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Managing Water Scarcity Futures: Identifying Factors Influencing Water Quality, Risk Perception and Daily Practices in Urban Environments after the Introduction of Desalination

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Abstract: During the last two decades on a global scale, there has been a significant development of desalination as a strategy to ensure the urban water supply in arid and semi-arid areas. Beyond issues related to the higher economic costs, one of the main barriers that may limit this water source's development is its supposed negative water quality perception. This research aims to understand better which factors are behind water quality perception in Antofagasta (Chile), where desalinated water was introduced in 2003. Since then, this urban water supply system has increasingly incorporated desalination, creating three parallel areas according to the water sources used in each of them (desalinated water, freshwater and a mix of both). To do so, more than 800 questionnaires to test water quality perception and water consumption habits were conducted in households. Up to six logistic regression models have been implemented to identify which variables better explain water quality satisfaction, risk perception and daily water practices considering the water supply area. It is worth noting that most of this type of research has been carried out in study cases with homogeneous urban water supply systems with conventional water resources. Results indicate that, among other factors, organoleptic water characteristics, such as taste, and socioeconomic status are some of the main factors that explain the perception of water quality and daily practices. In addition, a lower water quality perception and greater risk perception have been identified where desalinated water has been introduced, which makes some households develop averting behaviors to improve water quality, such as boil water.

Keywords: desalination; perception; tap water quality; averting behaviors; Chile

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1. Introduction

Water availability is a vitally important factor in expanding and developing urbanization in coastal arid and semi-arid environments. Thereunder, to guarantee water supply and reduce water shortages, different measures have been developed based on diversifying water sources and blending strategies, high investment to finance water conveyance from the hinterland or, more recently, seawater desalination [1]. Overall, these measures have contributed to increase water price and a perception of poor water quality by residents. This mistrust in tap water quality is usually related to taste, water hardness or the presence of chlorine [2,3]. At least in more developed countries, perceived water quality understood as the users' perception of tap water organoleptic characteristics, used to be the main drivers behind the drinking water use habits along with health and safety concerns [4]. Public perception of water quality impacts a wide range of issues drawing from water use habits to trust in water utilities [1,5]. In that sense, the rise of bottled consumption in coastal environments is highly related to a poor water quality perception, which occurs despite compliance with drinking water quality guidelines. A low water quality perception can lead residents to over-finance additional expenses to improve water quality through averting behaviors as boiling or filtering tap water or purchasing bottled water [6,7]. However, some researchers have proved through blind tests that consumers do not appreciate quality differences between tap and bottled water, indicating that quality perception may be influenced by factors other than tap water organoleptic characteristics [8]. In this sense, it has been found that the perception of tap water quality from different sources is usually similar even though they present great differences in the actual quality and that resident's previous experiences play a fundamental role in the development of their perceptions [1]. Identifying these factors can be helpful to promote communication campaigns and action strategies to public administrations and water utilities and propose alternatives to the consumption of bottled water to reduce the environmental impacts related to its use, production, distribution and waste management.

Expected climate change effects in reducing conventional water resources availability will suppose a growing development of desalination in arid and semi-arid urban environments around the world [9]. Therefore, increasing knowledge about the perception of water quality will be helpful to propose policies to avoid over-finance measures to improve water quality at the household level, especially in socio-economically vulnerable households. Most of the research related to identifying the factors that influence the perception of water quality has not considered the influence of water supply sources, especially in case studies where desalinated water has been introduced into the urban water supply system. Beyond theoretical acceptance among potential domestic consumers [10,11], to the best of our knowledge, the perceived tap water quality and risk perception has not been evaluated in the same city where parallel water supply sources are flowing. Likewise, in these case studies, it can also be assessed whether there is a relationship between water drinking habits, including adopting averting behaviors carried out to increase the quality of tap water and the water supply sources or other factors. This study may contribute to the international literature regarding the identification of water quality and risk perception influential factors, as well as those which explain daily practices such as drinking water habits and averting behaviors, considering water supply sources and their perception or knowledge by the population in cities where desalination has been introduced.

Tap Water Quality and Risk Perception and Averting Behaviors

Previous research has already evaluated the factors that explain consumers' risk perception related to drinking tap water, as well as reasons behind water quality perception and the adoption of averting behaviors to improve tap water quality. As stated by Doria [5] (p. 1) "perceptions of water quality result from a complex interaction of diverse factors", although many of them appear to be shared between study cases, the relative importance of each one is site-specific [1]. In the first place, perceived water quality is influenced mainly by tap water organoleptic characteristics, namely taste, smell and transparency [12,13]. Taste and smell are often interrelated as they rely on similar physiological processes, however, in western countries water taste is usually more valued than smell and appearance, since it may indicate the presence of water chemicals [5]. Some studies have indicated certain relationships between water chemical composition and the organoleptic characteristics of water. Specifically, the taste of high mineral content water is usually better evaluated, while the opposite occurs with tap water with high content of chlorine, limestone or hardness, although a bad taste is not necessarily related to risk perception [5]. Nevertheless, it is suggested that the public links organoleptic characteristics of water to the perception that drinks tap water may pose or not health risks [5]. In other cases, only the concern with chemicals, beyond the knowledge of tap water composition, lead to lower ratings of water quality [5]. In this sense, the perception of safety or risk is another of the main factors influencing the acceptance of tap water for drinking [12,14,15]. It should be noticed that the public perceives tap water quality and its potential and associated health risks regardless of analytical or technical evaluations, which has been defined as the risk perception gap [15]. In addition, risk and tap water quality perception may be influenced by new and controversial hazards of which residents have little personal experience, such as introducing a new raw water source that residents are not used to [5,16]. This situation is especially relevant when residents perceive that there has been a variation in water quality [17] and changes in water taste and smell, which may induce the feeling that tap water may produce negative health effects [18]. As well, as stated by Doria [5], past experiences and neo-phobia can influence the acceptance or rejection of new water sources. This is because risk perception is also conditioned by the residents' direct experience concerning water quality, shaped by possible past events related to water quality or contamination, the information provided by the mass media, or interpersonal sources [5,19,20]. Additionally, water supply service deficiencies, the introduction of a new water source in the system, or the variability in the water quality, may affect the concern and dissatisfaction with tap water [5,17,18]. Even though knowledge about the origin of water supply sources is, in principle, weakly associated with poor water quality or high-risk perceptions, this issue has not been analyzed in a context where desalination has been introduced [15]. Likewise, it should be noticed that public knowledge about water supply sources is usually limited [16,21]. Another factor that can influence the perception of water quality and risk is trust in water companies and public institutions, which is directly associated with service satisfaction. However, the influence of this issue is not evident at all since the relationship may be the opposite, being the perception of water quality and risk the factors that determine trust [5,12,14,17,22].

