or Imhoff tanks. The quality of the effluent produced is shown in Table 2, which describes mean conditions for the years 2009 and 2010. Stabilization ponds are common in Nicaragua due to their low investment, operation and maintenance costs. However, most of the time the effluent does not meet the accepted faecal coliform concentration of 103 MPN/100 mL, set by the national norm (Decree 33-95) and WHO criteria. There are two possible explanations: either the stabilization ponds are overloaded (which is true for some plants), or, according to Blanco & Lanuza (2001), the criteria used for design is not suitable for that particular country. In a study they performed on local stabilization ponds they found that neither of the frequently used international models satisfactorily described their results, as much lower bacterial inactivation was observed. This low performance could not be attributed to the dispersion factor and the authors recommended performing other types of studies to find a possible explanation. The plants using septic or Imhoff tanks include a disinfection step for reasons of cost.

As a result of the lack of trained personnel, concentrations of helminth eggs are not measured at all in Nicaragua. Nevertheless, some data from 2002 was obtained to give an idea of the content. In wastewater from Masaya, Platzer et al. 2002 found a content of 23 eggs/L, of which 71% were Ascaris eggs, 21% Strongyloides stercolaris, 6% Trichuris trichiura, 1% Enterobius vermicularis and 1% Taenia spp. The reported values are lower than would be expected for the region (Hays 1977). Platzer and colleagues compared the removal efficiency of helminth eggs for a stabilization pond (94.2%), an anaerobic filter (81.4%) and a biofilter (99.6%). Of these technologies, only the biofilter was capable of achieving the target of 1 helminth egg/L. Since this study was performed in 2002, no further tests on the content of helminth eggs in wastewater or their removal during wastewater treatment has been performed.

Considering the characteristics of the treated wastewater and its potential to be reused, the treatment systems for all WWTPs were classified according to their potential to:

- supply organic matter to soil: septic tank þ anaerobic filter >stabilization ponds> Imhoff tank þ anaerobic filter or biofilter > UASB >trickling filter
- supply phosphorus to soil: stabilization ponds ≈ trickling filter > Imhoff tank þ anaerobic filter or biofilter ≈ UASB > septic tank þ anaerobic filter
- supply nitrogen to soil: UASB > anaerobic filter or biofilter>>trickling filter>>stabilization ponds> septic tank þ anaerobic filter
- clog sprinklers or drip irrigation systems assuming a total suspended solids (TSS) concentration of 50 mg/L is not exceeded (Pescod 1992): stabilization ponds ≈ septic tanks þ anaerobic filter
- create bacteriological risks: septic tank þ anaerobic filter > anaerobic filter or biofilter > stabilization ponds.

TABLE 2: INFLUENT AND EFFLUENT CHARACTERIZATION FROM THE WWTPS REUSING WATER FOR AGRICULTURAL IRRIGATION, IN MG/L, UNLESS OTHERWISE INDICATED

Parameter	Stabilization ponds 26,288 m³ /d		Imhoff tank combined with anaerobic filter 2,980 m³ /d		Septic tank combined with anaerobic filter 1,221 m³ / d	
	Range	Mean	Range	Mean	Range	Mean
Influent						
BOD	275 - 744	495	232 - 684	351	298 - 621	438
TSS	216 - 885	520	215 - 828	400	304 - 884	465
TP	4 - 13	9		8.4		6.9
TKN	25 - 34	29		36		39.9
Faecal Coliforms*	3.4×10^7 - 2.8×10^8	9.1×10^7	3.3×10^7 - 1.6×10^9	4×10^8	3.3×10^7-1.6×10^8	8.4×10^7
Effluent						
BOD	7 - 92	49	47 - 194	101	55 - 183	121
TSS	39 - 222	109	30 - 142	80	54 - 243	112
TP	5 - 9.8	6.9		6.5		ND
TKN	6.6 - 35.4	17.63		40		ND
Faecal Coliforms	3.3×10^4 - 5.4×10^7	5.4×10^5	1.4×10^6 - 2.2×10^7	$6.9.5 \times 10^6$	4.7×10^6 - 1.6×10^8	1.8×10^7

Flow data available only for two of the five WWTPs.
Data from 2009 and 2010
*In MPN/100 mL. UASB: up-flow anaerobic sludge blanket; BOD: biological oxygen demand; TSS: total suspended solids; TP: total phosphate: TKN: total Kjeldahl nitrogen; ND: Not detected.

