NEGOWAT

Facilitating Negotiations over Land and Water Conflicts in Peri-urban upstream Catchments

RESEARCH REPORT Nº 3

Wastewater Irrigation in the Periurban Area of Tiquipaya (Cochabamba, Bolivia)

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The NEGOWAT Project (Facilitating Negotiations over Land and water Conflicts in Peri-urban Upstream Catchments) is a research project developed in Cochabamba (Bolivia) and Sao Paulo (Brasil). It is focused to develop tools to better understand water related competition and conflicts among different stakeholders in these areas.

In Bolivia, the NEGOWAT Project is executed by the Andean Centre for Water Management and Use (Centro AGUA) and the Study Centre of Social and Economic Reality (CERES). The Centro AGUA is an education and research centre of the Faculty of Agriculture and Livestock Sciences (FCAyP), San Simon University (UMSS).

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/ wastewater / wastewater irrigation / irrigated agriculture / water quality /

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CONTENT

SUMMARY

Before now, farmers of Tiquipaya were known for their abundant water for irrigation from superficial and underground sources. With passing years, most of the groundwater sources have diminished their availability. This issue and the change of the rainfall regimen have decreased the water availability for irrigation. Nowadays, farmers are forced to use wastewater in the agricultural production as a complementary or supplementary water source, in a context where the subsistence of the farmers interacts with urbanization, water scarcity and poverty. The objective of this study is to analyze the characteristics of the wastewater use for irrigation in Tiquipaya and its possible consequences on environment and health, starting from the monitoring of the temporal and spatial variations of the wastewater quantity and quality, the knowledge of the current farming practices and the farmer's perceptions.

Three areas were identified with intensive use of wastewater without treatment: Bruno Moqho, cultivating vegetables; Kanarancho, irrigating grassland; and Chiquicollo, producing forage. Wastewater sources were monitored in the dry and wet periods. The results in both periods show high concentrations of microbiological contamination; the biological demand of oxygen indicates that they are not appropriate neither for irrigation, nor for discharge in water receivers (Law 1333). It is necessary to implement, at first, wastewater treatment plants and then to measure the adaptation of irrigation practices, to use protecting clothes and appropriate techniques for washing and disinfecting agricultural products. This should be supported by the municipality and institutions.

1. INTRODUCCION

In arid regions of the world, where water is scarce, the use of wastewater from domestic or commercial uses seems an obvious solution for irrigation needs of urban and peri-urban agriculture. Wastewater in these areas should be considered as a viable resource for irrigation when it is utilized safely. Nowadays, irrigation with treated and even untreated wastewater is already being practiced on a small scale in urban and peri-urban areas in many developing countries (OPS, 2002; CEPIS, 2002; Duran et al., 2003).

Some decades ago, farmers in Tiquipaya had enough quantity of water from several superficial and groundwater sources. With passing years, the springs have dried off due to the overexploitation of groundwater and the rapid increase of water demand for domestic use and the unfavorable rainfall patterns (PEIRAV, 1993). Consequently, farmers in Tiquipaya are forced resort to alternative water sources for irrigation such as wastewater coming from the anthropogenic activity.

Currently, a space has been created for the evolution of wastewater use. While the traditional water sources diminish in volume and confidence, this resource is presented as a secure water source with a volume in constant increment. These two characteristics make of wastewater an attractive water source for irrigation in the present and immediate future. In Tiquipaya, the urban center (Casco Viejo) has a sewage system, covering approximately 4000 inhabitants. The domestic wastewater generated in the rest of the municipality, composed of 33000 inhabitants, (INE, 2001), is discarded in diverse ways, generally using the irrigation canals.

The objective of the study is to analyze the characteristics of wastewater use for irrigation in Tiquipaya and the consequences on environment and health, starting from the monitoring of the temporal and spatial variations of the wastewater quantity and quality, the knowledge of the current farming practices and the farmer's perceptions related to irrigation with wastewater. This objective was reached responding the question: How can spatial and temporal variations in water quality and water availability be more adjusted to the current use and management of wastewater in irrigation in Tiquipaya?.

Nowadays, the wastewater use for irrigation is a common practice in the peri-urban areas of Tiquipaya, involving a considerable group of farmers. This article is based on the master thesis on "Wastewater irrigation in the peri-urban area of Tiquipaya", carried out by Van Rooijen (2004) and in the acquired experience supporting the development of this research.

2. GENERAL CONTEXT

2.1 Location

The Tiquipaya municipality is the third section of the Quillacollo province, department of Cochabamba (Figures 1). It is divided into six municipal districts, from which 3 (districts 1, 2 and 3) correspond to the mountainous part and foot of mount, and the others 3 (districts 4, 5 and 6) are part of the central valley of Cochabamba. The study area considers the districts 4, 5 and 6, being in these districts where most of the population of the Tiqupaya municipality is settled.

