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## Water quality monitoring system in Santa Cruz, San Cristóbal, and Isabela

Javier López and Danny Rueda

Galapagos National Park

### Introduction

Economic development and population growth in Galapagos have generated a significant increase in the demand for goods and services. The consumption of these goods generates human waste, which is often dumped directly into the subsoil or the sea. This results in the contamination of surface seawater and the water table, affecting human health and the fragile ecosystems of the archipelago. Degradation of water can occur due to high concentrations of nutrients (eutrofization) and contamination by fecal coliform and heavy metals.

Water quality is an important factor for the wellbeing of the Galapagos human population and the native flora and fauna. Regular monitoring of water quality, both on land and in the sea, is important for detecting changes in quality and implementing measures to mitigate any contamination. This article presents the results of a 2008 analysis of water quality in eight sites on the three islands with the greatest human population. It concludes with recommendations for the local population and the institutions responsible for water management in the province.

Monthly water quality monitoring began in Santa Cruz in 2005, led by the Galapagos National Park (GNP) with the support of the Japan International Cooperation Agency (JICA). Water quality monitoring was extended to San Cristóbal and Isabela in 2007. Currently the GNP runs this program on all three islands.

A key objective of the program is to monitor the quality of the water used for human consumption and domestic use. A total of seven terrestrial sites were selected in areas where the local municipality

extracts water for distribution to the population. An eighth site, the Ninfas Lagoon in Santa Cruz, was selected because it is an important recreational site for the residents of Puerto Ayora (Table 1). The four sites in Santa Cruz have been monitored since the project began in 2005.

### Criteria for selecting sampling sites

Various criteria were taken into account to select both terrestrial and marine monitoring sites, including accessibility, representativeness, existing information and data from previous studies, needs of users, and level of contamination. Both terrestrial and marine sites were selected in Santa Cruz, while in San Cristóbal and Isabela two terrestrial sites with water for human consumption and domestic use were chosen (Table1).

### Sampling characteristics

**Sites:** Santa Cruz, San Cristóbal, and Isabela

**Sampling frequency:** Monthly

**Analysis:** Conducted in the Water Quality Lab of the Galapagos National Park (GNP) and Environmental Chemistry Lab of the Central University of Ecuador

**Maximum Permissible Limits (MPL):** Norms established under the national environmental legislation TULAS (Texto Unificado de la Legislación Ambiental Secundaria, 31 March 2003)

**Table 1.** Water quality monitoring sites.

Santa Cruz	San Cristóbal	Isabela
Terrestrial	Terrestrial	Terrestrial
INGALA Crevice	Municipal Plant	Manzanillo
Deep Well	House in Puerto Baquerizo	House in Puerto Villamil
Colegio San Francisco Crevice		
Coastal		
Ninfas Lagoon		

### Determination of the analyzed parameters

Norms established under TULAS were used to select the parameters to be included in this study. Due to financial limitations, it was not possible to monitor all

of the recommended parameters. Therefore, a preliminary analysis was conducted to determine the parameters considered the most important for decision-making on water management for human and domestic use and for the conservation of flora and fauna (Table 2).

**Table 2.** Parameters analyzed in the water quality monitoring program in Santa Cruz, San Cristóbal, and Isabela.

Physical	Chemical	Biological
Temperature	Nitrate	Fecal coliform
Salinity	Nitrite	Total
pH	Total phosphorous	
Dissolved oxygen		
Turbidity		



**Figure 1.** Measuring dissolved oxygen and pH of the water in the Ninfas Lagoon, Santa Cruz.

## Results

The results of the study show that with the notable exception of fecal coliform, the parameters monitored fall within the maximum allowable limits for water used

for human consumption and domestic use (Table 3).

The monitoring stations in the highlands and those close to the sea measured lower levels of salinity, pH, and dissolved oxygen than water on the continent.

**Table 3.** Average annual values registered during 2008 for each parameter measured in the different sampling sites in Santa Cruz, San Cristóbal, and Isabela.

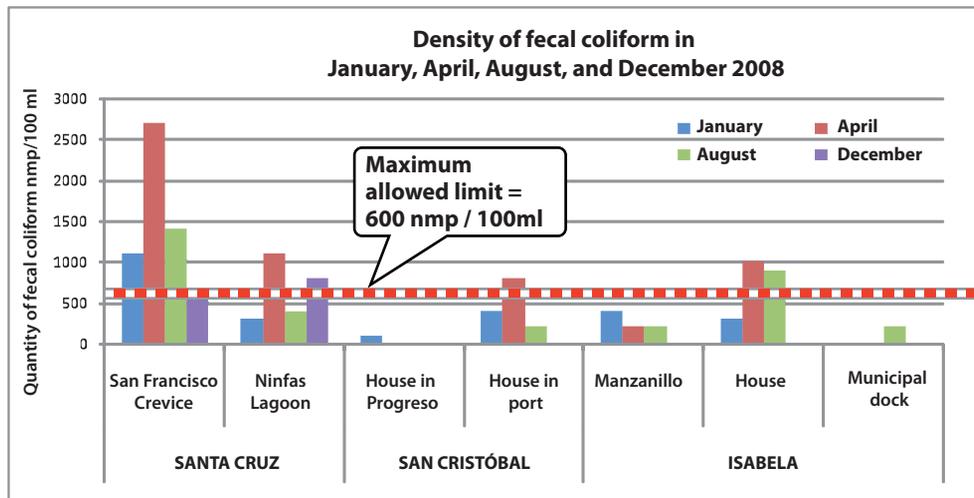
Parameter	Site							
	Colegio San Francisco Crevice	Deep Well	INGALA Crevice	Ninfas Lagoon	Municipal Plant	House in Puerto Baquerizo	Manzanillo	House in Puerto Villamil
Fecal coliform (nmp/100 ml)	1236	9	18	481.1	0	433	756	1011
Hydrogen potential (pH)	7.8	7.5	7.5	7.2	7.1	7.6	7.4	7.8
Dissolved oxygen (mg/l)	7.7	7.8	8	5.6	10.1	9.6	4.4	6
Salinity (mg/l)	2.3	1.1	1.6	20	*	*	1.2	1.5
Turbidity (NTU)	0.4	0.9	0.7	1.6	2.7	3.7	0.8	0.8
Temperature	24.5	24.7	24	24.3	22.8	25.5	24	23.1
Nitrite (mg/l)	0.003	0.006	0	0.007	0.011	0.003	0	0.05
Nitrate (mg/l)	0.15	0.1	0.1	0.12	0.05	0.04	0.2	0.06
Total phosphorous (mg/l)	0.57	0.57	1.1	0.22	1.62	1.22	0.9	0.99