Yield increase

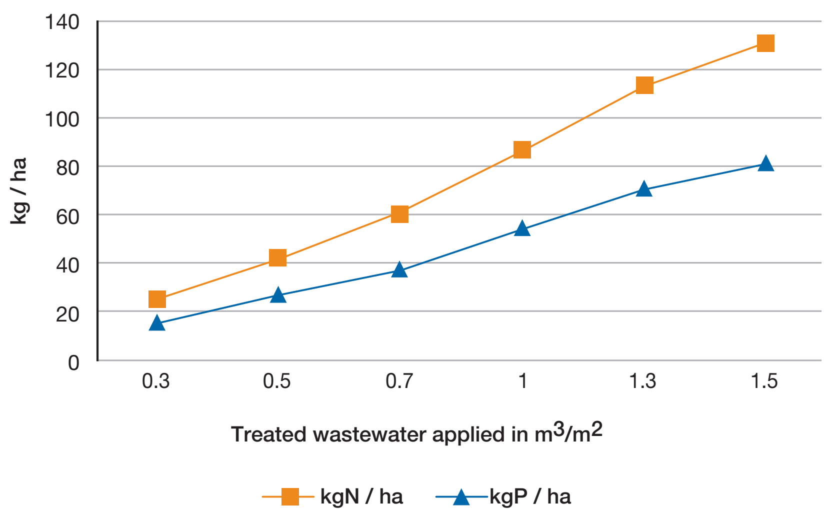
Productivity was increased firstly because of the availability of water all year round, the wider variety of crops that could be cultivated 21 instead of 14 for rain-fed agriculture and the lower dependence on fertilizers (65% of the farmers did not use it at all while for the rest the consumption was lower). The approximate rate of application of chemical fertilizers in Nicaragua is 773 kg/ha. Each 45.45 kg costs 26 USD and contains 15% N, 15% P and 15% K.

CEPIS (2002) estimated for the Jinotepe region that reuse increased farmers' income nearly two-fold (from 340 USD/ha to 680 USD/ha) when sowing three crops per year. This increase is less than that reported for arid or semi-arid regions (Keraita et al. 2008), but this is a humid area. Yields are also increased by 60% for maize (Zea mays) when the effluent used comes from an Imhoff tank þ anaerobic filter (Umaña 2010). Figure 2 shows the average amount of N or P that is added when the effluents from stabilization ponds are used. For the local crops this represents 50% to more than 100% of the P demand, and 15 to 85% of the N demand. This is an interesting result as reusing effluents for irrigation is of economic importance while disposing of effluents to surface water sources is causing eutrophication in Nicaragua. Tertiary treatment is simply unaffordable as it represents an increase in treatment costs of 50–70%. In economic terms, the reuse of just five stabilization pond effluents results in savings of 265,170 USD/yr as nitrogen or 167,636 USD/yr as phosphorus.

Health conditions

So far, in spite of the quality of the reused water, no major health problems or epidemic outbreaks have been associated with the non-planned reuse of treated water in Nicaragua. Even though this is a positive situation, the national morbidity rate for diarrhoea is relatively high at 252/10,000 inhabitants with a mortality rate of 1.34/ 100,000 (Gutiérrez 2009). The annual cost of medical attention for each child with acute diarrhoea is 5 USD, meaning that 69,155 USD per year are lost, an amount that increases to 110,649 USD per year if it is considered that one working day may also be lost for an adult to care for the child (Gutiérrez 2009). This cost and the high incidence of diarrhoeic diseases suggests that future studies should be performed to assess the impact on health of the use of partially treated wastewater. No information was found concerning the rates of helminthioses, but in surveys it was discovered that all targeted groups were consuming antiparasitic drugs once or twice per year.

FIGURE 2: AVERAGE AMOUNT OF N AND P ADDED TO SOIL AS A FUNCTION OF THE AMOUNT OF REUSED WASTEWATER FOR IRRIGATION FROM STABILIZATION PONDS



Perception

Governmental institutions

Before becoming aware of the results of the field study, 62% of the institutions considered that reusing water was a beneficial activity; and their acceptance increased to 88% when they specifically considered reuse for agricultural irrigation. However, only 38% accepted produce irrigated with wastewater for their own consumption. A wide range of positive aspects were also mentioned for reuse, such as the efficient use of water, avoiding groundwater overexploitation, protecting water resources, contributing to food 192 B. security, economic benefits, yield increase, drought management, eutrophication control and adaptation to climate change. After the first workshop on reuse, the positive opinions were much more focused on recognizing the benefits of yield increase, the contribution to income and food security and savings to allow additional treatment of effluents. Food security was of particular interest, as in Nicaragua there is a successful on-going program called Zero-Hunger, in which people of low income receive tools for agricultural and livestock production for consumption by the family. In some cases, the limited availability of water still remains a problem for agricultural production. Negative opinions before and after the workshop were very focused. Before the first workshop they were limited to three aspects: (a) the risk of dissemination of diseases, (b) the problems faced in the selling and exportation of products; and (c) the negative effects on soil notably due to salinization. Following the workshop the first two were considered to be prevalent.

