Chapter 9
Urban Water Management

María Molinos-Senante

Abstract Over the last 30 years, the Chilean water industry has carried out significant legal and institutional reforms to improve water and sanitation services (WSS), becoming a success example from the point of view of coverage and service quality. One of the most important reforms was the privatization of the urban WWS, so currently fully private and concessionary water companies provide WSS to 95.8% of urban customers. The reform also involved a change in the regulatory model followed to set water tariffs. It is based on the definition of a hypothetical efficient company. However, the Chilean water industry presents important challenges to address in coming years. The average percentage of non-revenue water is larger than the established for the efficient model. It reveals a problem of asymmetric information in the process to set water tariffs among the regulator and water companies. In addition, water tariffs do not integrate effectively the scarcity value of water. Further improvement of wastewater treatment systems is also a challenging issue for the Chilean water companies. As in many areas, climate change has increased the probabilities of droughts, floods and extreme turbidity events which require several adaptation strategies to be managed properly.

Keywords Chile · Cost recovery · Privatization · Urban water · Wastewater treatment

9.1 Introduction

Chile is a middle-income country that has implemented significant reforms to improve urban water and sanitation services (WSS) (Hearne and Donoso 2005), and in 10 years became a success story and an example throughout Latin America

M. Molinos-Senante (✉)
Departamento de Ingeniería Hidráulica y Ambiental, and Centro de Derecho y Gestión del Agua (Water Law and Management Center), Pontificia Universidad Católica de Chile, Santiago, Chile

Centro de Desarrollo Urbano Sustentable (Center for Sustainable Urban Development) CONICYT/FONDAP/15110020, Santiago, Chile
e-mail: mmolinos@uc.cl

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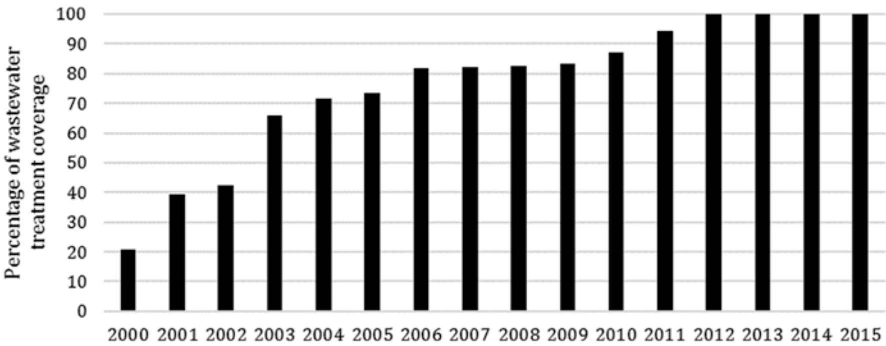

Fig. 9.1 Evolution of the coverage of wastewater treatment for Chilean water companies (Adapted from SISS 2015a)

(Marques 2011). In urban areas, in 2000 the coverages of drinking water supply, wastewater collection and wastewater treatment were 99.69%, 93.19% and 20.9%, respectively. Hence, in terms of coverage, the main problem was associated to wastewater treatment. However, thanks to the reforms conducted since then, the coverage levels have improved up to 99.9%, 96.8% and 99.8% for drinking water supply, wastewater collection and wastewater treatment, respectively. Figure 9.1 shows the evolution of the coverage of wastewater treatment across years.

Currently, these large coverages are provided by 28 main water companies which supply WSS to 16,812,391 people which represent 99.6% of the total urban population. The privatization of the Chilean water industry led to two main types of water companies namely fully private companies (FPC) and concessionary companies (CC). On the one hand, 12 out of 22 main Chilean water companies are FPC and they provide water and sewerage services to 72.7% of the urban population. On the other hand, 22.7% of the urban population is supplied by 10 CC. Moreover, several Chilean water companies belong to the same economic group. Actually, 74.8% of the urban customers are served by water companies belonging just to two economic groups. These figures evidenced the concentration of the ownership of the water companies in Chile.

As in other countries, water consumption per capita shows a downward trend (see Fig. 9.2) and between 1998 and 2015, it reduced from 23.9 to 19.1 m^3 per customer per month. It involves an average water consumption of 137 liters per capita per day. However, water consumption is not uniform across the country since water demand of companies ranges between 73 and 491 liters per capita per day. This finding means that there is a non-negligible room to reduce water use in some urban areas which requires awareness building about the need for more sustainable use of water resources.

The source of raw water depends mainly on its availability and quality. In the North of the country, most raw water is groundwater. By contrast, in the South of

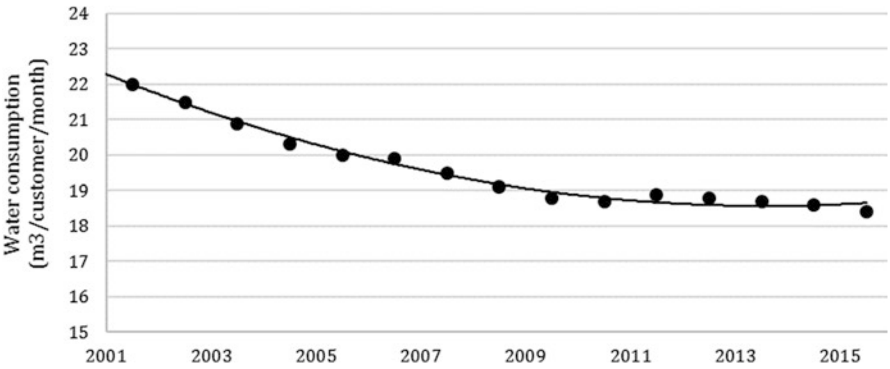

Fig. 9.2 Evolution of the average water consumption in Chile (Adapted from SISS 2015a)