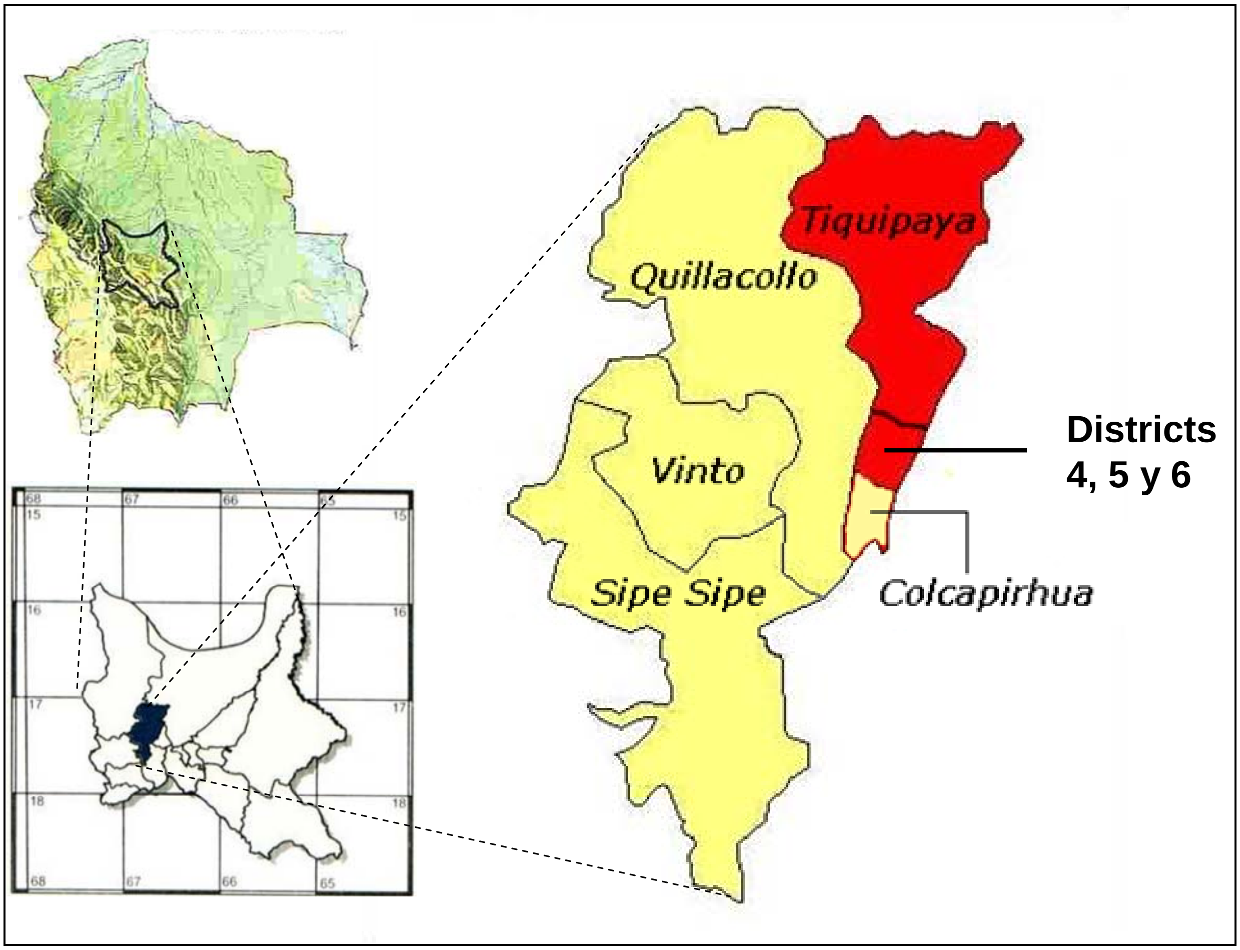

Figure 1. Location of the Tiquipaya municipality

2.2 Irrigation water sources

In Tiquipaya, there is a diversity of superficial and groundwater sources managed by the same farmers. Among the water sources that are considered clean water and that provide water for irrigation, we find:

- Surface water from mountain range, made up mainly by the water from the Khora Tiquipaya River, corresponds to the ‘Machu M’ita’ system. On the other hand, the Tolavi, Khora, Chuta Khawa and Taquiña Rivers that have a seasonal behavior, are occasionally used as a water source for irrigation.

- Water from the Lagum Mayu, Sayt'u Kocha and Chankas reservoirs are natural lagoons improved through hydraulic works (dams) to increase their storage volume (Saenz, 1997).

They are property of the farmers who use water for irrigation in a rotatory distribution system.

- The North canal of the “Sistema Nacional de Riego N° 1” carries water from the “La Angostura” dam.

- Private and communal wells (being the last ones the most common situation) are used mostly on water supply for domestic consumption, which is more important with passing days.

- The springs are also used for irrigation although they have diminished their flow significantly and, in some cases, they have dried off due to the over usage of the underground aquifers.

From the previous context, it can be deduced that the irrigation water management in Tiquipaya is very complex. Besides, rivers in Tiquipaya can be considered as a very serious menace for the inhabitants settled in their vicinities. After intense rainfalls, these rivers flow large water amounts and silt from the mountains.

2.3 Evolution of water scarcity

Extreme periods of drought have damaged agricultural production, causing hunger and migration in several agricultural areas. However, historically, dry and wet years have been described as periods with l serious problems like that of the ecological crisis and the consequences of the dry years are referred to taking into account 1987 and 1992, when the water supply for irrigation and drinking water were at risk. This situation gave an impulse for investment in the improvement of the irrigation systems and natural reservoirs in nearby mountains (Cordillera del Tunari), searching for the betterment of the water supply coming from these sources (PEIRAV, 1993).

At the end of the 80s and the beginnings of the 90s, in the Central and Low Valley of Cochabamba, several deep wells were dug to provide drinking water to the growing population of Tiquipaya and Cochabamba city because the wells without a spurting pump (pozo surgente) did not give away much water anymore as a result of the over usage of groundwater. In spite of the intentions of some municipal authorities and residents (irrigators) to stop drillings of wells sometimes up to 100 m of depth, this has led to a fall of the phreatic level and this will surely drive to severe problems of drought affecting natural vegetation.

2.4 Current situation of wastewater use in Tiquipaya

In Tiquipaya, there are several areas of punctual discharge of wastewater, presenting a great variability in the discharged flow and in the intermittence of the discharge. Three important areas were identified where wastewater is used in the agriculture: Chiquicollo, Bruno Moqho and Kanarancho (Figure 2). Each area has its own wastewater source, except Chiquicollo that has two sources: the North Canal of the *“Sistema Nacional de Riego Nº 1”* (SNR Nº 1) and the discharge of the *“El Carmen”* and *“Cruce Taquiña”* neighborhoods sewage system.

