

Integral Management of Water Resources, from the Water Footprint Assessment of La Paz City

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1. SUMMARY

In response to a growing need for an integral management of water resources, new indicators are being developed and applied as a basis for the design of public policies aimed at increasing resilience, especially in cities, in the face of the enormous challenge of global urbanization. The Water Footprint is an indicator of water management that allows visualizing the use, consumption and pollution of water, identifies deficiencies and prioritizes measures to maintain the supply for various sectors, restore and/or maintain a good quality of water bodies and avoid social conflicts, among others. The methodology developed by the Water Footprint Network, was applied for the first time at the level of cities in the framework of the “Cities Footprint” project¹, of which one is La Paz, Bolivia.

This city shares the water supply system with the city of El Alto, which has an important demographic growth (5% per year), with a consequent increase in the demand for water. Both cities are supplied by dams that capture water from precipitation (90%) and glaciers in

the Cordillera Real (10%). The glacier contribution appears to be insignificant, however, in times of drought the contribution can reach up to 25% of the total. The total extinction of these glaciers is expected during this century, so this volume of water – which will not be available in the future – must be obtained from other sources or reduced of the city's water demand through improved management.

The assessment of the Water Footprint of La Paz aided in identifying the residential sector as the one with greater impact (85% of the total), which highlights the importance of more efficient water use at the household level. With the reduction of the residential Water Footprint, are also reduced the possibilities of water scarcity and reliance on glaciers, which in turn increases the resilience to the current and future impacts of climate change. The management of effluents in all sectors is also fundamental, as they are currently untreated and discharged directly into rivers: the gray Water Footprint of the city represents 98% of the total.

The purpose of the study is to propose public policies for integral water management in order to achieve a city that is resilient to climate change and sustainability in the use of water for future generations, starting mainly from the demand-side management. Taking

¹ Supported by CAF, CDKN, facilitated by FFLA, implemented by SASA in coordination with the MG of La Paz, Quito and Lima, and the technical assistance and validation of the Water Footprint Network and Carbonfeel. www.citiesfootprint.com.

into account that the largest volume of water used by a citizen is used for personal hygiene, measures proposed include incentives for the use of water-saving equipment, which can reduce up to 100% of water used in toilets, showers and faucets, changes in the billing of water to large consumers, etc. These measures are discussed and proposed as basis for the development of public policies at the municipal level.

2. INTRODUCTION

The demographic growth in La Paz city and, the adjacent city of El Alto, has substantially increased the water demand in the basin.

Furthermore, due to climate change and the global temperature rise -which is higher in the range of the Andes² - the surface of the glaciers is shrinking. In the case of the city of La Paz's annual contribution of glacier is 5 to 12%, but in the dry season this contribution can rise to 25% (Olmos, 2011 (a)) (Soruco, Medio siglo de fluctuaciones glaciares en la Cordillera Real y sus efectos hidrológicos en la ciudad de La Paz., 2012).

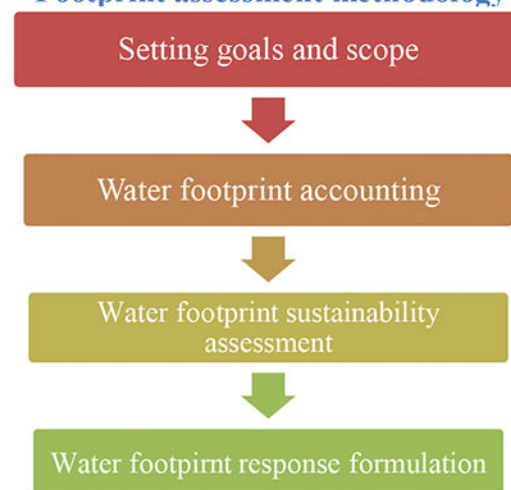
Both cities are supplied from dams that collect water from the high basins of tributary rivers of the Choqueyapu River and Titicaca Lake, to a lesser extent by the waters of Kaluyo River (high Choqueyapu basin³), and glaciers of the Cordillera Real.

For both cities, improving and implementing enhancements in water management is vital to address possible future water scarcity.