In the second place, other factors that may intervene in tap water quality and risk perception are socio-economic and sociodemographic characteristics of households [5,14,16,23,24]. Among demographics, gender has been the focus of much attention since women tend to rate lower the tap water quality and have higher perceived risks expressing more concern than men about these issues [1,15,22,25,26]. However, this relationship is not always fulfilled [14,27]. In some cases, this trend showed by women is transferred to water consumption habits since they present higher bottled water consumption than men [26]. Age is another demographic factor that may influence perception. Younger respondents are more likely to be dissatisfied with the service or perceive drinking tap water as slightly riskier or less safe [5,16]. Notwithstanding, there is no consensus about this relationship as Syme and Williams [17] indicate the opposite. Furthermore, in the same way, households with children tend to perceive tap water as risky [15]. Other variables, such as income, appear to be inversely associated with the risk perception of drink tap water [16,21]. Anyhow, again, the impact of this variable remains ambiguous [17]. In that sense, some literature shows that income level produces different tap water quality perceptions, as low-income households appreciate less quality [18,28,29]. Other studies also remark that factors such as personal vulnerability can also affect the perceived risk and the poor water quality evaluation of tap water, which is generally higher among groups with debilitating diseases [24]. Likewise, some researchers have pointed out that willingness to pay for water may play a significant role in creating the perception, as affordability and satisfaction with water quality and service could be interrelated [5,20]. Lastly, some studies indicate that in developed countries, minority households of ethnic, racial or national origin tend to identify tap water as unsafe because of the legacy of residential segregation and the related variations in the quality of water provision [3,20,29]. This perception leads them to use bottled water for drinking uses more often than the local population.

Perceptions of water quality and potential health risks are highly related to drinking choices and behaviors [20,25,30,31]. Risk perception is a primary factor that explains the habit of drinking tap water, adopting some averting behavior or purchasing bottled water [26,30]. However, relying on averting behaviors to improve tap water quality or buy bottled water may impact household expenditures, especially in cases that require a large initial investment such as sophisticated in-home water treatment systems or sustained additional expense such as bottled water. Therefore income level can be an essential factor in understanding daily practices and household water consumption habits [20,31]. Even though in some studies, income appears as a significant variable explaining bottled water consumption there is inconclusive evidence about this driver, as some research indicates a positive relationship [32,33] while there are studies that suggest otherwise [34]. Factors related to affordability, convenience and environmental awareness may explain the drinking water choices at the household level [31]. For instance, in households with no perception that tap water is unsafe, greater environmental awareness or affordability problems of purchasing bottled water, it is more likely that the primary source for drinking uses selected is tap water [31]. Nevertheless, bottled water is usually perceived as safer than tap water and of better quality, so the choice of this water source is highly dependent on the negative perception of tap water quality [19,20,30]. In addition, the lack of in-home treatment systems and the presence of children at home or big households are other factors that may explain the use of bottled water [4]. Apart from the consumption of bottled water, the adoption of other averting behaviors has been increasingly implemented in larger households where there is a poor water quality perception [4]. The more widespread systems are filters in taps or jugs equipped with filters, since are less expensive and easier to install. Even though the consumption of bottled water is highly related to doubts about the safety of tap water, the installation of filters is linked to a poor perception of organoleptic characteristics, such as taste or smell [4]. In addition, income and housing tenure appear as explanatory variables when considering systems that require installation since households with lower incomes or those that reside on a rental basis do not carry out the investments and operating costs [4]. Finally, the option of boiling water is usually carried out by smaller and low-income households [31].

Given the increasingly key role of desalinated water in guaranteeing water supply in urban areas in semi-arid and arid environments it is necessary to discern several potential barriers and effects for its development. Specifically, in this paper we focus on social and behavioral issues to evaluate the factors that explain consumers' perception of tap water quality and risk perception of drinking tap water to discern if the water source supplied or the perception about its origin may influence these issues. Some studies have identified that desalinated water quality is worse perceived than other sources [11,35,36]. In addition, it is intended to evaluate the reasons behind the daily domestic practices performed regarding the election of the water used for drinking uses (tap or bottled water), and the adoption of an averting behavior (boil water or install a tap filter) to increase tap water quality. Again, these analyses aim to identify whether the introduction of desalination is related to the water habits developed by the population. For this purpose, we focus on the case study of Antofagasta (Chile), where the progressive introduction of desalination has formed three differentiated urban areas according to the water supply source (desalinated seawater, inland freshwater, and a mixture of both). The identification of these factors or variables may help water utilities and policy-makers to propose actions to address consumer concerns.