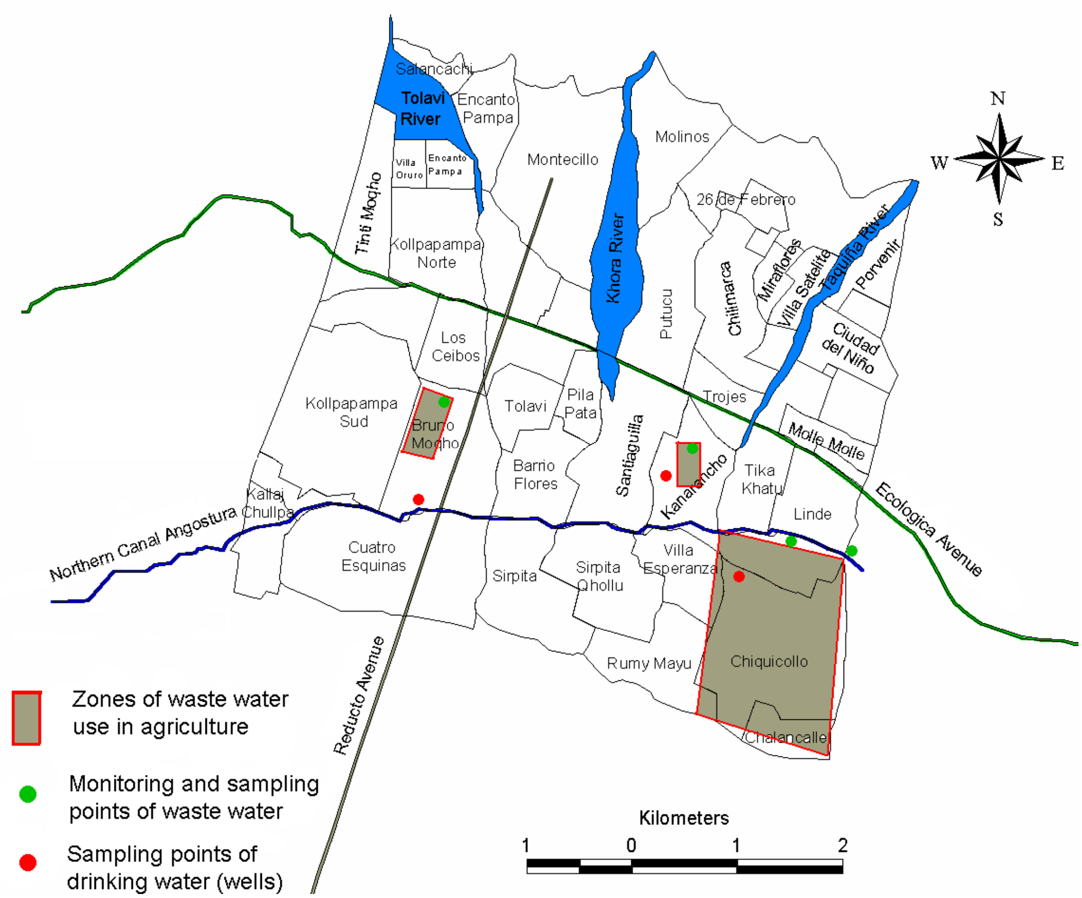

Figure 2. Location of wastewater use areas in Tiquipaya

Some neighborhoods located in the North area of Cochabamba city and of the same Tiquipaya municipality, are discharging their wastewater to the North canal of the SNR N° 1 that was designed to provide irrigation water to Tiquipaya from the *"La Angostura"* dam. Also, people from outskirt houses made clandestine connections of their sewage system toward this canal.

The household with wastewater is mixed with irrigation water when water from the "La Angostura" flows through this canal. When this is not the case, the canal only conveys wastewater without any treatment and sometimes lightly diluted with rain water, being finally used as irrigation water in the Chiquicollo area for forage cultivation and dairy cattle (mainly maize, oats and alfalfa).

In Bruno Moqho, the wastewater from the sewage system of the Tiquipaya town is used for irrigation, after being treated in an Imhoff tank that carries out the primary treatment. However, the effluent water quality can still be classified as not treated, due mainly to the low treatment efficiency of this tank (less than 35%), which for the lack of maintenance is full of sludge (Technical Agency, 2003). The wastewater is directed to vegetable cultivation (mainly spinach, radish, parsley, among others) and in a small proportion to forage growth (alfalfa).

In Kanarancho community, the wastewater from several agro industries that elaborate "chichi" (alcoholic drink based on maize fermentation) is being used in a small scale to irrigate forages (mainly grassland).

The municipality of Tiquipaya acknowledges the use of wastewater on its territory although the national government prohibits by law the use of untreated wastewater in irrigation by law since 1992 (Ley del Medio Ambiente Nº 1333). The municipality agrees on the use of wastewater in Tiquipaya may have implications on the population health (oral communication with those in charge of the environmental aspects at the municipality; October, 2002).

2.4 Mapping land distribution and crop types

Interviewed farmers own various plots about one hectare in size. Cultivated crops highly differ strongly to zones as it is observed on Figure 3. It is clearly visible that in the case of Bruno Moqho a large variety of crop types exists. Dominant crops are spinach, alfalfa, tomato and grassland.

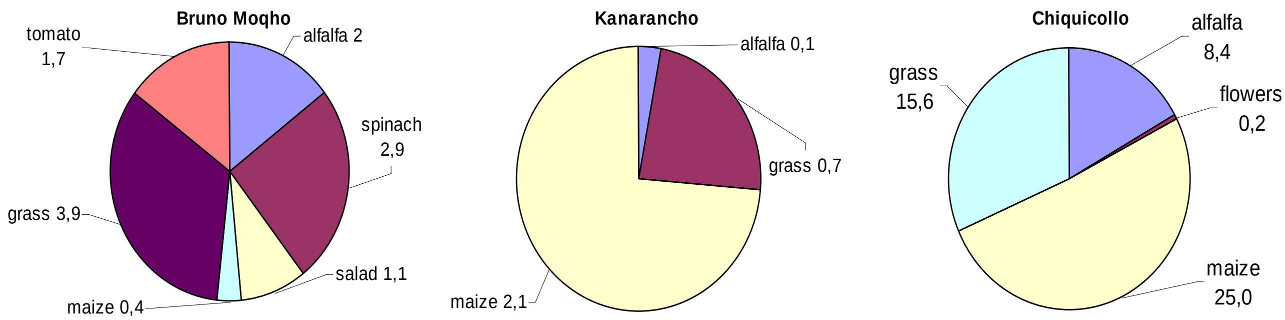

Figure 3. Composition of land use per zone by crop type and area (ha)

It is necessary to clarify that in Kanarancho the grassland are irrigated with wastewater because of its low water quality, low pH level (average 5) and the excessive content of lime (average 114 mg/l). In Chiquicollo, maize, alfalfa and grassland are the dominant crops. Differences of the total area inside the three areas should be taken into consideration when analyzing the importance of the crop percentages of cultivations in a broad context. In general, maize, alfalfa and grassland dominate in the three areas.

