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Wastewater Re-use in Lima Metropolitana: A Concept for an Integrated and Sustainable Water and Wastewater Management

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AAA	Regional Water Authority
ALA	Local Water Administration
ANA	National Water Authority
BOD	Biochemical Oxygen Demand
CENCA	Urban Development Institute
COD	Chemical Oxygen Demand
DIGESA	General Directorate of Environmental of Health
ECA	Environmental Quality Standards for Water
Ecosan	Ecological Sanitation
Edegel	Energy Company
EPS	Water Supply and Sanitation Service Company
FC	Faecal Coliforms
GTZ	German Society for Technical Cooperation
IDRC	International Development Research Centre of Canada
INEI	National Institute for Statistics
IPES	Institution for Sustainable Development in Latin America and the Caribbean
IWRM	Integrated Water Resource Management
LMP	Maximum Values for Effluents of Wastewater Treatment Plants
MINSA	Ministry for Health
MINAM	Ministry of Environment
MVCS	Ministry for Housing, Construction and Sanitation
NGO	Non Governmental Organisation
PAHO	Pan American Health Organisation
PMO	Master Plan
SEDAPAL	Water Utility Company
SUNASS	Regulatory Entity for Water Suppliers
TC	Total Coliforms
TSS	Total Suspended Solids
UNI	National University of Engineering
UNITRAR	Wastewater Treatment Plant of the UNI
WWTP	Wastewater Treatment Plant

ABSTRACT

Wastewaters generated in urban areas represent a non-conventional water resource, which has been developed in the last decades. The fundamental concept hereby is the integration of wastewater reclamation and reuse in water utility management as alternative resource. The purpose of this thesis is to elaborate how Lima Metropolitana an urban growth centre suffering from water scarcity, meets the requirements for wastewater reuse as part of an integrated and sustainable water and wastewater management. This paper gives an overview of existing practices, its potentials, and constraints characterising the current situation of Lima Metropolitana.

ABSTRACT

Städtische Abwässer stellen gerade in Großstädten mit sehr hoher Bevölkerungsdichte, eine nicht-konventionelle Wasserressource dar. Diese hat in den letzten Jahrzehnten aufgrund von steigendem Wasserdefizit immer mehr an Bedeutung gewonnen. Die grundlegende Idee dieser Abschlussarbeit basiert auf der Integration von Abwasser-Rückgewinnung und Wiederverwendung als Teil eines integrierten und nachhaltigen Ressourcen Managements. Das Ziel dieser Arbeit besteht in der Ausarbeitung und Evaluierung wie Lima Metropolitana -eine schnell wachsende Großstadt in mitten einer Wüstenregion die unter Wasserknappheit leidet-, die Anforderungen an Wiederverwendung von Abwasser als Teil eines integrierten und nachhaltigen Wasser- und Abwassermanagements erfüllt. Diese Thesis gibt einen Überblick über die bestehenden Praktiken, ihre Potenziale und Einschränkungen, welche die derzeitige Situation in Lima, Peru charakterisieren.

RESUMEN

Las aguas residuales generadas en zonas urbanas representan un recurso de agua no convencional, que se ha desarrollado en las últimas décadas. La idea fundamental del concepto sostenible de reutilización es la integración de un sistema de recuperación de aguas residuales y su reuso en la gestión del agua como recurso alternativo. El objetivo de esta tesis es explicar cómo Lima Metropolitana, una megacuidad con un alto crecimiento urbano, ubicada en una zona desiertica, cumple con los requisitos para la reutilización de aguas residuales como parte de una gestión integrada y sostenible. Este trabajo ofrece una visión general de las prácticas existentes, sus potencialidades y limitaciones, las cuales caracterizan la situación actual de Lima Metropolitana.

1 Introduction

Nowadays, the original direct human requirements of the water resources are far exceeded. Increasing population, improved sanitation, better living standards, urbanisation, economic development and poor resource management are only some of the many reasons why the consumption of drinking water is continuously increasing in numbers of consumer as well as in individual demand (Asano, T. (2002)). The importance of water as part of human livelihood and welfare of every person and community changed over the last decades resulting that now the natural harmony is imbalanced. However, natural water resources are not unlimited (Seifert, R. (2009)).

During the current decade until 2008, there had been registered fifty-five water conflicts world wide, among them fifty cases under circumstances of violence or threat of the use of force. The reasons for them had been mostly disputes of authorities, shortages in water supply or denied access to water resources in the context of water scarcity (Gleick, P. H. (2008)). On the example of Peru, a developing country with an arid coastal region can be described what it means to be daily confronted with water scarcity. Ever since the dry years of 2004, and again in 2005 when several regions of Peru were confronted with serious problems in water supply, the situation of water scarcity is well known (Borghetto E.E. (2006)). Until today, the solution to the persistent conflict has been sought via the short-term policies of rationalising water supply and extending the reservoir system. However, the increasing problematic hydrological situation gives cause for concern and shows, in an unambiguous manner, the need for an appropriate water resource management.

To tackle this problem, several sustainable and integrated methods can be applied. Water reclamation and reuse represents a pervasive and diverse one (Unesco (2006)). The amount of water in the world is constant and referring to the water cycle, it has always been naturally recycled and reused. Nevertheless, this specific approach refers to an acceleration of the natural process by using appropriate technology.

In Latin America, less than 6% of the recollected residual wastewaters receive a treatment before they are discharged to surface water and natural drains. Around two and a half million hectares of cultivated fields are irrigated with contaminated water because of water deficit (WHO (2005)). In the case of Lima Metropolitana – an urban agglomeration of more than 9 million inhabitants constructed in the middle of a desert without any natural green spaces – it is particularly challenging to maintain parks and green areas. Water has become a highly expensive input due to the fact that absolutely all environmental areas had been replanted and depended on artificial irrigation. In the majority of the public green spaces drinking water is used to irrigate, but during dry seasons untreated wastewater is additionally used to cover the demand (Roman et al. (2007)).

In the 21st century the technology of wastewater treatments designed for multiple use is available, and its investment and maintenance costs are reduced to a moderate level (Asano, T. (2001)). Although it is preferably applied in industrial applications and small-scale projects like golf clubs and sport areas, which can be technical easily managed and controlled, wastewater reuse represents a diverse option for national water strategies (UNEP (1997)). Experiences world wide have been gained documenting benefits by integrating wastewater recycling in environmental and urban infrastructure planning (Duran A. et al. (2003)). Examples range from Israel, where 90% wastewater reuse is planed till 2020, to the water-short Guanajato river basin in Mexico, where the whole crop production is irrigated with reclaimed water. These experiences have shown the opportunities and potentials for arid regions under similar climate conditions (Friedler, E. (2001); Scott C.A. et al. (2000)). Now, referred to the national policy *EL PERU AVANZA* (Peru moves forward), it is time for Lima to incorporate wastewater reuse as part of an integrated and sustainable water and wastewater management exemplary for Peru.

2 Scope Definition

2.1 Objective

The aim of this master-thesis is to elaborate the potentials of wastewater reuse as a component of the overall strategy to combat the problematic hydrological situation in the particular case of Lima Metropolitana. The emphasis is set to analyse what requirements must be met for such a strategy to work, and what kind of significance the strategy has for the specific case of Lima. The central question is how Lima/Peru fulfils the criteria for an integrated and sustainable water and wastewater management and which points have to be improved for wastewater reuse to represent a reliable option.

2.2 Approach

This master-thesis is written in collaboration with the investigation project: *"Sustainable Water and Wastewater Management in Urban Growth Centres. Coping with Climate Change - Concepts for Lima Metropolitana (LiWa), Peru"*, provided by the German Federal Ministry of Education and Research. In alignment with the project LiWa is orientated this work as a part of the problem solving approach for the water deficit situation in Lima Metropolitana.

The thesis is subdivided in five bottom-up steps, illustrated in Figure 1.

The first section consists of scope definition (Chapter 1), introduction and general background information (Chapter 2&3) of the study context focusing on the problematical hydrological situation of Lima Metropolitana.

In the second step (Chapter 4) will be introduce the fundamentals of water reclamation and reuse in the context of an integrated and sustainable water and wastewater management model.

How Lima/Peru meets under the current infrastructural, technical, legal, social and institutional conditions these requirements will be analysed in the following section (Chapter 5).

In collaboration with the investigation team of the wastewater treatment plant UNITRAR from the *Universidad Nacional de Ingenieria, Lima* will be assessed in the fourth step (Chapter 6) the feasibility on a concrete example for water reclamation and reuse.

The last section (Chapter 7, 8&9) summarizes the outcomes received in section three and four to discuss changes and adoptions that would have to be made. The actual potentials and weaknesses of reusing treated wastewater for irrigation, as part of future governmental policies will be evaluated.

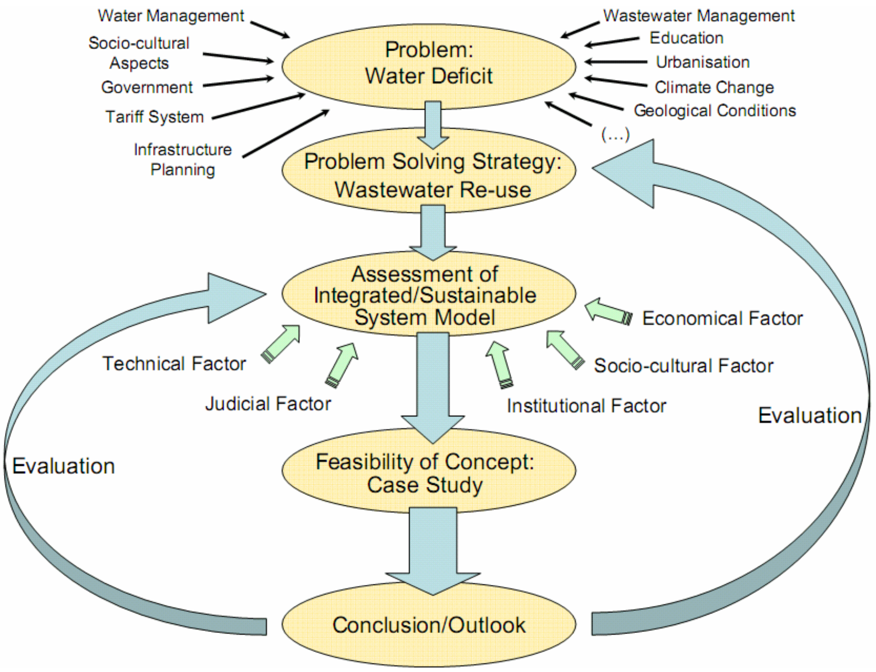

Figure 1: Operating Sequence

The investigation was exclusively realized in the districts of Lima and Callao, Peru during March and July 2010. Most of the information was accessed by local institutions and non governmental organizations. It was taken from literature, formal and informal reports as well as from personal interviews and conferences[1]. This information should be considered as the best available data in that time period.

[1] Reliable information based on scientific references to make exact statements is mostly unknown or has never been documented. Data of fast changing plans in context of the Peruvian development process could only be accessed by conferences and interviews.

3 Lima, Peru

3.1 General Information about Lima and Peru

The Republic of Peru is situated in the central west part of Latin America, located between the 0°01'48'' and 18°21'03'' parallels southern latitude and the 68°39'27'' and 87°19'05'' meridians western length (MINAM et al. (2009)). With its surface area of 1,285,215.60 km² Peru is -after Brazil and Argentina - the third biggest country on the South American continent (IMP (2008)).

Political Situation

The Republic of Peru has a presidential, unitary and decentralized governmental system, politically divided in 24 departments and 26 Regional Governments (considering the special position of Lima Metropolitana and Callao). The departments are further split up in 192 provinces divided in 1,800 districts. The department of Lima is formed by 11 provinces. The Conglomerate Lima Metropolitana and the constitutional province of Callao belong as two provinces to the department of Lima representing 49 districts (43+6). Each district has a councillor and a community council *(Consejo Municipal)*, elected democratically by the population; for the first time in 2002 (PCM (2009)).

All three branches of the State Government, the Executive, the Legislative and the Supreme Court are settled in Lima. Since two years, a regionalization process has been stimulated in order to transfer decision-making, governmental representation and control to autonomous and regional entities, and with this to end with Lima's centralism (Moscoso C., J. and Alfaro, T. (2008); MINAM et al. (2009)). As direct indicators for the important role of Lima Metropolitana can be taken the production of more than 50% of the GDP, the concentration of 70% of all industries, the around 80% of private investments made and the concentration of one third of the population in these 49 districts (Muller, S.A. (2009)). This negative phenomenon leads to an economical development in the Capital of Peru whilst the rest of the country remains a less developed region.

Urbanisation

In Peru, 75.9% of the population is currently living in urban regions and more than one third of the Peruvians are settled in Lima Metropolitana, including Callao (INEI (2010a)). The main reasons for the migration especially from isolated mountain regions were search for better living conditions, access to education and health services and the broader possibility to find a job (GEA (2005)). According to the National Institute for Statistics, (INEI) the population will reach in the end of 2010 up to 29,461,933 people, which is more than four times more than in 1940 (GEA (2005); INEI (2010a)).

Population Census Urban and Rural (1940 – 2007) & (2010*)

Population	1940	%	1972	%	1993	%	2007	%	2010*	%
Urban	2,197,133	35.4	8,058,495	59.5	15,458,599	70.1	20,810,288	75.9	22,361,608	75.9
Lima Met.	645,172	10.4	3,302,523	24.4	6,321,173	28.7	8,472,935	30.9	9,018,018	34.1
Rural	4,010,834	64.6	5,479,713	40.5	6,589,757	29.9	6,601,869	24.1	7,100,325	24.1
Total	6,207,967	100	13,538,208	100	22,048,356	100	27,412,157	100	29,461,933	100

*) Population estimated, INEI, Feb 2010

Table 1: Population Distribution 1940-2010 (Source: INEI (2010a); INEI (2010b))

Lima Metropolitana is one of the most rapid urban growth centres world wide (Schütze, M. et al. (2007)). Estimated by INEI, the annual growth rate (2009-2010) is 1.42% in Lima and 1.56% in Callao; decreased compared to previous years (1940-2007: 3.92%) but still above the national rate of 1.13% (INEI (2010b)). In the end of 2010 Lima Metropolitana (8.076.750 inhabitants) and Callao (941.268 inhabitants) will have more than 9 million inhabitants (INEI (2010a)). The territory of the provinces Lima Metropolitana and Callao (in the following named as Lima Metropolitana) is 2,819.26km² of which 32% are classified as suitable for urban development and agricultural applications (INEI (2010c); IMP (2008)). The rest of the area is considered as arid ground, occupied by hills with steep slopes thus being difficult to access (IMP (2008)).

The heterogenic city structure shows a European style city centre with green spaces and shopping malls, surrounded by a large dusty and dirty belt of informal settlements. The regional and local governments are unable to manage the high migration pressure and recently emerged settlements are not considered in infrastructure planning (Acevedo T., A. (2010)). At this time 43% of Lima's inhabitants are living in illegal or semi-illegal human settlements (Schütze, M. et al. (2007)). Until today, more than 14 districts are without geographic identification or limitations, and only partly considered in urban planning. Insufficient public utility installations like sanitation systems medical-hygienic services, water supply and sewerage systems are characteristic to them (Rodriguez C., I. (2010)).

Geology and Climate

The territory of the country shows various ecosystems with great differences in demography, infrastructure, land use and available resources which are defined in three main regions: The Coast *(costa)*, the Andean Mountains *(sierra)* and the Jungle *(selva)* in the Amazons Region (MINAM et al. (2009)).

These three different regions of Peru show further significant heterogeneity in climate, topography and vegetation. The difference in altitude reaches from sea level up to the highest mountain with 6768m.a.s.l. The annual precipitation in average is 250mm although most of them are received in summer during December and February in the south-eastern parts during heavy rainfalls in the mountains; e.g. 855mm in Cusco (MINAM et al. (2009)). The climate varies from sub topical Jungle in the Amazonian area over the cool highlands of the Andean Glaciers to the desertic Coast. The districts of Lima and Callao are with an annual average precipitation of 9mm after Cairo (15 million inhabitants, precipitation of 25mm/year) the second biggest city situated in a desert under conditions of extreme hydrological stress (Leon Suematsu, G. (2009)). The average temperature at the coastal region is 18°C with maximal values of 30°C in summer and minimum values of 12°C in winter (IMP (2008)).

Figure 2: Climate Map, Peru (Source: INRENA (2001))

Hydrological Resources

In Peru, mainly superficial waters are considered as its hydrological resources; groundwater is not exactly specified and becomes of importance only in the Pacific side. For the future, new potable water and wastewater reuse for agricultural purposes are being investigated at the moment (Callery, A. G. (2009)). A pilot plant of desalinisation including reverse osmosis is planed for 2015 in the south of Lima (Leon Suematsu, G. (2009)).

Lima's main fresh water supply comes from the downstream of the river Rimac. Its basin area with 3,398km² reaches 135km to the east and rises up to 5,800m.a.s.l. (MINAM et al. (2009)). Over the last years there was built a widespread and complex network of artificial lakes, reservoirs and pipeline connections to capture not only the superficial waters of the pacific side, but also to transfer waters of the Atlantic part of the Andean mountain (Leon Suematsu, G. (2009)). In the context of this extension trans-Andean tunnels are built to divert additional water into the basin of the river Rimac. The actual capacity of this system is 282 million m³ and it serves as a reservoir supply into the river Rimac during dry winter months (Muller, S.A. (2009)).