\* Fresh water.

## Fecal coliform

In 2008 the average concentration of fecal coliform in the Colegio San Francisco Crevice in Santa Cruz was 1236 colonies per 100 ml of water, compared to the norm established by TULAS of 600 colonies per

100 ml (Table 3). The World Health Organization (WHO) recommends even more conservative levels of zero colonies per 100 ml for drinking water. Both standards confirm that the water from the Crevice is not suitable for human consumption.



**Figure 2.** Fecal coliform density in January, April, August, and December of 2008 in Santa Cruz, San Cristóbal, and Isabela.

In the case of El Manzanillo in Isabela, the level of fecal coliform during 2008 averaged 756 colonies per 100 ml (Table 3). This indicates that although the level of contamination is approximately 40% less than at the Colegio San Francisco Crevice, the water is unsuitable for human consumption.

Another site showing high contamination by fecal coliform was the house selected at random in Puerto Villamil, where the results showed levels of 1011 colonies per 100 ml.

Houses monitored in Puerto Baquerizo Moreno registered an average of 433 colonies per 100 ml, and the Ninfas Lagoon in Santa Cruz had an average of

481.1 colonies per 100 ml (Table 3).

Only the Municipal Plant in San Cristóbal showed no presence of fecal coliform in 2007-2008, while the Deep Well and the INGALA Crevice, both in Santa Cruz, had annual averages in 2008 of nine colonies per 100 ml and 18 colonies per 100 ml, respectively. The levels at these two sites in Santa Cruz were much lower than the other sites monitored (Table 3).

The INGALA Crevice is the source of 70% of the water extracted by the municipality of Puerto Ayora for distribution to the local population. Only 27% of the water is taken from the Colegio San Francisco Crevice.

**Table 4.** Average annual values of fecal coliform recorded during the years 2005, 2007, and 2008, in the sampling sites on Santa Cruz, San Cristóbal, and Isabela.

PARAMETER	Year	SITE							
		Colegio San Francisco Crevice	Deep Well	INGALA Crevice	Ninfas Lagoon	Municipal Plant	House in Puerto Baquerizo	Manzanillo	House in Puerto Villamil
Fecal coliform (nmp/100ml)	2005	*	0	0	400	*	*	*	*
Fecal coliform (nmp/100ml)	2007	3148.9	16.6	8.3	1458.3	0	150	391.6	425
Fecal coliform (nmp/100ml)	2008	1236	9	18	481.1	0	433	755.5	1011.1

\* No analysis was done.



Photo: Mary Witoshynsky

The levels of fecal coliform contamination exceed the limits set by TULAS in some sites (Table 4). However, following the completion of this study, considerably lower levels of fecal coliform were measured in Ninfas Lagoon and in the Colegio San Francisco Crevice (Santa Cruz). This reduction is probably the result of mitigation measures implemented after the study was presented to local authorities and the general public through meetings, workshops, and conferences.

Although results varied slightly from one site to the next, parameters other than fecal coliform fell within the limits for human consumption (Table 3). It appears that fecal coliform is the parameter of greatest concern and which requires most urgent attention.

## Conclusions and recommendations

Based on the results of this study, the following conclusions and recommendations are presented:

- Direct comparison of water quality among the three islands is not possible, given that San Cristóbal uses fresh water from the highlands (precipitation) for human consumption and domestic use, while Isabela and Santa Cruz rely on brackish water, which is extracted from subterranean fissures.
- Due to the high levels of fecal coliform contamination detected in the Colegio San Francisco

Crevice in Santa Cruz and in El Manzanillo in Isabela, these sites should be closed and no longer used for human consumption and domestic use.

- The high concentration of fecal coliform in the Ninfas Lagoon in Santa Cruz suggests that there is inadequate management of water run-off in the surrounding area. Mitigation measures should be coordinated by the appropriate institutions. Recreational use of the area for swimming and snorkeling should be avoided.
- It is critical for all institutions in Galapagos to become involved and work in a coordinated manner to conserve water resources, which are critical for a high quality of life for the local population.
- It is important to include biological parameters, such as phytoplankton, zooplankton, chlorophyll, and organic carbon in future analyses. This information would help to determine possible sources of contamination and necessary mitigation measures.