3. CONCEPTUAL FRAMEWORK

3.1. Facing water scarcity

Water scarcity is a problem that makes the world population suffers. While the population increases, the production of garbage, water consumption, and environment contamination increases more rapidly. A potential way to diminish and to avoid future problems of water scarce is the multiple water use. It is important to point out that multiple water use has as challenge the alimentary security, the environment protection and the conservation.

3.2. Wastewater use in agriculture

In general, irrigation with wastewater is carried out in a disorganized way due to bad infrastructure conditions, and to the absence or little execution of local and national regulations. These create difficulties to face the social and the rapid environmental changes due to the advance of the urbanization, water scarcity and the environment pollution. Besides, it is evident that the increase of the water demand for other household and industrial sectors are relegating the importance of irrigation water demand, which creates difficulties for the agricultural sector.

Compared to non- polluted water, wastewater is often a more secure water source for agriculture in terms of availability because it flows continually all year long and its availability increases according to the population's growth. If an appropriate use of the wastewater is done, to irrigate certain crops, the possibility of changing the wastewater problem, in a potential resource for agriculture, is facilitated (Huibers, 2003). In the last years, the need for solving the wastewater elimination has increased.

Among the different solutions, wastewater use in the irrigated agriculture is one of the best options from an environmental and economical point of view. Nowadays, wastewater is being used progressively; the question is whether it should be used or not, but how a better management and an appropriate use should be carried out (Huibers, 2003). The wastewater use consequently should be fomented to search opportunities to improve the control of water quality to reduce health risks.

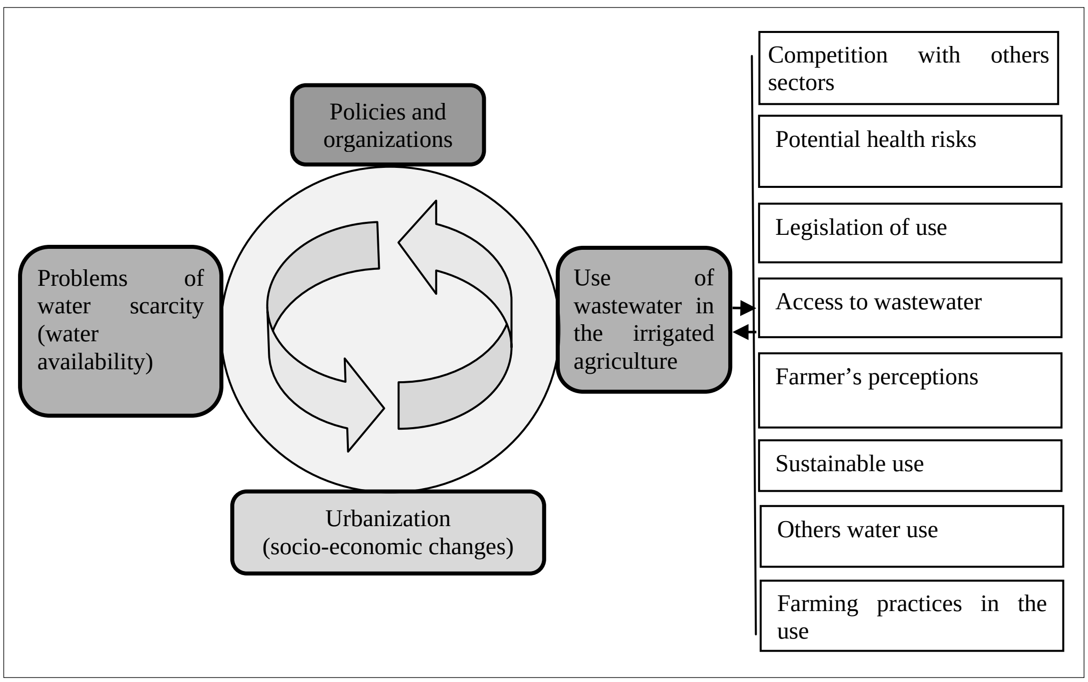

Figure 4. Conceptual framework of the wastewater use in agriculture (Van Rooijen, 2004)

Figure 4 presents the socio technical approach in which the use of wastewater is contemplated in agriculture. It is based on a more general and more comprehensible focus on the use of the treated residual water proposed by Martijn and Huibers (2001); in which “farming practices” take part. This, however, is briefly discussed and focused on treated wastewater only. It leaves more room for further analysis about sustainable use of wastewater in irrigation.

4. METHODOLOGY

The methodology applied in the study considers two components: one technical and the other social.

4.1 Technical component

On the technical side, monitoring with a series of basic measurements of water quality and wastewater discharges, water samplings and crop surveys were carried out. The basic measurements of water quality, such as: electric conductivity (CE), pH, temperature, salinity and dissolved oxygen, were carried out with electronic field equipment that allows determining the water quality. Firstly, four monitoring points were identified in open canals without lining (Figure 2):

- In Bruno Moqho: in the discharge point of the Tiquipaya sewage system to the Angela Mayu River.

- In Kanarancho: approximately 100 m. away from the discharge of “chicha” factories.