3. METODOLOGY

The quantification of Water Footprint (WF) of the city of La Paz, was performed using the methodology of The Water Footprint of Assessment Manual (Hoekstra, Chapagain, Aldaya, & Mekonnen, The Water Footprint Assessment Manual, 2011), developed by the Water Footprint Network.

Figure 1: Phases of the Water Footprint assessment methodology



Source: Own elaboration based on (Hoekstra, Chapagain, Aldaya, & Mekonnen, The Water Footprint Assessment Manual, 2011)

This methodology has been applied for the first time to a city level. The WF gives the possibility to visualize some problems and prioritize actions to maintain the water supply of the different sectors, restore and maintain a good quality of water bodies.

3.1 OBJECTIVES AND SCOPE

The objective of this evaluation was to lay foundations for the development of public policies aimed at better management of water from a new quantifiable, verifiable and easy-to-communicate indicator: the Water Footprint.

The scope of the evaluation covered the urban area of La Paz, and activities from the residential, commercial, industrial and public sector.

² Hoffmann & Requena, 2013

³ Basin unregulated, it means without reservoir

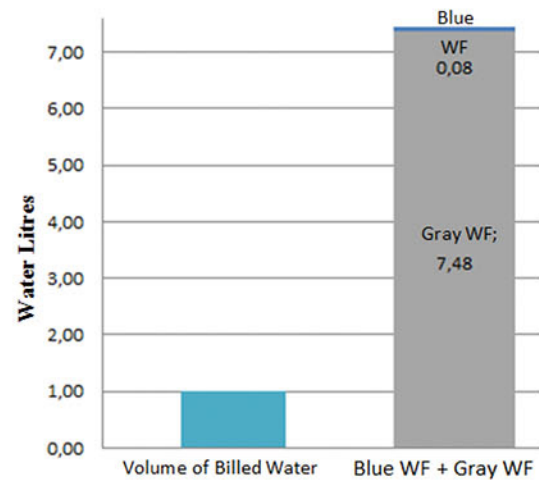
3.2 ASSESSMENT RESULTS

The total WF of La Paz City is 208.489.287 m³ for the year 2012, composed by Blue WF⁴: 3.474.592 m³ and Gray WF⁵: 204.836.986 m³. The residential sector contributes 85% to the total footprint, the industrial sector 10% and the public and commercial sectors 5%.

The Gray WF represents 98% of the total, which evidences that the main problem of water in La Paz is the contamination of water bodies by untreated effluents.

The total volume of La Paz WF is about 8 times larger than the volume of water used in the city⁶, and 5 times larger than the volume removed⁷.

Figure 2: WF Volume versus 1 liter of water billed



Source: Own elaboration base on WF La Paz city results.

⁴ The Blue WF refers to the volume of water that is extracted from the basin, evaporated or incorporated, and does not return to the same basin.

⁵ The Gray WF refers to the volume of water that a water body needs to assimilate pollutant loading to appropriate environmental standards.

⁶ It refers to the volume of water evaporated or incorporated, and does not return to the same basin.

⁷ It refers to the volume of water extracted from the basin that is not necessarily evaporated or incorporated.

3.3 SUSTAINABILITY ASSESSMENT

At the end of the dry season -between October and November-, the water volume available in the basin is minimal, and when most glacier contribution occurs.

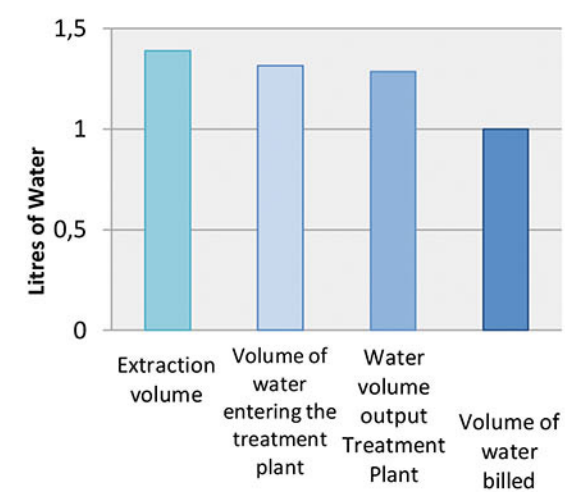
Table 1: High Basins Water Availability, year 2012 (in Hm³)

