WATER SUPPLY AND DEMAND IN SANTA CRUZ ISLAND - GALAPAGOS ARCHIPELAGO

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ABSTRACT

Water demand has been growing dramatically in Santa Cruz, the most populated island of the Galápagos Archipelago. Due to a significant increase in tourism throughout the last decades, Santa Cruz is experiencing extreme pressure on its water resources. Consequently, its water supply cannot sustain the current demand growth rates. The two main settlements, Puerto Ayora and Bellavista, have separate billing practices: Puerto Ayora has a fixed-water tariff in absence of individual metering, while Bellavista has a consumption-based tariff and a metered system. The difference in tariff structure causes significant variation in consumption, as well as challenges in the quantification of demand. This paper analyses the water supply and demand on the island by assessing the total demand based on the results of field survey developed for four categories of consumers: (i) domestic, (ii) tourist, (iii) commercial and (iv) laundries. The paper also summarizes the demand originating from different sources, portraying the differences between the two settlements. Additionally, estimates of non-revenue water according to different scenarios and demand per capita per source of water have been included.

Keywords: Water Supply, Water Demand, Tourism, Alternative Sources, Galapagos

1   INTRODUCTION

Tourism in many tropical islands around the world has increased dramatically over the last decades. It is one of the most dominant economic sectors in several island states, such as in the Caribbean (Charara, Cashman et al. 2010). Even though tourism is a major source of income and employment for many islands (Briguglio 2008), it has been one of the main causes of environmental degradation and pressure on natural resources such as water. The proportional increase of water demand is also amplified by the growth of local population providing facilities and services for tourists. Despite the fact that islands have limited water resources, the expansion of tourism to such destinations over the last 40 years has been overwhelming (Essex, Kent et al. 2004). Visitors in these environments exert demand on infrastructure and resources, often without a sustainable balance.

The Galápagos Archipelago, located in the Republic of Ecuador, has also felt the influence and threats exerted by tourism. This group of islands has always been admired for its beauty, uniqueness and biodiversity (González, Montes et al. 2008). That has led to a significant increase in tourism and growth of local population especially on Santa Cruz, which is the most inhabited island with around 60% of total population of the archipelago. The fast increase in number of hotels, restaurants, bars, and other tourist facilities, has amplified the water demand in order to satisfy tourists' and customers' needs.

The two main settlements on the island are Puerto Ayora and Bellavista, with total population of approximately 14,500 inhabitants (INEC 2010). As a result of tourism and the consequent growth of local population, these two settlements have encountered major problems with water supply over the past years. Furthermore, the water demands in these two settlements vary mainly as a consequence of the different water-tariff structures. Puerto Ayora has a fixed-priced tariff per month, varying between demand categories established by the municipality. On the other hand, Bellavista has a metered

system, with a fixed cost of USD 1.21 per cubic meter (GADMSC 2012). Nevertheless, the municipal water service for both settlements has been perceived as low and unreliable. Moreover, water supplied is of non-drinking quality. Therefore, the local population needs to find alternatives, such as water supplied by trucks and bottled water as the main source of drinking water.

Due to the lack of metering in Puerto Ayora, water demand quantification has been a challenge. Previous studies on water-related issues, such as the one carried out by Guyot-Tephiane, Orellana et al. (2012), explain the differences regarding the various types of sources. However, those few researches have not been sufficient for accurate quantification of total water demand on the island.

This paper analyzes water supply in Santa Cruz by surveying different types of water sources used. Furthermore, the water demand has been assessed and quantified per category: (i) domestic, (ii) tourist, (iii) commercial and (iv) laundries. Finally, the supply and demand have been compared in order to estimate the non-revenue water (NRW) for different scenarios. All results are based on the information gathered from specifically developed field survey, combined with the information provided by the Municipality of Santa Cruz and other relevant organizations involved in water resources management in Galápagos.

2   PROBLEM STATEMENT

Tourism in Galápagos increases by eight percent annually, mostly on Santa Cruz, while this island is without sufficient infrastructure and water resources for this exponential growth (Orellana 2014). Furthermore, the current management of these resources has been inefficient. Mostly the construction of low cost hotels has increased significantly, as well as small private accommodations or camping sites, opened with little environmental consideration. In addition, the number of restaurants has also increased.

