Water Quality in the Americas

Risks and Opportunities

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The Inter-American Network of Academies of Sciences IANAS

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Costa Rica

Costa Rica is a land of contrasts: on the one hand, the country has been acknowledged for its efforts in the environmental field and conservation, as a result of which it is widely considered a green country and it has also achieved excellent drinking water coverage. On the other hand, however, the country has severe pollution in most of its urban and some of its rural rivers. Fortunately, although a great deal of work remains to be done, significant efforts are being made to address these problems.

Reserva de Monteverde, provincia de Puntarenas, Costa Rica © iStock

Water quality in Costa Rica

Hugo G. Hidalgo, Monika Springer, Yamileth Astorga,
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1. General Introduction

1.1 Background, context and main problems

In Costa Rica, water has been used for human consumption, agriculture, tourism, industry, transportation and hydroelectric generation. The first four of these uses have the greatest potential to significantly alter the quality of the resulting water.

As happened in other parts of the world, the supply of drinking water through the construction of aqueducts was possibly the first step in the construction of infrastructure for water resource management in Costa Rica. The Guayabo National Monument, in the city of Turrialba, contains an aqueduct used from 1000 BCE to 1400 CE.

In the 17th century, water was used for domestic supply, livestock raising and agriculture. During the 18th century, livestock activity developed in the North Pacific, whereas in the Central Valley, water from rivers and streams (streams) was used in agriculture. In the 19th century, water was mainly used in coffee and banana monocultures and for washing gold as part of the mining process. The watercourse of rivers served as a means of transport for colonizing the northern zone, while the high water potential contributed to the generation of hydroelectric power. However, the type of agricultural production technology, coupled with the lack of awareness on the part of the population led to the deterioration of the quality of water resources, particularly surface water (Vargas Sanabria, 2001).

Perhaps the most obvious example of water pollution from agricultural causes was coffee activity (the leading Costa Rican export product for many years). Due to its impact on health, this pollution was strenuously opposed by the population, which created an environmental conflict (Montero Mora and Sandí Morales, 2009). This pollution continued to be a problem for a long time, affecting many rivers, until a series of actions were implemented to halt the dumping of coffee products into waterbodies, which include Resolution No. 210 of July 2, 1997, in which the Office of the Attorney General of the Republic ordered the Minister of Health to enforce legal actions to defend national waters due to contamination by the coffee processing agroindustry.

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Due to the lack of quality control, "Water was often an agent of death since it transported bacteria such as cholera, which caused nearly 10 000 deaths in 1856" (Vargas Sanabria, 2001). The first modern aqueduct was inaugurated in 1868 in San José (Vargas Sanabria, 2001). In 1915, five years before the construction of the first water treatment plant in the city of San José, renowned scientist Clodomiro Picado Twight, together with his collaborator Francisco Sancho, undertook the first microbiological and physical-chemical analyses of drinking water for this city (Picado Twight, 1915).

The first sewerage works were inaugurated in 1911, and were subsequently constructed in the main cities of Valle Central, at the beginning of the 1940s (Mora-Alvarado and Portuguez-Barquero, 2016). The treatment system was then built through stabilization ponds in Guanacaste (1959). Unfortunately, the treatment plants in Valle Central were abandoned in 1963 (Mora-Alvarado, 1992), thereby increasing the organic contamination of the basin formed by the Virilla and Tárcoles rivers. However, thanks to an agreement between the government and the National Institute of Aqueducts and Sewers, known as AyA (1972-1975), facultative ponds were built in a number of cities outside Valle Central, and the Limón Submarine Emissary was inaugurated in 2004 (Araya *et al*., 2009). Yet despite these works, Costa Rica ranks nearly last in treatment with conventional systems in Latin America (Reynolds, 2002, Mora-Alvarado and Portuguez-Barquero, 2016). Paradoxically, according to the Joint Monitoring Program of the United Nations Children's Fund (UNICEF) and the World Health Organization (WHO), Costa Rica occupies one of the highest places in the region as regards the concept of "Improved Sanitation Instruments". This is because the UNICEF/WHO concept covers the *disposal* of excreta, whether through sanitary sewers, untreated sewage, septic tanks or latrines, and does not focus on water *treatment* (UNICEF and WHO, 2006).