The water supply and sanitation service company Sedapal - *Servicio de Agua Portable y Alcantarillado de Lima* as responsible regional entire is regulating this water resource. Nevertheless a much bigger reservoir system for energy production is managed by the energy utility company EDGEL. The continuous discharge even during rain seasons in summer creates a permanent conflict with Sedapal. To satisfy the increasing drinking water demand for Lima also in the future, new mega projects have been planned. Lima has an expected deficit of 13.40m³/s in 2040 according to the current conditions (Leon Suematsu, G. (2009)). Two examples are *Proyecto Huachipa*, a water purification plant designed for 10m³/s to supply 2.400.000 inhabitants in the Northern region of Lima (*Zona Norte*) and *Laguna de Huascacoacha* (*Marca IV*) an extension of the capture system with an additional capacity of 78 million m³ (Leon Suematsu, G. (2009)).

Regarding the fresh water quality brought by the three rivers Rimac, Chillon and during summer Lurin, it has to be mentioned that the water is classified as highly contaminated (Castañeda L., L. (2005)). The main reasons for the contamination are several mining industries located in the river basins. These mines are contaminating detectable with heavy metals, such as arsenic, lead, cadmium, mercuric, manganese and cyanide. Moreover, untreated industrial and domestic wastewaters enter along the inflow to the Rimac (Muller, S.A. (2009)). Furthermore, these mining-regions are isolated and difficult to reach; hence mine operators possess an autonomous status and are not regimented into the governmental control system (Budds, J. (2010)).

Water Supply Service

The company Sedapal has the exclusive authority in Lima Metropolitana covering 84% of the population (Sunass (2010); Appendix 2). The daily service is provided in average by 21h/day and accounted by about 70% water meters; the rest is charged by average taken of the quarter.

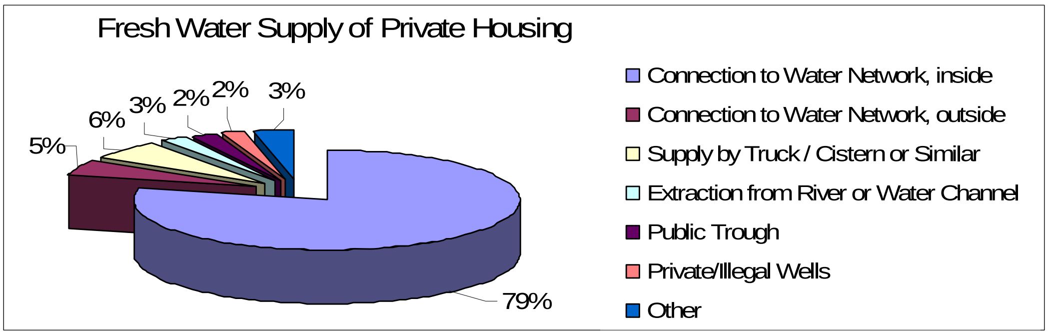

Figure 3: Fresh Water Supply (Source: INEI (2008a))

Sedapal purified in 2009 a volume of 21.12m³/s for drinking water usage; 17.86m³/s treated in the two plants Atarjea (max. capacity 18m³/s discharged from River Rimac) and Chillon (max. capacity 2m³/s discharged from River Chillon) supported by 3.44m³/s from 158 working groundwater wells. Additional 293 wells are in resting condition in order not to over pump the aquifers (Sedapal (2010)). According to INEI approximately 15% of the inhabitants get their supply by alternative ways including around 1500 illegal groundwater wells impeding exact statements regarding requested water demand. These illegal wells are not under any quality supervision (INEI (2008a); Muller, S. (2009)).

3.2 Controversial Water Situation in Lima Metropolitana

The superficial fresh water volume of Peru is around 5% of the world wide existing, whereas the country counts with only 0.4% of the world population (Schütze, M. et al. (2007)). Furthermore, the longest and most watery river, the Amazon, as well as the highest situated navigable sweet water lake, Titicaca, are on Peruvian territory. Considering these facts it sounds quiet strange that Peru is the only South American State listed under the thirteen poorest countries of the world regarding water supply, suffering local water scarcity and nationwide water stress (Valee, D. et al. (2009); Boghetto E., E. (2006)).

Water Stress

Talking about a deficit is always something relative. According to the UNESCO is Peru since 2005 exposed the permanent situation of water stress (Valee, D. et al. (2009); IMP (2008)). That means that the availability of fresh water nationwide is less than 1700m³/year/habitant (Arbenz, P. (2005)). In particular, this situation occurs during hot and dry periods, when the water demand is bigger than the offer available at this time. The term is often used in relation with desert regions, poor developing countries and areas where misuse of drinking water as lack of technology or education is common a practice (Borghetto, E. E. (2006)). All these facts combined can be studied in the example of Lima/Peru indicated by dry rivers, eutrophication, organic matter pollution and withered plants getting worse year by year (Seifert, R. (2009)).

Water Scarcity

Water scarcity is a more alarming situation announcing that annually less than 1000m³ fresh water volume is available per inhabitant (Arbenz, P. (2005)). Considering Lima as part of the Pacific region, there can be observed the following controversial phenomenon regarding Peru. The great majority with 97.7% of the national water resources are in the less populated Atlantic region (see Figure 4). In the Coast, the Pacific drainage area is only 1.8% of the fresh water resources available meeting 70% of the population settled there (MINAM et al. (2009)).

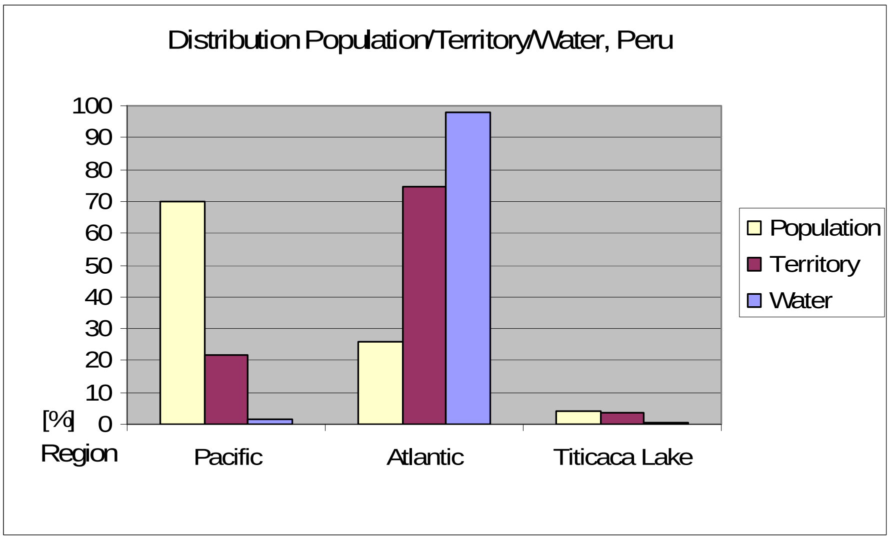

Figure 4: Distribution Population/Territory/Water, Peru (MINAM et al. 2009)

In the first instance geological and climate factors may be responsible for this discontinuity and lack of supply and distribution. But on a closer look it can be observed that it is not only due to natural reasons, but more so is it intensively influenced by the Government and society; by the consumers themselves. Poor resource management and infrastructure planning in addition to a lack of awareness amongst the population concerning drinking water utilisation create the situation of local water scarcity in which Lima is situated now. Calculations considering global climate change, melting of glaciers and socio-cultural tendencies forecast an extension of the local problem to a national-wide water scarcity till 2025 (Valee, D. et al.2009)).

Deficit

Sedapal, Lima's water company is calculating at this moment that the demand exceeds with 6.45m³/s the existing offer of 21.12m³/s (see Table 3, p. 29) (Leon Suematsu, G. (2009)). Especially during winter periods since the year 2004 concentrated problems to satisfy Lima's residents demand appear. Several circumstances are responsible for this deficit. According to Sunass, the national supervising and regulating entity in the water and sanitation sector is one of the biggest problems: the 43% loss of potable water in conductions (Sunass (2009)). Sedapal ratified for 2009 around 38% of "not paid water" (Sedapal (2010)). The daily use per person is calculated with 250l, which is alarmingly high bearing in mind the desert situation of Lima (Seifert, R. (2009)). Subtracting the around 40% of losses in conduction the consumption is still 150l/p/d more than the 130l/p/d compared to Germany (BMU (2006)). Further reasons are seen in the low water prices and the geographic conditions; dusty air calls for daily cleaning of sidewalks, car washing and irrigation of even the public green areas in front of the houses with drinking water. Even in less developed districts, where the supply by truck costs 3-5 times more it is quite common to retain these extravagantly habits (Acevedo T., A. (2010)).

4 Wastewater as Alternative Water Resource

4.1 Background and Justification

Generally water that once has been used in households or for industrial processes is considered as waste and mostly discharged, either treated or untreated into the natural water cycle. After a process of self-purification, especially in the larger river systems the water can be reused indirectly several times before reaching the sea (UNEP (1997)). Lima Metropolitana with its collector system followed by subterranean sea outfalls into the Pacific, which makes it the last link in the water-chain.

Wastewater

The appearance of wastewater can have many forms. In urban areas it might have a domestic or industrial origin, it could be treated, partially treated or even raw. Depending on its characteristics it can be mixed with fresh water sources to dilute or otherwise to contaminate them (Duran, A. et al. (2003)). Especially for mega cities the monitoring of these huge wastewater flows to a controlled disposal is highly challenging concerning technical and economical feasibility (Asano, T. (2002)). Nevertheless in most of the development countries, where wastewater is still a safety risk for human and environmental health, international guidelines are not being applied (WHO (2006)).

Wastewater reclamation and reuse

Water recycling is predominately considered to enclosed water cycles for multiple use in industry (Asano, T. (2002)). To distinguish from industrial wastewater recycling and the common level of wastewater treatment dedicated to natural water bodies, the terms wastewater and reuse had been defined (see Figure 5). According to Takashi Asano is *"Wastewater reclamation (…) the treatment or processing of wastewater to make it reusable, and water reuse (…) the use of treated wastewater for beneficial purposes such as agricultural irrigation"* (Asano, T. (2001), p.3).

Depending on the needs and technology can be continued the process to reach highly purified water like the New-Water in Singapore, or even for potable water application like in the City of Winhoek, Namibia (Muller, S.A. (2009); Asano, T. (2001)).

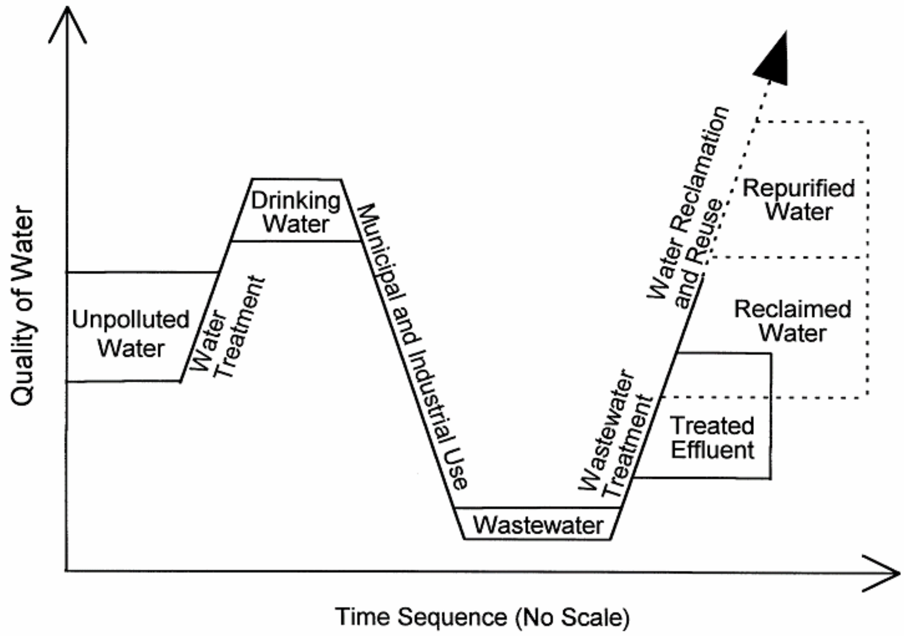

Figure 5: Water quality changes during municipal uses of water in a time sequence (Source: Asano T. (2001), p.8)

Many countries have integrated water reclamation and reuse for process water such as for industrial cooling, sanitary flushing and irrigation. The treated effluent in some extend with better quality than natural water streams is considered in water resource management as alternative water resource additionally to the offer of natural freshwater (UNEP, (1997)). The second fundamental function is the reduction in terms of contaminating receiving water bodies. Instead of the polluting effluent is brought back via irrigation reclaimed nutrient-rich water into the natural environment (Asano, T. (2001)). Especially in desert areas millions of dollars are spent in water and fertilisers to revitalize the ground for agriculture and reforestation (Friedler, E. (2001)). The controlled use of treated wastewater in these cases can substitute the dependency on artificial nitrite and phosphate (Scott et al. 2000)).

Categories

Water reclamation and reuse can be applied for several activities. Generally the applications are divided into the following categories depending on the treatment process and water quality of the effluents (Asano, T. (2001)):

- Agricultural irrigation
- Landscape irrigation
- Industrial activities
- Groundwater recharge
- Recreational and environmental use
- Non-potable urban use
- Potable Reuse

The first five represent suitable applications for Lima Metropolitana. Especially the demand for irrigation activities in the urban area corresponds to a large volume of potable water where high potential for reuse exists (Seifert, R. (2009)).

Direct and indirect Water Reuse

The reuse in the Latin American case means in the great majority indirect reuse for irrigation, where the treated wastewater is discharged back to the natural environment and brought through a downstream - diluted - to the user (Duran A. et al. (2003); Asano, T. (2002)). In the suburban area of Lima it is commonly practised that consumers make their own connections to the open water channels carrying the effluents of the WWTPs to their receptive areas, lagoons, rivers or sea. Direct water reuse requires more of certain infrastructure conditions. It is favourable for central concepts like golf areas or big city parks via permanently installed conductions (Asano, T. (2002)). These applications can be easier managed and controlled; competence and responsibility are clearly defined and abuse can easily be detected.

Formal and informal Use

The formal use of reclaimed water is based on a legal agreement between the user and the corresponding management of the WWTP defining to delivering volume, time periods and quality (Asano, T. (2002)). In general the majority of consumer such as irrigation organisations, industries and/or local governments prefers the informal use, which is not supported by any agreement. This allows more scope of action including fewer restrictions (Scott et al. 2000)).

4.2 Conceptualization of the Integrated and Sustainable Wastewater Management Model

Definitions

The system model is based on the two principals of “integrated water resource management - IWRM” and “sustainable development”. One of most often published definition for IWRM is formulated by Global Water Partnership as:

> *“Integrated Water Resource Management is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems”* (TAC (2000), p. 22).

Sustainability is not a precisely defined term and shows diverse meanings according to the background in which it is used. In the context of this thesis sustainable development is understood according to the definition formulated by the World Commission on Environment and Development in 1987:

> *“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (UN (1987) Part 1, Ch. 2).*

Criteria for a wastewater reuse concept

The criteria of the concept have been developed according to the identification of potential risks in the wastewater reuse concept. Referring to the guidelines developed by the International Development Research Centre of Canada (IDRC) and the Pan American Health Organisation (PAHO/WHO) integrated systems of wastewater treatment and reuse are defined by technical, environmental, social and economical aspects (PAHO/CEPIS (2002)). To adopt these for the analysis of the specific case of Lima Metropolitana are environmental and social aspects divided more in detail to legal framework, institutional aspects and social acceptance.

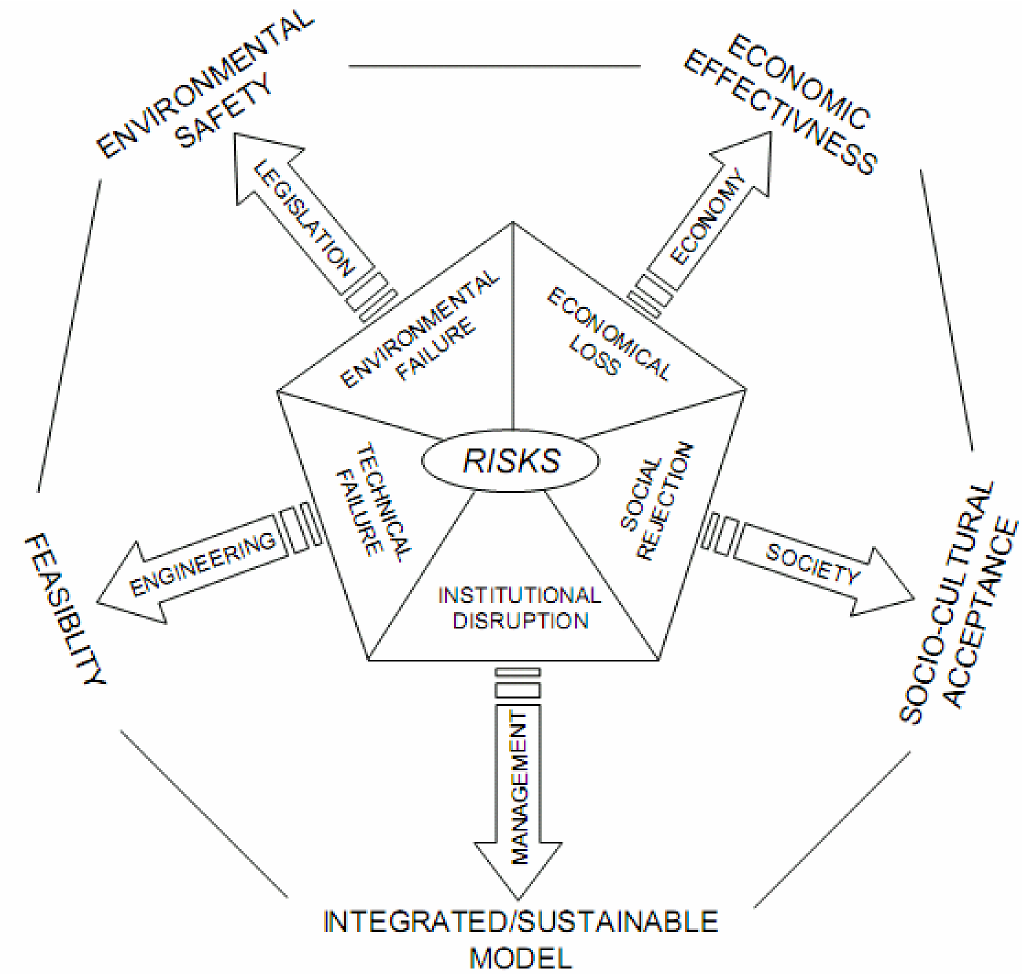

Figure 6: Criteria (adopted from Ganoulis, J. (2003) p.12)

The main risks of this approach are directed in five dimensions as shown in Figure 6. In order to minimize them the impacts of the principal factors on the concept – engineering, management, society, economy and legislation – have to be assessed (Ganoulis, J. (2003)). The impact of the potential risk factors, displayed in a circle surrounding the model represent the five criteria according to them Lima/Peru are analysed and further be evaluated the potentials of the concept.