Basin	Availability	Demand = Extraction
Milluni	19,63	16,61
Kaluyo	26,51	3,53
Incachaca	8,07	5,19
AjuanKhota/Hampaturi	23,35	14,19
TOTAL	77,55	39,53

Source: (Proyecto de adaptación al impacto del retroceso acelerado de glaciares en los Andes tropicales (PRAA), 2012)

Furthermore, the losses of water on the production and distribution of drinking water, reach 39% (Olmos, 2011 (b)), that means that for 1 liter of water billed, 1,4 liters are drawn from the basin (**¡Error! No se encuentra el origen de la referencia.**).

Figure 3: Losses of water for 1 liter of billed water

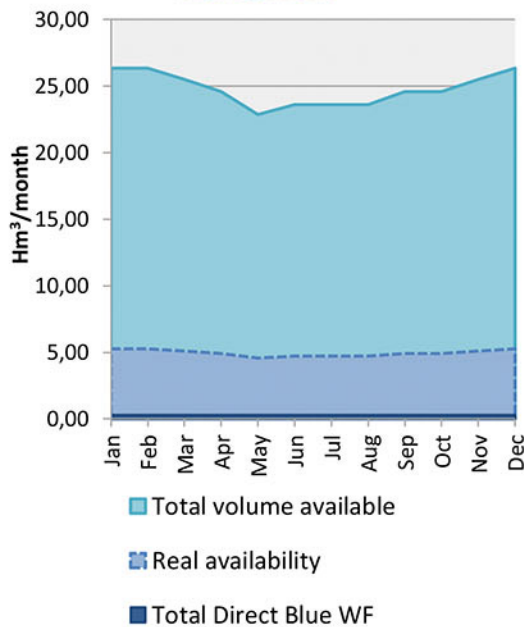


Source: Own elaboration based on (Olmos, 2011 (b))

Even those lost volumes return to the basin, are an important factor to consider for the future water supply and the operation costs for the local water company.

Regarding the Sustainability Assessment (Figure 4), it is observed that the **Blue WF** does not affect the ecological river flow, therefore it is sustainable⁸.

Figure 4: Blue WF Sustainability Assessment

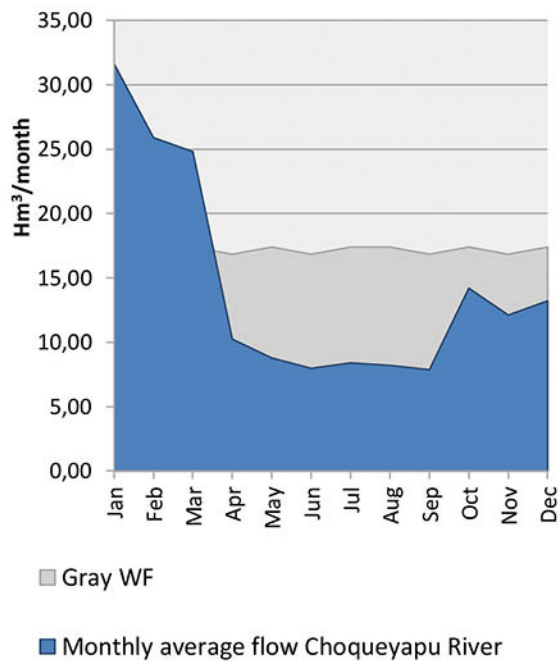


Source: Project Footprint of Cities – La Paz results

For the **Gray WF Sustainability Assessment** used as a starting point the monthly flow data at the output of Choqueyapu River. As seen in Figure 5, the Gray WF of the city repeatedly exceeds the Choqueyapu River flow. It requires 1,5 times the entire surface runoff to dilute its waters, and meet the minimum standard Class D⁹. The Gray

WF between the period of April to December is not sustainable.

Figure 5: Gray WF Sustainability Assessment



Source: Cities Footprint Project, (SENAMHI – Flow Data 1990 – 2012, 2012)

If a treatment plant for domestic wastewater were implemented, the Gray WF would be reduced between 54%¹⁰ and 73%¹¹ of the current footprint. In both cases, the Choqueyapu River would dilute the pollutant load in all months of the year, so, the gray WF could become sustainable (Figure 6).