2. Materials and Methods

2.1. Study Case: Antofagasta, Chile

This study focuses on the city of Antofagasta, the capital of Chile's homonymous region, located in the Atacama Desert, one of the world's leading sources of copper. In this city, the interconnection between mining and urban water use began as early as 1892, when Antofagasta was the gateway of extracted saltpeter to the rest of the world. Water was imported from the Loa and San Pedro Rivers through 340 km of pipes built by the Ferrocarriles Antofagasta Bolivia Company (Figure 1). On 9 June 1892, the people of Antofagasta gathered in the city's main square, anxious to see the first drop of clean freshwater arriving [37]. Nevertheless, worries over tap water quality have been a long-lasting issue for its dwellers because the city's freshwater sources have naturally had high concentrations of arsenic, due to the region's mineral-rich soils. It was not until 1970 that an arsenic abatement plant was built for urban water supply after the authorities realized that the concentration of arsenic in tap water was around 100 times over World Health Organization limits. As a result, Antofagasta has one of the country's highest rates of bladder, lung, kidney, and skin cancer [38], all associated with arsenic intake.

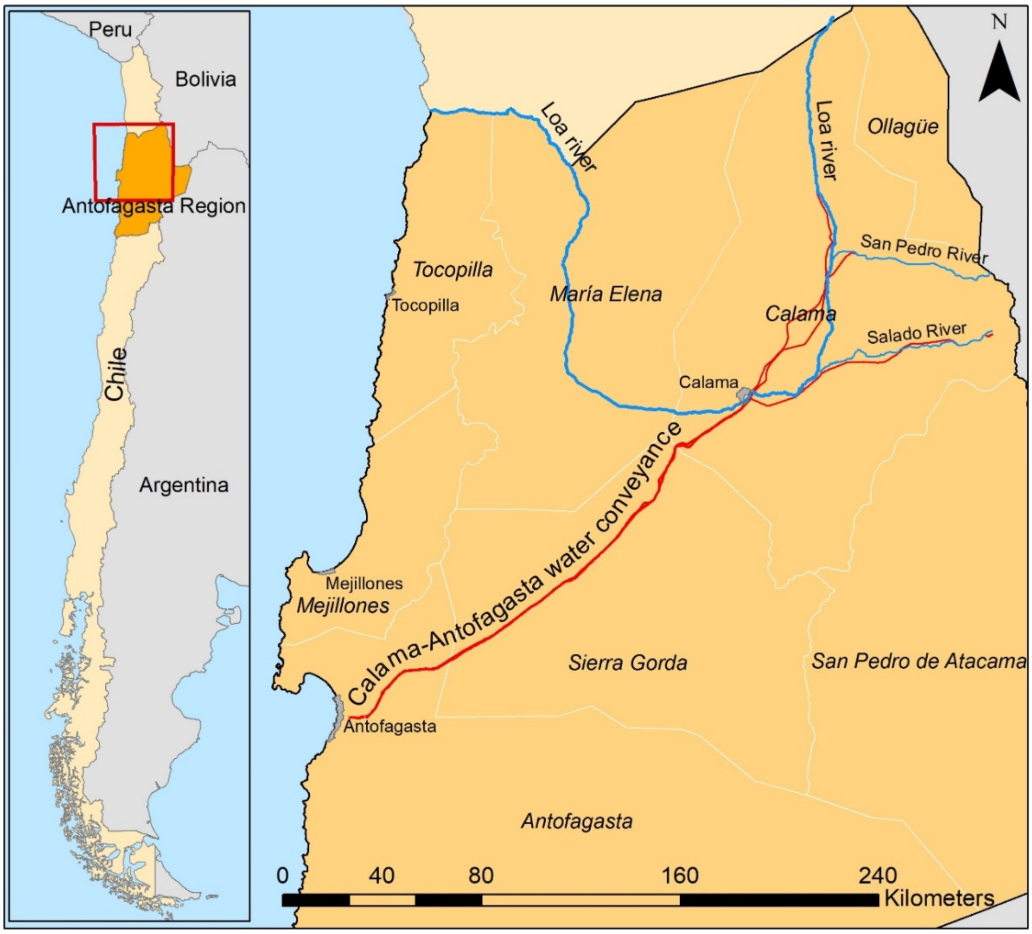

Figure 1. Antofagasta's location and regional water conveyance system.

The economic, demographic and urban development since the 1990s and the increasing water demands by mining in the region hinterland motivated the introduction of desalination to guarantee the water supply in coastal cities, where 70% of the population resides, and simultaneously free up water resources for the mining industry. The Chilean Water Code, created under general Pinochet's dictatorship with the help of technocrats from the University of Chicago's School of economics, led to the possibility for water right transactions separating water from land rights, intending to let the market "naturally" allocate water in the most profitable activity without state control or intervention [39]. In the case of Antofagasta, these processes favored the assignation of water rights to the mining companies [40,41]. By the 1990s, the regional water utility company, ESSAN (Empresa Sanitaria de Antofagasta S.A.), a state-led company created during the first democratic governmental period, entered into contracts with regional mining companies for the provision of untreated water for industrial use. Even though water utility companies in Chile cannot make their water rights available in the market, they can sign water supply contracts with private parties as long as they can guarantee the water supply for their urban concession areas. In Antofagasta, to secure the water supply and maintain these contracts, the so-called La Chimba desalination plant started operating in 2003, allowing the water utility to "free up" water rights for the direct sale of inland freshwater to the mining sector [42]. Since then, there has been a gradual replacement of the water sources used in the city, creating three different supply areas. One maintains inland freshwater supply, another, the closest to the plant, is supplied with desalinated water, and a third, the broader one, supply a mixture of both.