- In Chiquicollo: in the discharge point of the sewage system (open canal) from the “El Carmen” and “Cruce Taquiña” neighborhoods.

- In the North canal of the SNR Nº 1 in the main canal, from water intake Nº 24, to 30 m of the water intake.

The monitoring with field equipment was done during four days in the dry period, the days 5, 7, 10 and 11 of November 2003 at the four described points, with an approximate duration of 10 hours (from 8:30 to 18:30). This monitoring was carried out in order to have a complete knowledge of the daily variation of monitoring parameters, and to establish a schedule to take water samples.

Later, at the same monitoring points the taking of water samples for the laboratory analysis was carried out. For sample taking, compound samplings were planned, on 4 and 12 of December, 2003 (dry period), and on 22 and 27 of February 2004 (wet period), taking four water samples in a period of 7 hours (from 9:30 to 16:30), which were blended forming a single sample called compound sample. The volume of each sample (aliquot) was determined on the basis of the discharge in the moment of taking of water samples.

Parallel to the taking of compound samples, were took three samples a day were carried out to measure values of the biochemical oxygen demand (BOD) and two samples to analyze fecal coliformes, because these parameters cannot be evaluated in compound samples. The methods used in laboratory were those of incubation along 5 days and filtering membrane, respectively. The analyzed parameters are detailed on Table 1.

Table 1. Parameters for water quality evaluation

Group	Parameters	Effects
Cations	Sodium, Calcium, Magnesium, Potasium (SAR) $SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$ Cations in meq/l	Risk of salinisation and problems with change of soil physical characteristics
Toxicity	Chlorine	Toxic to sensitive crops
Nutrients	N-tot, ammonium, P-tot, P-PO4, SO42-	Advantage of nutrients to crop growth
Solids/Organic matter	BOD, COD, total and suspended solids	Level of treatment of wastewater, amount of organic compounds.
Microbiologic	Total and fecal coliformes	Health risks regarding coliformes
Various	HCO3, CO3	Affects growth of sensitive crops

The flow measurements were carried out with two purposes: to quantify the wastewater use in irrigation, and to calculate the nutrients load in the water. RBC flumes were used with capacities to measure: 4, 12 and 24 l/s.

Also, water samples from three wells for drinking water for household consumption were taken, with the purpose of finding possible influences of the wastewater use for irrigation over water from wells that are used as water source for household consumption.

The criteria for wells choice were that these be located downstream and as close as possible to wastewater use areas. Water samples from wells were taken in the well mouths in the water systems of Kanarancho, Chiquicollo and “Cuatro Esquinas” (Figure 2).

A detailed description of the total water samples taken appears on Table 2. All samples were analyzed in the “Centro de Aguas y Saneamiento Ambiental” Laboratory of the “Universidad Mayor de San Simon” (CASA-UMSS). The samples were composed in the same laboratory.

Table 2. Composition of total number of samples analyzed in laboratory

Sampling water	Sources monitored	Number of sampling	Total
Waste water	4	4	16
Drinking water (wells)	3	1	3
Total number of samples			19

In the three areas of wastewater use, field recognition to obtain a land use map was carried out, identifying the agricultural plots and the crops settled in each one of them. The data were processed with IDRISIW software (GIS software for mapping), calculating the agricultural areas and percentages of established crops. The data of agricultural areas were necessary to approach the annual load of the contained compounds in the wastewater such as nutrients.

4.2 Social component

The social component consisted on carrying out interviews to farmers and people in charge of water distribution for irrigation in the three areas. For each area, at least two farmers were interviewed, the criteria to choose interviewees was that the farmer would necessarily have to be a user of wastewater.

The interviews considered the following aspects: irrigation practices, organization, use of the irrigation infrastructure, perception about use and quality of wastewater, risks and benefits of the use of this resource, and differences and similarities of the situation of farmers and the irrigation practices.

Also, those in charge of the Environmental Department of the municipality and of the Central Hospital of Tiquipaya were interviewed to determine their knowledge, experience and opinions on wastewater use in the municipality.

5. RESULTS AND DISCUSSION

It is important to mention that due to the sensitive topic that waste water use can bring about; farmers sometimes were not likely to tell the truth about their irrigation practices with waste water. Among farmers' reason to use waste water was identified a lack of water rights in some conventional water sources, lack of physical access to irrigation water (location, Bruno Moqho case) which can inhibit the acquisition of irrigation water, and a lack of money to buy more irrigation turns.

5.1 Waste water availability and variation

Measurement of discharges gave a first impression of their daily variation and showed differences between the three studied zones. Figure 5, represents maximum, minimum and average discharges that were measured in the Kanarancho, Bruno Moqho and Chiquicollo.