5 Wastewater Re-Use in Lima Metropolitana

The first experiences regarding the use of wastewater for irrigation in agriculture activities in Lima where reported in the sixties. It shows how irrigation organisations recollected and treated residual wastewater in stabilisation lagoons and used it to irrigate their corps (Moscoso C, J. (1993)). This situation did not change; in periods of scarcity the main source of water for agriculture and urban green spaces irrigation is still the same.

5.1 Technical and Infrastructural Conditions

The location of the study area in the context of its infrastructural environment and its technical conditions define the potentials of reuse activities. The water source, its quality, the sewerage system and the treatment processes gives the information of the available volume. Furthermore for the water balance the realistic demand of existing areas likely to be irrigated has to be evaluated. Since Lima is a rapidly changing mega-city further possible lands and applications areas have to be considered to calculate up to which volume/percentage wastewater reuse can be implemented (PAHO/CEPIS (2002)).

5.1.1 Sewerage System

The conduction to the sewerage system is provided to 82.3% by Sedapal and 1.1% by local governments (see Appendix 3). According to INEI 83.4% of the private households are connected to the public sewerage system while the rest of the population is disposing their wastewater in alternative forms, as shown in Figure 7 (INEI (2008b)). Sedapal estimates the whole generated wastewater volume in Lima Metropolitana to be 22.05m³/s for 2010 (Leon Suematsu, G. (2009)).

Industrial wastewater has been discharged to the sewerage system by 10,187 registered companies. 5,551 of them are officially under the control of Sedapal. The result of 1,557 inspections and 2,481 monthly controls in 2009 was that 36% were able to fulfil the standards (see Appendix 5) set by the legislation for industrial wastewater disposal written in the *Decreto Supremo No. 003-2002-Produce* (Seifert, R. (2009)). According to Ruben Palacio in 43% of the industries officially controlled by Sedapal it was possible to take examples, whereas in the rest of the cases the access to the area was denied or modified examples were handed in (Palacio, R. (2010)).

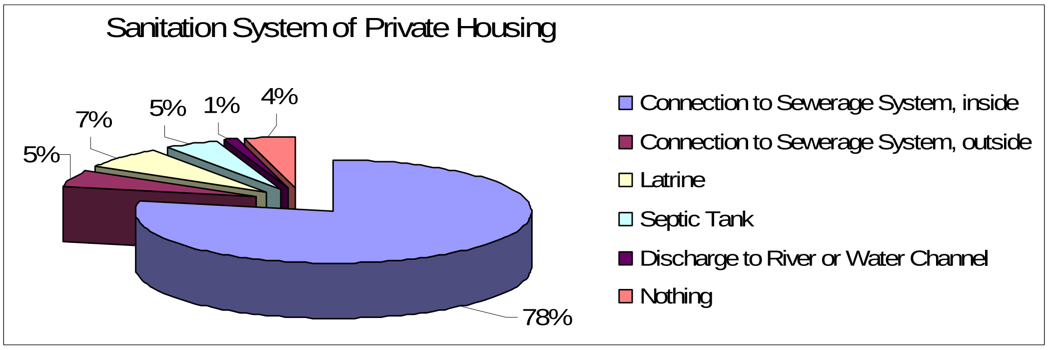

Figure 7: Sanitation Service (Source: INEI (2008b))

Sedapal

In the last twenty years the recollection system was notably increased; in 1990 there were only 6130km of installed pipelines and in 2009 there are 10,553km. Furthermore, the primary recollection system of Sedapal with its principle outfalls (shown in Table 2) has been renewed in the second half of 2009 (Sedapal (2010)). The first step in the improvement process of the sewerage system is done but to reach the requested 100% of wastewater treatment (*Plan Aguas Limpias,* MVCS 2008) for the year 2011 the facilities are still missing.

Corresponding with the annual report 2009 of Sedapal, it has currently regulated the disposal of untreated wastewater by two collectors. The collector *La Taboada* including screening device followed by a sea outfall of 3km length received 10.833m³/s of wastewater, and by the seconded collector *La Chira* including screening device followed by a sea outfall of 8km length discharging 4.769m³/s. Only 15.3% corresponding to 2.775m³/s are considered for the 18 WWTPs (see Appendix 4) (Sedapal

(2010)). The 84.7% of untreated wastewater corresponding to an annual volume of 492 million m³ of wastewater discharged into the Pacific. This procedure is technically speaking in conflict with the Environmental Quality Standards of Water (ECA) defined in Art. 79 of the *Ley de Recursos Hidricos.*

Recollection/Outfall System Sedpal 2009				New 2009/2010			
No.	Outfall Pipeline	m3/s		Collector/Outfall	m3/s	%	
1	Emisor Surco	4.769	Sea	La Chira	4.769	30.6	Sea
2	Emisor Comas	2.830	Sea	La Taboada	10.833	69.4	Sea
3	Emisor Centenario	2.540	Sea				
4	Interceptor Norte	2.251	Sea				
5	Colector #6	2.478	River				
6	Colector Condevilla	0.438	River				
7	Emisor Bocanegra	0.296	Sea				
	Total	15.602			15.602	100	

Table 2: Outfall Pipelines, Sedapal (Source: Sedapal (2010))

5.1.2 Wastewater Treatment

New stricter regulations of discharge for industry to the sewerage system as well as new guidelines for effluents of WWTPs are favouring projects of advanced biological processes in future plants (Callery, A.G. (2009)). Currently most treatments are facultative stabilization ponds, and/or oxidation ponds (Moscoso C., J. and Alvaro, T. (2008)). The processes of the existing WWTPs in Lima Metropolitana can be summarised in four procedures:

- Without or only with pre-treatment in form of screening devices: domestic and industrial wastewater is directly discharged into the water bodies or ground by river or sea outfall, latrines, etc.
- With primary treatment: Preferably Imhoff tanks and Septic tanks.
- With secondary treatment: Mostly stabilisation ponds and/or oxidation ponds, in new (planned) projects mainly activated sludge.
- With tertiary treatment, (Disinfection): considered in the design of the plants but operating in only few plants occasionally (Sedapal (2009a); Guinot C. (2010); Moscoso C.J. (2010b)).

Sedapal

Sedapal is operating at that moment 21 WWTP, including pre-treatment of the two sea outfalls *La Chira* and *La Taboada* and, the lagoon Hipodromo Punto A. (see Appendix 3&4). According to the master plan (*Plan Maestro Optimizado-PMO)* of Sedapal 18 WWTPs have the design for pre-treatment, biological treatment and disinfection done by Chlorine (Sedapal (2009b)). In all cases there exists a possibility for consumers, in the suburban area mainly farmers, to connect to the effluent channels and use it as water source for irrigation (Torres, J. (2010)).

The required quality is in not achieved at nearly any plant and disinfection is not being applied (Seifert, R. (2009)). In the South *Zona Sur*, not even 10% of the WWTP are working in a satisfactory manner (Guinot, C. (2010)). The reasons why the majority of the WWTP are not working well are because of:

- *Hydrologic overload caused by bad design*: As seen in Appendix 4 are 11 of 18 plants running over their real capacity (not included WWTPs with only pre-treatment). Bad design, unexpected population growth and lack in management are only some reasons for (Mendez V., J.P. and Marchan P., J. (2008)).
- *Organic overload*: New sewers not considered in the original design, unexpected population growth and shortage of water supply which let increases the organic load. For example the WWTP San Antonio designed for a max. organic load of BOD 250mg/l received during 2007 in average value of BOD 378mg/l (Mendez V., J.P. and Marchan P., J. (2008); Torres, J. (2010)).
- *Lack of maintenance and operation*: Maintenances and reparations are not realized because of insufficient knowledge or lack of economical resources. The WWTP San Bartolo has been in reparation since years, the WWTP Pucusana is only running by the

half of the capacity because of a lack in the pond (Mendez V., J.P. and Marchan P., J. (2008); Guinot, C. (2010)).

- *Contamination by no domestic affluxes:* Maximum values, defined in the *Decreto Supremo N° 021-2009-Vivienda* are not be complied by industries which leads to uncontrollable afflux characteristics in the sewerage system (Palacio, R. (2010)).

Plans for improvement, increase in coverage and enlargement of WWTPs are specified in the *PMO*. New WWTPs are designed or yet in construction and will be introduced into the service of Sedapal in the next years (Sedapal (2009a)). The project *La Taboada* is the biggest investment made in the history of Sedapal. The plans for 2015 include pre treatment, anaerobic treatment and disinfection with a capacity of 14m³/s. Because of financial disputes and several changes of subcontractors the final design is yet to be specified (Seifert, R. (2009)).

Others

The other half of the existing 38 WWTPs (not included WWTPs with only pre-treatment) which are not under the authority of Sedapal are small private distributed reuse concepts for irrigation and/or investigation. Due to scarcity of water for irrigation of green areas in the urban areas both the municipalities and the private sector have been forced to search for alternative sources. Compact wastewater treatment plants have been installed to replace the use of potable water. Most of them are invisible for passers-by, hidden under bridges, in parks behind trees or even build subterranean (Berrospi, U. and Galvez, M. (2010)). The treatment is mostly very simple in form of septic tanks, stabilisations or sedimentation ponds (Moscoso C.,J. and Alvaro, T. (2008)). According to the Institution for Sustainable Development in Latin America and the Caribbean (IPES) the required values for irrigation shown in Chapter 5.2.1 are not being fulfilled by nearly any plants (Muller, S. (2009)).

The 17 WWTPs counted in 2008 are (Moscoso C., J. and Alvaro, T. (2008); (Berrospi, U. and Galvez, M. (2010)):

- 7 WWTPs of the communities, (in 2015 increase to 21 WWTPs),
- 4 WWTPs of Private Sector, like Golf Club San Isidro,
- 2 WWTPs from Universities for investigation and private use,
- and 4 WWTPs of irrigation organisations like in Santa Maria where they have build a recollection system preferably to reuse water for agriculture (Guinot, C. (2010)).

Furthermore, there have been developed several decentralized projects, managed by NGOs to create basic sanitary systems for poorer regions. These are mostly bathroom concepts independent of connection to public sewer (Acevedo T., A. (2010)). Since 1997, also GTZ and CENCA are providing projects as Ecosan-Systems in San Juan de Lurigancho (48 ecological toilets in combination with an irrigation system for 700 ha) and 55 individual projects in other regions of informal settlements (Roman et al. (2007)).

5.1.3 Infrastructure and Reuse Activities

The infrastructural design of Lima Metropolitana shows actually around 1,400ha green areas and 12,680ha for agriculture subdivided in suburban and urban zone (Roman et al. (2007); Rodriguez S., N. and Cespedes S., S. (2007)). All in all, according to the WHO, Lima with 1,98m² of green space per inhabitant is Lima under the recommended area, which is at least 8m²/inhabitant, in order to maintain a healthy living environment. Expectable values between 8 and 10m²/inhabitant are found in the districts of San Borja, La Punta and Santa Maria del Mar. In comparison in poorer districts like Breña, Lurigancho, Pachacamac, Pucusana and Villa Maria del Triunfo there are registered values with less than 0.5m²/inhabitant (Castañeda L., L. (2005)). However to fulfil the international recommendations of a healthy mega city and thus reach the required 4600ha, it would be necessary to create public parks (Roman et al. (2007)).

The currently applied reuse activities in the area of Lima Metropolitana can be summarized to agriculture, recreative area and landscape irrigation[2] (Moscoso C., J. and Alvaro, T. (2008)):

- Productive Activities: Agriculture and fish farming are considered as productive activities. 84% of them are in the suburbs. Since a few years the farmers in the northern and southern districts historically used to river downstream, depend now on domestic wastewater produced in the housings settled around in the last years. Currently farmers are forced to take indirectly 77% form wastewater streams mixed with fresh water and industrial effluents for irrigation of crops; which includes fodder grasses, vegetables, ornamental plants, trees, timber crops and fruit trees (Moscoso C., J. and Alvaro, T. (2008); Roman et al. (2007)).
- Recreative and Environmental Activities: Parks, sport areas, golf clubs and gardens are considered as recreative areas. Activities regarding environmental architecture like avenues, coast line, cemeteries and forestation projects are understood as environmental ones. In total approximately 65% of them are located in the urban area of Lima Metropolitana (Moscoso C., J. and Alvaro, T. (2008)). The modern districts following the trend of horizontal growth compensate the concentration of people with small parks and tree framed boulevards considering their infrastructure planning (Castañeda L., L. (2005)). Because of the desertic climate conditions greens and trees are depending completely on artificial irrigation preferably done by trucks.

[2] Generally, applications of water reclamation and reuse are divided in seven categories according to the water quality as shown in Chapter 4.1, p.17.

5.1.4 (Waste-)Water (Re-)Use

The drinking water consumption for Lima Metropolitana is estimated by 75% for human, 22% agriculture (productive activities) and 3% for industrial usage (Rodriguez S., N. and Cespedes S., S. (2007)). Public environmental and recreative areas are irrigated by water 80% of which is taken from potable water (IMP (2008)). Other sources are:

- Groundwater wells or river water.
- Treated wastewater (indirect) reused via irrigation canals.
- Raw wastewater direct taken from sewerage system.

Direct reuse of reclaimed water in commercial form is only known in two cases of industrial entities supplied by Sedapal (Rodriguez C., I (2010)). The legal framework for those kinds of agreements is due to actual legislation unclear. Taking the advantage of this legal grey area is wastewater reuse done in private applications (see Figure 8).

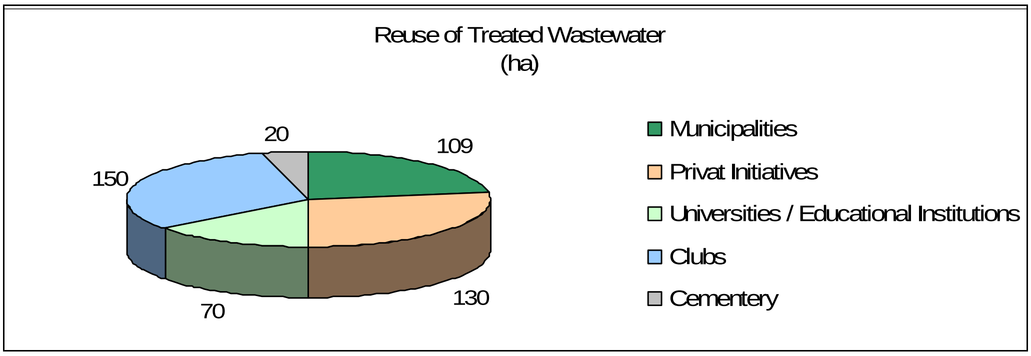

Figure 8: Reuse of Treated Wastewater to irrigate gardens and parks (Source: Roman et al. (2007) p.7)

The wastewater taken from the public sewers is treated in specific treatment facilities or in private sewerage systems i.e. installed in Inka Golf Club before used for irrigation in their own domain. The same procedure has been adapted by district municipalities of Surco, Miraflores, Punta Hermosa and Villa El Salvador for parts of their urban green spaces (Moscoso C., J. and Alvaro, T. (2008)).

In a case study of IPES (in 2008) analysing 982ha of urban green spaces and urban agriculture it has been found out that approximately 1,7m³/s domestic wastewater is used for irrigation; 40% of it was used without any treatment (Muller, S. (2009)). District municipalities justified the practice for example with economical limits and water scarcity (Roman et al. (2007)). Hence it is not surprising that the quality of green areas is heavily discussed by Lima's inhabitants. According to a study of DIGESA, published by the newspaper *El Comercio* at the 20.06.2009 it is reported that 74% of the public parks have been contaminated by the water used for irrigation (Muller, S. (2009).

5.1.5 Water Balance

The used volume of wastewater for irrigation is overall estimated with less than 10% in 2009 by Sedapal recollected wastewater volume (Moscoso (2009); Sedapal (2010)). This 10% represents productive and environmental applications in suburban and urban areas; including the 497ha of urban greens shown in Figure 8 (Roman et al. (2007)).

Potential Volume of Wastewater for Reuse

The generated wastewater volume for Lima Metropolitana is roughly calculated as shown in Table 3. These computations consider a decreasing growth rate, extension of drinking water supply and decreasing water consumption per inhabitant estimated by Sedapal/MVCS (Leon Suematsu, G. (2009)).