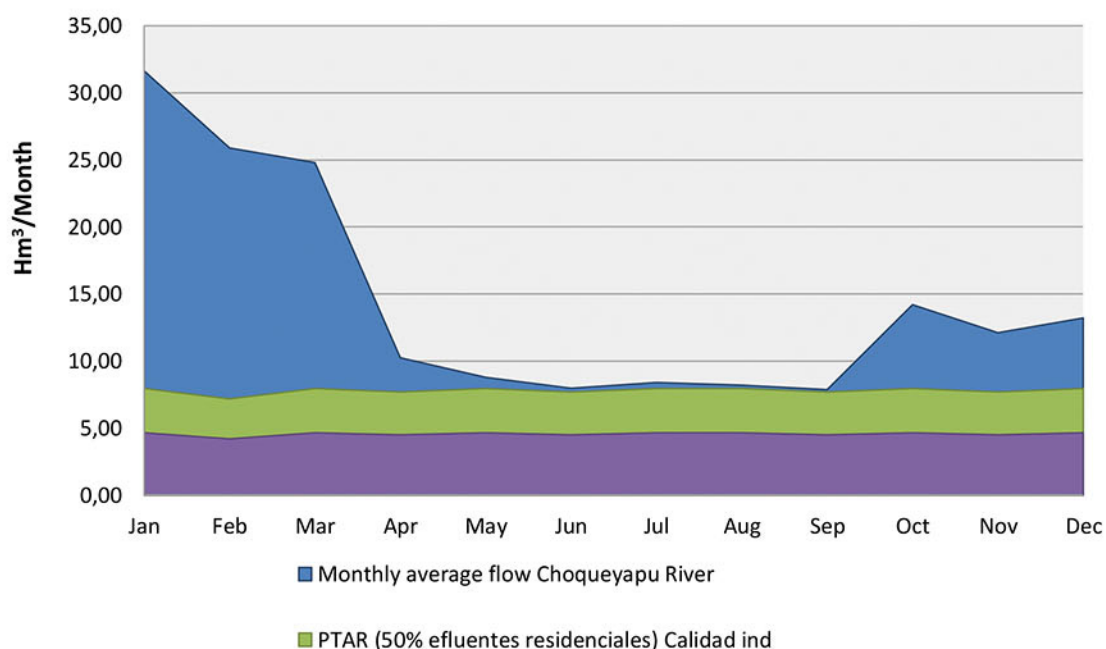
⁸ The real availability – considers only the 20% of the water volume available, the remaining 80% is considered ecological flow. (Hoekstra, Chapagain, Aldaya, & Mekonnen, The Water Footprint Assessment Manual, 2011)).

⁹ Class D Quality, refers to the maximum concentrations to body waters. (Estado Plurinacional de Bolivia, 1992)

¹⁰ Using 80 mg/l as value of maximum concentration industrial effluents. (Ind. Quality)

¹¹ Using 30mg/L as value of maximum concentration for BOD₅ (corresponding to Class D)

Figure 6: Gray WF Sustainability Assessment with treatment



Source: Own elaboration

4. RESULTS AND RECOMMENDATIONS FOR INTEGRAL WATER MANAGEMENT

The volume of water abstracted from the basin depends primarily on two factors:

- The actual demand of city sectors, reflected in the volume of water billed.
- Losses in the system from catchment, treatment and distribution to the consumer (responsibility of the local water company).

4.1 WATER DEMAND REDUCTION

To define measures to reduce water use, it's important to identify the uses differentiated activities within a household and their percentages of water use.