2.2. Data Collection and Analysis

Even though the arsenic-related episodes have not occurred again, it has been found that low perception of water quality remains [36]. However, the factors that explain this perception have not been empirically determined. The characteristics of this case study make this analysis especially interesting to check what role desalinated water plays in water quality and risk perception, as well as in the residents' daily water-related practices. To analyze these questions, a household survey was designed and conducted between July 2015 and July 2016. Even though the total sample is made by 1.163 households, after accounting for missing data on some of the study control variables, our final usable sample size comprised 877 observations or households. The sample has been estimated for the whole city, with 402,444 inhabitants in 2015, with a 3.3% statistical error margin and 95% confidence level. The survey contained seven-point Likert items for organoleptic water characteristics (taste, smell and transparency) and close-ended questions about water quality perception and daily water practices. The questionnaire also included inquiries related to sociodemographic characteristics and a spatial reference, from which the socio-economic group to which each household belongs has been calculated, based on GeoAdimarck's classification of 2013, commonly used in Chilean statistics. Additionally, spatial reference has allowed to determine which the water supply area that household belongs to, after requesting each area's spatial limits to the Antofagasta's water utility.

Usually, literature on perceived water quality and averting behaviors have developed models to identify which drivers or factors explain these perceptions and daily habits. As the combination of multiple factors explains the public perception of water quality is has been raised that the implementation of a regression model is the best way to identify these factors. To model water quality perception and identify the factors behind different techniques have been implemented: structural equation models [23], generalized linear models [27], multinomial logit model [20] or logistic regression models [1,4,25]. In our study, we implemented up to six logistic regression models with R software, as our dependent variables are binary, as presented a logit distribution. To identify factors or variables related to water quality perception, we used as a dependent variable the response to the question "Are you satisfied with tap water quality?". In the second model, the binary variable "I think drinking tap water causes negative health effects" acts as a proxy for general risk perception. Likewise, the other four models have been developed to identify the factors or variables that explain the habits of tap water and bottled water consumption for drinking uses and the averting behaviors of boiling and installing a filter on the tap to improve water quality. The goodness of fit has been verified in all the models by calculating the chi-square and its significance, which must have a p-value lower than 0.05. In order to evaluate the goodness of fit of the models the Hosmer-Lemeshow test has also been calculated, as well as Cox and Snell's and Nagelkerke's R^2 which indicates the variance proportion of the dependent variable explained by the model. Likewise, it has been calculated that the confidence intervals of the significant variables of each model do not cross the value of 1, which validates the interpretation of the results. It has been verified that the residuals fit well to the observed data, considering the value of the standardized residuals, the leverage statistic and the DFBeta values. Furthermore, in all models, the number of cases that can predict the dependent variable correctly is greater than 50%. Finally, it has been verified that the models comply with the assumptions of linearity, independence of errors and multicollinearity, calculating the VIF value for each of the variables of the models. The description of the dependent and independent variables used in the models, taking into account those analyzed in the literature review summarized in the previous section and their basic descriptive statistics, are presented in Table 1. Both water supply area (WSA) and the socioeconomic group (SEG) variables have been introduced in the models as factors, with desalinated water area and lower socioeconomic group acting as control groups, respectively. Likewise, the variables related to the perception of the origin of the water have been discretized (through a dichotomous answer Yes/No). These variables show a high degree of negative responses since, in general, the population assumes that they are unaware of this question. Likewise, the fact that they answer that they know the origin of the source does not imply that they are correct. Still, it is intended to check whether this variable influences the perception of water quality or consumption habits.

Table 1. List of dependent and independent variables used in the regression models and descriptive statistics.

Label	Description	Units	*n*	Avrg./%
	Dependent variables			
WQ satisfaction	Satisfaction with the water quality	1 = Yes 0 = No	221 656	25.2% 74.8%
Risk perception	The perception that tap water produce negative health effects	1 = Yes 0 = No	690 187	78.7% 21.3%
Tap_drink	The household members use tap water for drinking uses	1 = Yes 0 = No	246 631	28% 72%
Bottled_drink	The household members use bottled water for drinking uses	1 = Yes 0 = No	729 148	83.1% 16.9%
Boil	Boiling tap water before consumption	1 = Yes 0 = No	422 455	48.1% 51.9%
Filter	Installation of a filter in the tap	1 = Yes 0 = No	115 762	13.1% 86.9%
	Independent variables			
Desalination WSA_ Freshwater WSA_ Mixed WSA_	Water supply area (WSA) to which the household belongs (factor)	Desalinated water Inland Freshwater Mixed water	262 254 361	29.9% 29% 41.2%
Desalination_know	Knowledge of the existence of the desalination plant	1 = Yes 0 = No	687 190	78.3% 21.6%
Desalination Per	Perception of being supplied with desalinated water	1 = Yes 0 = No	253 624	28.9% 71.1%
Freshwater Per	Perception of being supplied with inland freshwater	1 = Yes 0 = No	42 835	4.8% 95.2%
Mixed Per	Perception of being supplied with mixed water	1 = Yes 0 = No	108 769	12.3% 87.7%
Taste	Tap water taste evaluation (worst = 1, best = 7)	1–7 scale	846	2.743
Smell	Tap water smell evaluation (worst = 1, best = 7)	1–7 scale	843	3.923
Transparency	Tap water transparency evaluation (worst = 1, best = 7)	1–7 scale	848	4.263
Trust	Satisfaction with the water service	1 = Yes 0 = No	431 446	49.1% 50.8%
Lower-SEG Middle-SEG Upper-SEG	Socio-economic group (SEG) to which the household belongs (factor)	Lower/Low-Middle Middle Upper/Upper-Middle	266 197 414	30.3% 22.4% 47.2%
Vulnerable	Presence of vulnerable members in the household (elderly, retired or disabled)	1 = Yes 0 = No	160 717	18.2% 81.7%
Subsidy	Households that receive a subsidy for the payment of the water bill	1 = Yes 0 = No	142 735	16.2% 83.8%
Compliant price	Agree with the amount paid on the water bills	1 = Yes 0 = No	207 670	23.6% 76.4%
Age	Age of the respondent	Age	877	39.18
Gender	Sex of the respondent	1 = Male 0 = Women	205 672	23.4% 76.6%
Years_in_city	Years living in Antofagasta	Years	877	25.03
Birthplace	Birthplace of the respondent	1 = Antofagasta 0 = Other	389 488	44.4% 55.6%
Household_size	Persons living in the household	Household members	877	4.59
Local_env_awareness	Awareness about water scarcity at the local scale	1 = Yes 0 = No	434 443	49.5% 50.5%
Reg_env_awareness	Awareness about water scarcity at the regional scale	1 = Yes 0 = No	533 344	60.7% 39.3%
Save water	Households that claim to save water	1 = Yes 0 = No	708 169	80.7% 19.3%