Wastewater Volume

		2010	2015	2040
Population Lima Metropolitana (10E3)		8.863	9.497	12.485
Fresh Water Demand (m3/s)	Offered	21,12	-	-
	Demand	27,57	27,83	38,44
WW-Volume generated (m3/s)*	82,3% captured	18,14	18,33	25,31
	100% captured	22,05	22,27	30,75
WW-Volume generated (10E6 m3/year)	82,3% captured	572,45	578,33	798,76
	100% captured	695,85	702,71	970,54
WW-treated (10E6 m3/year)	16% (for 2010)	91,59	-	-

*) Discharge coefficient of 0.8

Table 3: Wastewater Volume (Source: Leon Suematsu, G. (2009); Sedapal (2010))

Potential Demand of Wastewater for Reuse

Decreasing fresh water supply by rivers, climate change and population growth will make increase use of alternative water resources, specific wastewater reuse (Wilderer, P.A. (2008)). The potential demand is set in direct relation to area where reuse can be applied. Under the condition that the required 4600ha of public green space are reached by urban infrastructure programs of ministry of housing, the PLANAA of the ministry of environment, lands reserved for green areas, reforestation programs by regional and local governments as well as protection of urban agriculture supported by NGOs, educational institutions and the private sector is the total area in urban zone assumed to 5570ha (see Figure 9).

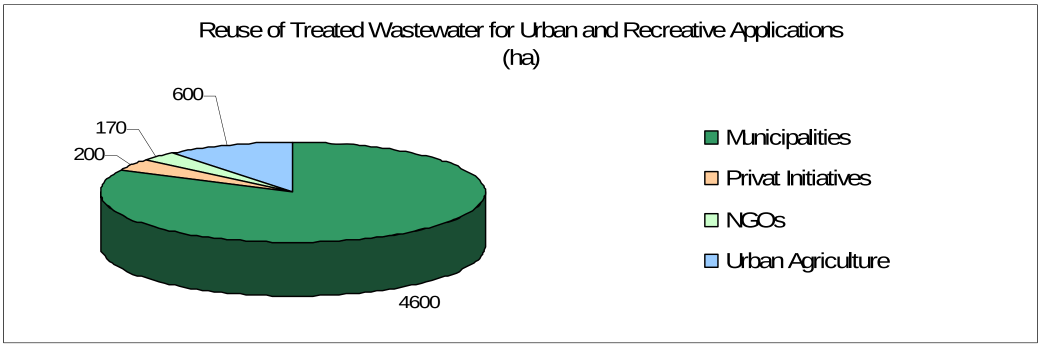

Figure 9: Potential Demand of Reclaimed Wastewater
(Source: Roman et al. (2007))

Under the condition that irrigation is done equally by flooding and dispersion, 1l/s/ha is taken as an average for the irrigation factor (Moscoso C., J. (2010b)). The potential wastewater demand is assumed to approximately 175.78m³ per year; an equivalent to 30% of the currently captured wastewater only for urban recreative applications. Further applications such as industrial usage, car washing or use in constructions have not been considered. Also suburban usages, mainly productive activities have been neglected.

5.2 Legal Framework

As in most of the Latin American countries, the legislation is focused on drinking water and there are lacks in domestic wastewater issues. However, the legislation has to be identified as a framework to assess legal instruments and procedures that could limit or promote reuse proposals. These can be technical standards for domestic wastewater treatment, quality parameters, and/or rights of water use for different applications (PAHO/CEPIS (2002)). Obviously, there does not currently exist any complete regulation for the handling of water reclamation and reuse but the legislation gives an idea how far reuse is integrated in governmental policies.

5.2.1 Peruvian Legislation

Several changes made in the last years lead to a currently confusing, inscrutable and double-acting statutory basis of the involved institutions. The expected improvement and the synergy effect in the sector of environment and water management are still missing (Seifert, R. (2009)). Most of the related rules are environmental laws regulating natural resources and defining areas in different categories according to its ecosystems. The most important ones regarding wastewater reuse are:

- *Ley de Recursos Hidricos - Ley N° 29338*: The Legislation, regulating the hydrological resources developed in 1969 (*Ley General de Aguas, Decreto Ley N° 17752*) has been reformulated in 2009 by the new founded National Water Authority (ANA). According to it, now the state obtains all rights over existing natural water resources administrated by ANA. The protection of natural water bodies is assigned to the Ministry of Environment (MINAM). The regulation of water use is done with the help of a licensing system giving concessions to autonomic organization and private entities. At a glance water now seems to be that water is a common good but via concessions the unlimited property of water for private interests is now possible. This favours primarily strong mining industries in river basin areas.

- *Decreto Supremo 003-2010-MINAM*: In Peru the focus is set on drinking water supply; wastewater disposal and reuse do not have clear regulations. Since March 2010 there has been adopted a new legislation called LMP defining maximum values for WWTP effluents into natural environment (see Appendix 5). WWTP operators have up to three years to adjust their plants to the standards given by MINAM. The annual control and administration of information regarding WWTP effluents is being done by Ministry of Housing and Sanitation (MVCS) and reported annually to the ministry of environment (MINAM (2010)). The chance to wipe out (sea) outfalls of untreated WW was not taken. Plants without, with pre-treatment or primary treatment are excluded by this law and are in a direct conflict with the following environmental regulation.
- The *Decreto Supremo N°023-2009-MINAM* proposed in July 2008 and adopted in December 2009, established to regulate different water streams according to its usage (see Appendix 5). All Peruvian aquatic ecosystems are divided into four application areas in the following:
    - Category 1: Population and Recreation: Most stringent category for effluents used for drinking water purification processes or received by recreational water bodies.
    - Category 2: Coastal Activities: Regulates water quality for fishing and shellfish collection areas.
    - Category 3: Vegetable Cultivation and Animal Husbandry Applications: Subdivided into regulated effluents for animal husbandry, short corps (vegetables and tubers) and tall corps (maize, arbour fruits, grains). The stringent limits are for short corps with a quality

demand of BOD<15mg/l, COD<40mg/l, TSS<15mg/l, occurrence of Helminth Ova in effluent <1egg/1000ml, E.coli<100/100ml, TC <5000/100ml.

- Category 4: Conservation of Natural Water Bodies: General category defining standards for all water ecosystems not included in Category 1-3 like lakes, rivers, lagoons and costal sea waters.

Based on this definition and limits called ECAs reuse of wastewater in agriculture processes and for irrigation activities is planned considering Category 3. The set of regulations does not specifically include domestic wastewater reuse and values defined in Category 3 are only relevant for natural water sources (Moscoso C., J. (2010b)). Furthermore logical connections with respect to other guidelines are missing. Those would be for example a relation between maximum limits for WWTPs' effluents LMPs and the definition of the natural water bodies ECAs, especially Category 4 of *Decreto Supremo N°023-2009-MINAM* is not found. Moreover there exist unclearnessess in form of significant lacks, unspecific formulations and missing guidelines for application hampering and exacerbating the execution. How untreated wastewater and natural waters extending these categorisations has to be handled, has not been considered in the legislation.

5.2.2 International Recommendations

The most known international water quality guidelines in the context of domestic wastewater reuse are the standards of the World Health Organization (WHO) published in 1989. These guidelines refer to domestic effluents, such which do no contain relevant industrial effluents. The National Environmental Quality Standards for Water (ECA) in Peru are based on these WHO standards.

The risk for human health beside other contaminants in treated effluents of domestic wastewater is defined by the pathogenic organisms.

“In general, (...) wastewater reuse regulations should be strict enough to permit irrigation use without undue health risks, but not so strict as to prevent its use” (UNEP (1997) p.2). However, the standards for wastewater reuse vary from country and by the application: Mexico set the limits for recreational areas to <10,000TC/100ml and 2,000 FC/100ml, for vegetables eaten raw and fruits with possible soil contact <1,000TC/100ml; European standards are 2,000FC/100ml and the recommended standards by the WHO are 1000FC/100ml (WHO (1989)). Stricter legal framework is recommended by the US-Government as displayed in the following figure.

Types of Reuse	**Treatment**	**Reclaimed Water Quality**	**Reclaimed Water Monitoring**
Agricultural Reuse – *Food Crops Not Commercially Processed* Surface or spray irrigation of any food crop, including crops eaten raw	• Secondary[2] • Filtration • Disinfection	• = 10 mg/l BOD • No detectable fecal coli/100ml[3] • 1 mg/l Cl_2 residual (min.)	• BOD - weekly • Coliform - daily • Cl_2 residual - continuous
Agricultural Reuse – *Food Crops Not Commercially Processed* Surface irrigation of Orchards and Vineyards	• Secondary[2] • Disinfection	• = 30 mg/l BOD • = 30 mg/l SS • = 200 fecal coli/100ml[4,5] • 1 mg/l Cl_2 residual (min.)	• BOD - weekly • SS - daily • Coliform - daily • Cl_2 residual - continuous
Agricultural Reuse – *Non Food Crops* Pasture for milking animals; fodder, fiber and seed crops	• Secondary[2] • Disinfection	• = 30 mg/l BOD[7] • = 30 mg/l SS • = 200 fecal coli/100ml[4,5] • 1 mg/l Cl_2 residual (min.)	• BOD - weekly • SS - daily • Coliform - daily • Cl_2 residual - continuous
Urban Reuse All types of landscape irrigation (e.g. golf courses, parks, cemeteries).	• Secondary[2] • Filtration • Disinfection	• =10 mg/l BOD • No detectable fecal coli/100ml[3] • 1 mg/l Cl_2 residual (min.)	• BOD - weekly • Coliform – daily • Cl_2 residual - continuous

Footnotes:

1 These guidelines are based on water reclamation and reuse practices in the U.S., and they are especially directed at states that have not developed their own regulations or guidelines. While the guidelines should be useful in many areas outside the U.S., local conditions may limit the applicability of the guidelines in some countries.

2 Secondary treatment processes include activated sludge processes, trickling filters, rotating biological contractors, and many stabilization pond systems. Secondary treatment should produce effluent in which both the BOD and SS do not exceed 30mg/l.

3 The number of fecal coliform organisms should not exceed 14/100 ml in any sample.

4 The number of fecal coliform organisms should not exceed 800/100ml in any sample.

5 Some stablization pond systems may be able to meet this coliform limit without disinfection.

Figure 10: US-EPA-Guidelines 1992 (Source: Blumenthal et al. (2000) p.11)

The WHO revised its guidelines from 1989 and published in 2006 “Guidelines for the safe use of wastewater, excreta and grey water, volume 2: wastewater use in agriculture” (WHO (2006c)). Different from the first version, provide these guidelines now procedures to calculate risks and related options for treatment. With the help of the so called "Stockholm Framework" is given a catalogue how to assess and manage risks associated with the use of wastewater in agriculture. These guidelines consider now local epidemiological, socio-cultural and environmental factors for the corresponding case (WHO (2006c)).

5.3 Political and Institutional Actors

The recognition of the main institutional actors involved in decision making process, their political interests and capabilities are essential statements to predicate the acceptance level of water reclamation and reuse (PAHO/CEPIS (2002)). The influence of these institutions can be seen as driving forces or quite the opposite hampering the implementation.

5.3.1 Institutions Involved

The main institutions involved in the decision-making processes regarding water and wastewater management form part of the politic body. They form together the large regulating and legislating apparatus. The functional operating part of water processing and treatment is mainly done by Sedapal but considering reuse activities are involved more and more governmental and no governmental actors with own WWTPs.

National Government (NG)

The National Government determine the rules and set the political agenda conforming decisions that have to be made. An active participation in the decision-making process is performed via decentralised ministries regulating and controlling water processing.

Regional Governments (RG)

The department of Lima is a constellation of three governments on regional level (Lima, Lima Metropolitana and Callao). These interfere in inter-provincial projects or conflicts which are exceeding local governments. In the case of Lima Metropolitana most of the decisions concerning environmental infrastructure planning are initiated by the city councillor preparing its presidential candidature in 2011.

District Municipalities - Local Governments (LG)

The district municipalities are developing and carrying out individual plans and programs for (environmental) infrastructure. In cooperation with the ministry of housings and Sedapal part of their objectives is the expansion of sanitation services and the improvement of urban living environments in form of recreative areas.

Ministry of Housing, Construction and Sanitation (MVCS)

The MVCS with the main objective to develop, formulate and implement guidelines for sector of housing, construction and sanitation was inaugurated in July 2002 (MVCS (2006)). The competence reaches from environmental infrastructure planning to technical licensing agreements regulating and controlling the water supply and sanitation service companies (EPS - *Empresas Prestadoras de Servicio de Saneamiento*). The organisation of the ministry is like other ministries: decentralised and acting on national, regional and local level.

Ministry of Environment (MINAM)

In May 2008 CONAM (*Consejo Nacional de Ambiente*) was substituted by MINAM. The objective is to conserve the environment and guarantee a sustainable, responsible and ethical usage of the natural resources. For this aspect the National Plan of Environmental Actions (PLANAA) has been formulated to define the national environmental policy for 2010-2021 (*Decreto Supremo N° 012-2009-MINAM*). Among its responsibilities and competences are to develop, execute, supervise and evaluate national environmental policies, regional plans and local actions. The division of hydrological competences between MINAM and ANA is still in process (MINAM (2009)).

General Directorate of Environmental Health (DIGESA)

DIGESA (*Direccion General de Salud Ambiental*) is the technical-normative organ of the Ministry for Health (MINSA) related to all aspects of human health as basic sanitation, (food) hygiene and human protection. It coordinates the technical and regulatory framework with specialized institutes and laboratories to develop technical standards and manage their control. In the water sector awards DIGESA health certifications and authorisation for sanitary systems of water purification. It is the responsible public entity to control the drinking water quality. Currently the discussion is to assign new task and/or combine existing parts with ANA, such as authorisation for sanitary systems of wastewater treatment, authorisation for sanitary disposal of industrial and domestic wastewater and authorisation for (agricultural) land use.

National Water Authority (ANA)

The National Water Authority has been operating since 2009 under the resort of the Ministry of Agriculture. It substitutes the Institute for Natural Resources (INRENA) as part of the strategy to respond to the problematic hydrological situation in Peru. It is the highest national institution combining the authority which had been divided in previous years to INRENA, MINSA, MINAM and Irrigation Communities. Still under construction, there are the regional and local entities called Administrative Water Authority (AAA) and Local Water Administration (ALA). The principal functions are: a) formulate political and national strategies of the hydrological water resources (former MINAM), b) administrate and formulate laws and guidelines for the water usage, c) guarantee an equal distribution (former Irrigation Communities), d) control the quality (former DIGESA) and e) facilitate solutions regarding hydrological conflicts (ANA (2009)). ANA has legislative and executive power on ministerial level concerning natural water resources. The necessary budget is still not approved and assigned tasks cannot be fulfilled at all or only partially.

SUNASS

The national institution SUNASS (*Superintendencia Nacional de Servicios de Saneamiento*) established in 1992 is supervising and regulating the whole market of EPS. On the one hand SUNASS has in its normative and regulative role the exclusive power to dictate directives and fix rates (water tariffs) for water supply and sanitation service. On the other hand it has in its supervising and controlling role the power to verify the compliance with legal obligations and impose sanctions (Sunass (2007)).

SEDAPAL

Sedapal is the unique EPS in Lima Metropolitana possessing the absolute authority of distributed water. The objective is to provide the access to drinking water as well as the connection to the sewerage system for all residents of Lima Metropolitana (A*guas Para Todos* (MVCS 2006)*; Plan Aguas Limpias* (MVCS 2008)). However its mission statement to reach these goals is seen in public as capturing as much as possible of fresh water to purify and distribute them. As the president of Sedapal is named by the MVCS long term planning and/or sustainable approaches over one election period are displaced by political interests.

NGOs, Private Sector and Scientists (PS)

This group of different actors can be identified in the first instance as constellation of autonomous projects concerning water reclamation and reuse. Intramural have been installed treatment facilities for specific purpose; most of them for private irrigation applications. A communication and exchange of information under them is not being realised hence everyone is acting individually.

***Junta de Usuarios de Riego* – Irrigation Communities (IC)**

The Irrigation Communities (*Juntas de Usuarios de Riego*) can be understood as big group of user (Municipalities, EPS, mining companies, industries, farmers, etc.) bounded by river basin. In former times inter-municipal fresh water streams have been regulated and administrated by them. Today, it is supposed that the whole functional structure has been adapted by the new model of ANA, AAA, ALA but in suburban zones the distribution of water for agriculture fields still administrated by irrigation organisations (Acevedo T., A. (2010)).

5.3.2 Technical Management

The technical management regarding water reclamation and reuse is divided in different competences. The main points are allocated in the following table according to their assigned responsibility defined in the statutory task description and how it can be observed at the moment.

Competence	Assigned	Observed
For wastewater treatment:	Sedapal, MVCS, (ANA)	Sedapal, MVCS, RG & LG, PS
for wastewater reuse:	Not assigned (ANA)	IC, PS, RG & LG, PS, MVCS
for water resource management:	ANA	ANA, MINAM, IC
For environmental control:	ANA, MINAM	DIGESA
for epidemiological control:	ANA, DIGESA	DIGESA
For legal regulation for WWTPs:	MVCS, SUNASS	MVCS, MINAM, DIGESA
For financial regulation:	SUNASS	SUNASS, MVCS

To illustrate the management situation in a more descriptive way there has been developed the overview in Figure 11. The situation, especially regarding wastewater is a legal grey area under auto-control. The operator of wastewater is in the same time monitoring itself. Any further control of conformance with legislation or sanctions in case of violation is not defined.