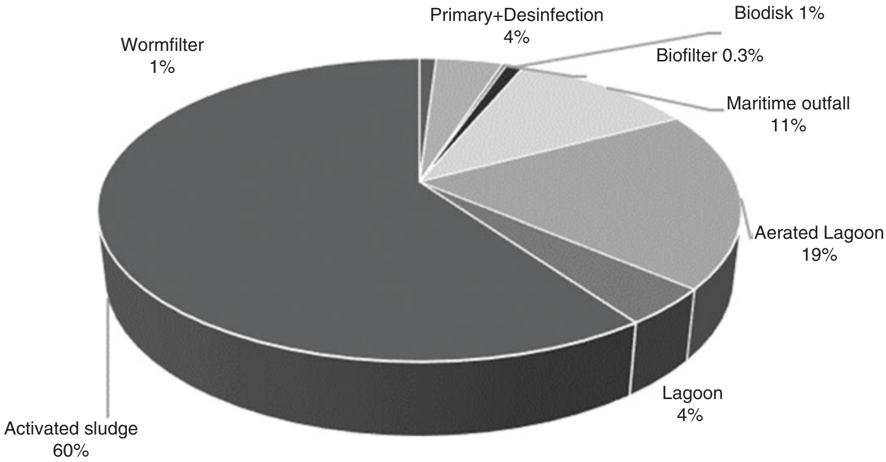

Fig. 9.3 Percentage of wastewater treatment technologies in Chile (Own elaboration based on SISS 2015a)

Chile, surface water is abundant and has good quality; hence, it is the main source of raw water. In the Center of the country, both groundwater and surface water are used. The total capacity of drinking water production is 91,029 l/s of which 47,156 l/s (51.8%) are from groundwater and 43,873 l/s (48.2%) are from surface water.

Regarding wastewater treatment, Fig. 9.3 shows that different technologies are implemented in Chile being activated sludge the most common one followed by aerated lagoons.

9.2 Legal and Institutional Framework

The current and legal framework of the Chilean water and sanitation sector is the result of several reforms carried out across the years. The first reform corresponds to the creation of SENDOS (National Service of Sanitary Works) dependent of the Ministry of Public Works (Ministerio de Obras Públicas, MOP). It was responsible for the administration and operation of the WSS throughout the country, through 11 regional directorates from 1977 to 1989. Only Santiago and Valparaiso regions remained managed by autonomous enterprises (EMOS and ESVAL). SENDOS was responsible of both urban and rural water management. However, in rural areas SENDOS focused its actions on drinking water supply, losing relevance sewerage services (Fuenzalida 2011).

The second reform of the Chilean water and sanitation sector was carried out between 1988 and 1990. In 1988 Law 382 (Gobierno de Chile 1988b) entitled "General Law of Sanitation Services" was adopted. This law established the operation rules of the water companies and the conditions in which WSS should be provided (Calvo and Celedón 2006). Moreover, in the same year Law 70 (Gobierno de Chile 1988a) entitled "General Law of Tariffs" was passed, which determined the procedures to set water and sanitation tariffs. The Law ensured a mechanism for full cost recovery of WSS service provision, introduced incentives to water companies to improve its efficiency and minimized cross-subsidies (Schuster 2017). It is in this second reform when the institutional and legal framework of urban and rural water management were separated. In 1990, SENDOS ceased to exist and the Chilean State started to provide WSS in urban areas through 11 regional companies.

The adoption of Law 18,902 in 1990 allowed for the creation of the national urban water regulator, the "Superintendencia de Servicios Sanitarios" (SISS) as a technical, regulatory and supervisory agency. From 1990 to 1996, the main objectives of the SISS were: (i) the fiscal control of the water companies; and (ii) the dissemination and interpretation of the new regulatory framework (Law 382). In this period, the SISS faced two notable challenges such as the development and implementation of the new process to set water tariffs and the implementation of the Law 18,778 of Subsidies (Gobierno de Chile 1989a). Moreover, important efforts were carried out to prevent cholera by intensifying the monitoring of the quality of drinking water (Molinos-Senante and Sala-Garrido 2015).

The third significant reform of the water and sanitation sector started in 1998 with the adoption of the Law 382 (Gobierno de Chile 1988b) which established the current legal framework for urban WSS. Its main principles are as follows: (i) separate the role of the regulators (SISS) from service providers; (ii) establish efficient tariffs that allow operators to finance operation, investment requirements, and obtain a minimum return on their investments; and (iii) establish a subsidy so as to ensure affordability of WSS to low income and vulnerable families (Donoso 2017). This legislation was the main transformative driver of the Chilean water and sanitation sector shift from public to private ownership.

Table 9.1 Main property transfers of Chilean water companies

Public company	Current name	Year of acquisition	% acquired	Economic group	Last acquisition	Year of last acquisition	% acquired
ESVAL	ESVAL	1998	40.4	Anglian water	Ontario TPP	2007	48.90
						2011	24.40
EMOS	Aguas Andinas	1999	51.2	AGBAR SUEZ	Several investors	2011	29.98
ESSAL	ESSAL	1999	51.0	Iberdrola	Aguas Andinas	2008	53.51
ESSEL	ESSBIO	2000	51.0	Thames water	Ontario TPP	2007	51.00
ESSBIO	ESSBIO	2000	51.0		Ontario TPP	2011	38.40
ESSAM	Nuevosur	2001	Transfer of the right to operate the concession		Ontario TPP	2007	–
ESSCO	Aguas del Valle	2003		Consorcio Financiero	Ontario TPP	2007	–
ESSAN	Aguas Antofagasta	2003		Grupo Luksic	Tracatal	2007	
EMSSA	Aguas Patagonia de Aysén	2003		Hidrosán-Icafal-Vecta	–		
EMSSAT	Aguas Chañar	2004			–		
ESSAR	Aguas Araucanía	2004		Grupo Solari	Marubeni and INCJ	2010	
ESSAT	Aguas del Altiplano	2004				2010	
ESMAG	Aguas Magallanes	2004				2010	