Tourist accommodation facilities are not stringently monitored by the Ministry of Tourism (MINTUR). Consequently, this lack of control and regulation boosts illegal accommodations. According to the MINTUR, as of December 2013, there were 106 unregistered accommodations out of the total 159 in the island. Moreover, according to the Department of Potable Water and Sewage (DPWS), there are approximately 40 service connections belonging to small and big hotels. In addition, even though the local authorities recognize the problem with lack of regulation of touristic facilities, in August 2014 the Minister of Tourism declared the banning of the moratorium on the construction of new infrastructure for tourist accommodations in the Galápagos Archipelago.

Similar to the tourist accommodations, the number of laundries has increased as well. However, in the land cadastre of Santa Cruz there are no premises categorized as laundries, while according to the DPWS there are only five service connections registered in this category. Evidently, an update of the land cadastre is lacking, as well as more strict control over this type of premises regarding operating licenses. It is commonly known that laundries are a profitable business. Therefore, the total number of these premises is unknown but it is certain that it is higher than the registered ones.

3   METHODOLOGY

In order to estimate the water demand for Santa Cruz, a quantitative survey was carried out during the fieldwork conducted from November 2013 to January 2014 in Puerto Ayora and Bellavista. The minimum sample size was calculated based on the total number of land properties according to the 2012 cadastre from the municipality of Santa Cruz. With a sum of 2460 properties in Puerto Ayora and 435 properties in Bellavista, the minimum sample size was calculated at 339 surveys (240 domestic properties, 30 hotels, 30 restaurants, 16 laundries in Puerto Ayora, and 60 domestic properties in Bellavista) (DeVault 2014).

Five sets of questions (in Spanish) were developed for survey of each category of customers. The domestic survey questionnaire contained five main parts: (i) general information on location and description of the household, (ii) water demand, referring to the estimates of actual consumption per type of supplied water (bottled, municipal and/or from trucks), (iii) environmental awareness and

water saving practices, and (iv) sanitation practices, addressing questions related the type of wastewater disposal. The questionnaires for other demand categories were less detailed and contained four groups of questions: (i) general information, (ii) average number of daily customers, (iii) water demand quantification regarding different type of sources and (iv) environmental awareness.

4   RESULTS AND DISCUSSION
4.1   Analysis of water supply in Santa Cruz

Three types of water are used in Santa Cruz Island: 1) municipal supply; 2) bottled water, and 3) 'private' extractions.

The first one refers to the Municipality of Santa Cruz providing water through the two independent systems for Puerto Ayora and Bellavista. Each system has its own source and distribution network. The distributed water is mainly brackish and consequently considered non-potable according to national and international regulations. Neither system includes water treatment.

The bottled water is the main source of drinking water. Several private companies desalinate brackish water with small-scale reverse osmosis plants and sell purified water in bottles and containers of different sizes. Costs for this water are very high, given that it is a basic need, and therefore the desalination businesses are very profitable in the island.

The 'private' abstraction takes place from different crevices located around Puerto Ayora, some of them coincidentally on private properties. That water is delivered in water trucks and sold by the property owners. Next to this, several privately owned pumps and pipelines are installed in the crevices which are located outside the private properties. These "practically illegal" infrastructures have mainly been set up by hotels, institutions or laundries with financial means. The pumping is neither monitored nor quantified; therefore, it is very challenging to determine the exact water abstraction per crevice. The quantification of total water supply within the island has been very challenging due to unreliable and incomplete data. Nevertheless, estimations have been made in order to approximate water supply per source (Table 1).

Table 1-Total water supply for Puerto Ayora and Bellavista

Supply source	Quantity supplied (m^3/day)	Specific demand (lpcpd)
Municipal supply	3283	226
Bottled water	150	10
Private crevices	1952	135
TOTAL	**5385**	**371**