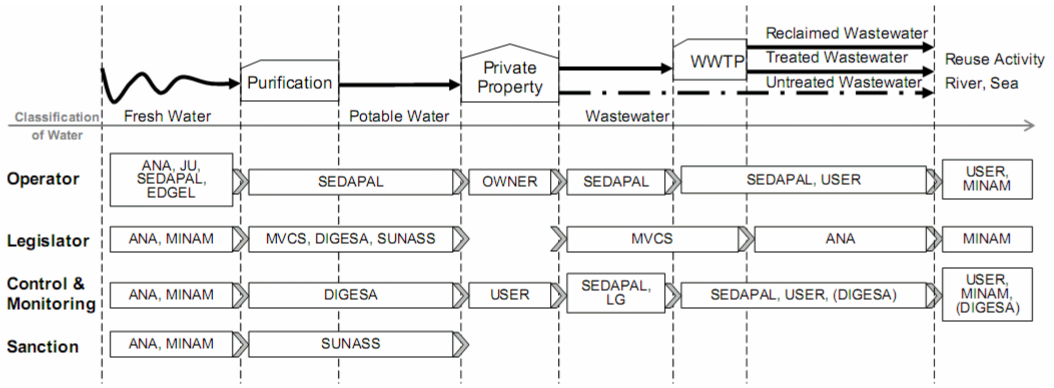

Figure 11: Operator, Legislator, Control & Monitoring and Sanction

5.3.3 Institutional Disputes

An institutional weakness regarding water and wastewater management shows especially the domains of planning and monitoring of water and wastewater resources. Overlapping competences on one hand and missing delegation of decisions on the other characterise the non-transparent network of actors. Disputes emerge because of:

- Legislation's emphasis on description of authorities for actors omitting the definition of responsibilities.
- Significant differences in technical statements to legislation, infrastructure planning, categorisation of grounds, water and environment management and private investments.
- ANA is overcharged while missing funds and technical know how.
- Missing intra- and inter-institutional coordination and communication concepts for public as well as private sector. Actors are working isolated and parallel without consideration for others. No common decisions are made and individually developed projects become incompatible.
- No agreements between infrastructure planning department of municipalities and planning and operation department of Sedapal.
- Conflicts and impacts from other sectors (political pressure, economical limitations, industrial and mining disposals) effecting the water and wastewater management.

- No participatory decision-making process.
- Legislation and guidelines are only partially applied. Even governmental institutions take the advantage of legal grey areas.
- Corruption and uncertainties make a control and resulting sanctions impossible.

Institutional Driving Forces

To be involved in the decision making process concerning wastewater reuse does not mean automatically to have influence or interest in it. The main two activities realised independently are treatment and reuse. For the proposed concept both are required (PAHO/CEPIS (2002)). The influence of wastewater treatment and the interest in reuse of the management units point out that real driving forces are not be identified.

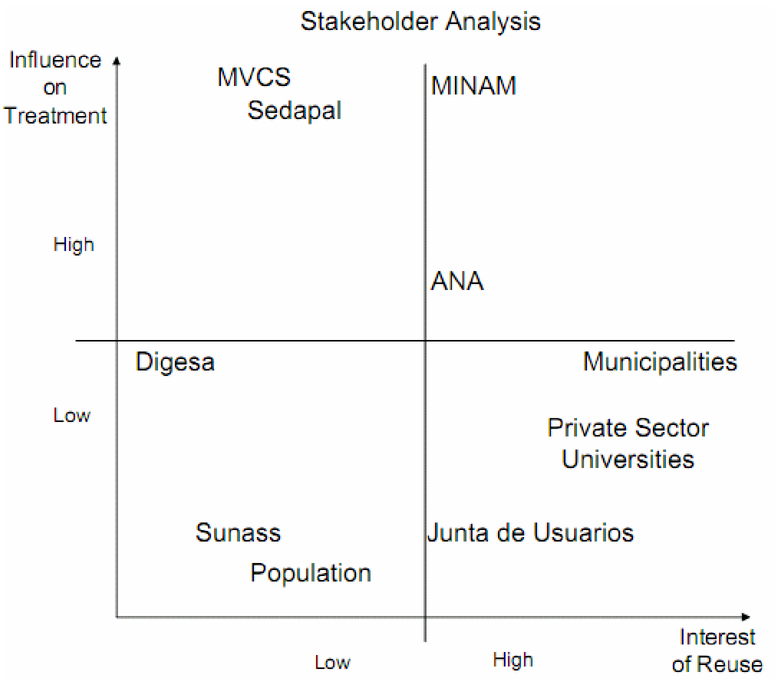

Figure 12: Stakeholder Analysis

The Figure 12 shows clearly that institutions with the highest influence on wastewater treatment have only little to middle interest in reuse. Users with high interest i.e. from the private sector or municipalities depend on collaboration. The ideal entity with high influence on treatment and high interest in reuse is not given.

5.4 Public Acceptance

The public education is one of the key figures in wastewater reuse. To eliminate and provide public fear is especially missing confidence in institution like in Peru one of the biggest challenges. *"The greatest obstacle (…) [is] the public acceptance"* (McKenzie, C. (2004)). Wastewater reuse is not only a technical problem which has to be solved it further represents a cultural question. A public relations program must be introduced and environmental education provided by the state.

Cultural aspect

The population is widely familiar with the desertic conditions and the scarceness of freshwater. Programs to save water are nevertheless strictly rejected or only planed but not carried out. The wasteful handling of water is deeply grounded in society and only partially considered in school education. The element water as natural resource is not added the appropriate value and mobile phones and television are more important in the everyday life (Acevedo T., A. (2010)).

The human responsibility for nature and the necessity to protect the environment is only partially established. In fact, neighbourhood movements are organising protests and sabotages against plans and constructions of WWTPs in their neighbourhood (Berrospi, U. and Galvez, M. (2010)). The most common prejudices against the plants and also against reuse are bad smells and the fear of infections (Palacio, R. (2010)).

A modification of the water tariff system including payments for wastewater disposal is with actual Peruvian politics seen as incompatible. A remarked additional separated quote by Sedapal as habitual in most of the European countries is nearly impossible to get accepted by Sunass in the next years (Rodriguez C., I. (2010)). The strategy of Sedapal now is that since May 2010 has been split up the costs in potable water (75%) and wastewater disposal (25%) to sensitise the people and prepare so a separated payment could be accepted in the future.

Missing confidence in institutions

Most of the Peruvians do not trust in the governmental institutions. Several cases of health problems, accidents and cases of corruption in the last two decades create a bad picture of institutions in the water sector (Acevedo T., A. (2010)). The 300,000 cases of Cholera occurred in 1991 have let a big doubt of the population in the sanitation systems (Moscoso C., J. (1993)). Also the dismissal of the chief executive of Sedapal accused of corruption and favouritism in February 2010 is making loose image to the water utility company. Consequences are for example shown in the case of the WWTP of Manchay. Neighbouring farmers are willing to pay for drinking water supplied by trucks instead of taking the treated wastewater afflux provided for free for agricultural irrigation purposes. The named reasons for this were that they do not trust that supplied water has the required quality and possible risks of infection (Guinot, C. (2010)). Although quality standards for water use (Chapter 5.2.1) exist there is little confidence that they are being fulfilled. The resulting threat of the population refers to increasing risks for human health by reuse of wastewater.

Missing Programmes

The integrated model is based on a participatory concept that means the public is integrated in decision making process. For this are required in Lima Metropolitana educational programs to inform and create capabilities amongst the population. One approach highly recommended by the WHO is to implement topics like safe water use and water saving early in school education (WHO (2006b)). Moreover has to be introduced a system of information in the first instance to signpost areas where wastewater is been used and how to deal with it. Furthermore there has to be trained workers assigned for groundskeeping about correct handling of treated wastewater and how to act in case of disasters.

5.5 Economical Circumstances

The cost of wastewater treatment, as in most of the Latin American cities, has not been included in the tariff system, which explains the low coverage of WWTPs. The budget in the case of Sedapal depends on own revenues according to the water tariff system established by Sunass and the budget assigned by the MVCS. The priority, 88% of the expenses is set in alignment with the government on the extension of conductions for potable water and sewerage system (Sedapal (2010)). Therefore in 2009 there had been taken an additional amount of 71,961,000 US-Dollars from external sources in addition to the own economical resources of 194,681,000 US-Dollars. This means indebtedness by 27%. By comparison to reach the national plan from 2006 developed by Sedapal and MVCS to provide safe water for all *(Agua para todos)* in Lima Metropolitana there are required approximately 3,500 million US-Dollars (Roman et al. (2007)). Expenses for maintenance and/or improvement of the treatment processes might be neglected.

Tariffs

To comprehend the high consumption of drinking water whilst suffering from a deficit situation, the actual tariff system has to be named responsible for at least certain parts (see Appendix 6). Compared to other Latin American countries, Peru belongs with 2.16S/m³ (0.76$/m³) in average to one of the cheaper ones. According to statements of Sedapal it would be necessary to increase by 30% the price to improve quality, enable new projects and maintain the existing technical units instead of the suggested proposal of 10% (Rodriguez C., I. (2010)). At this point it has to be mentioned that only 62% of the produced potable water is charged for, the rest 38% are apart from physical and also an economical loss (Sedapal (2010)). Contrary to the monthly fix-rate for drinking water for wastewater the connection to the sewerage system has to be paid only once. Big consumers with own wells are charged 3,082S/m³ (1.07$/m³) for utilization of the sewerage system, based on their own data (Sedapal (2010)).

Funding and Borrowing Capability

The funding and borrowing capability depend on the different institutions. Most of the private projects depend on calculations of profitability concerning estimations of fix investments and capital required by the development proposal (PAHO/CEPIS (2002)). In the case of public proposals managed by Sedapal financial capabilities are limited by the estimated annual income predefined by Sunass and the confirmed budget by the MVCS. But this is only partly true. Taking the example of the mega-project *La Taboada* it can be shown that in the financing strategy an individual temporary model is chosen. This approach consists of an additional fix-rate of 1.30S/ (0.46$), which will be paid monthly by all consumers for the next twenty years (Lucich, I. (2010)). Developing the project financing as part of an integrated management plan it would have been possible to break down the expenses in smaller packages assigned to further sectors and programs enabling additional capabilities; i.e. urban infrastructure program, plan of costal conservation, PLANAA, etc..

Until now new sources of direct incomes for Sedapal have not been considered. As wastewater reuse is done indirectly and informally by farmers and on private level for own applications is still no tariff developed. Nevertheless former agreements and public surveys proposed a rate of 1S/ (0.35$) per cubic meter for treated wastewater (Acevedo T., A. (2010); Rodriguez C., I. (2010)). The economical benefit would be one convincing argument for users such as district municipalities. Currently the MVCS is calculating with costs of 2.5-3.5S/ (0.87-1.22$) for one cubic meter water reclaimed by their own compared to 2.675S/m³ (0.93$/m³) charged by Sedapal for potable water (Berrospi, U. and Galvez, M. (2010); Sedapal (2010)).

6 Case Study: UNI

The real and potential reuse activities in Lima Metropolitana focus mainly in recreative and environmental activities in form of parks and green spaces. Hence, the conceptual approach in the case study of the National University of Engineering (UNI) emphasizes towards defining the feasibility of the integrated wastewater reclamation and reuse proposal to improve existing measures and propose further options. The required technical information has been collected by interviews with employees[3], from inner-institutional documentation, as well as from working in the UNI, UNITRAR and Viveros.

Methodology to determine and evaluate the concept feasibility

To determine the feasibility and sustainability of the integrated system model there have been analysed 32 factors in alignment the PAHO/WHO guidelines (PAHO/CEPIS (2002)). The situation described in Chapter 5 defines the boundary conditions. Similar to the five criteria outlining an integrated system there is structured the case study in technical, legal, institutional, social and economical aspects (see Figure 6, p. 19). Some overview describing the situation is given by the SWOT-analyses of Reclamation and Reuse Activity of UNI (see Figure 14, p. 51) that combine the main points of all five aspects.

6.1 Technical Aspects

6.1.1 Infrastructural Characteristics and Water Resources

<u>Location</u>: The study area of the UNI, including the wastewater treatment plant UNITRAR is situated in the border of the districts Rimac and Independencia, in the north of Lima. The plant UNITRAR is located near to the faculties in the north end, “Sector T” inside the university area. The territory of 4.5ha borders in the north and east to the rising housings of

[3] All collected data for Chapter 6 had been checked by Alarcon Condor, J. C. and/or Cornejo Landers, J. in their management functions of UNITRAR and Viveros.

the district Independencia, to the west to the supermarket METRO, highway Tupac Amaru and opens to the south to the university side.

Source of WW: The catchments area is limited to the human settlements “El Angel” and “El Milagro“ in the district Independencia situated hillside, east of the plant. Geographical conditions allow that the transportation till the plant is forced by gravity. The incoming wastewater stream can be categorized as exclusively of domestic origin. Up until now there is no knowledge of industrial activities in this area. Significant variations of the characteristic occurred in the past only due to shortage of water in form of highly concentrated inflows (organic load) or in few specific cases of discharge of colours or oils to the sewer system by the residents. Characterising to this area is the periodic production of wastewater because of the restricted water supply by 14 hours per day (Sedapal (2010)). That means that the main inflow into the plant is arriving at daytime with peaks of organic load in the morning hours. The effluents produced by the UNI themselves are consciously not linked with the UNITRAR. Although it would be seen as a good approach to treat own generated wastewaters are effluents of the laboratories making it much more difficult to manage and foresight the treatment processes (Alarcon Condor, J. C. (2010)).

6.1.2 Wastewater Treatment

Technology: The wastewater treatment plant UNITRAR was built in 1994 and started to work for the first time in 1996. It is equipped with a treatment system consisting of pre-treatment, anaerobic reactor followed by two stabilisation ponds. The natural processes based treatment by stabilization ponds is due to its low maintenance costs one of the most wide spread technology for the coastal region of Peru. The inconvenience of the required large space, which often results to high land cost, is in this case not present. Furthermore the whole plant is forced by gravity, which leads to low operation costs. The objective of the UNITRAR is in the first instance to represent a centre of investigation in wastewater treatment technologies. Projects in form of Master- or PhD Thesis are realized in cooperation with the UNITRAR-team on topics like wetlands, septic tanks, aquiculture and reforestation (Alarcon Condor, J. C. (2010)).

Design of the System: The plant is designed as WWTP according the guidelines (OS90) of MVCS for a maximum capacity of 10l/s. Nevertheless the average of the monthly volume (11,189m³/month) of the last three years indicates an operating capacity of less than 50%. The actual influent is around 5l/s adjusted by an overflow system.

- **Pre-treatment**, the incoming stream passes through two screening devices (2,5cm and 1,5cm) removing the big solid compounds and cleaned daily manually by the employees. The screened wastewater continues with a homogeneous flow of 0,2m/s via two parallel rectangular sand canals used alternately.
- The **primary treatment** step is an anaerobic bio-reactor (H/W/L 6.0m/8.4m/10.4m) designed for retention time of 8h by an influent of 10l/s. The actual efficiency of removing organic material is estimated with 75%, by 15h corresponding to 5l/s.

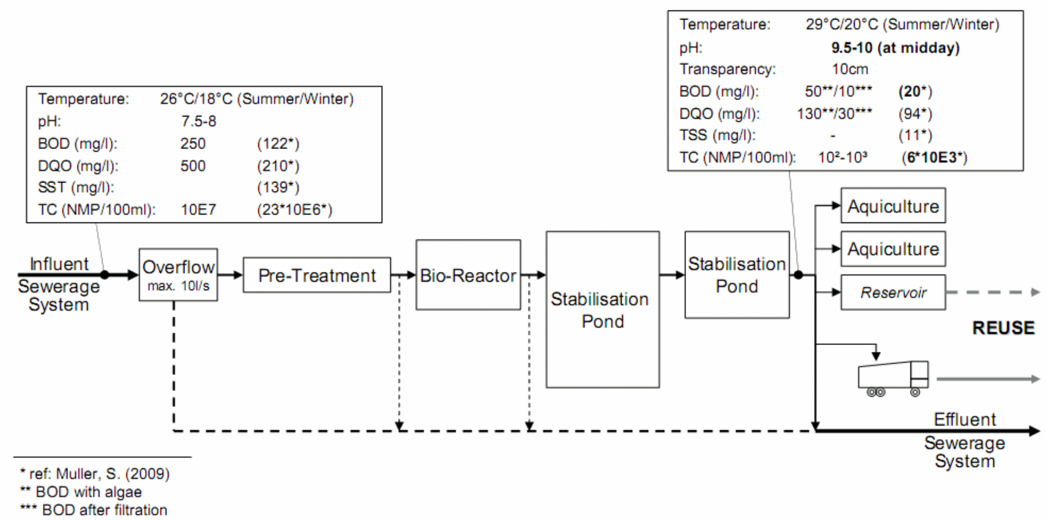

Figure 13: Design of WWTP UNITRAR
(Source of Data: Alarcon Condor, J.C. (2010); Muller, S. (2009))

- The **secondary treatment** is realised in by two consecutive facultative stabilisation ponds (depth: 1,5m). The retention time is in the first pond designed for 10 days and in the second one for 6 days expecting a flow rate of 10l/s. According to the minor flow of 5l/s there are currently calculated 20 and 12 days for both lagoons with an efficiency of 50-60% (BOD). An installation of a typical surface aeration system, e.g. by motor-driven floating aerators can be achieved 80-90% removal of BOD (Muller, S.A. (2009)).
- **Reservoir**: In the end of the treatment process there are installed three reservoirs, each with a volume of 700m³ and an entire fill-station for trucks. Two of the ponds are used for investigations in aquiculture using a small part of the effluent to equalize the lost water through evaporation or infiltration. The main stream is going back to the sewerage system.

Disinfection: The neutralization of any infectious agents or pathogenic organisms is in the design of UNITRAR based on natural processes, no further chemical or physical treatment is practised. For reuse applications of the UNI (environmental irrigation) may be acceptable the effluent of the secondary treatment, but it must be assured by regular controls that the required quality is been achieved. The main threat regarding this system and on the same hand the main weakness of this plant is the risk of infection (see Figure 14). Hence, it has to be proved if not a final step guaranteeing a sufficient disinfection should be included. This tertiary treatment could for example consist of micro-filtration followed by chlorination or UV-lamps to guarantee the required water quality in the effluent.