Source: Adapted from SISS (2015a)

The privatization of the Chilean water industry was carried out in two main steps following two approaches (Table 9.1). A first step was undertaken between 1998 and 2000 when some public companies sold strategic participations to private consortia with experience in the water industry, stock exchanges were opened and shares were offered to the employees of the water companies (SISS 2015a). Under this approach the five main Chilean water companies were privatized. The second privatization period was between 2001 and 2004 when the Chilean Government decided that WSS services should be delivered by private operators und a concession. In this context, water companies have the exclusive right to provide WWS in a given urban area for a period of 30 years. The concession holder must satisfy water quality standards, conform to the tariff regime and implement the required investment plans to ensure continuous WSS supply. Finally, in 2011, the Chilean Government sold part of the shareholdings of the largest private water companies.

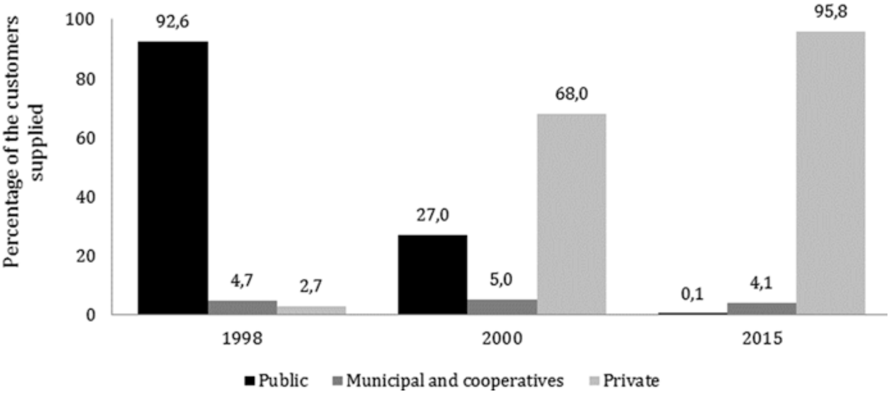

Fig. 9.4 Distribution of public and private water companies by percentage of serviced customers (Adapted from SISS 2015a)

As a result of the privatization of the Chilean water industry, currently 95.8% of the customers are supplied by private water companies and only 0.1% by public companies. In particular, the property distribution of the Chilean WaSCs is shown in Fig. 9.4.

9.3 Regulatory Model and Water Tariffs Setting Process

The privatization of the Chilean water industry involved a new regulatory system managed by the SISS. In this context, it should be noted that the Chilean Law 382 establishes that concessions to supply drinking water and treat wastewater can only be granted in urban or developable areas. On the other hand, rural areas are not subjected to the regulatory framework since they are generally supplied by cooperatives and committees of rural drinking water (see next chapter about rural water management).

As one of the main reasons to privatize Chilean WaSCs was to increase the efficiency of water utilities, the SISS uses a particular process to set water tariffs. The regulator's review of water tariffs is set to take place every 5 years, or if and when any unexpected changes in the contract conditions occur. The process to set water tariffs is based on the definition of a hypothetical efficient firm, i.e., an "ideal firm" (Marques 2011). Under this approach, the performance of the "real" water company is compared with a virtual, efficient company known as the "model" company, which is considered to be the benchmark. It is a theoretical water company created by the regulator which satisfies the demand in an optimal manner taking into account prevailing norms and the geographical, demographic and technological restrictions that characterize the operation of the service (Gobierno de Chile 1988a, b, c). This model corresponds to a water company without assets, which must make the investment to provide WWS and establish a development investment plan (Donoso 2017).

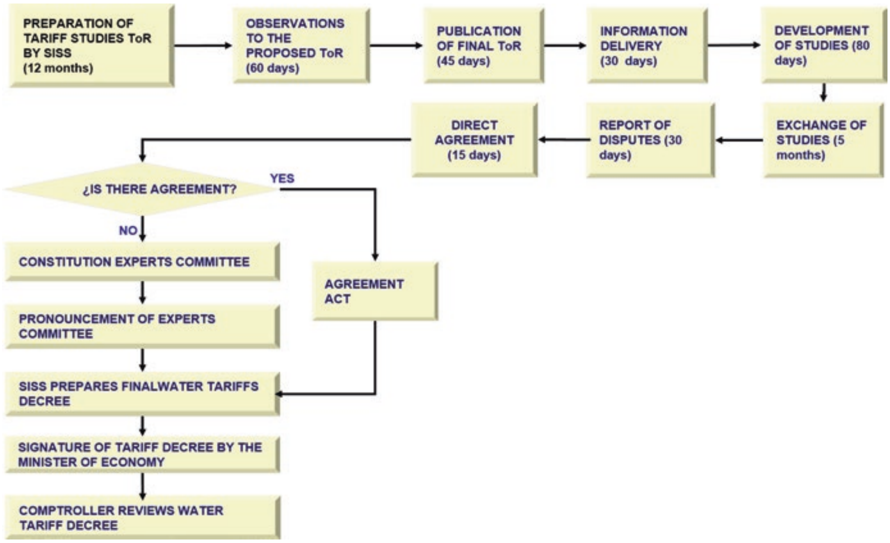

Fig. 9.5 Procedure to set water tariffs (SISS 2015b)

The procedure to set water tariffs is established by the Law 70 and the Tariff Act Regulation 453 (Gobierno de Chile 1989b) as is shown in Fig. 9.5. A year before the end of the tariff cycle, SISS prepares terms of reference (ToR) for the tariff studies to be conducted by the water company as well as the SISS. Based on the estimation of the long-term costs of the hypothetical efficient water company, both the SISS and the water company propose the water tariff to be charged by the regulated firm. If an agreement is reached the tariffs are set in a Decree signed by the Minister of Economy and ratified by the Nation's Controller (Molinos-Senante and Donoso 2016). If the parties cannot agree on the price, the disagreement is settled through an arbitration process. The water company and the SISS do not submit to the arbitrator a single offer for the entire firm but rather they submit an offer for each item cost such as cost of raw water, cost of capital, etc. Thus, the arbitration mechanism looks more like a hybrid between final-offer arbitration and conventional arbitration (Montero 2005). The water tariff set by the arbitrator cannot be appealed either by the SISS nor the water company.