4.2   Analysis of water demand
## 4.2.1   Domestic Category Demand

The survey indicated that 92% of the respondents of Puerto Ayora and 81% in Bellavista are connected to the municipal network. This reflects the faster growth in number of households in Bellavista and inability of the municipality to cope with it. Furthermore, water supply is intermittent in both areas. 99% of respondents in Puerto Ayora answered to have service every day, but only 2% have maximum five hours of supply per day. The majority (47%) reported to have the water service on average 2 hours every day. In Bellavista, about one third of households receive water supply only once in three days, portraying a lower level of service than in Puerto Ayora. Only 24% of all the households in Bellavista receive water from municipal system every day for two or three hours only. Hence, this service level is clearly worse than in Puerto Ayora. The responses from the households however differ from the information provided by the municipality, who claim that the water service is provided every day.
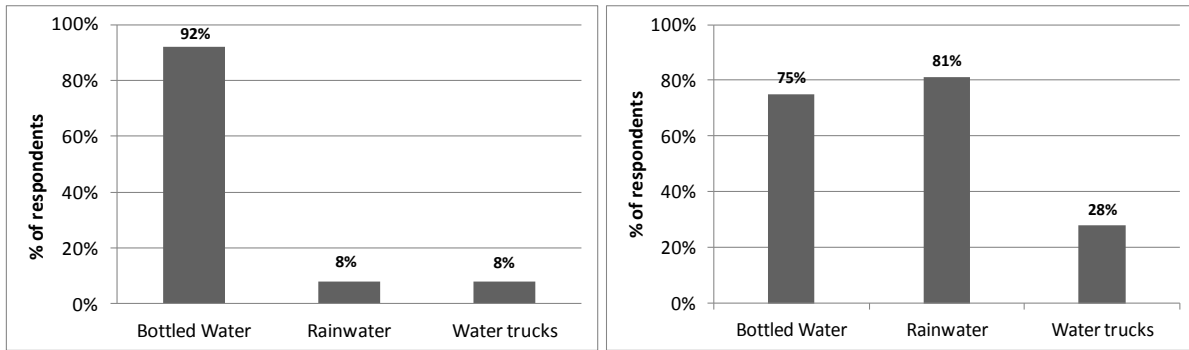
Figure 1. Use of additional sources of water in Puerto Ayora (left) and Bellavista (right).

Figure 1 show all three types of water used by the local population. For bottled water, several questions were included regarding the quantities bought per week, type of container, or in bulk. Due to an evidence of occasional contamination of bottled water (Liu 2011), some households perform additional treatment consisting of filtration, disinfection or boiling.

Furthermore, to mitigate the intermittency, the households use different types of storages, mainly cisterns and tanks of various capacities, depending on the family size and habits (Figure 2).
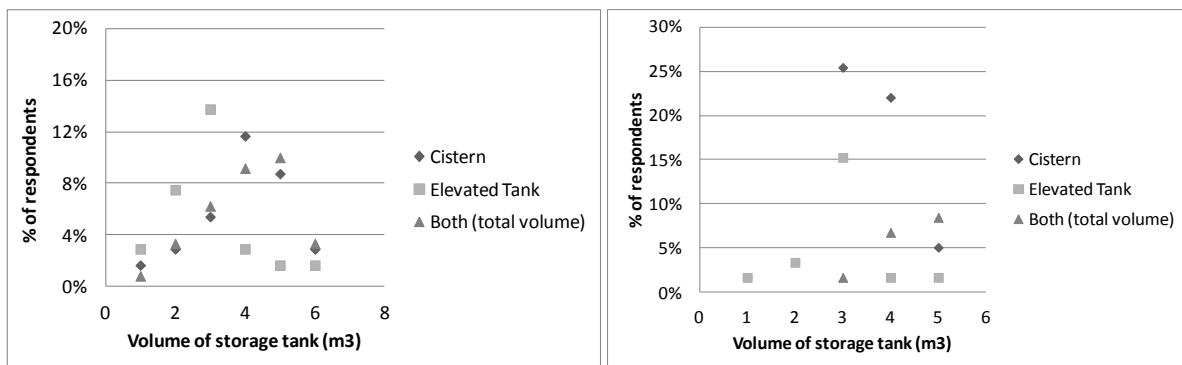

Figure 2. Type of storage and volume used for municipal water in Puerto Ayora (left) and Bellavista (right).

Using the information regarding the capacity of household storage, the reported frequency of filling and the number of users, an attempt was made to estimate the total water demand from the municipal supply, as well as the specific demand per capita. The water demand per capita per household based on the number of inhabitants per premise is shown in Figure 3.