3. Results

Survey results indicate extensive knowledge about the existence of the desalination plants as 78.3% of households claim to be aware. Even though, surprisingly, the population residing in the inland freshwater supply area has the greatest knowledge. However, the population is unaware that there are different water sources and supply areas in the city and generally does not know which one they belong to 54% of the population assumes they do not know the origin of the water supplied. In contrast, only 21% guessed right when asked, most of it belonging to the desalinated water supply area. Regarding tap water quality, survey results indicate that in Antofagasta exists a poorly perception, expressed mainly in the low scores given to the organoleptic characteristics of water, especially taste, which presents an average score of 2.7 out of 7, while smell and transparency have been evaluated on average with 3.9 and 4.2, respectively. The worst average scores occur in the mixed WSA, both for taste (2.65), smell (3.69) and transparency (4.06), followed by desalinated WSA (2.67, 3.96 and 4.25, respectively) and inland freshwater WSA (2.93, 4.19 and 4.54). Likewise, these differences in the perception of water qualitytraslante into statistically significant differences between mixed WSA and inland freshwater WSA in the evaluation of transparency (p-value = 0.006) and smell (p-value = 0.003) after having performed the Kruskal Wallis H test (Figure 2).

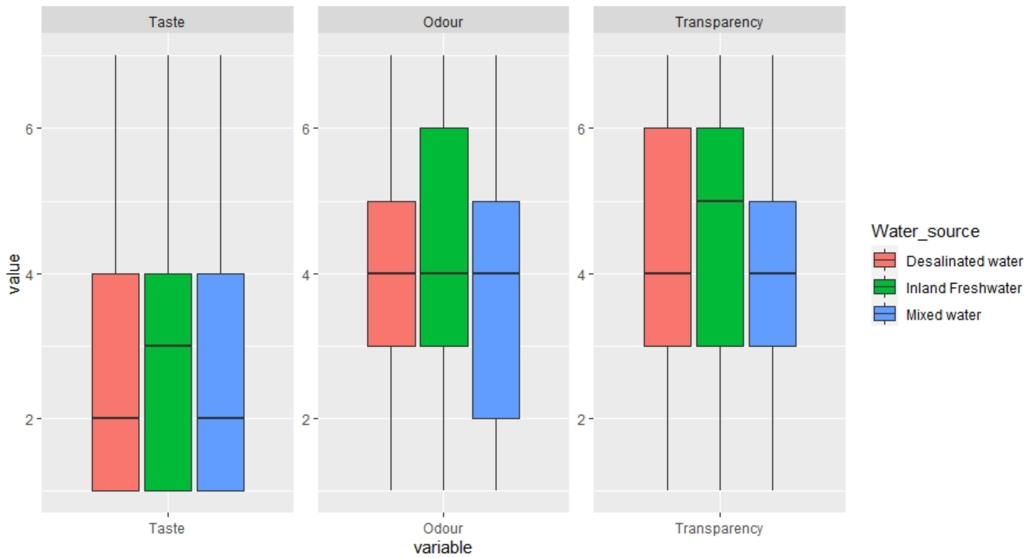

Figure 2. Boxplot of tap water organoleptic characteristics according to water source area.

As a result, only 25.2% of the population claims to be satisfied with water quality, although there are no significant differences between the water supply areas. This low perception of quality is closely related to risk perception, since a similar proportion of the population, 78.7%, believes that tap water intake can negatively affect health. However, despite this, about half of the respondents are satisfied with the water supply service. In any case, the perception of tap water quality and risk perception can explain the population's daily practices and water consumption habits. First of all, only 28% of the households surveyed use tap water for drinking uses. In this case, significant differences are found between water supply areas (Kruskal-Wallis test p-value = 0.02), since in the desalinated water supply area, a smaller number of households have this habit (22.1%). This low confidence in tap water implies a widespread consumption of bottled water for drinking uses (83.1%), or the development of averting behaviors to improve tap water quality, such as boiling water before consuming it (carried out by 48.1% of those surveyed) or installing a filter on the tap (carried out by 13.1%). It is worth noting that there are significant differences between water supply areas regarding boiling water (Kruskal-Wallis test p-value = 0.02) since this practice is carried out to a greater extent in the desalinated water supply area. The results of the logistic regression models are presented below, identifying the variables that explain satisfaction with water quality, risk perception and the main water consumption habits and averting behaviors.