The government institutions considered that the main drivers to reuse wastewater were: (a) combating water scarcity and making efficient use of water; (b) alleviating the problems of competition among water users, and (c) contributing to the economic incomes of farmers. Before knowing the actual extent of reuse, these institutions believed that the major barrier to its implementation would be the farmers' rejection of the switch to low-risk crops and the fear of not being able to sell their produce because of consumer rejection. Other barriers that were mentioned were: (a) the lack of existing knowledge concerning water reuse and the setting up of regulations; (b) the lack of proper agricultural infrastructure to allow irrigation with reused water and the fuel cost of pumping water; (c) the lack of knowledge of the advantages; (d) the lack of definitions of water rights among the people producing effluents and those wanting to reuse them; (e) the need to once again review the wastewater discharge standard 33-95 (Decree No. 33-95), previously reviewed and approved in April 2010; (f) the lack of economic resources to properly survey the practice; and (g) the need to develop a reuse standard that could be harmonized with the rest of Central America, as the entire region is cooperating in order to produce a homogeneous legal framework to enhance cooperation and commerce (SICA 2011).

Less than half of the institutions admitted knowing, prior to the presentation of the results of this study, whether or not wastewater was actually reused in Nicaragua. Among those who were aware, a small number believed that used water was of low quality. Eighty-two per cent admitted they were unaware of the WHO criteria of 2006, and 90% did not know the quantitative risk microbiological assessment (QRMA) methodology. It was, however, recognized that the use of a multiple barrier approach to control health risks would be useful in Nicaragua. It was accepted that there are different sources of pollution moving from agricultural fields to sites of consumption, namely the lack of hygiene in handling produce in the agricultural fields and during its sale at local markets and by street vendors. These risks may be controlled independently of the existence of a reuse programme. In addition, before knowing the actual state of reuse, the institutions' opinions were equally divided between those who believed that reuse projects should be promoted if they were only profitable to farmers and those who believed that the focus should be profitability for water utilities. Some mentioned that reused wastewater should be charged to farmers considering a water tariff depending on the availability of local water supplies, the level of income of each farmer, the size of the agricultural field and the advantages it bestows. After acknowledging the actual state of reuse, the institutions reached an agreement that reused water should be made available to farmers at no cost in the same way as first use water. It was also recognized that it is the government's responsibility to promote reuse as a way to safely dispose of effluents that have negative impacts on surface water (eutrophication problems). Moreover, 63% of the institutions surveyed considered that the government should finance reuse projects.

At the end of the study, all of the institutions agreed on the importance of promoting reuse in the country. However, it was felt it should be limited to low risk crops. Reuse on crops that are consumed raw represents a high risk due to the difficulties of producing suitable quality effluent, as the level of investment needed to complement or adapt existing treatment infrastructure would be very high. In addition, it was thought that reuse should be limited to municipal effluents and exclude toxic industrial ones.

Water utilities

ENACAL (the public water and wastewater utility) faces the double challenge of operating the existing WWTP infrastructure and also improving it to extend coverage. Considering the available budget, it is not feasible to add a tertiary treatment level to existing WWTPs to remove nutrients. Moreover, it is not considered viable to add disinfection steps to all of the facilities, notably to stabilization ponds, in order to reach the 103 faecal coliforms MPN/100 mL level set by the national norm. In this context the use of a multiple barrier approach seems a viable option, combining suitable quality treated wastewater with the proper selection of crops and irrigation procedures. During the survey, 11 utilities were interviewed, but only 10 replied. These companies operate most of the WWTPs studied. Only nine were concerned with reuse practices near their facilities, and of these, eight considered reuse as beneficial.

Water utilities were aware of all the sites where water was reused, but in 60% of these cases the local authorities were not. Where reuse was practised, it was affirmed that farmers fully accepted the practice and at 56% of the sites they were even requesting more treated wastewater. Where treated wastewater was not used, farmers have asked for the permission of the utility to use it but there are no norms or procedures for water utilities to reply. All of the utilities maintained that reuse was risky or even illegal but it was practised because it rendered water available to farmers where there was no other option to irrigate, either due to the lack of water of because effluents were discharged into the rivers that were used for this purpose.

According to the water utilities the main drivers for reuse were: (a) the availability of water all year round; (b) the flexibility of using reused water compared to other water sources; (c) the low cost of using it where pumping or transport is unnecessary; (d) the yield increase; and (e) the higher income associated with the possibility of growing more crops per year, with a higher yield, and growing produce of higher profitability. The barriers to reuse water for water utilities were: (a) the lack of a proper legal and institutional framework; (b) the lack of knowledge of the advantages; and (c) the negative aspect of effluents (most are stabilization pond effluents having a high load of algae). At all the sites reusing water, negative effects on soil or crops were not observed; for three WWTPs it was considered that the effluent was polluted with pathogens, two with nitrogen and phosphorus and one with algae. In five of the nine water utilities, operators mentioned they would not buy products irrigated with reused wastewater, and seven mentioned that at home they took additional precautions to wash and cook vegetables and fruits bought at the local market. One utility preferred not to reply. The procedures to wash and disinfect food varied widely therefore a specific pattern could not be identified. Only at two sites was it considered that reusing water was the source of diseases.