The expected trend is confirmed: larger households have lower water demand per capita. Very likely, the general activities such as garden irrigation, cleaning of common areas, or cooking are done more or less independently of the number of occupants. Furthermore, the figures for Puerto Ayora show wider range of water demands for the same number of inhabitants, suggesting diverse water use i.e. different living standards than in Bellavista.

Eventually, the average specific water demands for Puerto Ayora and Bellavista are 163 and 96 lpcpd, respectively, while standard deviations for the surveyed households are 60 and 34 lpcpd, respectively. As observed, the average water demand per capita from the municipal source differs significantly between the two settlements, which reflects the difference in habits clearly influenced by the cost of water.
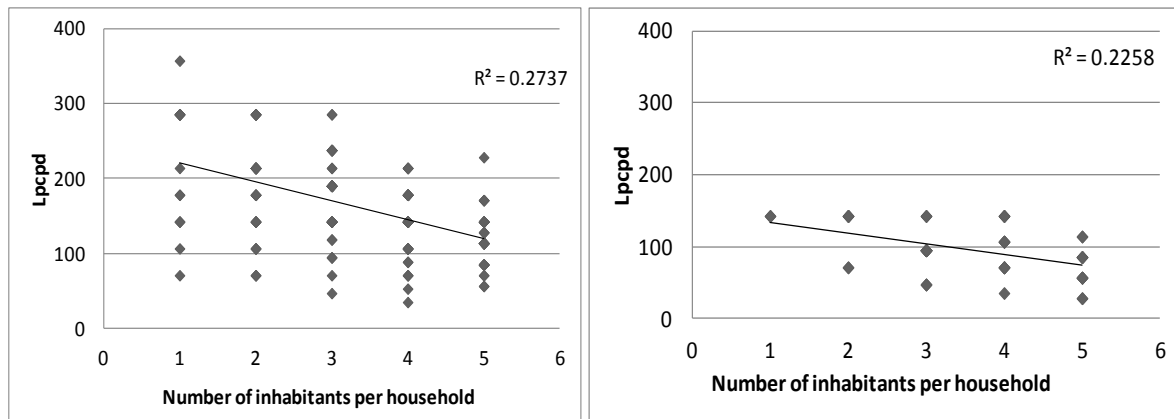
Figure 3. Relation of water demand per capita and number of inhabitants per household in Puerto Ayora (left) and Bellavista (right).

The different tariff structures influence the habits of population with respect to water use. The households in Bellavista tend to be more cautious with wasting of water and consequently their consumption is not as excessive as in Puerto Ayora; the customers are more aware of the value of water, unlike in Puerto Ayora where the wastage of water and lack of awareness tends to be overwhelming. The fixed monthly fees in Puerto Ayora seem to be the main contributor to such behaviour. Some households have shown to use much lower quantities than the others for the same number of occupants, which in broader terms could reflect different style of living. The high standard deviation of water demand suggests that locals use water randomly and there is no obvious tendency regarding social stratum or number of occupants or the neighbourhood.

According to the municipality, the biggest losses occur at the moment of filling up the tanks when water supply service is still available. Because of unpredictable water service of only few hours per day, local population keep the faucet open to let the water flaw into the tank, and tend not to close it when full because the service will stop anyway. When precisely, is less important for the spilled water is not charged to them. Therefore, the questions addressing the water leaks and spilling of individual tanks were also asked. Respectively 70% and 50% of the respondents in Puerto Ayora and Bellavista do not close the faucet when the tank is filled and almost 50% and 40%, respectively, do not have an automatic device to prevent the overflow. The latter was frequently observed during the fieldwork that the water continues to flow even when the tank is full.

Although the local population often complain about the lack of proper water supply service and recognize the importance of saving water, they rarely practice it. Furthermore, the use water saving devices such as water efficient toilets or showers is not widespread, although the interest in having one is demonstrated in the majority of answers. Furthermore, a high percentage of responses in Puerto Ayora (32%) pointed out leaks within their households. Unfortunately, these leaks are rarely fixed, probably due to the fact that the water lost is not charged to the consumer. On the other hand, the leaks within premises in Bellavista are much lower (reported in 15% of responses), implying that the tariff structure influences the decision to fix them.