The legal framework of the Chilean water and sanitation tariffs system defines four main principles to set water tariffs: (i) economic efficiency, (ii) water conservation incentives, (iii) equity, and (iv) affordability. In this context, the objectives of the Chilean tariff model are to:

1. Finance the operation and maintenance cost of WSS, investment needs and infrastructure and equipment replacement.
2. Finance a minimum agreed operational margin consistent with the alternative cost of capital of the water company.

3. Incentivize efficiency gains in the provision of WSS which should be transmitted to customers by reducing tariffs.
4. Provide water value signals to promote the rational use of resources.

To achieve these objectives, water and sanitation tariffs in Chile are based on a two-part structure, a fixed part ($) and a variable tariff ($\$/m^3$). The fixed charge is per connection and depends of the connection diameter and metering costs. The variable tariff is almost uniform since an extra charge for over-consumption is applied only in very exceptional cases. However, the variable component internalizes changes in seasonal demand by establishing a peak and non-peak charge. Thus, in summer months when water demand is high but water availability is low, a peak tariff is applied in contrast to the rest of the months. Hence, the difference in the provision costs of WSS during both time periods is covered.

Formally, the tariff (τ) is set such that:

$$\tau = \frac{AI + OMC + MR + T}{V} \tag{9.1}$$

where AI is the annualized value of the required investments by the efficient water company; OMC are the annual operating and maintenance costs; MR is the minimum guaranteed returns; T represents the taxes that the water company must pay, and V is the total annual projected water consumption for the next 5 years in the concession area. It should be noted that the term AI integrates the market value of the required water rights and therefore, water tariffs should, in principle, reflect the scarcity value of water.

9.4 Water and Sanitation Tariffs and Affordability

As a result of the regulation model based on the efficient water company, water tariffs vary across Chilean regions. Figure 9.6 illustrates that the bill that customers pay for consuming 20 m^3 per month varies from less than \$ 3 to more than \$ 43.5. According to the objectives of the Chilean tariff model described previously, water tariffs should reflect water scarcity value. However, the cost differences observed in Fig. 9.6 are not associated to water availability. Donoso and Molinos-Senante (2017) evidenced that water tariffs and water availability are not always related in Chile resulting in non-sustainable water consumption. Thus, the highest level of water consumption is presented in the Center-North area which consumes 23%, 108% and 105% more water than the Central-South, South and South-South zones. It evidences that in practice, water tariffs do not provide correct signals to customers to achieve sustainable water consumption based on water resources availability (Donoso and Molinos-Senante 2017).

Affordability and water poverty are an important issue in many countries since WSS are essential for human development and for health. In this context, the

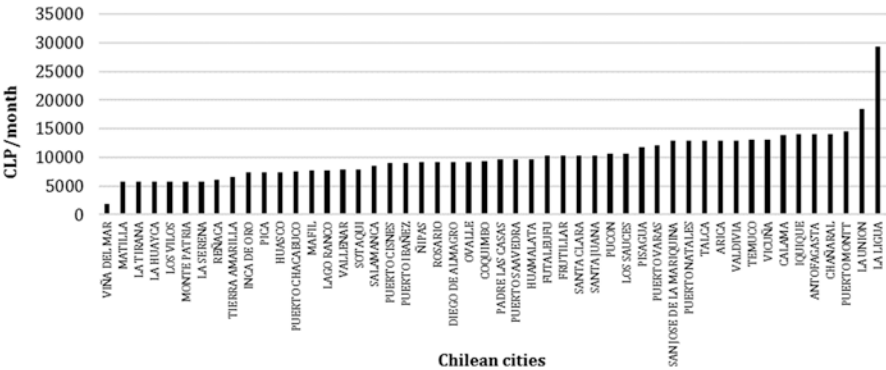

Fig. 9.6 Water supply cost for 20 m³/month (SISS 2015a)

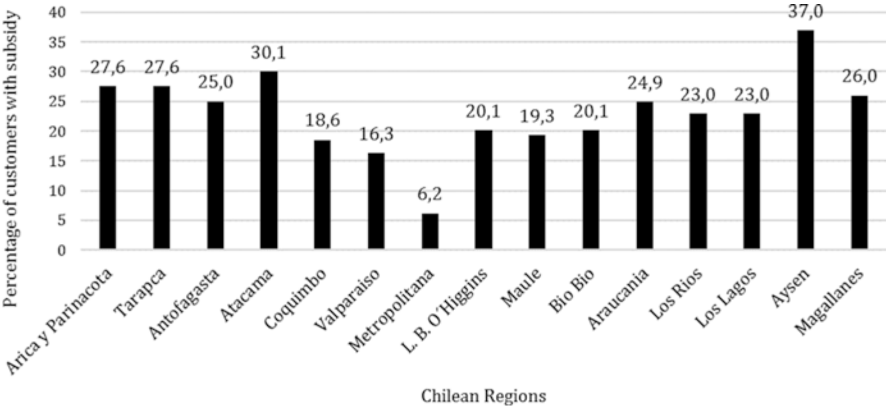

Fig. 9.7 Percentage of customers with subsidy to WSS respect to total number of customers (SISS 2015a)

Chilean Government adopted the Law 18,778 which established subsidies for drinking water and sanitation (Gobierno de Chile 1989a). The system is a direct subsidy to the most vulnerable household which are classified based on an annual survey (Casen). The payment share ranges between 15% and 85% of the water bill, with the poorest households receiving the highest share. The subsidy covers a consumption of up to 15 m³/household/month. The central Government transfers the subsidy to the municipalities which use this to pay a share of the water bill to each eligible household. In order to not distort price signals to customers, the water company bills the benefiting households for the full consumption cost and then charge the municipalities the subsidies granted.