Table 2: Water use in the home by activity and reduction potential

USE	CONSUMPTION			POSSIBILITIES OF REDUCING
	Germany	Spain		Estimated as % of sector
	%	%		
Toilets	32	27	Implementation of low-consumption toilets	Up to 40%
			Implementation of waterless ecological toilets	Up to 100 %
			Implementation of vacuum systems	Up to 80 %
			Reuse of shower and sink gray water in toilets	Up to 100 %
			Use of rainwater in toilets	Up to 100 %
Cleaning	5	6	Reuse of shower and sink gray water	Up to 100 %
			Use of rainwater	Up to 100 %
Irrigation	3		Reuse of shower and sink gray water	Up to 100 %
			Use of rainwater	Up to 100 %
Laundry	13	19,8	Implementation of low-consumption equipment	More than 50 %
Personal Hygiene	38	35,9	Implementation of low-consumption taps and showers	More than 50 % (algunos grifos pueden ahorrar hasta 90 %)
Dishwashing	7		Implementation of low-consumption taps	Up to 70 %
Food	2	11,4		
Entire House			Use of water flow valves in the supply line	Up to 50 %

Source: Own elaboration based on (Umweltbundesamt, 2001) (CEPYME) (Abbotsford Mission Water & Sewer Services., 2011)

If the reduction potential of each proposed alternative is added, water use in a home could be reduced by up to 87%.

It is important to encourage the importation and adoption of equipment and accessories of low consumption, sensitize the population about its benefits and/or subsidize their purchase.

Furthermore, the promotion of Green Building standards in the construction sector, through property tax relief, for example, aimed at saving, reuse and recycling of water, such as:

- The construction of ecological toilets without water use with the reintegration of products with nutrients contained in compost.¹²
- Flow segregation at level house, building and/or condominium with focus on reuse and recycling of gray water for toilets, cleaning, irrigation.
- Rainwater harvesting for irrigation. With the implementation of double sanitary pipe, rainwater can also be used for toilets, washing clothes, cleaning etc.

In the city of La Paz, in an area of 100 m² roof can be harvested about 35 m³ of rainwater (based on (Boese, Regenwasser fuer Garten und Haus, 2011)). Activities can be encouraged with intensive use of irrigation water to change the source of irrigation from tap water to rainwater.

The use of rainwater and recycling gray water in the residential sector, needs

segregation of flows inside the house or condo, as well as the implementation of a second sanitary distribution piping. If captured or recycled water is only used for watering the gardens, a second pipe is not essential.

The implementation of a vacuum system¹³. These systems reduce the demand for water, Blue and Gray WF, and also produce fertilizer for green areas and energy in the form of biogas.

An important measure is the creation of models in the form of new ecological condos, with ecological management of the entire water system. Researches about different decentralized models of urban water management are being produced in Germany and China. (Dezentrales Urbanes Infrastruktur-System) (Institute for Social-Ecological Research)

4.1 REDUCCIÓN DE LA HH GRIS

It is important to reduce pollution from wastewater before it is discharged into the rivers. Water pollution reduction can be achieved by:

- Reuse and recycle of a part of the wastewater in a closed cycle (which also reduces overall water demand)
- Change to a separate sewer system. In the oldest parts of the city there is a mixed sewer. Carry stormwater to the rivers. Carry wastewater to treatment plants. Thus, bypasses to the treatment plants are avoided from water diluted during the rainy season and severe storms.
- Take sewer pipes directly to one or more purification plants. Decentralized partial treatment at

¹² 663 implementing composting toilets until 2036 is expected to serve 3978 people in peri-urban areas (Planes Maestro Metropolitanos de Agua Potable y Saneamiento de La Paz y El Alto, Informe Etapa II: Demandas futuras y estrategias de expansión, VOLUMEN IV - Escenarios y Estrategia de Mejoramiento y Expansión de los Servicios de Saneamiento, 2013)

¹³ Sewer vacuum equipment on airplanes and cruise ships, it can be used in new developments, with biogas production and use of waste as fertilizer.

least, is recommended. For example, Imhoff tanks or modern compact stationary and mobile plants could be implemented (Zeolitas e Insumos Nacionales) (Agua Market). The Imhoff tanks only treat pre sediment solids, their installation is not expensive, and are easy to operate and maintain. Implementation of a purification plant, with at least a mechanical and a biological phase with activated sludge¹⁴.

- Use sludge formed during the purification process for agricultural purposes¹⁵.