4.2.2   Total demand quantification for domestic sector

The quantification of municipal water demand was made based on the questions regarding the frequency of purchase and volume of bottled water. Moreover, based on municipal supply, an estimation of NRW was made as show in Table 2.

Table 2. Non-revenue water in Puerto Ayora and Bellavista

Settlement	Demand (lpcpd)	Total Demand	Total Supply (m³/year)	NRW (m³/year)
Puerto Ayora	163	712,188	1,103,760	391,820
Bellavista	96	87,600	94,608	7,008

Additionally for the case of Bellavista, other scenarios have emerged along the analyses of obtained data by using the water cadastre. The NRW estimates vary for different scenarios as shown in Table 3. The figure calculated from the official information provides a high NRW value, which indicates large economic losses for the municipality due to 32% of malfunctioning water meters.

Table 3. Different water demand scenarios for Bellavista

Scenario per source of information	Demand (lpcpd)	Total Demand (m³/year)	Total Supply (m³/year)	NRW (m³/year)
Surveys	96	87,600	94,608	7,008
Municipal Cadastre*	56	50,862	94,608	43,746
Municipal Cadastre (average calculation)**	87	79,130	94,608	15,478

4.2.3   Domestic water demand from other sources

Based on questions on storage of additional sources, it was possible to estimate the total demand regarding all the types of supplies for both settlements as shown in Table 4.

Table 4. Water demand from different sources of water in Santa Cruz

Settlement	Municipal supply (m³/year)	Bottled water (m³/year)	Water trucks* (m³/year)	Rain water** (m³/year)	Total demand (m³/year)	Specific demand (lpcpd)
Puerto Ayora	712,188	7243	57,518	N/A*	776,949	177
Bellavista	82,481	2683	48,307	97,444	230,914	253
TOTAL	**794,669**	**9925**	**105,825**	**97,444**	**1,007,863**	**190**

*Water from trucks refers to partial pumping from ' private' crevices.**Rainwater was not considered in Puerto Ayora for it is practiced by less than 10% of surveyed households.

Table 4 shows that additional water is needed besides the municipal supply. Nevertheless, rainwater is barely collected in Puerto Ayora. One reason for that is lower precipitation than in Bellavista, but the practice is also less popular because the rainwater harvesting has been perceived as archaic. Oppositely, people in Bellavista collect rainwater regularly and use it for all household activities. Bottled water is used mainly for drinking and for personal hygiene, while brackish water is used for the rest of domestic activities such as cooking, washing dishes, clothes, toilets and showers. Moreover, the water from trucks contributes significantly to the demand in Bellavista, which is due to lower number of connections to the municipal service. Finally, it is to be noted that all the results presented are based on assessments of the responses to questionnaire based survey of the customers. The high figures of supply and demand resulting from the questionnaire therefore should be verified; the reported rainwater use and the water supplied by trucks may be overestimated by the respondents.

4.2.4   Demand from other categories (tourist accommodations, restaurants and laundries)

Several questions were asked during the analysis of different tourist accommodations and restaurants, regarding consumption per water type. 87% of hotels and 93% of restaurants participating in the survey indicated to use municipal supply as their main source of water. Furthermore, the volume

of storage for municipal water is shown in Figure 4. 43% of hotels have their own purification system, while in restaurants only 13% said to have one. Moreover, different types of filters are used in both types of facilities. The majority of hotels (61%) use a sand filter, while 90% of the restaurants do not have any purification system. In addition, three stars hotels commonly do not perform any treatment in order to satisfy their customers.
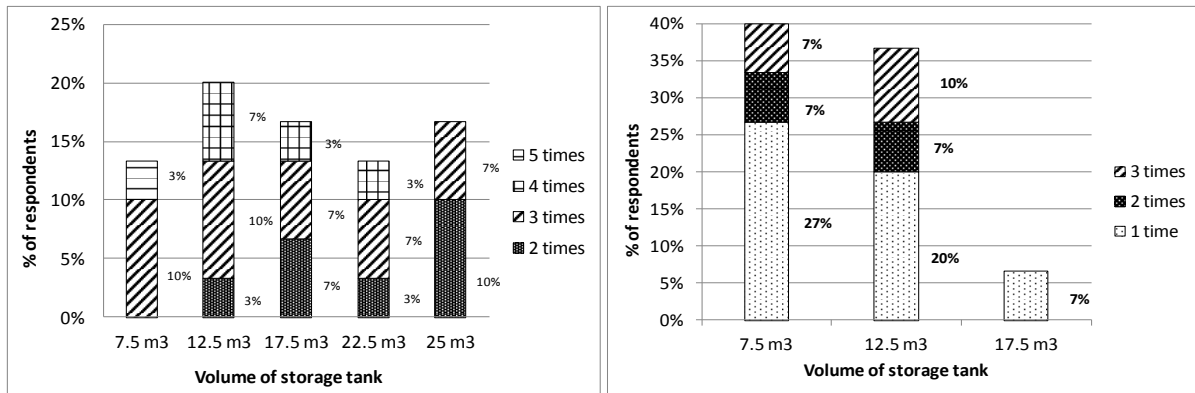
Figure 4. Frequency of filling of storage tanks in hotels (left) and restaurants (right).