From its implementation, the subsidy has evolved from a low initial use to the current high levels, making it possible for poor people access to WSS. As is shown in Fig. 9.7, in 2015, 14.8% of customers with WSS were benefited with subsidies (5.2% of total sales). In general, Chile's subsidy performs better in its ability to identify vulnerable households than other countries. However, there is evidence that there have been several errors of inclusion and exclusion. Moreover, the system is expensive to administer and requires high institutional capacity at the local level (Gomez-Lobo and Vargas 2002).

9.5 Quality of Water and Sanitation Services

To improve WSS service and quality, water companies and the regulator implement several measures and policies. Some of them are short-term actions whilst other are focused on long term. Regarding the long-term actions, the fulfillment of the investment commitments proposed in the Development Plans of the water companies is essential. Moreover, SISS uses a basic set of seven indicators to measure the quality of WSS provided by the Chilean water companies. The seven indicators monitored by the SISS are: (i) water supply pressure, (ii) water supply quality; (iii) wastewater treatment quality, (iv) water supply continuity; (v) wastewater treatment continuity; (vi) billing accuracy, and (vii) complaints. Given that Chilean water companies span a range of sizes, the regulator calculates each indicator on a scale from 0 to 1 (Molinos-Senante et al. 2017). This is a benchmarking system that allows for the comparison of the service quality of the main Chilean water companies. The position of each company indicates a greater (closer to 1) or smaller service quality (towards 0) and not necessarily a failure to comply with the standards. Moreover, as it has been reported previously, unlike other countries, information about the quality of service is not considered to set water tariffs.

9.5.1 Development Plans

The construction, replacement and improvement of water supply and sanitation infrastructure committed in the Development Plans of the water companies allows to ensure future provision of WSS, as well as to maintain or increase the quality of the service provided. The Chilean water companies must inform the regulator about the achievement of commitments of their Development Plans. The SISS directly monitors the veracity of the information and when there are breaches of the Development Plans, it may initiate sanction procedures. Figure 9.8 shows the percentage of commitment of Development Plans achieved by the Chilean water companies. It illustrates that between 2007 and 2010 the percentage of commitment improved from 85% to 96%. Unfortunately, from 2012 to 2015 water companies worsened its behavior in relation to this important indicator. This could be explained by hypothesis that the regulator's monitoring has not been exhaustive and few sanctions have been applied to water companies for breaches in Development Plans in the last years; however, SISS has not analyzed this and there is no evidence to support this hypothesis, or others.

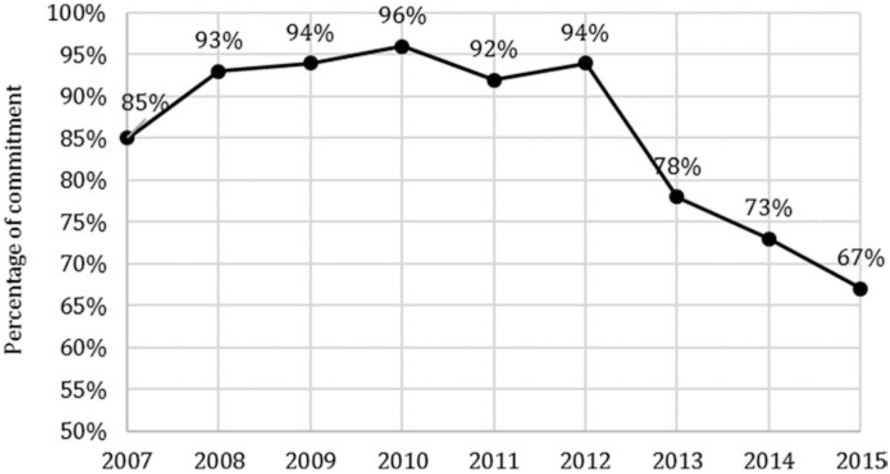

Fig. 9.8 Percentage of commitment of Development Plans by Chilean water companies (SISS 2015a)

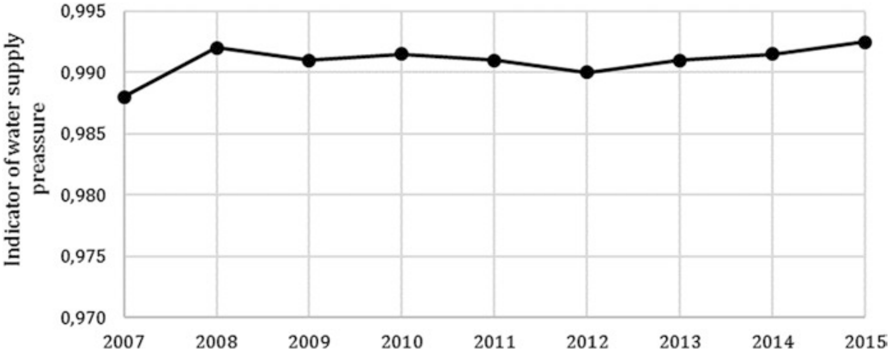

Fig. 9.9 Average indicator of water supply pressure for Chilean water companies (SISS 2015a)

9.5.2 Water Supply Pressure

The Chilean regulation NCh691 (Gobierno de Chile 2015) defines proper water supply pressure as being between 15 and 70 meters of water column. To calculate this indicator, the SISS considers the percentage of customers whose water supply pressure was outside this standard range. Figure 9.9 shows the evolution of the average water supply pressure indicator from 2007 to 2015. In spite that the average indicator of water supply is close to one, some low-pressure events occur; only 0.7% of the Chilean urban water customers present problems of low water supply pressure.