Binary Logit Models Results

The model results presented in Table 2 show the variables that better explain the likelihood that residents were satisfied with water quality, the perception that drink tap water poses health risks, the use of tap water or bottled water for drinking uses and the adoption of an averting behavior to improve tap water quality, as boiling or installing a tap filter. We report odds ratio and significancy for each variable and some measures related to the goodness of fit of the models. Firstly, concerning satisfaction with water quality, the model results indicate that the variables Taste, Trust and Subsidy are statistically significant at the $p < 0.01$ level. The odds ratios of these variables indicate a positive relationship with water quality satisfaction. These results suggest that families who positively evaluate tap water taste, are satisfied with the service, and receive a subsidy to pay the water bill are more likely to be satisfied with water quality. In addition, model results at a lower level of significance ($p < 0.1$) indicate that Gender is negatively related to the likelihood of being satisfied with water quality. This relationship implies that from those surveyed, men are less satisfied with water quality than women.

Table 2. Odds ratio and goodness-of-fit for each Binary Logit Model.

Variable	WQ Satisfaction	Risk Perception	Tap Drink	Bottled Drink	Boil	Filter
Intercept	0.023 ***	22.040 ***	0.274 **	2.145	5.410 ***	0.010 ***
Freshwater WSA	0.980	1.005	1.060	1.212	0.658 **	0.807
Mixed water WSA	0.992	1.545 *	1.176	1.156	0.729 *	0.925
Desalination know	0.814	0.983	0.688 *	1.553 *	0.842	1.345
Desalination Per	1.154	0.661 *	1.005	0.889	0.960	0.923
Freshwater Per	0.952	0.967	1.573	0.923	0.690	1.275
Mixed Per	0.596	1.081	0.964	0.521 **	0.961	1.505
Taste	1.759 ***	0.681 ***	1.425 ***	0.831 **	0.942	0.991
Smell	1.042	0.946	0.937	1.083	0.949	1.025
Transparency	1.052	0.918	1.095	0.949	0.915	0.959
Trust	4.460 ***	0.509 ***	1.097	1.102	1.117	0.833
Middle-SEG	0.729	1.468	0.564 **	2.247 ***	0.852	1.813 *
Upper-SEG	0.713	1.621 *	0.529 ***	1.416	0.799	1.771 *
Vulnerable	1.468	0.945	1.417	1.175	1.236	0.586 *
Subsidy	2.167 ***	1.466	1.671 **	0.403 ***	0.753	0.456 *
Compliant price	1.488*	0.690 *	0.878	0.949	1.280	1.109
Age	1.003	1.014	0.980 *	1.009	0.990	1.036 **
Gender	0.667 *	0.978	0.895	1.035	0.765	0.921
Year in city	0.992	0.993	1.006	0.986	0.997	0.987
Birthplace	0.986	0.915	1.313	1.271	0.765	1.287
Household size	0.982	0.960	1.004	1.036	0.983	1.187 ***
Local env awareness	1.381	0.856	1.025	0.616 *	1.053	1.133
Regional env awareness	0.966	1.254	0.965	1.904 **	0.916	1.454
Save water	0.698	1.040	1.106	1.590 **	1.230	1.017
Model Fit:						
Model χ^2	277.655 ***	140.053 ***	110.021 ***	58.870 ***	44.699 ***	36.810 **
Hosmer-Lemeshow	0.295	0.168	0.117	0.080	0.038	0.056
R^2 Cox-Snell	0.284	0.155	0.124	0.068	0.052	0.043
R^2 Nagelkerke	0.419	0.245	0.178	0.117	0.069	0.079

Notes: All models have d.f. = 23 and n = 830; * p-value <0.1; ** p-value < 0.05; *** p-value < 0.01.

In the second place, the risk perception model presents two significant predictors at a 0.05 significance level. Again, both Taste and Trust appear as being inversely related to this dependent variable. Odds ratios indicate that households who consider tap water to be bad tasting and distrust or are not satisfied with water service are more likely to believe that drinking tap water implies a health risk. It is worth noting that households that believe they received desalinated water show a lower probability of risk perception at a significance level of $p < 0.1$. On the contrary, at the same significance level, mixed WSA households have a higher likelihood of presenting risk perception than those of the desalinated WSA. These results indicate that households in Antofagasta do not identify that the desalinated water supply poses a risk to their health. On the contrary, the risk perception seems more related to the organoleptic characteristics since tap water in Mixed-WSA received the worst evaluation for each parameter. Likewise, risk perception may also be influenced by socioeconomic issues, although this interpretation should be taken with caution as these variables are also significant at the $p < 0.1$ level. Specifically, households belonging to the Upper-SEG have a higher probability of showing risk perception than the control group, i.e., the Lower-SEG. Additionally, being satisfied with the price paid on the water bill is related to a lower probability of believing that tap water produces adverse health effects.

Third, a logistic model has been developed to determine which variables influence tap water consumption. In this case, tap water taste, socioeconomic group to which the household belongs, and receive a subsidy for the payment of the water bill are the variables that better explain the probability of drinking tap water at a significance level of 0.05. The odds ratio of these variables indicates that both Taste and Subsidy are positively related to the likelihood of drink tap water. However, belonging to the Middle-SEG or Upper-SEG is associated with a lower probability of drinking tap water than Lower-SEG households, where this practice is more widespread. At a lower statistical significance (p-value < 0.1), the variables Age and Desalination know are negatively related to this practice. These results may imply a lower probability that older respondents and those who are aware of the existence of the desalination plant will engage in this practice.