In contrast to the large percentage of drinking water supply coverage nationwide (93.5%), the most serious and visible problem of water quality in Costa Rica is the low percentage of wastewater treatment and the resulting contamination of rivers, particularly in urban areas. In the past four years, significant efforts have been made, including the start-up of the Los Tajos Treatment Plant and the installment of sewerage networks, collectors and sub-collectors for 11 of the San José cantons, from 4.2% wastewater sanitation coverage in 2014 to 12.4% in 2018. In 2016 the National Wastewater Sanitation Policy was approved (AyA, MINAE and MS, 2016), accompanied by a National Plan for Investments in Sanitation 2016-2045 (AyA, 2017b).

In recent years, significant efforts have been made to comply with the Millennium Development Goals and the Sustainable Development Goals (SDGs), including the provision of drinking water, sanitation and hygiene service. Although the situation in Costa Rica with respect to these aspects is better or similar to that of countries in the Central American region (given the country's achievements in aspects such as drinking water supply, adequate basic sanitation to eliminate open fecalism and gender issues), serious problems related to the quality of surface water in rivers have yet to be solved. Moreover, more studies are required to determine the extent of groundwater contamination more accurately. The differences in the quality of drinking water available, as well as the wastewater in urban and rural areas is also an aspect requiring further study at the national level. Factor such as: a) administration systems in rural and urban aqueducts, b) natural conditions of surface and groundwater sources, c) sources and types of contamination, and d) the prevalence of different sanitation systems (sewage system, septic tank or septic tanks), account for the differences in water quality in urban and rural areas. The first inter-institutional efforts were recently made to measure the quality of the country's waterbodies. Lastly as will be seen in later sections, there is a large body of legislation related to the quantity and quality of water resources, although in practice, these laws and regulations are often not enforced, due to several factors, including the low capacity for control of the authorities in charge, and the lack of human and economic resources.

1.2 Chapter objectives

The main objective of this chapter on water quality in Costa Rica is:

- To provide a diagnosis of the current and historical status of water quality in the country.
- Specific objectives include:
- Providing a vision of the laws and regulations related to water quality.

- Identifying the main problems impacting water quality in the country.
- Relating water quality to its social and economic impacts.
- Verifying the country's compliance with SDGs.
- Providing examples of challenges and successful experiences in the country.

The focus of the chapter is to summarize historical and current information on the main challenges in the country and the way they are addressed. The aim is to provide an overview of the situation, by way of a comparison with the results in the other American countries included this book. The idea is to seek or provide experiences that can be replicated in other parts of the continent.

2. Institutional authority and water quality governance

2.1 Legal framework

Detailed information on the laws, executive decrees and other regulations in the country is available in the Costa Rica System of Legal Information on the Attorney General's Office at http://www.pgrweb.go.cr/scij. The Costa Rican legal framework on water quality includes the following laws:

Water Law (Law No. This law has all the regulations related to water use and concessions. A new law was voted on by Congress in November 2017, but the Constitutional Tribunal described it was inviable due to the procedure used for its approval.

Article 114 of the Water Law states that the concessionaire of the latter must build public works such as bridges and culverts, and if they cross other aqueducts, they should not modify their quantity or quality.

General Drinking Water Law (Law No. 1634, 1953). Article 3 mentions that, "*it is the responsibility of the Ministry of Public Health and the AyA to select and locate the water destined for the pipeline service, the type of treatment of the latter and the type of potable water system to be built. It will also be responsible for the recommendations that must be given from the health point of view including the design, construction, operation and maintenance of drinking water systems*".

The Law stipulates that the AyA and the Ministry of Health must guarantee the quantity and quality of drinking water in works constructed partially or totally with funds from the Treasury or another form of guarantee from the government. Facilities, buildings or works included in areas close to the supply sources that affect the physical or chemical composition of water are prohibited.

General Health Law (Law No. 5395, 1973): Article 148 of the General Health Law (LGS) states that "*every person must also be diligent in complying with personal hygiene practices designed to prevent the emergence and spread of communicable diseases; preventing the contamination of vehicles of infection such as water and food, the infestation and contamination of movable and immovable property and the formation of foci of infection*". The law thereby implies that water pollution must be avoided by all people.

This law contemplates permit requirements for industrial or scientific activities to prevent water contamination by natural or artificially radioactive substances. Environmental alterations that produce a decrease in the quality or aesthetics of water, or make this good unusable, affecting possible future uses, health, flora or fauna, are also prohibited.