In all of the wastewater utilities it was considered that reuse should be promoted if it was profitable to farmers and only two considered that it should be promoted only if it was also profitable for the utility as well. All utilities agreed on the need for training to disseminate knowledge of the advantages of reusing water and also on ways to better manage it. In six of the nine wastewater utilities it was believed that the present situation could be improved if a reuse norm was established and a project to properly reuse water was implemented. In addition, all utilities considered that they should be responsible for the operating of such reuse projects as they are on site and can directly survey the use of their effluent.

Farmers

Of the 35 farmers surveyed, 17 used treated wastewater. Of these, 97% considered that reused water is merely polluted water that can still be used. This contrasted with the opinions of the other two groups that were simply unable at first to appreciate the usefulness of the effluents. For farmers, the main drivers to reuse water were: (a) its availability all year round; (b) the increase in income it provides by allowing more crops per unit area and per year; (c) its proximity to agricultural fields and its flexibility of use; (d) the lack of cost in using it; (e) the savings on fertilizers; (f) the fact that they had always used it, even when untreated, and they knew how it should be handled; and (g) it improves the quality of the soil. Those reusing wastewater qualified it as: (a) very important for family food security; (b) of high risk; and (c) possessing the capability 194 B. to increase the profitability of crops. Only 1% mentioned that it was an illegal practice. Even though reuse was widely accepted by farmers, 86% considered that consumers might not buy their produce if they were aware of the origin of water, even if it was offered at a lower cost (71%). Moreover, during the survey the farmers avoided directly admitting that they were reusing water. When they were asked who was actually reusing it, the reply was: 45% their neighbour, while they thought the remainder was equally divided among the owners of the land or the water utility; the sugar cane industry, their family and the tobacco growers. Only 5% admitted reusing water themselves. For farmers, the main concerns were the possibility of disseminating diseases among consumers (36%) or themselves (26%) and the fear of being unable to sell their crops (19%). Even though in the literature (Oron et al. 1999) and among members of local institutions the suspended solids content is a concern, only 6% of the farmers agreed. This is certainly due to the irrigation methods they are using. All of the farmers expressed concern with safe reuse and appeared to use caps and boots for protection; however, according to the water utilities this is not always the case.

All farmers mentioned that they were unaware whether or not the reuse of water was forbidden; but 31% admitted to knowing somebody for whom the practice had been restricted by an authority. Six per cent mentioned they had formally requested a permit from ENACAL to use their effluents but had not received a reply. A major concern for farmers was the lack of interest shown by the government in promoting and controlling reuse. They believe that if the government developed and implemented a reuse program, including education on safety, the practice could be improved, increasing incomes (83%), complementing the family diet (11%) and increasing the area of irrigated land (11%). As water for irrigation is provided at no cost in Nicaragua, almost all farmers considered that reused water should also be provided at no cost. All farmers were prepared to follow rules concerning the types of crops to be irrigated and the water application methods provided they were established by the government. Practically none of the farmers, regardless of whether they were reusing water (34/35), admitted to having had any health problem or having suffered from diarrhoea or parasites over the previous year. This result might be due to the methodology of the survey which consisted of directly asking farmers.

Comparison between groups and the literature

There were notable differences of opinion (Table 3). On the one hand, government institutions expressed a fear of initiating reuse practices, while farmers and water utilities accepted these practices and expressed a wish for the government to intervene. This showed a clear difference between a group that believes there is a need to develop new practices, and those that are already practising reuse and are conscious not only of the advantages but also the risks (although these are not perceived as being exactly the same for all groups). This difference in opinion also reflects the difference in responsibilities. The first group would be responsible for dealing with problems while water utilities and farmers would be those receiving benefits. Analysing the types of crops irrigated, it can be seen that somehow farmers have developed their own controls, mainly by selecting low risk crops. The situation could be significantly improved with more active participation by the government.

In the literature, social perception of reuse has been studied mainly in developed countries (Po et al. 2004). From these surveys a list of factors that may influence behavioural acceptability has been suggested. However, this proposed list is difficult to apply to developing countries where criteria linked to economic conditions, such as the increase in income, contributions to food security, and even the access to low or no cost water and fertilizers are more important factors.

Institutional framework

Legal aspects

One aspect that could explain the lack of institutional capability to establish the process is the complexity of the legal framework to regulate reuse. The 620 General National Water Law states that properly treated wastewater can be reused for agricultural irrigation provided it is assessed that it would cause no harm to health or to the environment and its use is regulated by the farmers' irrigation associations. In addition, Decree 33-95, dating from 1995 and referring to domestic, industrial and agricultural discharges to the environment, sets conditions for the direct reuse of water for agricultural irrigation (Table 4, column a). The decree does not set restrictions on crops but mentions that additional parameters can be set if negative effects are observed on soil. The indirect reuse of water is not controlled by norms but parameters to discharge to any receiving body are set considering: pH: 6–9; total suspended solids: 100 mg/L; oil and grease concentration: 20 mg/L; settleable solids: 1 mg/L; biological oxygen demand: 110 mg/L and chemical oxygen demand: 220 mg/L.