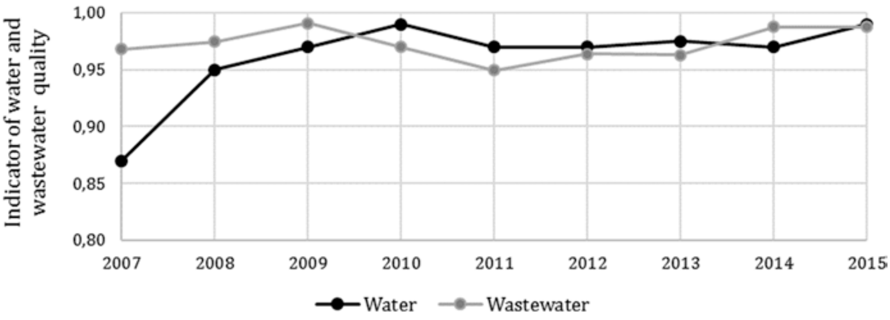

Fig. 9.10 Average indicator of water supply and wastewater treatment quality for Chilean water companies (SISS 2015a)

9.5.3 Water Supply Quality and Wastewater Treatment Quality

The Chilean regulation NCH490 for drinking water quality establishes minimum standards that drinking water must meet to be supplied by the water companies. This indicator is calculated by the SISS based on the degree of compliance with regulatory requirements, in terms of both water quality and verification sampling. Figure 9.10 shows the evolution of the average water supply quality indicator from 2007 (year in which the quality regulation was adopted) to 2015. It is evidenced that from 2009 to present, the water quality improved notably and on average, water companies fulfilled the drinking water quality regulation. Nevertheless, it should be noted that there are still some smaller companies whose indicator of water supply quality is lower than 0.9.

The indicator about wastewater treatment quality is calculated by the SISS based on the degree of compliance with the quality standards defined for each wastewater treatment plant. These standards depend mainly on the water body where the effluent is discharged. The number of people served by the wastewater treatment plant is used as a weighting factor when calculating this indicator for each water company. Although on average terms, the percentage of compliance was good (98.7% in 2015), it should be noted that one-third of the companies monitored presented lower values than average. In general, they correspond to small water companies whose wastewater treatment plants (WWTPs) present some technical problems.

9.5.4 Water Supply and Wastewater Collection Continuity

Chilean Law 19,549 on WSS (Gobierno de Chile 1988c), establishes that water companies must guarantee water supply continuity, except in specific cases determined by the SISS for planned interruptions, which must be communicated to

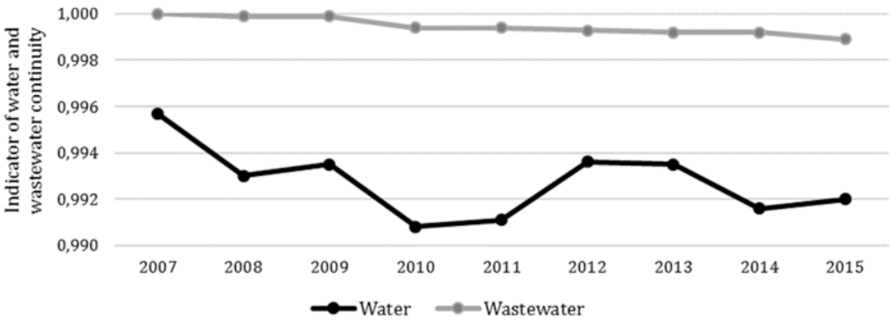

Fig. 9.11 Average indicator of water supply and wastewater collection continuity for Chilean water companies (SISS 2015a)

customers at least 24 h in advance. The water supply continuity indicator is calculated based on the number of customers whose water supply service was interrupted and the duration of the interruptions, with a penalizing factor if customers were not given advance notice of the interruptions. In 2015, the 28 main Chilean water companies presented 51,131 water supply interruptions being 27,436 (52.6%) of them, unplanned interruptions. The average duration of the water supply interruptions was 4 h. Figure 9.11 shows the evolution of the water supply continuity indicator from 2007 to 2015.

Water companies must also guarantee wastewater treatment collection continuity. This indicator is calculated based on the number of customers whose wastewater collection was interrupted due to obstructions in the sewer networks managed by the water company and the duration of the interruptions with a penalizing factor if customers were not given advance notice of the interruptions. Figure 9.11 shows a slight decline in the average value of this indicator between 2007 and 2015. In 2015, there were 110,652 unplanned sewer obstructions affecting each one, on average, seven customers.

The large values of both continuity indicators are associated to their calculation methodology. As has been reported previously, the quality of service indicators are based on a benchmarking approach. Hence, the average values of water supply and wastewater collection continuity close to one do not mean that there are no interruptions in the service, but that all water companies present a similar behavior. To evaluate the continuity of water supply, a complementary indicator is the number of pipe breaks. In this context, 20.8 breaks per 100 km of pipes is the average for the Chilean water companies for 2015. However, an analysis at local level illustrates that the problem of pipe breaks is concentrated in some particular customers (SISS 2015a). In other words, within a city, the quality of service in terms of water supply continuity differs notably by areas.

9.5.5 Billing Accuracy and Complaints

In Chile, user fees for WSS are calculated based on measurements of household-level drinking water consumption. Water companies have the obligation to reimburse customers for any payments associated with improper or erroneous charges. The indicator of billing accuracy is calculated based on errors made in reimbursements, with a penalizing factor if failures were repeated throughout the year for the same customer. Figure 9.12 shows that since 2010 the indicator of billing accuracy has remained almost constant and close to one. In the Chilean water industry, in 2015, on average, 1.1% of the bills presented some reimbursement requirement. Most of them were associated to incorrect measurement of water consumption and non-applicable charges. In 2015, 75% of the reimbursements were due to revisions made by the water companies themselves, 21% to customers' complaints and 4% by order of the regulator.