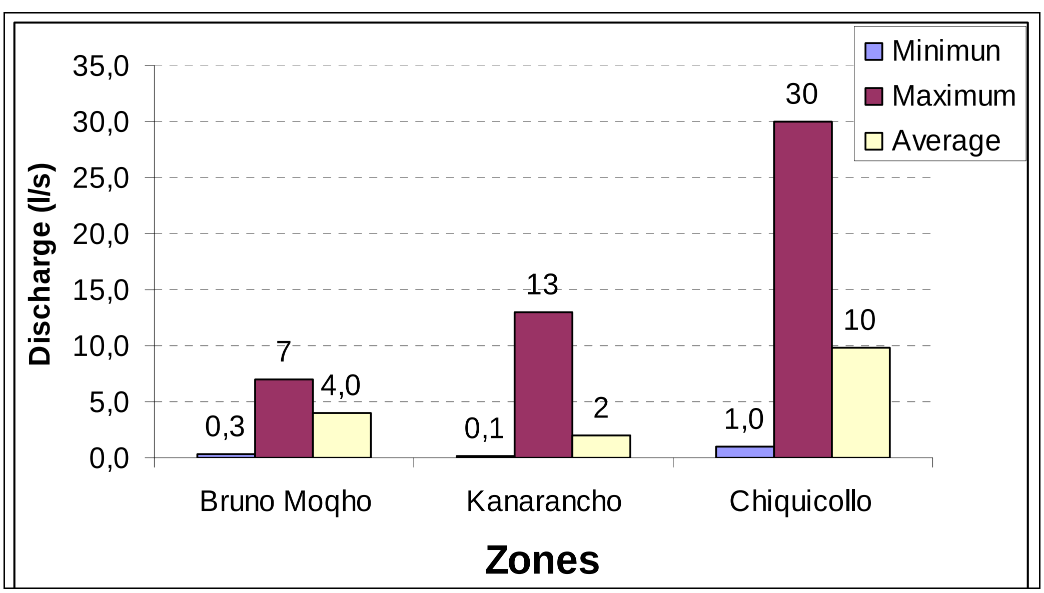

Figure 5. Measured waste water discharges in the three zones

The variation of the discharges in Bruno Moho was between 3 and 7 l/s, showing a sudden drop in discharge 0.3 l/s (November 10th, 2003, Figure 5). This drop was only at the measuring point (end of pipe), because in that afternoon the irrigation turn shifted to an upper stream irrigator (near the Imhoff Tank), consequently the measured discharge was only the run-off.

A difference in the discharge can be observed between dry (November and December) and wet (January) periods. This can be explained by the physical circumstances under which this waste water is being produced by the Tiquipaya town, because it has been observed a variation in the characteristics of the monitored waste water, and during the evaluation, rainfall water was not being discharged inside the sewer system and was not receiving a contribution from other sectors. Contribution of precipitation to the measured waste water volume can therefore be neglected. In Tiquipaya there are illegal house connexions to discharge rainfall water and them flow away a short time after the rain. This event has not been noted during the monitoring time.

In Kanarancho zone, the minimum measured value was 0.1 l/s and the maximum 13 l/s (Tuesday), but it is necessary to remark that the measured values lie between 0.25 and 1.5 l/s. Additional measurements were done on the 11th of November (not included) to check whether on Tuesdays extra discharge was regular because of weekly cleaning of the “chicha” factories. This was so, in the morning, discharges kept constant at around 13 l/s. On other Tuesdays, discharges were observed in the same range. No convincing difference can be observed between the dry and wet periods. This can be explained by the short distance between the “chicha” factories (source) and the field where it was irrigated with this waste water.

In Chiquicollo, water of the northern canal of the national irrigation system of the Angostura lagoon that conveys water to Tiquipaya can be classified as household waste water with some indirect dilution from earlier precipitation. Likewise, the results of water quality analysis show as untreated waste water. Measured values of discharge are variables in the rainy season, because this canal is used to evacuate the rainfall water. In the dry season, effluents of the drinking water treatment plant are conveyed (from Cala Cala) and some household sewer connexions.

For all zones it should be mentioned that waste water discharges are not sufficient to fulfil water crop needs.

5.2 Variation of water quality

Based on the results of the sampling analyzed in laboratory, all waters can be classified as raw or untreated waste water. Taking into account the indicators of salt contents like Sodium Adsorption Rate (SAR) and Electrical Conductivity of the water (EC_W), a classification according to the monogram of the USDA was made (1984). Table 3 shows the obtained results.

Table 3. Waste water classification according to SAR and EC

Zone	Class	Salinity and Sodium
Bruno Moqho, Kanarancho and Chiquicollo (northern canal)	C3S1	Highly saline that can affect the soil characteristics. There are no problems with sodium content
Chiquicollo (neighbourhoods "El Carmen" and "Cruce Taquiña")	C2S1	Quite saline water, could affect the soil characteristics. There are no problems with sodium content

In the three studied zones the waste water can be classified as saline with levels that can affect the soil characteristics. The sodium values found do not achieve a harmful level. From the interviews with waste water irrigators no problems were reported that are related with salinity on drainage. This can be explained by good the soil characteristics like the internal drainage and the relatively low ground water level.

Farmers´ perception on the quality of irrigation water is mostly based on water colour and odour. These indicate that the surface and subterranean waters have been still clean used for washing and drinking (household use). In the rivers except in the first discharge from the lagoons, it brings a lot of dirt (sediment). In the farmer's insight, good quality means clean (transparent) and without odour. Water from the Angostura lagoon is perceived as having a lot of sediment and bad smell, this is due to this water along the canal is mixed. When this canal conveys only waste water it has a very dark colour and smell. Nevertheless, some farmers see this wastewater as an important source of irrigation water, especially during dry season.

5.3 Nutrients load to the fields

It should be noted that values of nutrients do not say a much on themselves. To say something about relations with crop requirements and to do a balance of components, it is necessary to include irrigation practices (discharge, duration of irrigation turn) and the physical tendency course of the irrigation water before reaching the field (microbiological processes). Also information on the use of other water sources for irrigation and climatic data are required to compose a water balance and balance of compounds. It is interesting however, to illustrate variations in nutrients contents among the three studies zones. These values were determined with the interview data and calculations of the annual amount of waste water applied to the plots in each zone (Table 4).

Table 4. Annual waste water volume applied per hectare

Zone	Average discharge (l/s)	Average irrigation time (hr/ha)	Number of irrigations per year	Annual volume applied (m3/ha/year)
Bruno Moqho	4,6	12	12	2385
Kanarancho	1,44	24	12	1493
Chiquicollo	19,6	6	10	4234

Table 5 was made up with the laboratory data and it shows the average concentration of the main three nutrients for the crops. The average was calculated taking the results of the four samples.

Table 5. Average contents of available nutrients in the waste water

Zona	N (mg N/l)	P (mg P/l)	K (mg K/l)
Bruno Moqho	48,9	7,1	19,3
Kanarancho	7,9	2,6	37,7
Chiquicollo	18,9	3,2	9,4

Figure 6 shows the estimation of the amount of nutrients (Kg/ha/year) that were applied to the plots by the irrigation waste water in each zone. According to these data, Bruno Moqho shows the highest nutrient load on the field, this can be explained by the use of undiluted waste water and more frequent irrigation turns. Comparing with Chiquicollo, this zone has a large volume of waste water applied. It shows that the waste water of the Northern canal is more diluted, and this is corroborated by the field work observations. The agro-industrial waste water in Kanarancho presents low concentrations in nutrients when is compared with the other two zones.