The fourth logistic model refers to the practice of using bottled water for drinking purposes. In this case, we find results that are consistent with those of the previous model. For example, some of the main variables at a significance level of 0.05 are tap water taste, socioeconomic group or the receipt of a bill payment subsidy. The odds ratios of these variables show the opposite effect as in the case of the previous model. However, the model results indicate that there is a higher probability of drinking bottled water in the Middle-SEG compared to the Lower-SEG, while there are no statistically significant differences between the Upper and Lower-SEG, as this practice is generally widespread in all households. In addition, other variables appear as significant, such as knowledge of the existence of the desalination plant, the perception that they are supplied with mixed water or variables related to environmental awareness. Among these variables, those showing greater statistical significance indicate that those households that claim to save water and are aware of water scarcity at the regional scale are more likely to drink bottled water. The results suggest that those households aware of regional water scarcity are more likely to drink bottled water, demonstrating that environmental awareness is not always related to environmentally sustainable practices. In addition, the extra expense associated with the purchase of bottled water may incentivize households to save water. In this sense, the survey asked why they carried out actions to save water, 83.7% indicating that it was for economic reasons. In comparison, only 51.6% indicated environmental reasons.

Fifth, the logistic model results for the averting behavior of boiling tap water indicate statistical significance only with the area of water supply. In this sense, household membership in the Inland Freshwater WSA or Mixed WSA implies a lower probability of boiling water than in households in the Desalinated WSA. As desalinated water supply area is an urban area developed over the last two decades, these results may be related to the fact that its inhabitants have lived less time and are more reluctant to drink tap water without boiling. Even though this variable also may be linked to the mistrust generated by this new supply source among residents. Finally, the model results on the averting behavior of installing a tap filter indicate that both Age and Household size are the two main variables explaining the probability of performing this practice. The odds ratios of these variables suggest that the greater the number of occupants in a household and the greater the respondent's age, the greater the probability of installing a filter. Likewise, at a lower level of significance ($p < 0.1$) three socioeconomic variables appear to be related to the performance of this practice. According to the model results, belonging to the Middle-SEG and Upper-SEG implies a higher probability of installing a filter than Lower-SEG households. Likewise, subsidy beneficiaries suggest a lower likelihood of installing this device, which may also be related to a lower socioeconomic level. In the last place, families with vulnerable groups (which refers to disabled, elderly, or retired members) also show a lower probability of adopting this averting behavior, which can be considered insufficient to improve tap water quality.

Overall, the models represent a significantly better fit than a null model, as can be checked from the *p*-value of the models' Chi-Square statistic, which in all cases is less than 0.05. The models also show a moderate explanatory power, although those explaining water quality satisfaction and risk perception present a better goodness-of-fit than the other models, as show higher values for the Hosmer-Lemeshow test (higher than 0.05) and the Cox and Snell and Nagelkerke's R^2 coefficients. However, the other models, especially those referring to averting behaviors, show a low overall explanatory power, although other studies have indicated this is not unusual for models using household-level data [20]. Tests and coefficients' values show adequate goodness of fit for almost all the models, except for the model of boiling tap water. In that model, the Hosmer-Lemeshow test is lower than 0.05, implying that the model does not adequately fit the data. However, the results of the Kruskal-Walis test showed significant differences between water supply areas in the adoption of this practice. Therefore, we can only state differences between supply areas in adopting this practice, especially between Desalinated WSA and Inland Freshwater WSA. However, none of the other independent variables considered in the model can explain this averting behavior.

4. Discussion and Conclusions

Previous studies have remarked that poor perception of tap water quality and safety may be explained by three different potential sources [20]: health-related contamination and the violation of legal quality standards; non-health-related but perceivable contamination due to the contaminants' sensory qualities; or pure misperception by water users. In our case study, water supply meets the national quality standards, so low perception of water quality is related to poorly evaluated water sensory qualities and public mistrust linked to past contamination events [43]. In Antofagasta, it has been identified that a large part of the population is dissatisfied with tap water quality and perceives that poses a health risk. The widespread risk perception showed by Antofagasta's population, close to 80%, contrast with that of other studies, in which 10% or less of the respondents perceive tap water as unsafe [15,20]. As identified in previous work developed in Antofagasta, high-risk perception is strongly linked to past experiences related to arsenic contamination [36,43]. The significant health impacts that tap water produced over Antofagasta's population remain in the collective memory and maybe a principal factor that explains risk perception, water habits and daily practices [36,43]. In this sense, these characteristics may help to explain why only one in four households uses tap water for drinking uses, and more than 80% use bottled water. Likewise, poor water quality perception has led to averting behaviors such as boiling water, a habit spread in almost half of the homes, and installing a tap filter. These results are in line with those of other research, where poorly perceived water quality is the main driver of bottled water use and the presence of in-home water treatments [44,45].

The results presented in this study have confirmed that taste is one of the main drivers of water quality satisfaction, risk perception and the consumption habits of drinking tap and bottled water. In other studies, smell used to be the primary reason for dissatisfaction with water quality [1,5,23,46], although, in Antofagasta, tap water taste has appeared to be the main organoleptic parameter. As in other research [5], a bad taste of tap water may be related to the belief that chemicals which can produce harmful health effects are present in tap water. In this sense, some chemical components such as chlorine, limestone and water hardness or mineral content could explain these results. Unfortunately, we have not been able to obtain information on actual water quality, which could provide additional information about its relationship to perceived quality.