Customers dissatisfied with WSS have the right to file complaints with water companies and the regulator. The indicator of complaints is based on the number of complaints received by both water companies and the SISS and also takes into account the response time of the water companies which should be at the most 10 working days, the maximum response time allowed by Chilean standards.

On average, Chilean water companies received 125 complaints for every 1000 customers. Nevertheless, there are notable differences among water companies since the minimum value of this indicator was 3 while the maximum was 406. Most of the complaints were associated to water supply continuity problems and excessive water consumption measurement. Moreover, 62% of the complaints were solved in favor of the customers.

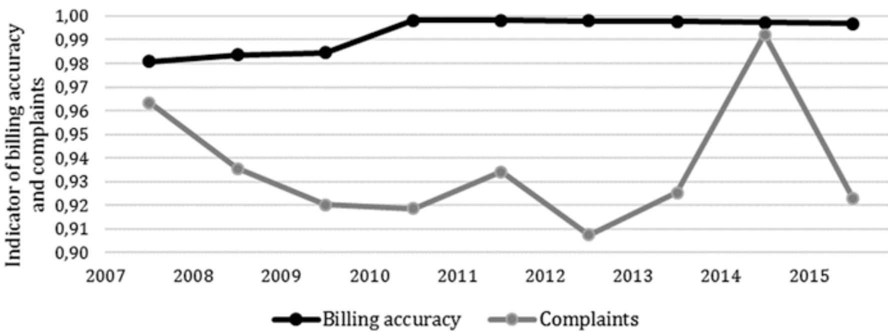

Fig. 9.12 Average indicator of billing accuracy and complaints for Chilean water companies (SISS 2015a)

9.5.6 Water and Sanitation Industry Challenges

Over the last 20 years, the Chilean urban water and sanitation industry has achieved significant improvement in both WSS coverage and quality. However, several challenges should be addressed by the water companies and the regulator in the coming years.

Non-revenue water (NRW) is water that has been produced (consuming energy and other materials) and is "lost" before it reaches customers. Losses can be physical losses (leakage) or apparent losses (water theft or metering inaccuracies). In other words, high levels of NRW reflect large volumes of water being lost through leaks, not being invoiced to customers, or both (Ferro and Mercadier 2016). Moreover, NRW means lower income for water companies which in many countries (not according to the regulatory model applied in Chile) can result in an increase in the tariffs paid by citizens. Therefore, minimizing NRW is essential to improve the environmental, financial and social sustainability of the urban water cycle (Hernández-Sancho et al. 2012). From a management point of view, a high NRW level is normally a surrogate for a poorly run water utility that lacks the governance, autonomy, accountability, and technical and managerial skills necessary to provide reliable service to their population (World Bank 2016).

Given the importance of this indicator, the SISS considers that the efficient water company has a maximum of 20% of NRW. This means that tariffs are set based on this value and therefore, water companies with a larger percentage of NRW receive less revenue than the estimated amount for the model company (Donoso 2017). In spite of this incentive, most of the Chilean water companies (20 out of 28) present percentages of NRW larger than 20%. In 2015, the average NRW was 33.6%. Moreover, the values of NRW are notably different among water companies since they range between 9.9% and 50.2%. This low performance of water companies, as illustrated in Fig. 9.13, has remained almost constant between 33.5% and 35.4% for the last 9 years.

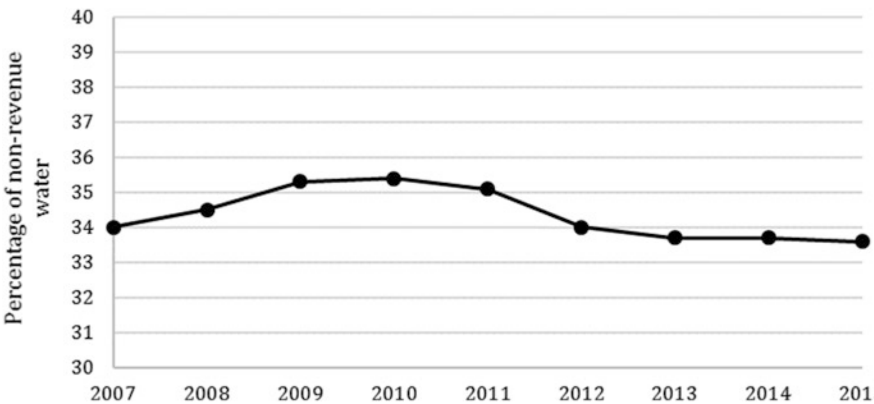

Fig. 9.13 Average percentage of non-revenue water for Chilean water companies (SISS 2009, 2010, 2011, 2012, 2013, 2014, 2015a)

According the SISS, 74% of the NRW corresponds to physical losses, i.e., to leakages whose origin are breaks or cracks in networks. This issue is related also with an important challenge for the Chilean water companies namely infrastructure replacement. Urban water supply and sewer networks in Chile have deteriorated over time reaching the end of its useful life and therefore, large investments and time are required to replace them. However, water companies have postponed networks replacement investments in favor of more profitable investments (Celedón and Alegría 2006). For example, in 2014 and 2015 the reposition rates of the water supply network were 0.57% and 0.56%, respectively. For sewer networks, the reposition rates were even lower, 0.24% and 0.22% for 2014 and 2015, respectively. These low reposition rates imply that the replacement of existing networks would take approximately 180 years for water supply and 500 years in the case of sewers. An increase of the reposition rate of networks is essential to improve the quality of service provided by water companies. On the one hand, it is essential to reduce the percentage of NRW contributing positively to the efficiency of the water companies. On the other hand, it contributes to improve the continuity of water supply and wastewater collection since unplanned water interruptions and sewer obstructions are minimized.