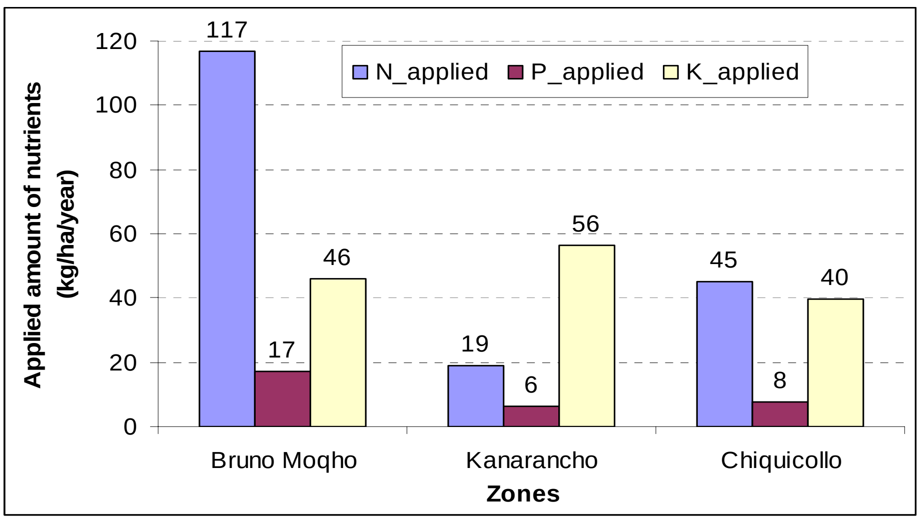

Figure 6. Comparison of annual nutrient loads to the plots. Nutrients are expressed in total N, P and K applied

Values of nutrient uptake by crops are very variable. The averages of removal by some crops are indicated on Table 6. Compared with applied amount of nutrient by irrigation waste water, the nutrient requirement for spinach was fulfilled. For the other crops (maize and alfalfa), they were met close to 50%.

Table 6. Nutrient removal or uptake values for selected agricultural crops

Crop	Yield ton/ha	N (kg N/ha)	P (kg P/ha)	K (kg K/ha)
Corn (stover)	13.3	123	13	179
Alfalfa	13.3	392	45	336
Ryegrass	11.1	241	49	224
Spinach	11.1	56	17	34

Source: Havlin et al (1999), quoted by Boom (2000)

It should be mentioned that the plots in the three zones receive an additional amount of nutrients from cow manure. This input of nutrients is not further investigated but it could be important to satisfy nutrients requirement of the crops. Nobody of the interviewed farmers has used a chemical fertilizer because it is expensive.

5.4 Health risks with coliform bacteria

The pathogen micro-organism concentrations in all sampled waste water are higher than standard norms prescribed for use (WHO, 1996), so treatment before use is advised. Figure 7 shows the levels of faecal coliforms in waste water at the four sample spots. The Illustrated data are means of the two samples that were analysed per day. Concentrations of faecal coliforms generally lie in the order of 106 to 107, unique of the untreated waste water. The first one (two) data correspond to dry season and the last one (two) to rainy season.

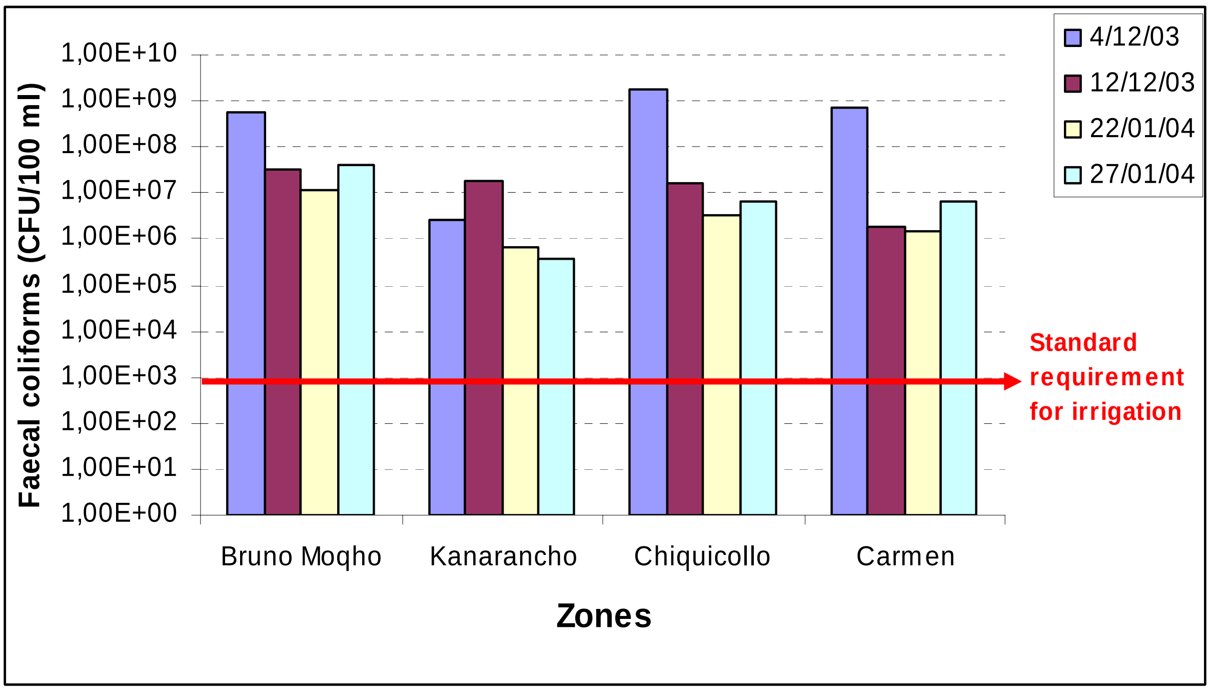

Figure 7. Concentration of faecal coliformes at the four waste water sources

Doing a relationship between the crops cultivated in Bruno Moqho (spinach or vegetables), there is a high health risk to the consumers of these vegetables, because farmers sell their crops without washing. Only a small part is for home consumption (self-consumption).