TABLE 3: SOME ASPECTS OF THE DIFFERENT GROUPS' PERCEPTION

Governmental institutions	Water utilities	Farmers
Is the reuse of water for agriculture a beneficial activity?		
88% Yes	89% Yes	83% Yes
Are farmers interested in reusing water?		
10% Yes	100% Yes	100% Yes
Would you buy produce irrigated with reused water for consumption at home?		
37.5% Yes	44% Yes	NA
37.5% No	56% No	
25% Maybe		
Do you use a particular method to disinfect produce at home?		
88% Yes	78% Yes	NA
	11% No	
	11% No reply	
What are the possible negative aspects of reusing water for irrigation?		
• Disease dissemination	• It is illegal	• Disease dissemination
• Difficulties in selling produce for exportation	• Disease dissemination	• Problems of commercializing
• Negative effects on soil	• Problems of commercializing produce produce	
What are the drivers to reuse water for agricultural irrigation?		
• Water scarcity and drought mitigation	• Availability of water all year round at no cost	• Availability of water all year round

TABLE 3: SOME ASPECTS OF THE DIFFERENT GROUPS' PERCEPTION *...CONTINUED*

Governmental institutions	Water utilities	Farmers
• Alleviation of competition among users	• Eutrophication control	• Livelihoods increase
• Making efficient use of water	• Increase in productivity and income	• Possibility of sowing crops with higher profitability
• Increase in productivity and income	• Use of its fertilization properties	• Food security
	• Flexibility of water use	• Increased income due to a higher number of crops per year
		• Low or no cost
		• Savings on fertilizer costs
		• The fact they know how to handle it
		• Soil quality improvement
What are the major barriers to reuse water for agricultural irrigation?		
• The need for farmers to change the crops that are sown and the need to learn how to handle it	• The lack of a proper legal framework	• Difficulties in selling produce
• Social acceptance	• The lack of knowledge of the benefits linked to negative social perception	
• Lack of experience of water reuse		
• Lack of knowledge to regulate the practices		
• Disease dissemination		
• The investment needed to set up the irrigation infrastructure and operate it		
• The possible hampering of exports		
• The lack of personnel to perform the surveillance		
Do you know if water is being reused for irrigation in the country?		
50% Yes	100% Yes	100% Yes
Is there need for more water to reuse for agricultural purposes?		
50% No	100% Yes	100% Yes
50% Don't know		
Does the reused water have to have a cost? (Before knowing the actual state of reuse)		
63.5% No	100% No	3% No
Does the reused water have to have a cost? (After knowing the actual state of reuse)		
100% No	100% No	3% No

TABLE 4: SELECTED PARAMETERS SET IN DIFFERENT LEGAL INSTRUMENTS TO REGULATE WATER REUSE FOR IRRIGATION, IN MG/L, UNLESS INDICATED OTHERWISE

		NTON 05 007-98		NTON 05 027-05		
	Decree 33 - 95	2-A	2-B	A	B	C
Parameter	(a)	(b)	(c)	(d)	(e)	(f)
pH	6.5–8.5	NR	NR			
Electrical conductivity (μ℧/cm)[a]	200	NR	NR	200	200	200
BOD_5	120	NR	NR	12	200	NR
TSS	120	NR	NR	200		
TDS	NR	3000	3000			
TN	NR	NR	NR	15	15	15
TP	NR	NR	NR	5	5	5
Aluminium	5.0	1.0	1.0	5	5	5
Arsenic	0.1	0.05[b]	0.05[b]	0.1	0.1	0.1
Boron	1.0	0.75	0.75			
Cadmium	0.01[b]	0.005	0.005	0.01	0.01	0.01
Chromium	0.1[b]	0.05[b]	0.05[b]	0.1	0.1	0.1
Iron	5.0	1.0[b]	1.0	5.0	5.0	5.0
Fluorides	3.0	NR	NR			
Lithium	NR	5.0	5.0	2.5	2.5	2.5
Lead	0.5[b]	0.05	0.05	0.2	0.2	0.2
Zinc	2.0	5.0	5.00	5.0	5.0	5.0
Sodium	NR	200	200			
Sodium	6	NR	NR	6	6	6
Faecal coliforms/100 mL	10^3	<100C	$<10^{3C}$	10^3	10^4	10^5
Helminth eggs/100 mL	1	NR	NR	0	1	1
Organophosphates and carbamates		0.1	0.1			

a 1 μ℧/cm = 1 μS/cm, as per convention, to avoid confusion between mhos and ohms. Since the 1970s siemens have been used rather than mhos.
b Indicated as total.
c MPN/100 mL monthly value.

BOD: biological oxygen demand; TSS: total suspended solids; TDS: total dissolved solids; TN: total nitrogen; TP: total phosphorus: NR: not regulated.