4.2 POPULATION AWARENESS

- Raise awareness among the population about the risks of some components of wastewater (use less detergent, do not throw drugs and other waste to toilets etc.)
- Encourage the use of composting toilets and use the remaining gray water for irrigation¹⁶.
- Encourage recycling of grey wastewater for use in toilets and cleaning.
- Implementation of streams segregated at the decentralized level.
- Encourage the creation of developments model including the treatment of wastewater.

4.3 SUSTAINABILITY AND POTENTIAL FOR INTRODUCTION OF DECENTRALIZED SYSTEMS

The following figure shows the decentralized water management at

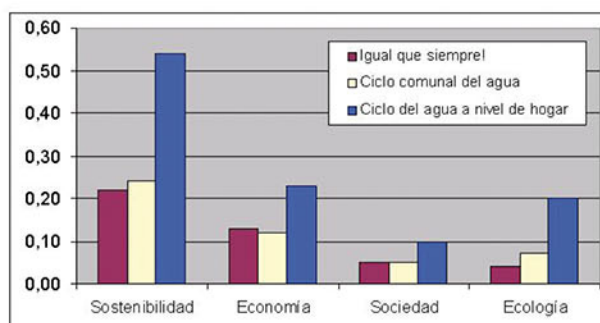
¹⁴ No stabilization ponds are recommended because of the large surface area required and its low performance.

¹⁵ Only if the contaminants are below of permissible limits.

¹⁶ The soil and plants retain the remaining contaminants by much, but the entry of toxic or pathogens are not allowed

household and state level is more sustainable, not only in ecological sense but also in an economic sense.

Figure 1: Evaluation of sustainability of three scenarios of water management



Source: (Hiessl & Toussain, 2002)

4.4 CONCLUSIONS AND VALIDATION OF WATER FOOTPRINT TOOL AS A BASIS FOR THE INTEGRAL WATER MANAGEMENT

The Water Footprint (WF) assessment methodology has been applied for the first time at city level through the Cities Footprint Project. The direct Water Footprint was measured in the geographical area of the watershed of La Paz to provide guidelines to local and national authorities on water resources management, oriented to increasing the resilience of the city.

Areas for improvement in the water supply management were identified, as the levels of losses in distribution. Unsustainability of the gray WF of the city, which is a hotspot¹⁷ throughout the urban area, is translated into the requirement of a volume of water 2 times greater than the available to assimilate the pollution load generated in the city. The sector contributes more to the total WF in La Paz is the residential (over 90%), so reduction

¹⁷ Critical point (physical or temporal) in which the volume of water in the basin is not enough to absorb the polluting load generated.

measures should focus on the Gray WF.

The Gray WF can be reduced through implementation of preferably decentralized measures of recycling wastewater treatment plants and reuse of water, on the demand side, such as:

- Separation of the wastewater disposal system and natural water
- Implementation of water-saving artifacts
- Creation of models in peri-urban areas and new housing developments, including the treatment of waste water in place.

On the other hand, the Blue WF is minimal because the water used in the city returns to the lower watershed and does not affect the ecological flow of the rivers in the watershed of La Paz. This is important for the natural system of running water, but says nothing about the ability of the upper watershed to supply enough water to the city.

For an integrated management of water, the study of the WF must be complemented with data of water withdrawals by the city. Water sources are limited to and defined by the availability of water in the watershed and the resulting “real offer”. In this case, the traditional tool of balance between water supply and extraction is required to judge the situation of current and future supply to the population. To increase the resilience of the city and of water management, critical problems to be attacked must be identified, such as losses in distribution and declining demand to a minimum.

The consumption of water per capita in the residential sector was on average 77 l/capita/day¹⁸. Up to 12% of this volume (9 l) comes from glaciers. To increase the resilience of the city, you could set the goal of eliminating the consumption of each citizen the glacier contribution.

To do this, it would suffice to replace the main component of consumption, showers and toilets, for water-efficient models. The reduction of a percentage of the volume of water used daily by every citizen may amount to the volume that provides a costly dam, or to that provided by a set of glaciers in extinction, contributing to the process of increasing the resilience of the city

The validity of the WF as a new tool for water management has been clearly demonstrated, although it is not the only factor that must be taken into account for the sustainable management of water resources. The WF especially allows to visualize and quantify the environmental impacts in monetary sense (Figure 3), showing the externalities, the cost which is currently absorbed by the environment. Both tools, the traditional and the new tool of the WF are essential for good management of water resources. Both complement each other.