5.5 Level of pollution of drinking water wells

For drinking water purposes, the WHO norms are clear indicating that water should be free of both total and faecal coliforms. The concentrations of microbiological pollution in three wells are described on Table 7.

Table 7. Measured total and faecal coliform in drinking water samples

Zone/Well	Concentration of coliforms (CFU/100 ml)		
	Total	Fecal	WHO norm
Kanarancho	0	0	0
Bruno Moqho	18	7	0
Chiquicollo	62	46	0

From a microbiological point of view, the water of the well in Kanarancho is safe to drink. Water from the well in Bruno Moqho and Chiquicollo, however, is not safe to drink. Water that is being pumped from the sampled wells might be influenced by wastewater that has infiltrated into the ground and has polluted the ground water. A relationship between investigated wastewater sources and quality of well water samples is more probable because of the absence of other source that may pollute ground water in the area. Sample points are chosen between 50 and 200 meter downstream the plots where it is irrigated with wastewater.

6. GENERAL ANALYSIS

The analysis has the objective to identify opportunities to achieve the sustainable wastewater use for irrigation agriculture in Tiquipaya.

Facing diminish the availability in the conventional water sources for irrigation, the untreated wastewater is a reclaimed resource inside the agriculture production, especially in the dry season. Farmers concerned about the water scarcity do not demonstrate their dissatisfaction on the sequels relative of their own, nor of their families.

On the other hand, the results show that a temporary variability does not exist for quantity and quality offered by the identified wastewater sources. This would permit to carry out a planning for an appropriate use of this resource; for example, the surface and variety of crops to be implemented, and the contribution of nutrients. Also, it would take advantage of the practical knowledge acquired by the farmers about the sensibility of the crops to these wastewaters, implementing crops that are able to develop under these conditions, although farmers are not still able to relate them to health risks.

In Tiquipaya there is not a monitoring or regulation on the wastewater use in irrigation, having an informal characteristic that is accepted by the municipality. Presently, nobody takes up the responsibility of taking measures on the re-use of wastewater in agriculture or to offer a technical support for the smallest risks, although according to Law, the municipalities should be the responsible ones.

In Tiquipaya, it is necessary to build a wastewater treatment plant, although it is almost impossible to think about a centralized system, it is necessary to think in decentralized systems, where the different treatment alternatives offered by the new treatment technologies can be used.

Until now, the production of vegetables in Bruno Moqho, represents a health risk for farmers, shopkeepers and consumers of these agricultural products. The authorities and institutions cognizant of this activity should train to the farmers about the health risks that represent, promoting the use of safe clothes during the irrigation and harvests tasks. Due to the fecal coliformes concentration in the water, even in the rainy season, it exceeds the standard norm, is necessary to build an infrastructure to wash and disinfect these products before sale. Health risks mitigation for the consumers using appropriate techniques to wash the products and the change of crops in Bruno Moqho can be an appropriate measure that has to be supported by the municipality and non government organizations, because health of the consumers can not put into risk.

Regarding the farmer´s insight of the wastewater use in Tiquipaya, they do not share the same points of view. Some farmers are negative and give the impression of passivity toward the development of the irrigation with wastewater and their organization. Others argue that they do not know what could happen and indicate that they have put their fate in the hands of God. Their opinion also depends on the fact that their sons will devote to agriculture.

Farmers know that it is a practice with a lot of risk. They are cognizant that wastewater is a resource available on the medium term. It will be available because a demand takes force about the necessity of a basic sanitation infrastructure. In the future if the resource would be available and farmers would use it, they would have problems with the urban neighbourhoods (non farmers), that is increasing in number as the passes by. In this context where the urbanization has a quickly and chaotic growth, the availability of wastewater is increasing, but, it causes inconveniences to the neighbourhoods located close to the re-use areas.

7. CONCLUSIONS AND RECOMENDATIONS

The unregulated use of wastewater for irrigation in Tiquipaya is a result of different interrelated and seemingly autonomous processes as water scarcity, poverty, urbanization and weak institutional attention and action. All with clear differences as to water source scale of use, organization, administration, crop selection and water quality. But, with the water shortage as the common and decisive factor that determines their use, as a sure and important water source in the dry season, for it could be the only alternative water available for a significant group of farmers. Although this represents a health risk to producers and consumers, also pollution risks for the underground aquifers that is source of water supply for household use.

The nutrients loads (nitrogen, phosphorus and potassium) applied to the plots with wastewater is the main potential of this resource. That is very well-known and exploited by the farmers. They have been saved up money by not buying chemical fertilizers. Comparing the three areas, there is variability in these nutrients contents, the biggest concentration presenting the household wastewater without dilution.

Farmers in Tiquipaya know the advantages and disadvantages when they use wastewater for irrigation, but they do not proceed according to this knowledge; for example, they do not avoid contact with wastewater by wearing safe clothes. This is very well acknowledged by them, but it is not generally applied. Likewise, farmers do not experiment changes in their agricultural practices related to water quality, in spite of existing a necessity for adapting their irrigation practices to use this resource.

Tiquipaya is and it will be for long an agricultural area; therefore the municipal authority is responsible for identifying and monitoring the areas where farmers are using wastewater in the agricultural production. At least, until the wastewater treatment plants or sewer system are built. Therefore, the untreated wastewater will continue being used for crop irrigation, while the water availability in the conventional water sources will be insecure. Moreover, the wastewater availability has a progressive increase, making it more attractive for its use in agriculture.

Consequently, a more sustainable wastewater use for irrigation would be through the blend with clean waters, by the adaptation of the physical irrigation infrastructure where ever this can be possible

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