In parallel, the norm NTON 05 007-98 classifies the different surface water bodies according to their possible use. It considers six types of water. Type 2 is the one that might be used for agricultural purposes. Category 2-A (column b, Table 4) is for the irrigation of vegetables that are consumed raw and 2-B (Table 4, column c) for any other type of crops and for cattle feed. Norm NTON 05 027-05 sets the conditions for treatment and reuse systems. This norm prohibits the reuse of non-treated wastewater to irrigate crops and defines six types of reuse, one of which is for agriculture and forestry. For agriculture and forestry there three categories: (a) Category A, for the restricted irrigation of crops that are consumed raw, or have direct contact with reused water such as vegetables or fruits growing in the soil; (b) Category B, for crops with medium restrictions which are crops that grow with no contact with soil or reused wastewater, such as beans, maize, wheat or sugar cane or are not edible, for example cotton and flowers; and (c) Category C, for perennial crops in which the plant and the fruit has no contact with the treated wastewater (such as cocoa or citrus). Some parameters for these three categories are presented in columns d, e and f in Table 4.

Finally there is another norm, NTON 05 031-07 for the reuse of industrial effluent from the sugar industry for irrigation, that is currently being successfully applied. This norm was promoted by private companies that were already reusing their water under controlled conditions to irrigate sugar cane. It was required to show environmental requirements were being fulfilled to certify their products at the international level. The norm ensures efficient use of water but also promotes the recycling of fertilizers while controlling risks to the environment and public health. Institutional capacity The survey illustrated that the major barrier to the introduction of a reuse program is the lack of acceptance of this practice by the government, even when wastewater is properly treated, due to only partial knowledge of the risks and, associated with this, the procedures to control them. However, once the extent of the practice was recognized, the governmental institutions accepted the need to implement a reuse program. One highly positive consideration in Nicaragua is that governmental institutions are used to working as team in different types of projects; a factor identified as a key element to implement a multiple barrier approach and reuse projects. In addition a program is being put in place to certify analytical laboratories, put organized teams of inspectors in place at a municipal level to survey different social projects and to introduce training programs for farmers. All of these elements can be successfully used to implement planned reuse projects.

Perspectives for planned reuse

The first step to redress the situation would be to acknowledge reuse and, in parallel, to change the perception of wastewater at the governmental level from a waste product to a resource. This should be expressed in the legal and institutional framework, water policy and government programs for the water, agricultural and environmental sectors, among others. It should always take account of protection of public health, the environment and agronomic needs (Bahri 1999; Huibers & Van Lier 2005). Figure 3 shows a diagrammatic representation of how to proceed. Although it has been planned, the ANA (The National Authority for Water) has not yet been created, and the process could therefore start by setting up a national inter-institutional committee in charge of: (a) planning; (b) defining the institutional roles; (c) reviewing the legal and institutional framework; and (d) setting up a communication and education strategy. As part of the planning process, priority regions to promote reuse should be selected, procedures to combine sanitation and reuse programs should be put in place and a budget established. During this planning phase, stakeholders need to be involved independently of whether or not they support reuse practices.

The second workshop, with regard to the WHO (2006) guidelines, concluded with the following proposals: 1. While rendering the practice safe, the actual quality of the treated wastewater should be matched with reuse needs at an affordable cost. 2. It would allow the selection of low-cost technology for new municipal wastewater treatment plants. 3. It would be beneficial to improve the whole management chain for crops from agricultural fields to sites of consumption, independently of the reuse of wastewater. However, to be implemented, it is necessary to: change the mentality of the whole country to make reuse an acceptable practice; review the entire legislative framework related to wastewater discharge and reuse, and improve the institutional framework as well as build the institutional and social capacity. To implement reuse projects it is envisaged that reuse permits could be granted in which the amount of water allocated and the types of crops to be irrigated would be stated. The government could use the facilities at public agricultural training centres to organize both training and research on reuse. These would be the first of their kind in Central America.

FIGURE 3: DIAGRAM TO AID DEVELOPMENT OF A STRATEGY TO IMPLEMENT A WATER REUSE PROGRAM FOR AGRICULTURAL IRRIGATION AT THE NATIONAL LEVEL

Exports

An important share of the national agricultural income comes from exports, particularly of bananas. Fortunately bananas can be considered a low-risk crop and reuse could be controlled by using specific water quality and irrigation criteria and a well-documented procedure that could be certified (as with the sugar cane industry) thus ensuring international commerce is not damaged.

Communication

Social acceptance is a key element to any reuse project, and can become the main barrier for a water reuse project. Therefore it is important to develop programs to properly communicate the importance of reusing water and the way in which the government will address the risks (Hartley 2006). One common mistake in developing countries is to use non-specialists, notably technical staff, such as engineers, to set up communication programmes. For this reason, the message frequently becomes misleading and mistakes are made concerning the type of media to be used and the groups that should be targeted. The communication program should be common for all of the institutions involved in the control and promotion of reuse. Messages should be carefully selected, as even in Figure 3 | Diagram to aid development of a strategy to implement a water reuse program for agricultural irrigation at the national level. 199 B. populations receptive to reuse they might be rejected (Friedler et al. 2006). They should contain actual data obtained in the field such as the amount of water that can be saved, economic benefits, yield increases, and measures to protect health and the environment at the personal, collective and public levels.