Water from different sources is used for different activities within hotels and restaurants. Bottled (desalinated) water is used mainly for personal hygiene, drinking and cooking. For the rest of activities, such as toilet flushing, dish washing, etc., the municipal and truck (brackish) water suffices. In the case of laundries, similar questions were asked regarding capacity of storage and filling per week, in order to calculate total consumption.

The total demand has also been assessed for tourist facilities in Puerto Ayora: different categories of hotels and restaurants as shown in Table 5. The figures were derived based on the questions regarding the volume of storage and the frequency of refilling, as well as the frequency of purchased bottled water or the one supplied by trucks.

Table 5. Water demand quantification for hotels and restaurants in Puerto Ayora

Type of accommodation	Average capacity (customers)	Municipal water (m³/day)	Water trucks (m³/day)	Bottled water (m³/day)	Specific demand (lpcpd)
Hostel	40	8.1	0	0	205
2-star hotel	35	4.0	12.3	0.1	470
3 star hotel	45	6.0	29.7	0.3	667
4-star hotel	35	9.6	9.0	0.1	535
AVERAGE	**38**	**7.0**	**11.3**	**0.1**	**469**
Restaurants	**15**	**0.2**	**0.9**	**0.1**	**126**
	25	0.5	1.7	0.1	158
	45	0.4	0.9	0.2	46
	50	0.4	1.8	0.3	79
AVERAGE	**34**	**0.4**	**1.3**	**0.2**	**102**

Figure 5 shows the daily demand of each of surveyed hotels; the horizontal axis represents each hotel, given a specific number as identification. The hotel rating as given in Table 6 grows with the serial number.
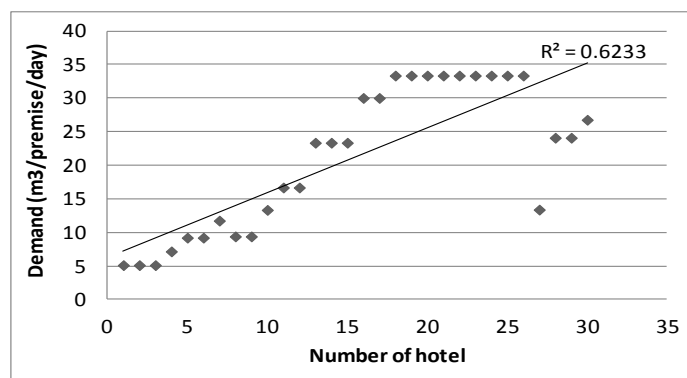
Figure 5. Demand per surveyed hotel

There is a correlation between the demand and the rating of accommodation: as the hotel is more luxurious, the average water demand is higher (Figure 5). However, in the case of four-star hotels, the water demand is relatively lower, which is explained by a higher percentage of own purification systems or additional treatment for the municipal water.

Majority of hotels and restaurants are connected to municipal supply, but some hotels (mainly three stars) and virtually all restaurants are mostly supplied by water trucks. The four-star hotels mostly have their own desalination systems and are less dependent on municipal supply, which is not the case of lower class tourist accommodations. Moreover, three-star accommodations use more water (in total) because of larger occupancy. The actual tendency of tourism in Galápagos is towards medium class tourists; those can hardly afford four-star accommodations at average rate of 350 USD per night.