In addition, as in other studies, water quality satisfaction and risk perception are highly influenced by trust in water utilities, which refers to satisfaction with the service, as has been noted in another research [5,12,14,17,22]. However, the direction of this relationship has not been identified, as satisfaction with water quality and risk perception may be the factors affecting trust. Likewise, as identified in results and previous research, frequent changes in tap water quality can increase the risk perception and decrease tap water quality [17,43]. In Antofagasta, this is the case of the mixed water supply area. In this area, the organoleptic characteristics of tap water are the worst valued, and the frequent changes in the composition of the water mixture result in higher risk perception. The limited knowledge of the water sources supplied, together with a high-risk perception, requires that predictable changes in organoleptic parameters related to improving water distribution or treatment systems must be communicated to households in advance [43]. No more relationships have been detected between water supply sources and satisfaction with water quality, risk perception or consumption habits at the 0.05 significance level. However, it has been identified that boiling water is more widespread in the desalinated water area. There is no evidence to ensure that this practice is carried out because the population considers desalinated water harmful. However, almost half of the surveyed population is aware of the origin of the water they drink in this supply area, in contrast with the rest, where only 10% of respondents have this knowledge. It should be noted that there is a higher proportion of the non-local population in the desalinated water supply sector who may have imported this practice from other regions or countries. Nevertheless, further research is needed to interpret these results, as this averting behavior may be influenced by the perception of new or controversial potential hazards resulting from introducing a new water source [5,16].

Apart from that, model results indicate that socioeconomic factors are relevant in explaining the dependent variables analyzed. In Antofagasta, the drinking water consumption habits are highly variable according to social class, expressed by the SEG and Subsidy variables, which is in line with findings of another research [32,33]. It has also been identified that households that receive a bill payment subsidy and/or are satisfied with the price paid for water are more likely to be satisfied with the water quality. Other studies, however, show that poor water quality perception is strong enough to have a higher impact on the use of bottled water than income [4]. It is worth noting that socioeconomic variables have also turned out to be explanatory for the risk perception and the installation of a tap filter. Probably, the lack of economic means and the need to drink water directly from the tap explain why the Lower-SEG presents a lower risk perception than Upper-SEG. Notwithstanding, the interpretation of the influence of these variables should be taken with caution. Wealthier households may have a higher risk perception linked to various unidentified underlying factors, such as educational or cultural level, previous household experience or habits and daily practices related to water consumption. Likewise, the interpretation of the compliant price variable may be similar to that of the trust variable since the results seem to indicate that households satisfied with the price they pay are less likely to show risk perception. Concerning installing tap filters to improve water quality, although they do not require complex or expensive installation, their presence does not usually occur in low-income households, which is in line with the results of other studies [4].

Lastly, concerning sociodemographic factors, there is little influence on perceptions and daily water use practices. There is only some influence of gender on satisfaction with water quality, as male respondents are more likely to be dissatisfied, which is in line with some studies [14,27]. However, these results contradict the general trend indicating that women tend to evaluate water quality worse [1,15,22,25,26]. In addition, respondents' age seems related to drinking tap water and installing a filter, although with relationships of opposite signs. While other studies relate dissatisfaction with water quality and risk perception to younger respondents [5,16], the opposite has been observed in Antofagasta, where the older the respondents are, the less likely they are to drink directly from the tap and the more likely they install a filter.

Without underestimating the complexity of effective risk communication, this study may support it by a better understanding of information needs and factors related to water quality and risk perception. Health and safety issues are some of the main factors that households consider about drinking tap water. In coastal areas, especially those which have suffered water contamination episodes as Antofagasta, this concern is even more remarkable, expressed in the low perception of tap water quality. The development of desalination has not changed this situation. Instead, it is presented as a factor contributing to the perception that tap water produces adverse effects on health. This perception is widespread, implying that public institutions and water operators will have to work ahead of them to motivate the population about the security of the water supply. Perception of water quality is based on a combination of multiple factors. Hence, a change in one may be balanced by the stability of the others [5]. In that way, perception is likely to be stable and the actions aimed to modify it need communication strategies that simultaneously address several influencing factors [5]. For instance, education campaigns at the school, public visits to water treatment facilities and the involvement of students' families may enhance the impact of educational strategies, raise awareness about water issues and promote trust and confidence in water suppliers [5]. In addition, some studies have demonstrated that transparency and information available related to purification processes and quality checks are essential contributors to increase customer trust and confidence about water quality and safety, as long as the information is easily interpretable by any user [15]. Nevertheless, the impact of scientific and technical information may be limited since interpersonal information sources (family members and friends) have been shown to have a more significant effect on the population's perceptions [5,43]. Likewise, personal experience via organoleptic parameters will remain at the top of the factors influencing perception. Therefore, facing poor water quality perception and reducing bottled water consumption will require addressing other types of measures, such as the promotion of in-home water treatment systems for uses that require higher quality (drinking and cooking) [4]. These measures are usually limited to high-income households, so promoting other alternatives such as activated carbon water pitchers or bottles is necessary to reach fewer wealthy households or those on a rental basis that do not usually make this investment [4]. Future research should solve the study limitations, such as the absence of potential explanatory variables such as educational or cultural level, reasons behind the adoption of averting behaviors and perception biases related to intertemporal pessimism or the belief in the decline of water quality. In addition, it could incorporate actual values of tap water chemical composition to identify whether there are objective parameters that explain the perception of households. To address these issues, qualitative research methods may complement the information gathered via surveys. These future studies can deal with, from a qualitative point of view through household's in-depth interviews, the reasons that explain the low perception of water quality and the perception that tap water intake may pose a health risk. Additionally, these interviews may be helpful to deepen knowledge on in-home water treatments or averting behaviors and how costs related to them and the purchase of bottled water affect the household economy, thus water affordability, especially in lower-income households. Furthermore, in this sense, it is possible to ask directly about the opinion of users on the introduction of desalinated water, to check if it contributes directly to increasing or decreasing their water quality and risk perception, as well as their confidence in the water supply service.

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