Training needs

From the surveys performed on the three targeted groups some themes for training were constantly mentioned: the general principles of water reuse; reuse of grey water; criteria to reuse water; wastewater treatment and management practices; irrigation methods; analytical techniques to quantify helminth eggs; the QRMA methodology; and examples of intervention methods that have been set up in practice, together with data on their performance.

V. Conclusions

The extent of the farmers' existing experience in reusing water for agricultural irrigation could be a distinct advantage in producing a program to fully control reuse while protecting health, the environment and the export market. This should be completed in the short term as non-planned reuse is rapidly growing in Nicaragua. This is of particular importance because, although to date no epidemic has been associated with the reuse of wastewater, an outbreak may quickly lead to social rejection of the practice. The risk is not negligible as many of the effluents currently used have faecal coliform contents well above the 103 MPN/100 mL level set by national norms and international criteria. The positive opinion of farmers and water utilities and their wish for the government to intervene should be the driver for this.

The lack of knowledge of reuse practices in developing countries, notably including practices that have already been implemented, limits the development of better ways to control unplanned reuse and to promote planned reuse. It is therefore recommended to perform these types of studies at sites where non-treated, partially treated or properly treated wastewater is being used to gather more hard data, coupled with data on the perception of different stakeholders. The present study for instance, besides assessing the importance of reuse to improve livelihoods for farmers in a wet country, clearly shows other aspects such as the possibility for reuse to become a low-cost tool to control eutrophication in developing countries.

Even though, as illustrated in this study, there are differences in perception and situations between developing countries and developed ones (Lazarova et al. 2001; Bixio et al. 2006), it is clear that at the global level new clearer institutional arrangements, proper economic tools and clear guidelines are needed for the reuse of water for agricultural irrigation.

VI. References

- Anderson, J., Baggett, S., Jeffrey, P., McPherson, L., Marks, J. & Rosenblum, E. 2008 *Public acceptance of water reuse. In: Water Reuse: An International Survey of Current Practices, Issues and Needs* (B. Jiménez & T. Asano, eds.) Scientific Report No 20, IWAP, London, UK, pp. 332–350.
- Asano, T. 2006 Water *recycling – A relevant solution? In: Water Crisis: Myth or Reality?* (P. Rogers, M. Llamas & L Martínez Cortina, eds.), Taylor and Francis, London, UK, pp. 261–283.
- Bahri, A. 1999 *Agricultural reuse of wastewater and global water management*. Wat. Sci. Technol. 40 (4–5), 339–346.
- Bixio, S., Thoeye, C., De Koning, J., Joksimovic, D., Savic, D., Wintgens, T. & Melin, T. 2006 *Wastewater reuse in Europe.* Desalination 187, 89–101.
- Blanco,M.& Lanuza, C. 2001. *Influence of the dispersion factor on coliforms removal on stabilization ponds for the Masaya.*
- Master degree Thesis, Environmental Engineering and Science Programme, National University of Engineering. Available from: http://www.ciema.uni.edu.ni/paginas/quienes.php (accessed November 2010) [In Spanish].
- CEPIS 2002 Regional Project for the Integrated Treatment and Use of Wastewater in Latin-American: (a) Regional Inventory; (b) Actual Situation in Nicaragua; and Complementary Study for Jinotepe. IDRC – CEPIS/OPS, Lima, Peru.
- Decree No. 33-95 *Provisions to control the pollution originated from domestic, industrial and agricultural wastewater Discharges*, published on the Official Diary of Nicaragua No. 118, June 26, 1995 [In Spanish].
- *Earth Trends* 2010 Available from: http://earthtrends.wri.org/ (accessed March 2010).
- Ensink, J., Mehmood, T., Van der Hoek, W., Rashid-Sally, L. & Amerasinghe, F. 2004 A *Nation-wide assessment of wastewater use in Pakistan: an obscure activity or a vitally important one?* Wat. Pol. 6, 197–206.
- Friedler, E., Lahav, O., Jiskaki, H.& Lahav, T. 2006 *Study of urban population attitudes towards various reuse option: Israel as a case study*. J. Environ. Manag. 81, 360–370.
- Gutiérrez, G. 2009 *Transmission of food diseases in Nicaragua. In: Technical Report of Agricultural and Food Engineering*, FAO, 6, 159–190. Available from: ftp://ftp.fao.org/docrep/fao/011/i0480s/i0480s06.pdf [in Spanish].
- Gutiérrez-Nájera, G. 2005 PAHO/WHO Nicaragua, Managua. *Food Diseases, Study Case. In Proceedings of the Regional Conference on Food Safety for the Americas and the Caribbean Region, San José, Costa Rica* CEDOC, PAHO/WHO. Available from: ftp://ftp.fao.org/docrep/fao/011/i0480s/i0480s06.pdf, pp. 159–175 (accessed 10 January 2012) [In Spanish].
- Hartley, T. W. 2006 *Public perception and participation in water reuse*. Desalination 187, 115–126.
- Hays, B. 1977 *Potential for parasitic disease transmission with land application of sewage plant effluents and sludges*. Wat. Res. 11, 583–595.
- Huibers, F. P. & Van Lier, J. 2005 *Use of wastewater in agriculture: the water chain approach?* Irrigat. Drain. 54, S3–S9.
- Jiménez, B. 2006 *Irrigation in developing countries using wastewater.* Int. Rev. Env. Strat. 6, 229–250.
- Jiménez, B. & Asano, T. 2008 *Water reclamation and reuse around the World.* In: Water Reuse: An International Survey of Current Practice, Issues and Needs (B. Jiménez & T. Asano, eds.), IWAP, London, UK, pp. 3–26.