Before the 1990s, Chile did not have a legal framework for wastewater treatment and therefore, only 10% of the urban wastewater generated was treated (SISS 2016). In 2001, the Decree 90/00 was adopted which regulates wastewater treatment. Since then, important efforts have been carried out to improve the coverage of wastewater treatment reaching 99% of the wastewater collected in 2015 (SISS 2015a). In spite of this large coverage of sanitation service, the Chilean water industry presents two important challenges in the framework of wastewater treatment, namely: (i) replace maritime outfalls by more effective treatment systems and; (ii) increase the number of WWTPs that remove nitrogen and phosphorus from wastewater before its discharge into water bodies.

In Chile, there are 278 wastewater treatment systems using different technologies (see Fig. 9.3); 32 of these systems are maritime outfalls (11.6% of total number of wastewater treatment systems) treating 254 millions of cubic meters of wastewater (SISS 2016). Maritime outfalls are located mainly in the coastal cities of the North of Chile representing 73% of the wastewater flow treated in the Arica-Parinacota, Tarapaca, Antofagasta, Atacama, and Coquimbo Regions (CEDEUS 2015). The SISS considers maritime outfall as wastewater treatment systems and therefore, they are included in the computation of the coverage of wastewater treatment. Nevertheless, maritime outfall do not carry out any physical, chemical or biological treatment but they use marine dilution and dispersion to comply with environmental regulations. In other words, maritime outfalls do not remove pollutants from wastewater but they dilute them in the ocean. In this context, the discharge of wastewater without previous elimination of its pollutants can alter the composition of the marine sediment (De la Ossa et al. 2016). Hence, maritime outfalls cannot be considered as effective wastewater treatment systems. The challenge for the Chilean water industry is to replace the maritime outfalls by effectively wastewater treatment systems.

The second challenge related to wastewater treatment is generalize the removal of nitrogen and phosphorus from wastewater before its discharge into water bodies. This is not only a technical challenge but a regulatory one. Decree 90/00 establishes different quality standards for the discharge of treated wastewater depending on the discharge area. In this context, only when treated wastewater is discharged to wetlands or lakes, the concentration of nutrients in the effluent is comparable with international standards such as the European Directive 91/271/EEC. Hence, the first step to protect Chilean water bodies of eutrophication is to modify the Decree 90/00. Subsequently, WWTPs should be updated to be able to eliminate larger concentrations of nitrogen and phosphorus from wastewater.

The process to set water tariffs and its structure is a challenging issue for the water regulator. As has been reported previously, the process to set water tariffs is based on an efficient model operator. It assumes that the regulator has enough information to estimate the costs of the efficient company. However, usually this has not been the case (Donoso 2017). In other words, the Chilean water industry presents asymmetric information problems. Legislation should enforce water companies to supply precise and validated information to the regulator to calculate efficient water tariffs. Moreover, the quality of the service is ignored when setting water tariffs and therefore, water companies have few incentives to improve service quality provided to customers. In the context of water tariffs, a second challenge is that tariffs reflect water scarcity value. In spite that one of the objectives of the Chilean water tariffs is to provide signals to promote the rational use of resources, water scarcity value differences across regions are not, in general, reflected on urban water tariffs. This is because water tariffs infrastructure investment and operational costs are comparatively much larger than the market value of the necessary water rights (Molinos-Senante and Donoso 2016). The replacement of the current uniform volumetric charge by an increasing blocks tariff strategy might help to internalize the scarcity value of water.

Climate change impacts on water resources pose an important challenge for the Chilean water industry. Water companies face increased probabilities of extreme events such as droughts, floods and extreme turbidity events. The latter are particularly relevant for the water supply of the metropolitan area of Santiago which concentrates around 40% of the total Chilean population. Currently, there is evidence that the frequency of turbidity events has increased in recent years (Suarez 2017). In the case of some extreme turbidity events, the production of drinking water has had to stop leaving a large number of customers (85% of the people living in the metropolitan area of Santiago) without access to drinking water. To face this challenge and increase the resilience of the urban water supply under extreme events, several adaptation strategies from different perspectives such as water supply, water demand, infrastructure and urban and territorial planning should be implemented. However, these strategies require high levels investment that will impact water tariffs.

9.6 Conclusions

Chile's urban water and sanitation system represents a successful and interesting case study given that virtually universal levels of coverage have been achieved in both drinking water supply and wastewater collection and treatment. It is characterized by two main features: (i) private water companies provide WSS to most urban customers (95.8%) and; (ii) the process to set water tariffs is based on the efficient water company model.

The privatization of the Chilean water industry was a gradual process that was carried out in two main phases and following two different approaches. As a consequence, currently in Chile there are two types of water companies namely: fully private and concessionary water companies. The Chilean process to set urban water tariffs is unique worldwide and compares the costs of the real water company with a virtual, efficient company which is considered to be the benchmark. This model has been successful in providing WSS to most of urban customers. However, it presents notable asymmetric information problems and does not integrate quality of service variables in the tariff setting process.

Some of the quality of service variables such as water supply pressure or quality of drinking water and wastewater have significantly improved across years. Nevertheless, the Chilean water industry presents an important challenge related to NRW which is associated to the low reposition rates of both water and sewer networks. Chilean WSS companies must also improve wastewater treatment, replacing maritime outfall by more effective wastewater treatment systems and by removing nutrients from wastewater before it's discharge into water bodies. Moreover, water companies and the regulator should develop and implement plans for climate change adaptation given that extreme events such as droughts, floods and extreme turbidity are already a reality in Chile.

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