Sludge Disposal: The produced sludge is removed once a year and dried by percolation and evaporation next to the reactor. Furthermore it is internally used as a natural fertilizer to revitalize the soil (Alarcon Condor, J. C. (2010)).

Gas Production: Biogas, produced in the reactor was measured and captured in the past (4.5-6 m³/month) and later burned for demonstration purposes (Alarcon Condor, J. C. (2010)). Currently is the gas containing (CH_4, CO_2, H_2S) escaping by a tube directly into air. Obviously to avoid any kind of air pollution there has to be installed a method to capture and/or burn it.

Operation and Maintenance: The plant is being operated during daytime manually from the office, located beside the plant by one engineer (operator) and 2 technicians. The operation and maintenance practices are done based on experiences gained in the last years. Examples are taken manually. In the laboratory existing by the plant are currently only measured pH, temperature and turbidity, any further analysis are made as part of investigations and/or have to be sent to external laboratories including the one of the Faculty of Environment.

Sanitary and Safety Requirements: Safety measures are directly related to costs and hence only partially considered. In order to protect workers and visitors the standards have to be urgently improved. Since daily visits and projects are done by students have to be at least installed railings, signs and separated sanitary rooms. Concerning the maintenance in form of cleaning and inspecting the system there must be provided more and better safety equipments for technicians and students. As part of the improvement has to be introduced an education program explaining risks concerning the human health. Incidents like small sicknesses of employees must be prevented on forehand by a strict separation of material used outside in treatment processes and in the office.

6.1.3 Reuse Activities

Land tenure: The authority of the available land is divided according to the faculties or identified as common areas. All 13 faculties on the area of the university are underlying a comprehensive improvement process to develop a common infrastructural design. Part of this is the *Plan*

Paisajistico considering 13ha available for recreative and environmental activities (Cornejo Landers, J. (2010)).

<u>Perspective of this area</u>: Expectations are considering a comprehensive environmental developing process improving the environmental infrastructure. The fact that a new irrigation system is being installed and that the environmental management is combined in one institution facilitate wastewater reuse activities.

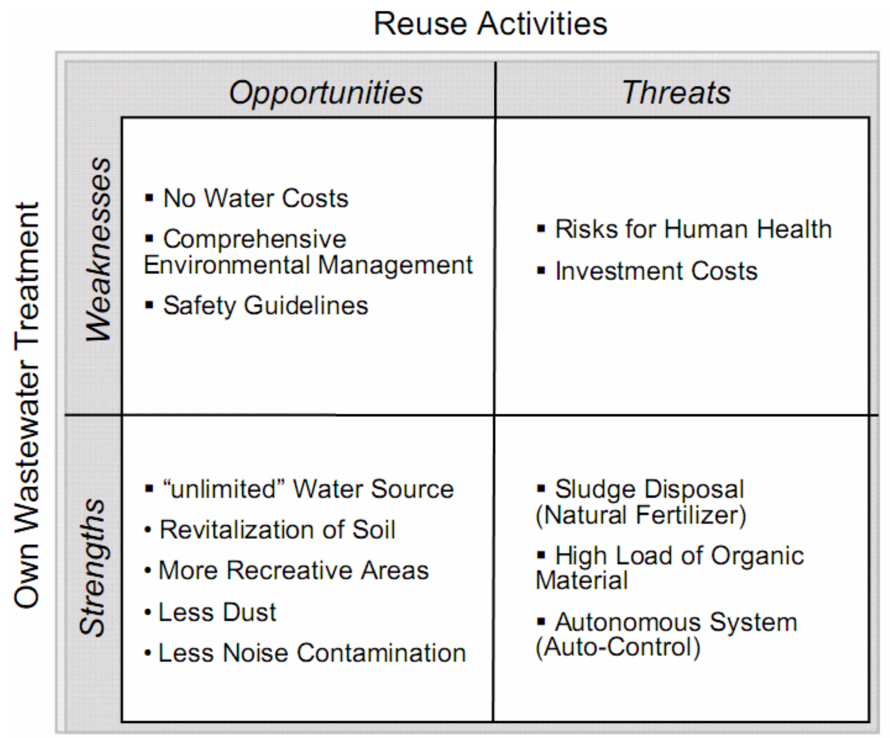

Figure 14: SWOT of Reclamation and Reuse Activity of UNI

<u>Soil capacity for activity</u>: Statements regarding capacity of soil are based on rough estimations. Typically for this region the soil is a composition of a mixture of sandy loam soil and clastic rock formations. Water is only slowly filtering into the ground. Through reforestation programs especially in the last three years the upper layer has been made artificially fertile. Supplements of organic material, nitrate and phosphate including the sludge disposal of the UNITRAR are precisely requested. According to the opinion of Viveros is the full capacity of nutrients and water not reached by irrigation (Cornejo Landers, J. (2010)). But investments

evaluating the required amount or an eventual contamination of soil have not been made.

Wastewater demand for irrigation: Assumed that there is an "unlimited" source of water available and that the maximum capacity of the soil and plants is not reached the irrigation technique is the limiting factor. Up to now are trucks being used to distribute and further irrigated by tube from the truck and by inundation for larger fields. This procedure is applied for approximately 7ha using 815m³/month of reclaimed water; 9% of the operating wastewater volume from UNITRAR (see Appendix 7). Compared with the maximum capacity of the plant are approximately 3% reused. The remaining 6ha are irrigated by potable water with no further documentation available. A new more efficient distribution and irrigation system for around 10ha is planned to inaugurate the year 2011. The demand of treated wastewater is estimated to 3300m³/month calculated by 1m³ of water required for 130m² green spaces per week (Cornejo Landers, J. (2010)). This would be 30% of the currently treated wastewater stream.

Irrigation system: The irrigation by truck (55m³-75m³, 5-7 trucks per day, five days a week) is being substituted by an automatical system. Form the third aquiculture pond modified as a reservoir the water over the area is distributed via an electrical pump. A primary connection network has already been installed. Depending on the activities will be further installed taps, with the possibility to connect a garden hose or a secondary pipe system for irrigation by dispersion (Cornejo Landers, J. (2010)). Safety measures are still missing; i.e. signs indicating that no potable water is been used. Since it is a private application quantitative measurements are not being considered in the design. The option to irrigate by truck will be managed as additional support if requested.

Markets and commercialization channels: Obviously can not be the only aim to ensure water for own irrigation purposes. The remaining 70% of treated but unused water stream represents an economic value. Selling the water for further environmental activities is primarily thought for commercializing this good. Potential buyers are neighbouring districts, municipalities and industries. Although technical conditions in form of filling stations for trucks are favouring this option, formal contracts including payments are precarious due to the unclear legal situation. Bad experiences have been gained in 2004 and 2007 with the district municipality of Independencia and San Martin de Porres. Although formal contracts had been signed and the treated effluent of UNITRAR had been used over one year were missing payment never been realised arguing that no legal basis exist (Alarcon Condor, J. C. (2010)).

6.2 Legal Context

Regulatory and legal framework for environmental management: In Peruvian legislation there are besides ECA no guidelines given specifying environmental management. The UNI obtains all authority on its territory; in other words the rights to design its environmental infrastructure autonomously. The decision to take reclaimed water for irrigation has no further effect for environmental management regarding national law.

Quality parameters for reuse: UNITRAR is as institution responsible for the water quality. Recently in May an investigation project to analyse micro-organisms involved in the efficiency of stabilisation ponds and its relation to the environment has started. One expected result is the analysis of all required parameters listed in Category 3 of the *Decreto Supremo 003-2010-MINAM* to demonstrate the compliance.

Technical standards for domestic wastewater treatment: The wastewater treatment plant UNITRAR fulfils all sanitation standards of the MINSA for treatment and reuse of wastewater; *Digesa 94/12/02 Autorizacion de tratamiento y reuso N°2658.* The required maximum values for effluents of WWTPs, except of the pH-value, are fulfilled (LMS); *Decreto Supremo N°003-2010-MINAM.*

Rights to use treated wastewater: The inflow of wastewater is directly taken from the sewerage system of Sedapal. A specific authorisation has never been signed. A special right for reuse does not exist and as long as it is applied for own application recognized by Sedapal as external support in treatment process (Torres, J. (2010)).

Rights to sell treated wastewater (provide service of reclamation): The condition for a commercialisation of reclaimed water is not specifically defined and regulated in Peruvian legislation. In theory, fulfilling all quality requirements mutual contracts are not forbidden.

6.3 Institutional Aspects

6.3.1 Institutions

The institutions with decision-making power acting in the study area are combined in six groups according to their competences, interests and relationships:

- UNI: The directory of the National University of Engineering as superintendence of the whole educational institution supports the implementation of wastewater reuse. The interest is besides its function of creation and distribution of knowledge seen for image purposes. A financial or management support is not been given.
- Faculty of Environmental Engineering: Although in general supporting wastewater reclamation and reuse the UNITRAR belonging to the Faculty of Environmental Engineering is only poor integrated in the faculty and study courses. The entity UNITRAR is not fully recognized as an autonomous functional working WWTP and by now handled as office for investigation and visit centre.
- UNITRAR: The chance to assign the effluent for reuse instead of discharging back in the sewerage system is seen as opportunity to redefine its institutional objectives. However a perspective of

commercialisation is still not given which let the question of financial adjustment open.

- Viveros: Receiving free water while charging the faculties for the provided service is an ideal situation. Moreover, an extension of service on the university area, included in the *plan paisajistico* is a great opportunity to gain experience to enter to external markets.
- Public (students, professors, working personal): People entering daily the area of the university request an environmentally friendly and green atmosphere. The treatment and reuse of wastewater is supported and seen as part of environmental protection. Considering possible risks for human health there is shown more confidence in UNITRAR as in governmental institutions.
- Neighbours show neither interest nor have any claims regarding wastewater reuse inside the area of the UNI.

6.3.2 Management

Water and wastewater management: The management is divided in two sections. The first one is consist of the whole treatment process operated by UNITRAR until the water runs in the final reservoir. This represents the interface between UNITRAR and Viveros, the second responsible entity. The Office for Infrastructure and Environmental Projects of the Faculty of Environment (Viveros) is providing the groundskeeping service for ten of the thirteen faculties. The other three institutes have charged external gardener services with this task.

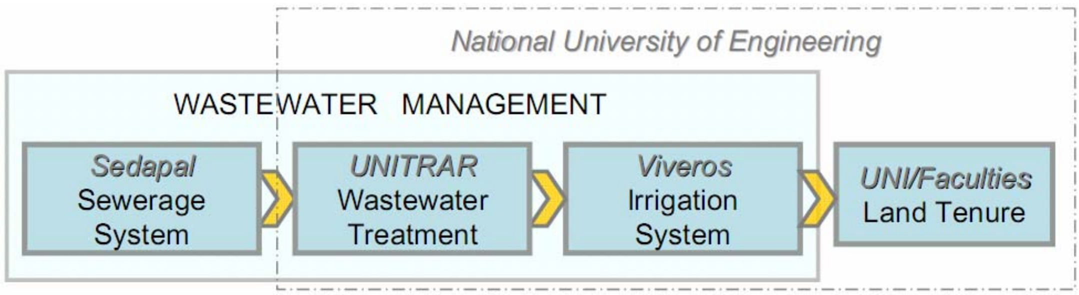

Figure 15: Wastewater Management UNI

Surveillance (control) of wastewater quality and human health: The water quality is monitored and controlled by UNITRAR. A laboratory of their own is nearly inevitable for appropriate monitoring and controlling of the plant. At least BOD, COD, TSS and Total Coliforms should be continuously analysed. Once running this laboratory there can be provided analysis for further WWTPs in Lima Metropolitana. Students disposed to participate as a part of regular laboratory trainings.

The control of the soil regarding contamination and possible effects for human health is not specified. It is supposed that Viveros as part of the task to manage the environmental development has to be also taken in account the human health. Nevertheless preventive actions such as putting up signs, where treated wastewater is used are not considered.

Management of sludge and wastewater surplus: The sludge, until it is dried, is managed by UNITRAR. Later it is collected and used from Viveros for own applications. The solid waste, mainly organic and plastic waste removed by the screening device is disposed nearby in an open hole treated with calcium. As an educational institution there should be applied a more sustainable alternative in order to be an example for environmental protection.

Risk management of hazard and contingencies: A special risk management plan in situation of hazards is not been developed. In case of any quality problems the water can be any time discharged back to the sewerage system opening a by-pass. Potential problematic events consider disposals of colours, oils or greases. The detection of any anomalies is confidentially done by the technicians working in UNITRAR.

6.4 Social/Cultural Aspects

Actors (direct, indirect, groups of interest): The largest group of stakeholders are all persons coming to the university, independent of the purpose, and getting indirectly in contact with the wastewater reuse. The determining facts for them are design and size of green spaces. The situation for students and professors is different where environmental management and environmental technologies form part of their field of studies. To fulfilling the task of an investigation plant UNITRAR should be integrated more in study courses, especially in the case of internships and laboratory analysis. The students are willing to gain practical experiences. Diverse tasks in environmental as well as in technical fields could be formulated as topics for student-projects and thesis.

Likewise, the employees working for UNITRAR or Viveros are recognized as direct actors. The situation, working with wastewater expresses no further personal problems. Important for them is that safety measures are being taken care of, and that the employer provides them with protective clothes. Social disadvantage or cultural disputes do not emerge.

Knowledge about wastewater treatment and reuse: Inside the university area referred to an education of the persons on academic level are general processes of treatment and possible reuse activities well known. The situation is different for the students getting in contact with reclaimed water. Students, having a picnic on the lawn or jumping through the irrigation system are frequently observed during summer months. Information specifying green areas irrigated by wastewater and how to behave has to be immediately published.

Public Perception Level: The vast majority of the people entering the area of the UNI accept without a doubt the use of reclaimed water for irrigation of lawn, trees and sports fields. The way how intensive controls of water quality are performed and which preventive actions have been established in case of non-conformance represent the key role in the acceptance. However, the confidence of the students and employees remains as long as no infections or diseases occur caused by potential presence of pathogenic organisms.

6.5 Economic Aspects

6.5.1 Capabilities

Investment, borrowing, and operation capability: Financial reasons in particular high investment costs are named as the limiting factor. The budget of the UNITRAR depends on the budget planning of the faculty of environmental engineering covering the fix costs. An economic profitability of its own is not designated until now. Further improvements and developments of the system including analyses that will be made are financed as part of investigation projects.

Different is the economical situation of Viveros. The possibility to charge for the provided service allows certain economic liberty regarding budget planning. Furthermore, the big investment, the new irrigation system is funded as part of the common project by the directory of the UNI. Under the current condition there has not been planned any payment or financial adjustment which would allow the use of "own" treated wastewater free of charge. Nevertheless the economical potentials are not exploited. Services for faculties are charged by approximately 30% of the common price and common areas, strictly seen under the responsibility of the directory are not been charged. A profit to invest in new machinery and own plants cannot be made.

Strategy funding (structure and funding sources): The idle situation would present auto-financing entities. That means that possibilities of income have to be created and/or exploited. These are:

• Profit by selling water • Profit by providing lab-analysis for other WWTPs	UNITRAR
• Profit by selling plants and natural fertilizer • Profit by selling service	Viveros

An alternative funding strategy is like in the past via investigation and research projects. However this approach seems to be more complex and depends more on external decisions than can be influenced by UNITAR.

Financing strategies of projects are specified for certain tasks and to gain economical advantages for the plant is not ensured. This approach can be used more for collection of data and laboratory analysis.

6.5.2 Indicators (Efficiency)

Financial profitability: It is difficult to make an exact statement to profitability in financial terms. Starting by the treatment process is due to no financial gains or benefits for UNITRAR is only seen optimistically in better image and reputation. The economic development of Viveros is under better conditions. Its income depends on prices fixed by agreements with faculties. For the end-user, the faculties have to evaluate how much was/is paid for potable water and external groundskeeping service compared to the new system now.

The situation, especially for UNITRAR changes when a price for reclaimed water will be fixed and external customers will be involved. In a sensitivity analysis it has been evaluated that the range of costs and prices to assess if a proposed price of 1 Sol per m^3 (0.35$/$m^3$) is realistic. This would be a financial benefit of up to 11.000 Soles (3860$) per month.

Economic valuation of environmental impacts: In general environmental impacts can be classified resulting as positive improving human health and environmental conditions. The environmental benefits are in revitalisation of soil, a related extension of green space which includes a reduction of dusty arid areas and less contamination through noise caused by the nearby highway. The economic profit due to the fact that the UNI is a public educational institution is seen more in satisfaction of environmental and human tasks as its financial benefit.

7 Evaluation

7.1 Feasibility

The analysis of the case study shows that under current conditions an integrated model of water reclamation and reuse is perfectly feasible. On the example of the UNI it is established how today at least partially wastewater reuse is implemented for irrigation activities. But on the other hand this example is also clearly demonstrated that there do still exist several serious problems in all five aspects.

Multiple reasons can be traced back to the current situation of Lima/Peru although many spaces for improvement exist on individual level like in the case of the UNI. Starting by the wastewater treatment process it has been shown that even by the half of the water flow it is insufficient regarding required ECA values. According to the analysis made by Muller it is demonstrated that values of BOD and Total Coliforms exceed required limits (Muller, S.A. (2009)). Capacity and efficiency could be improved by additional aeration unit in the stabilisation ponds and final disinfection with the aim to meet legal requirements. Furthermore sustainable solutions for solid waste disposal and escaping gas have to be thought about.

The division between water reclamation and reuse like it is done in the UNI is one possible approach to subdivide competences and responsibilities in wastewater management (see Figure 15, p. 55). The vulnerably of this system model is the risk management. Monitoring and controlling as well as emergency plans have not been established.