- Jiménez, B., Drechsel, P., Kone, D., Bahri, A., Rashid-Sally, L. & Qadir, M. 2010 *General wastewater, sludge and excreta use situation*. In: Wastewater Irrigation and Health: Assessing and Mitigating Risks in Low-Income Countries (P. Drechsel & C. Scott, eds.), Earthscan Press. London, UK, pp. 3–28.
- Juanico, M. & Salgot, M. 2008 *Northern Mediterranean World*. In: Water Reuse: An International Survey of Current Practice, Issues and Needs (B. Jiménez & T. Asano, eds.), IWAP, London, UK, pp. 483–502.
- Keraita, B., Jiménez, B. & Drechsel, P. 2008 *Extent and implications of agricultural reuse of untreated, partly treated and diluted wastewater in developing countries.* CAB Rev. 3, 1–15.
- Lazarova, C., Levine, B., Sack, J., Cirelli, G., Jeffrey, P., Muntaus, H., Salgot, M. & Brissaud, F. 2001 *Role of water reuse for enhancing integrated water management in Europe and Mediterranean countries.* Wat. Sci. Technol. 43, 25–33.
- MAGFOR 2008 *Subprogram for the Development and Reactivation of the Irrigation to Contribute to the Food Security in Nicaragua. Ministry of Agriculture, Livestock and Forestry.* Available from: http://www.iica.int.ni/programasObservatorio.html (accessed April 2010).
- Oron, G., Campos, C., Gillerman, L.&Salgot, M. 1999 *Wastewater treatment, renovation and reuse for agricultural irrigation in small communities*. Agricul.Wat. Manag. 38, 223–234.
- Pescod, M. 1992 *Wastewater Treatment and Use in Agriculture. Paper 47. Rome: Food and Agriculture Organization of the United Nations, Geneva.*
- Platzer, M., Cáceres, V. & Fong, N. 2002 *Biofilters in Nicaragua*, In XXVIII Inter American Congress on Sanitary and Environmental Engineering Cancún, México, 27–31 October, 2002, pp. 250–265 [In Spanish].
- Po, M., Kaercher, J. & Nancarrow, B. 2004 *Literature Review of factors influencing public perceptions of water reuse*, Technical Report 54/03, Australian Water Conservation and Reuse Research Program, CSIRO Land and Water, Australia.
- Post, J. 2006 *Wastewater treatment and reuse in eastern Mediterranean region*. Water 21, 36–41.
- Qadir, M., Sharma, B. R., Bruggeman, A., Choukr-Allah, R. & Karajeh, D. 2007 *Non-conventional water resources and opportunities for water augmentation to achieve food security in water scarce countries*. Agricult. Wat. Manag. 87, 2–22.
- Raschid-Sally, L. & Jayakody, P. 2008 *Drivers and characteristics of wastewater agriculture in developing countries: Results from a global assessment*. IWMI Research Report 127, IMWI, Colombo, Sri Lanka.
- SICA 2011 *Central American Integration System*. Available from: http://www.sica.int/ (accessed September 2011).
- Toze, S. 2006 *Reuse of effluent water-benefits and risks*. Agric. Wat. Manag. 80, 147–159.
- Trang, D., Hien, B., Mølbak, K., Cam, P. & Dalsgaard, A. 2007 *Epidemiology and aetiology of diarrhoeal diseases in adults engaged in wastewater-fed agriculture and aquaculture in Hanoi, Vietnam*. Trop. Med. Int. Health 12, 23–33.
- Umaña-Gómez, E. 2010 *Effects on soil and maize* (Zea mays L.) C*rop as result of using a treated effluent from the city of Jinotepe*. Research Center for the Studies on the Environment, National University of Engineering Available from: http://www.ciema.uni.edu.ni/paginas/quienes.php (accessed May 2010), [In Spanish].
- WHO 2006 *Guidelines for the Safe Use of Wastewater, Excreta and Grey Water; Vol. 2*: Wastewater Use in Agriculture.
- WHO-PAHO-UNEP, World Health Organization, Geneva, Switzerland.
- Yang, H. & Abbaspour, K. C. 2007 *Analysis of wastewater reuse potential in Beijing*. Desalination 212, 238–250.

wsp
water and
sanitation program

THE WORLD BANK