For the case of laundries, similar questions regarding storage and filling of it were asked in the survey. Estimations of water demand for this category were also made in order to complete the demand of major consumers.

Finally, the total water demand for Puerto Ayora was calculated based on the average consumption derived from the survey, multiplied by the total number of premises per category according to the land cadastre of the municipality (Table 6).

Table 6. Total water demand quantification considering all categories

Category	Municipal supply (m^3/day)	Bottled water (m^3/day)	Water trucks* (m^3/day)	Total demand (m^3/day)
Domestic	1951.2	19.8	157.6	2128.6
Hotels	1107.2	20.6	1788.8	2916.6
Restaurants	69.3	7.6	51.1	128.0
Laundries	28.5	0	20.1	48.6
TOTAL	**3156.2**	**48.0**	**2017.6**	**5221.8**

*Water trucks refer to pumping from 'private' crevices.

Table 6 shows that the highest water demand belongs to the hotels, especially supplied by water trucks. This is not surprising since a similar situation is occurring in many other tropical islands. The biggest consumers are tourist accommodations, proportionally to the ranking of hotel. On the other hand, restaurants and laundries do not contribute as significantly to the total demand in Santa Cruz. Nevertheless, the total number of registered restaurants and laundry premises in the land cadastre is questionable. Therefore the survey included 16 laundries evident in the settlements.

5   DISCUSSION OF THE RESULTS AND RECOMMENDATIONS

This research provides an insight into the total water demand in Santa Cruz per source of water and category of users. The survey has provided a scenario reasonably close to the reality and has permitted

to make preliminary calculations for different categories. It is however necessary to determine the exact number of accommodation/premises per category, in order to make these estimations more precise. In addition, the private abstractions from crevices need to be registered, monitored and controlled. Furthermore, the supply from desalination companies needs to be verified. Since the owners from these companies were not willing to provide exact figures, this should be researched by the authorities, to whom the information would be difficult to deny.

It was observed that the highest water demand is from the hotels in Puerto Ayora. Here, the Ministry of Tourism needs to monitor systematically the legal registration of tourist facilities that are the biggest water consumers. Furthermore, this institution should be more involved in the promotion of environmentally-friendly tourism, and not a massive tourism like is occurring nowadays. If eco-tourism measures are not developed in time, the Galápagos Islands may lose all their natural attraction and endanger the unique species living there.

Regarding the domestic category, there is an evident difference in consumption behaviour between Puerto Ayora and Bellavista. This variation is caused mainly due to different tariff structures. Therefore, the fixed tariffs should be abolished in Puerto Ayora and reviewed in Bellavista. An increase in water price (which is now too low) will increase environmental awareness among inhabitants and therefore the demand could reduce significantly. Moreover, local population will hopefully understand better the value of water and will change their perception. The higher revenues will also benefit the municipality, which will have additional financial means to improve the service. The installation of water meters is also essential in Puerto Ayora in order to control losses within premises. This would also help to obtain more accurate figures on consumption from different categories and consequently a solid basis to change policies regarding water demand management.

The analyses of the responses provided a better insight into the water supply and demand for both settlements. The actual physical leakage levels are yet to be assessed, due to the absence of good monitoring from the municipality. Furthermore, the NRW for Puerto Ayora tends to be high, possibly due to the age of the distribution system, as well as the lack of maintenance. On the other hand, the NRW in Bellavista is lower than in Puerto Ayora. Nevertheless, these conclusions are based exclusively on the responses of the field survey. In general, the presented figures should be verified in order to conclude on the actual water supply and demand situation. The fact that an average of 30% of water meters in Bellavista are defective, suggests that the municipality records are not accurate. Therefore, the NRW water is extremely high, resulting in significant financial losses.

Based on the information gathered during the survey, the authorities within the island of Santa Cruz can proceed with more concise policies regarding water management. With these results, an initial scenario for both settlements regarding demand is clear. Furthermore, these results also suggest that the tendencies of water consumption are exponential; therefore, the solutions need to be addressed as soon as possible. The fragility and uniqueness of Galápagos is calling desperately for sustainable measures, especially regarding water resources. Moreover, based on these results it can be concluded that there is no real scarcity of the resources but instead, a deficient management of water supply and demand.

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