An economical efficiency is hard to evaluate regarding the area of Lima Metropolitana. Values for environmental protection or new green areas are not identified. Nevertheless to cover the costs of wastewater treatment there have to be established payments suggested as part of the tariff system for consumers. A further step would be an allocation of financial value and the rights to sell reclaimed water. Developing a system with economical profitability would facilitate the implementation of wastewater reuse and eliminate arguments concerning economical limitations from Sedapal's side.

7.2 Strengths and Opportunities

The strength of wastewater reuse in Lima Metropolitana is obviously in the high potentials of water conserved for human consumption and environmental protection. This much more to offer for human consumption without extending the caption system means a sustainable adjustment of already existing resources. A further advantage for the arid soil in the coastal region regarding agricultural and landscape irrigation is the additional source of nutrients, such as nitrogen and phosphorus; reducing the need for costly synthetic fertilizers.

Under the condition that that water has been reclaimed properly are several opportunities in the urban zone conceivable for consumers with various non potable applications:

- Irrigation of public parks, schoolyards, golf courses, soccer fields, avenues, etc.
- Car washing, especially for big consumers like the central bus station, the airport and the harbour.
- Dust control for small roads.
- Artificial lakes, landscape projects including regeneration of river streams (Rimac, Chillon, Lurin).
- (toilets in big commercial and industrial buildings)
- (Industrial Refrigeration)

Although in all five criteria are points to improve it can be concluded that infrastructure and basic technical requirements in the form of treatment technology and related know-how are fulfilled. A market for wastewater does not exist but for several private and public applications it is an economically attractive alternative instead of potable water usage. Most of the people understand the reasoning of reusing wastewater and accept it as alternative for irrigation, but meanwhile justifiedly mistrust in effectiveness of public treatment facilities and resulting threats for infections.

7.3 Weaknesses and Risks

Lima Metropolitana respective for Peru has currently an unclear situation regarding environmental legislation. Although standards for water quality (ECAs and LMPs) have been established are not considered wastewater reuse and deleterious impacts of untreated wastewater discharge. The task to elaborate a legal framework by the state is even by its strict defined ECAs not been fulfilled. Who is responsible, how controls have to be performed, how should an emergency action plan be defined, which are the sanction methods, etc. are management topics, which are only considered for drinking water process. Referred to handling of wastewater it is shown that an independent autonomous control by private actors and municipalities themselves is not sufficient. The risk for environmental and human safety is omnipresent. Especially public reuse activities by municipalities are demonstrated several cases of contamination.

Moreover, the second significant weakness is the institutional framework. The performance of licensing and controlling of wastewater treatment plants is not in adequate conditions. The hope is set in the creation of ANA as governmental oversight in the water sector for the future. But whether it will have the power of self-assertion to put required guidelines and supervising tasks into practise is questionable. Furthermore the little information in social, technical and economical aspects is hindering the process. However regarding soil capacity and its level of contamination is first of all reliable information needed to make exact statements about effectiveness and economic benefits.

8 Outlook Lima 2040

A greener city with adequate water management is commonly wanted, and this is expressed by politicians, government officers and citizens (Roman et al. (2007)). However the real potential for Lima Metropoilitana is not known. The stringent necessity of integrated and more sustainable water management strategy is slowly getting recognized but the research for alternative models is still in the beginning. The approach suggested in this thesis is to implement wastewater reuse for irrigation as part of regional and local strategy to adjust water demands to existing offers.

8.1 Potential for Linking Urban Green Space, Agriculture & Wastewater

The potentials for linking green space, agriculture and wastewater in Lima Metropolitana are in the substituting the drinking water used for irrigation by reclaimed water. A potential scenario regarding the situation of Lima Metropolitana in 2040 compared with the situation of today is shown in following Figure 16.

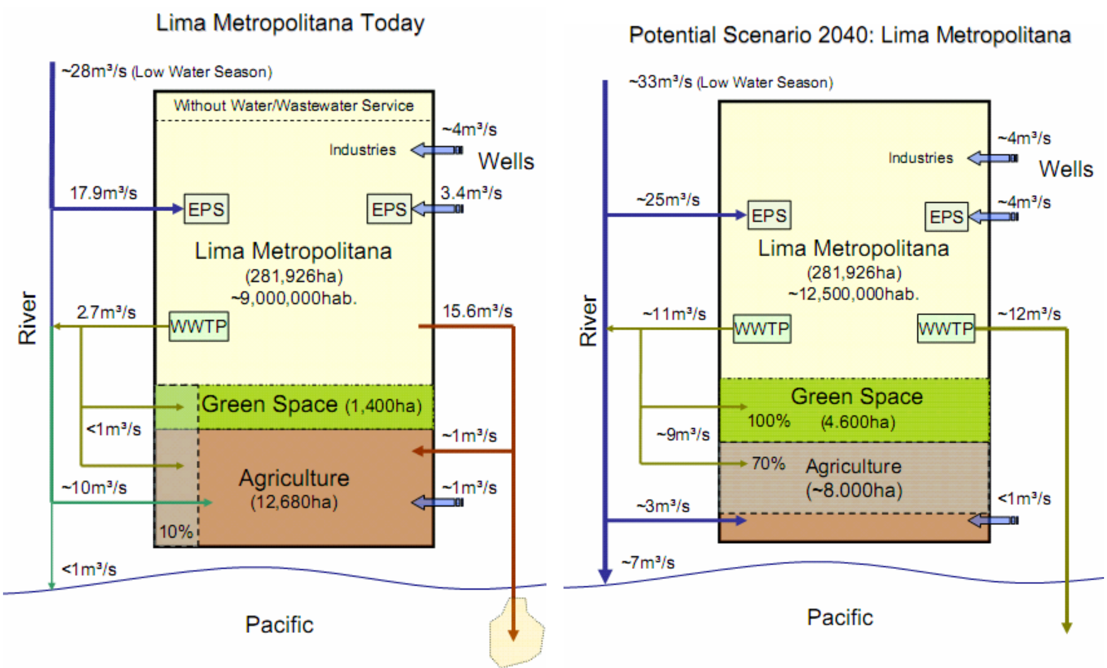

Figure 16: Scenarios for Lima: Today-2040
(adopted from Moscoso C., J.(2009); Source: see Appendix 1)

The situation of today, as previously described in the report consists of around 85% of residents connected to water and wastewater system with a daily water demand of 250l per habitant (Sedapal (2010)). The existing 1,400ha of public green space as well as the approximately 12,680ha used for agriculture are irrigated with mainly potable water (Roman et al. (2007); Rodriguez S., N. and Cespedes S., S. (2007)). Private green areas are not being considered. Less than 15% of wastewater is treated before disposed in the sea and the reuse of wastewater for irrigation is under 10% (Sedapal (2010); Moscoso C., J. (2009)).

Under optimal conditions for 2040 are 100% of the residents connected to drinking water supply and sewerage system. The reservoir system in the mountains and the drinking water system have been improved and upgraded to capture over 70% of the river flow supported by $4m^3/s$ from wells without overstraining the aquifers (Leon Suematsu G. (2009)). The demand of $29m^3/s$ is assumed to an ideal consumption of 200l/day per resident. Environmental and recreative areas have been extended as by the WHO required to 4600 ha (IMP (2008)). The whole volume of generated wastewater is been treated before up to approximately 40% of it can be reused to irrigate 100% of the green areas and 70% of agricultural zone. The other half of the wastewater is discharged to the river and sea after having been treated.

This potential future scenario illustrates an ideal situation for an environmental healthy city. Water demands for residents and green spaces are satisfied and aquatic contamination by untreated wastewater effluents is eliminated. It can not be seen as strategy to solve the water deficit situation completely, but it shows in a clear form what potential there is behind the concept of wastewater reuse.

8.2 Strategy for Lima/Peru

The stringent necessity of integrated and more sustainable water management strategy is being recognized, and environmental protection and water scarcity are the two main points for future policies regarding water and wastewater management. The plan for 100% treatment of domestic wastewater is in progress but up to which degree water quality will be treated/reclaimed is not defined. As shown in Figure 16 a 100% wastewater reuse approach is not reliable, which leads to the suggestion to divide the treatment processes into two levels of quality as defined by Asano in Figure 5, p.16 (Asano, T.2001)):

- Treated wastewater, fulfil the quality requirements established as LMS before it is discharged into the sea.
- Reclaimed water, fulfil quality requirements predestined for reuse.

The proposed strategy of wastewater reuse favour two approaches concerning the conditions of Lima Metropolitana: A decentralised model and a combination model of central and decentralised concepts.

Decentralised Model

This approach is a development and extension of the already existing structure. Small, independent wastewater treatment unities installed near the reuse areas. Especially for parks and green areas in districts in the city centre is this model proposed because of the long distance to existing WWTPs operated by Sedapal (see Appendix 4). This model is facilitating the technical operative process but includes a range of individual actors. The administrative burden and the regulation of many “small” actors are some of the prime inconveniences of this proposal.

Combination of Decentralised & Central Model

The fact that the plan *Aguas Limpias* has as objective the 100% of wastewater treatment by the two WWTPs, *La Taboada* and *La Chira* is the demand of wastewater treatment theoretically satisfied. This model implies a development of a separated conduction network with various reservoirs. The user can conduct directly to these reservoirs or like in the case of municipalities continues, with its irrigation practices charging their trucks from these stations. In this approach, Sedapal would be integrated as the main responsible entity for wastewater treatment and distribution and would be overtake the monitoring and controlling tasks for existing autonomous projects. The big difficulty is in the non-cooperation of institutions concerning infrastructure planning and related funds for investment.

The main driving force for Lima Metropolitana in both models could be Sedapal. It is the central actor in water and wastewater management operating water supply, sewerage system and wastewater treatment plants in the city. The required knowledge and technology is (although not working satisfactorily) available.

8.3 Recommendations

The main points of concern which have to be improved to represent water reclamation and reuse a reliable option can be summarised as follows:

- Improve wastewater treatment technology, especially implementation of disinfection processes and maintain them regularly.
- Evaluate the area of Lima Metropolitana according to potential demands of reclaimed wastewater.
- Support public programs for broader acceptance and provide participative projects.
- Introduce continuous payments for wastewater disposal and establish a rate for wastewater reuse activities (in order to create economical benefits for Sedapal).
- Develop/define management body focused on control and monitoring of wastewater treatment and reuse processes. This includes also an evaluation of the possibility to transfer Sedapal under the competence of the Regional Government of Lima Metropolitana and

the assessment of the opportunity to hand all WWTPs to a private company supervised by Sedapal.

- Develop a legal framework for wastewater reuse specified for different reuse activities in order to provide human and environmental safety.

9 Conclusion

Wastewater reuse should not be seen as strategy to solve the deficit situation but it has to be recognized as a sustainable approach to tackle this problem while protecting the environment from water pollution. The first step to implement wastewater reuse is done as shown by several private and public projects operating half of the WWTPs in Lima Metropolitana to reuse wastewater for irrigation purposes.

The main tasks correspond now to developing the framework for water reclamation and reuse and improving the existing practises. The huge backlog is on governmental level. It has to accept, in the first instance, that wastewater reuse is a reliable alternative to reduce water demand, contamination and environmental destruction by hydrological constructions in the Andean region. And, in the second step the population has to be sensitized by educational and informative programs to promote a participative development process.

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APPENDIX

Appendix 1: Calculations

Exchange Rate: (27.04.2010)

1 [€] Euro (EUR) = 3.7480 [S/] Peru Nuevo Soles (PEN)
1 [$] US Dollar (USD) = 2.8765 [S/] Peru Nuevo Soles (PEN)

Figure 1: Distribution Population/Territory/ Water, Peru

Distribution Population/Territory/Water, Peru

Region	Population [%]	Territory [km2]	Territory [%]	Water [%]
Pacific	70	279.689	21,8	1,8
Atlantic	26	956.751	74,4	97,7
Titicaca Lake	4	48.775	3,8	0,5
Total	100	1.285.215	100	100

Source: MINAM, INEI, PNUMA (2009): "Iniciativa Lationoamericana y Caribena para el Desarrollo Sostenible: Indicadores de Seguimiento - Peru 2008"; Published by MINAM, INEI and PNUMA, Lima 2009, p. 7.

Figure 16: Scenarios for Lima: Today-2040

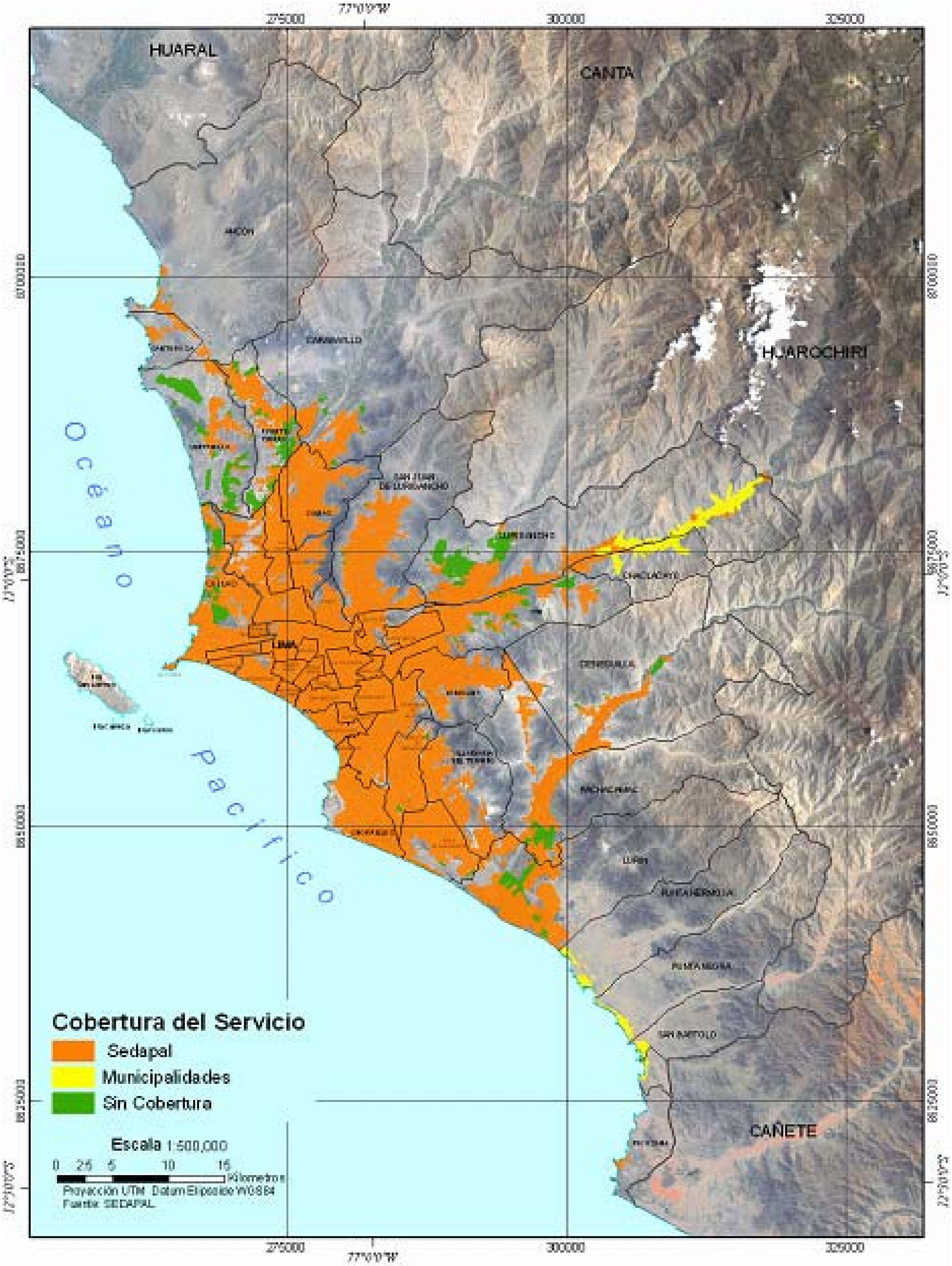
Lima Metropolitana Today:

Riverflow: (Rimac: 26m³/s, Chillon: 2m³/s, Lurin:0m³/s); Senamhi, Gamarra Molina, W. (2008)
Drinking Water Consumption: 21.3m³/s; Sedapal (2010)
Consumption Industries: 4m³/s; Moscoso C., J. (2010b)
Green Space: 1,400ha; Roman, A. et al (2007)
Agricultural Space: 12,680ha; Rodriguez S., N. and Cespedes S., S. (2007)
Wastwater Treatment/Disposal: 2.7m³/s + 15.6m³/s; Sedapal (2010)
Wastewater Reuse: Moscoso C., J. (2009)
Untreated Wastewater Use: Rodriguez S., N. and Cespedes S., S. (2007)
Agricultural Use from Wells: Rodriguez S., N. and Cespedes S., S. (2007)

Lima Metropolitana 2040:

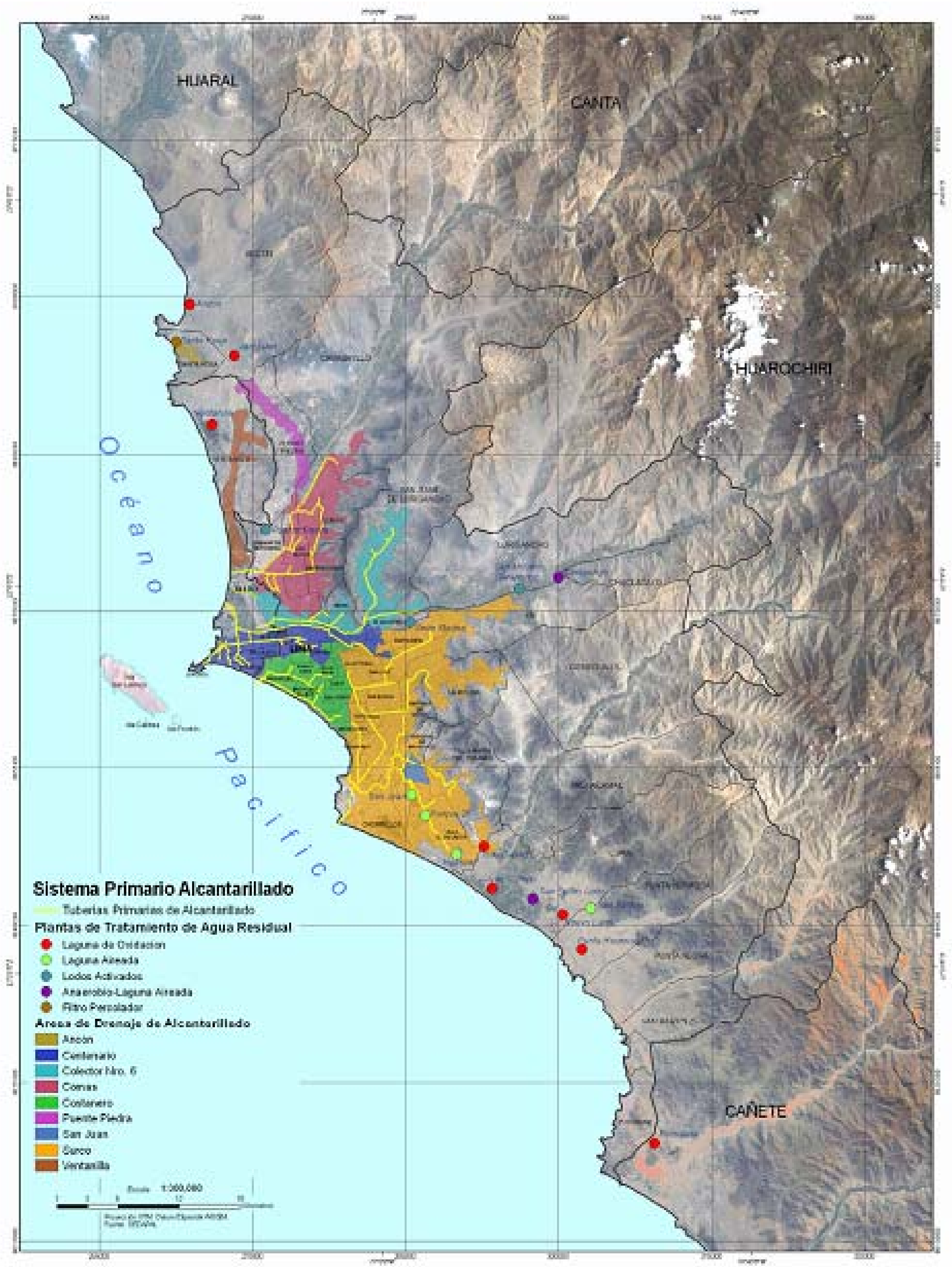
Riverflow: additional 5m³/s by Marca IV, Leon Suematsu, Guillermo (2009)
Drinking Water Purification: La Atarjea 18m³/s, Chillon 2m³/s, Huachipa 5m³/s, max. Wells 4m³/s; Leon Suematsu, Guillermo (2009)
Consumption Industries: 4m³/s; Moscoso C., J. (2010b)
Green Space: 1,400ha; Roman, A. et al (2007)
Agricultural Space: 15%less in last 10 years, Rodriguez S., N. and Cespedes S., S. (2007)
Wastewater Reuse in Agriculture for non food production: ~70%; Moscoso C., J. (2010b)
Agricultural Use from Wells: Rodriguez S., N. and Cespedes S., S. (2007)

Appendix 2: Covered Area of Drinkwater Supply, Lima, Peru



Source: Sedapal: (2005), “Atlas Ambiental de Lima 2005”

Appendix 3: Sewerage System, Lima, Peru



Source: Sedapal: (2005), "Atlas Ambiental de Lima 2005"

Appendix 4: WWTPs/Collectors operated by Sedapal

WWTPs/Collectors Sedpal 2009

No.	Area	WWPT	l/s	Sub %	Total %	Real Capacity l/s	Occupancy %	Pre-treatment	Primary & Secondary Treatment	Disinfection (designed)
1	North	Ventanilla	296,59	10,7		250	119	Yes	Primary Pond + Secondary Pond (anerobic-facultativ)	Yes
2	North	Punte Piedra	442,67	16,0		420	105	Yes	Sequence Batch Reactor (SBR), Aeration Tank (activated sluge)	Yes
3	North	Ancon	38,22	1,4		20	191	Yes	Primary Pond + Secondary Pond	Yes
4	North	Santa Rosa	9,13	0,3		18	51	Yes	Primary Pond + Secondary Pond + Biological Filter	Yes
5	East	Carapongo	422,87	15,2		500	85	Yes	Reactor UASB/Anareobic Pond + Aeration + Sedimentation	Yes
6	East	San Antonio	16,14	0,6		20	81	Yes	Sequence Batch Reactor (SBR), Aeration Tank (activated sluge)	Yes
7	East	Atarjea	1,00	0,0		1	100	Yes	Sequence Batch Reactor (SBR), Aereation Tank (activated sluge)	Yes
8	East	Cienguilla *	52,76	1,9		-	-	Yes	no infromation available	-
9	East	Hipodromo Punto A	-	-		220	-	Yes	No	No
10,11	South	Huascar - Parque 26 **	77,71	2,8		70 (25)	111	Yes	Oxidation Ponds + Sedimentation Pond + Maturation Pond	Yes
12	South	San Juan	422,57	15,2		400	106	Yes	Oxidation Ponds + Sedimentation Pond + Maturation Pond	Yes
13	South	Jose Galvez	51,38	1,9		100	51	Yes	Reactor UASB/Anareobic Pond + Aeration + Sedimentation	Yes
14	South	San Pedro de Lurin	23,92	0,9		20	120	Yes	Reactor UASB/Anareobic Pond + Aeration + Sedimentation	Yes
15	South	J.C. Tello	22,79	0,8		10	228	Yes	Primary Pond + Secondary Pond	Yes
16	South	Nuevo Lurin	20,58	0,7		10	206	Yes	Primary Pond + Secondary Pond	Yes
17	South	Pucusana	24,02	0,9		10	240	Yes	Primary Pond + Secondary Pond	Yes
18	South	San Bartolo	838,71	30,2		800	105	Yes	Oxidation Ponds + Sedimentation Pond + Maturation Pond	Yes
19	South	Punta Hermosa	14,13	0,5		10	141	Yes	Primary Pond + Secondary Pond	Yes
Subtotal			2.775	100	15,3	2659	104			
		Collector/Outfall								
20	North	La Taboada	10.833	69,4	58,4	14.000	77	Yes	No	No
21	South	La Chira	4.769	30,6	26,3	6.500	73	Yes	No	No
Subtotal			15.602	100	84,7	21.500				
Total ***			18.140		100	45499				

*) starting from june 2009

**) WWTP Parque 26 receive effluent from WWTP Huascar (2 plants forming 1 system)

***) Total numbers adoped from the same report, they do not correspond to the sum

Source: Sedapal (2010); Sedapal (2009a);Sedapal (2009b)

Appendix 5: Legislation

Decreto Supremo N° 023-2009-MINAM:

National Environmental Standards of Water Quality (ECA)
Category 3: Irrigation and Water for Animals

CATEGORÍA 3: RIEGO DE VEGETALES Y BEBIDAS DE ANIMALES

PARÁMETROS PARA RIEGO DE VEGETALES DE TALLO BAJO Y TALLO ALTO		
PARÁMETROS	**UNIDAD**	**VALOR**
Fisicoquímicos		
Bicarbonatos	mg/L	370
Calcio	mg/L	200
Carbonatos	mg/L	5
Cloruros	mg/L	100-700
Conductividad	(uS/cm)	<2 000
Demanda Bioquímica de Oxígeno	mg/L	15
Demanda Química de Oxígeno	mg/L	40
Fluoruros	mg/L	1
Fosfatos - P	mg/L	1
Nitratos (NO3-N)	mg/L	10
Nitritos (NO2-N)	mg/L	0,06
Oxígeno Disuelto	mg/L	> =4
pH	Unidad de pH	6,5 – 8,5
Sodio	mg/L	200
Sulfatos	mg/L	300
Sulfuros	mg/L	0,05
Inorgánicos		
Aluminio	mg/L	5
Arsénico	mg/L	0,05
Bario total	mg/L	0,7
Boro	mg/L	0,5-6
Cadmio	mg/L	0,005
Cianuro Wad	mg/L	0,1
Cobalto	mg/L	0,05
Cobre	mg/L	0,2
Cromo (6+)	mg/L	0,1
Hierro	mg/L	1
Litio	mg/L	2,5
Magnesio	mg/L	150
Manganeso	mg/L	0,2
Mercurio	mg/L	0,001
Níquel	mg/L	0,2
Plata	mg/L	0,05
Plomo	mg/L	0,05
Selenio	mg/L	0,05
Zinc	mg/L	2
Orgánicos		
Aceites y Grasas	mg/L	1
Fenoles	mg/L	0,001
S.A.A.M. (detergentes)	mg/L	1
Plaguicidas		
Aldicarb	ug/L	1
Aldrín (CAS 309-00-2)	ug/L	0,004
Clordano (CAS 57-74-9)	ug/L	0,3
DDT	ug/L	0,001
Dieldrín (N° CAS 72-20-8)	ug/L	0,7
Endrín	ug/L	0,004

PARÁMETROS PARA RIEGO DE VEGETALES DE TALLO BAJO Y TALLO ALTO		
PARÁMETROS	UNIDAD	VALOR
Endosulfán	ug/L	0,02
Heptacloro (N° CAS 76-44-8) y heptacloripoxido	ug/L	0,1
Lindano	ug/L	4
Paratión	ug/L	7,5

CATEGORÍA 3: RIEGO DE VEGETALES Y BEBIDAS DE ANIMALES

PARÁMETROS PARA RIEGO DE VEGETALES.			
PARÁMETROS		Vegetales Tallo Bajo	Vegetales Tallo Alto
	Unidad	Valor	Valor
Biológicos			
Coliformes Termotolerantes	NMP/100mL	1 000	2 000(3)
Coliformes Totales	NMP/100mL	5 000	5 000(3)
Enterococos	NMP/100mL	20	100
Escherichia coli	NMP/100mL	100	100
Huevos de Helmintos	huevos/litro	<1	<1(1)
Salmonella sp.	Ausente		Ausente
Vibrion cholerae	Ausente		Ausente

PARÁMETROS PARA BEBIDAS DE ANIMALES		
PARÁMETROS	UNIDAD	VALOR
Fisicoquímicos		
Conductividad Eléctrica	(uS/cm)	<=5000
Demanda Bioquímica de Oxígeno	mg/L	<=15
Demanda Química de Oxígeno	mg/L	40
Fluoruro	mg/L	2
Nitratos-(NO3-N)	mg/L	50
Nitritos (NO2-N)	mg/L	1
Oxígeno Disuelto	mg/L	> 5
pH	Unidades de pH	6,5 – 8,4
Sulfatos	mg/L	500
Sulfuros	mg/L	0,05
Inorgánicos		
Aluminio	mg/L	5
Arsénico	mg/L	0,1
Berilio	mg/L	0,1
Boro	mg/L	5
Cadmio	mg/L	0,01
Cianuro WAD	mg/L	0,1
Cobalto	mg/L	1
Cobre	mg/L	0,5
Cromo (6+)	mg/L	1
Hierro	mg/L	1
Litio	mg/L	2,5
Magnesio	mg/L	150
Manganeso	mg/L	0,2
Mercurio	mg/L	0,001
Níquel	mg/L	0,2
Plata	mg/L	0,05
Plomo	mg/L	0,05
Selenio	mg/L	0,05
Zinc	mg/L	24
Orgánicos		
Aceites y Grasas	mg/L	1
Fenoles	mg/L	0,001
S.A.A.M. (detergentes)	mg/L	1
Plaguicidas		
Aldicarb	ug/L	1
Aldrín (CAS 309-00-2)	ug/L	0,03
Clordano (CAS 57-74-9)	ug/L	0,3
DDT	ug/L	1
Dieldrín (N° CAS 72-20-8)	ug/L	0,7
Endosulfán	ug/L	0,02

Endrín	ug/L	0,004
Heptacloro (N° CAS 76-44-8) y heptacloripóxido	ug/L	0,1
Lindano	ug/L	4
Paratión	ug/L	7,5
Biológicos		
Coliformes Termotolerantes	NMP/100mL	1 000
Coliformes Totales	NMP/100mL	5 000
Enterococos	NMP/100mL	20
Escherichia coli	NMP/100mL	100
Huevos de Helmintos	huevos/litro	<1
Salmonella sp.	Ausente	
Vibrion cholerae	Ausente	

NOTA:
NMP/100: Número más probable en 100 mL
Vegetales de Tallo alto: Son plantas cultivables o no, de porte arbustivo o arbóreo y tienen una buena longitud de tallo. las especies leñosas y forestales tienen un sistema radicular pivotante profundo (1 a 20 metros). Ejemplo; Forestales, árboles frutales, etc.
Vegetales de Tallo bajo : Son plantas cultivables o no, frecuentemente porte herbáceo, debido a su poca longitud de tallo alcanzan poca altura. Usualmente, las especies herbaceas de porte bajo tienen un sistema radicular difuso o fibroso, poco profundo (10 a 50 cm). Ejemplo: Hortalizas y verdura de tallo corto, como ajo, lechuga, fresas, col, repollo, apio y arveja, etc.
Animales mayores: Entiéndase como animales mayores a vacunos, ovinos, porcinos, camélidos y equinos, etc.
Animales menores: Entiéndase como animales menores a caprinos, cuyes, aves y conejos
SAAM: Sustancias activas de azul de metileno

Source: MINAM (2008): "Aprueba los Estandares Nacioinales de Calidad Ambiental para Agua"; Decreto Supremo N° 002-2008-MINAM, Published in *El Peruano* p.222-227, Lima, 31.07.2008.

Decreto Supremo N° 003-2010-MINAM:

Maximum Values for Effluents of WWTPs (LMP).

LÍMITES MÁXIMOS PERMISIBLES PARA LOS EFLUENTES DE PTAR

PARÁMETRO	UNIDAD	LMP DE EFLUENTES PARA VERTIDOS A CUERPOS DE AGUAS
Aceites y grasas	mg/L	20
Coliformes Termotolerantes	NMP/100 mL	10,000
Demanda Bioquímica de Oxígeno	mg/L	100
Demanda Química de Oxígeno	mg/L	200
pH	unidad	6.5-8.5
Sólidos Totales en Suspensión	mL/L	150
Temperatura	°C	<35

Source: MINAM (2010): "Aprueba Limites Maximos Permisibles para los efluentes de Plantas de Tratamiento de Aguas Residuales Domesticas o Municiplaes"; Decreto Supremo N° 003-2010-MINAM, Published in *El Peruano* p.675-676, Lima, 17.03.2010.

Appendix 6: Water Economics

Water Tariff System/Costs of Water 2009

	Use	m3	Soles/m3
Sedapal (4,44S/ as monthly rate for connection)	Domestic	social	1,311
		<20	1,311
		20-30	1,735
		30-50	2,675
		50-80	2,675
		80<	4,005
	Industrial		5,291
	Comercial		5,291
	Government		2,675
Truck Supply	Domestic		8~10
	Irrigation/Agriculture		6~8
Reuse of WW by Municipalities	Irrigation		2,5~3,5

Source: Sedapal (2010): "Anuario Estadistico 2009". Published by: Gerencia de Desarrollo e Investigacion, Equipo Planeamiento Operativo y Financiero, Lima 11.03.2010.
Acevedo, A.M. (2010).

Appendix 7: Wastewater Volume UNITRAR

Water Volume Unitrar

			Reuse				
		influent	total	UNI	external	of treated V.	of max. V.
		m3	m3	m3	m3	%	%
max.cap.		25.920					
Feb 07		13.545	1.898	810	1.088	14	7
Apr 07		16.992	1.610	1.610	0	9	6
Mai 07		13.382	1.535	910	625	11	6
Jun 07		16.404	1.115	1.070	45	7	4
Jul 07		10.992	430	430	0	4	2
Aug 07		11.123	430	430	0	4	2
Sep 07		9.492	430	430	0	5	2
Okt 07		9.205	430	430	0	5	2
Nov 07		14.227	430	430	0	3	2
Dez 07	?	29.093	430	430	0	1	2
Jan 08		12.148	1.340	1.340	0	11	5
Feb 08		13.038	940	940	0	7	4
Mrz 08		3.795	910	910	0	24	4
Apr 08		10.592	1.170	1.170	0	11	5
Mai 08		10.592	1.170	1.170	0	11	5
Jun 08		10.593	1.170	1.170	0	11	5
Jul 08		10.761	860	860	0	8	3
Aug 08		10.180	400	400	0	4	2
Sep 08		10.291	710	710	0	7	3
Okt 08		10.761	710	710	0	7	3
Nov 08		10.094	590	590	0	6	2
Dez 08		10.342	840	840	0	8	3
Jan 09		6.543	890	890	0	14	3
Feb 09		7.593	780	780	0	10	3
Mrz 09		24.642	1.020	1.020	0	4	4
Apr 09		20.463	960	960	0	5	4
Mai 09		10.304	940	940	0	9	4
Jun 09		10.393	990	990	0	10	4
Jul 09		10.179	400	400	0	4	2
Aug 09		2.744	620	620	0	23	2
Sep 09		4.001	517	517	0	13	2
Okt 09		5.621	1.236	1.236	0	22	5
Nov 09		3.230	913	913	0	28	4
Dez 09		7.067	670	670	0	9	3
Average		11.189	867	815		10	3
New system		11.189		3330		30	13

Source: Alarcon Condor, Juan Carlos (2010)