¹⁸ Data for the year 2012.

5. REFERENCES

- Abbotsford Mission Water & Sewer Services. . (2011). *Our Water Matters - Indoor Water Conservation*. Retrieve March 14, 2014, from www.ourwatermatters.ca/Indoor-Water-Conservation
- Agua Market. (n.d.). *Agua Market*. Retrieved April 5, 2014, from www.aguamarket.com/productos/productos.asp?producto=3998&nombrepProducto=panta+movil+para+tratamiento+de+aguas+residuales
- Boese, K. (2011). *Regenwasser fuer Garten und Haus*. Staufen bei Freiburg, Deutschland: Oekobuch.
- CEPYME . (n.d.). *Guía práctica sobre ahorro de agua*. Zaragoza, Spain.
- Dezentrales Urbanes Infrastruktur-System. (n.d.). *DEUS 21*. Retrieved March 10, 2014, from www.deus21.de/
- Estado Plurinacional de Bolivia. (1992). *Ley de Medio Ambiente N° 1333 - Reglamento en Materia de Contaminación Hídrica*. La Paz - Bolivia.
- Hiessl, H., & Toussain, D. (2002). Szenarien urbane Wasserinfrastruktursysteme – Perspektiven fuer eine langfristige Modernisierung.- En: Oekologische Sanitaerkonzepte contra Betriebs- und Regenwassernutzung? *Febrero*, 9, 47 – 55.
- Hoekstra, A. Y., Chapagain, A. K., Aldaya, M. M., & Mekonnen, M. M. (2011). *The Water Footprint Assessment Manual*. London • Washington, DC: Earthscan.
- Hoffmann, D., & Requena, C. (2013). *Bolivia en un mundo 4 grados más caliente. Escenarios sociopolíticos ante el cambio climático para los años 2030 y 2060 en el altiplano norte*. La Paz.
- Institute for Social-Ecological Research. (n.d.). *ISOE*. Retrieved March 3, 2014, from www.isoe.de/en/projects/current-projects/wasserinfrastruktur-und-risikoanalysen/semizentral/
- Olmos, C. (2011 (a)). *Gestion des ressources hydriques des villes de La Paz et d'El Alto (Bolivie): modélisation, apportsglaciaires et analyse des variables.-Tesis de Doctorado*. Brussels - Belgium: Brussels University.
- Olmos, C. (2011 (b)). *Pérdidas de agua entre extracción y consumidor.- Base de datos EPSAS- Estudios Université Libre De Bruxelles, PRAA (Resiliencia) y Plan Maestro Metropolitano del 2014*. La Paz, Bolivia.
- Planes Maestros Metropolitanos de Agua Potable y Saneamiento de La Paz y El Alto, C. S. (2013). *Informe Etapa II: Demandas futuras y estrategias de expansión, VOLUMEN IV - Escenarios y Estrategia de Mejoramiento y Expansión de los*

Servicios de Saneamiento. La Paz, Bolivia.

Proyecto de adaptación al impacto del retroceso acelerado de glaciares en los Andes tropicales (PRAA). (2012). *Estrategia de Gestión del Sistema de Distribución de Agua Potable para Enfrentar Impactos del Cambio Climático – Programa de gestión de agua no contabilizada. Informe No. 3: Programa Integrado y de Gestión Sostenible de Reducción de ANC.* La Paz, Bolivia.

SENAMHI – Flow Data 1990 – 2012. (2012). *Caudales en el Río Choqueyapu 1990 - 2012.* La Paz, Bolivia.

Soruco, A. (2012). *Medio siglo de fluctuaciones glaciares en la Cordillera Real y sus efectos hidrológicos en la ciudad de La Paz.* La Paz - Bolivia: IRD.

Umweltbundesamt. (2001). *Ohne Wasser laeuft nichts.* Berlin, Germany.

Zeolitas e Insumos Nacionales. (n.d.). *Zeolitas e Insumos Nacionales.* Retrieved April 5, 2014, from www.zeolitas.info.



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