Title III, Chapter I of the LGS entitled "*Water for human use and consumption and the duties and restrictions to which people are subject in the matter*" in Article 264 states that "*water is a public good and its use for human consumption will have priority over any other use*". This chapter defines what is regarded as drinking water, the requirements of drinking water systems and which institutions are responsible for their administration and supervision. It is explicitly forbidden to contaminate water supplies and add anything foreign to water (except elements that improve water quality); water quality is regulated for diverse various such as food production, the operation of spas, crenotherapy establishments, swimming pools and similar establishments.

Article 275 of this chapter states that "*it is prohibited for any natural or legal person to contaminate surface, ground or territorial waters, directly or indirectly, by means of drainage or the voluntary or negligent discharge or storage of liquid, solid, gaseous, radioactive or non-radioactive waste, wastewater or substances of any nature which, by altering the physical, chemical and biological characteristics of water,* *make it dangerous for the health of people, and terrestrial and aquatic fauna or unserviceable for domestic, agricultural, industrial or recreational uses"*. Solid or liquid polluting waste may only be discharged with permission from the Ministry of Health. Contamination of watersheds is prohibited. Every person who owns real estate must provide the necessary drainage so that water does not become a source of infection. Owners must guarantee proper excreta and sewage disposal.

Organic Law of the Environment (Law No. 7554, 1995): Chapter III, entitled "Water", states that "*water is in the public domain, and its conservation and sustainable use are of social interest*". Certain criteria must be adopted for the conservation of water resources, such as the protection and conservation of ecosystems and the maintenance of the equilibrium of the water system. These criteria must be used in the design and implementation of any water resource management, the granting of concessions and permits for the use of the resource and soil and water conservation practices and works.

Chapter XV, entitled "Contamination", stipulates that the state, municipalities and other public institutions will prioritize the establishment of services such as excreta, sewage and rainwater disposal. "*In order to prevent water contamination, the competent authority shall regulate and ensure that water management and use do not alter the quality and quantity of this resource, according to the limits set in the corresponding regulations*". Moreover, "*wastewater of any origin must receive treatment before being discharged into rivers, lakes, seas and other bodies of water; in addition, it must reach the quality established for the receiving body, according to its current and potential use and its future use in other activities*". In any water management or use, the responsibility for the treatment of discharges corresponds to whoever produces the pollution. Individuals, legal entities, public or private are obliged to ensure that watersheds are not contaminated.

Forest Law (Law No. 7575, 1996): This law mentions the protection of water for urban, rural or hydroelectric use as one of the uses of forests. It establishes a forest fund to "*implement actions and projects designed to reduce pollution and the deterioration of renewable natural resources (soil, air and water)*". Article 33 of this law defines the protection areas that constitute fringes around the various waterbodies, including springs, streams, rivers, lakes and reservoirs as a measure to reduce the impact on water by preserving the forest cover near water sources.

These protection areas are defined by the waterbody and the inclination of the terrain as follows: a) 100 meters measured horizontally around permanent springs; b) 15 meters in rural areas and 10 meters in urban areas on either side of riverbanks, streams and streams if the terrain is flat and 50 meters in the event of rough terrain; c) 50 meters (measured horizontally) on the banks of lakes and natural reservoirs, as well as in artificial lakes and reservoirs built by the state. The limits for the recharge areas and the aquifers of the springs are determined in the complementary regulation to this Law.

Biodiversity Law (Law No. 7788, 1998): This law mentions payment for environmental services (including actual or potential water services), authorizing the collection of costs from users for these services. It includes wild protected areas such as geographic zones dedicated to the conservation of natural, cultural and ecosystem resources (including water resources).

A number of executive decrees (regulations) related to the issue of water quality are described below. In these decrees the various activities are regulated and the actions to be taken are detailed, together with the respective methodologies. In addition, each one establishes the entities responsible for its implementation and the composition of the technical committees in charge of reviewing and modifying each of these decrees.

Wastewater Discharge and Reuse Regulation (Decree No. 33601, MINAE-S, 2006): Given the importance of water and the fact that its contamination is one of the problems with the greatest negative impact on the environment, this regulation stipulates that wastewater discharges from any source must receive treatment before being discharged into rivers, lakes, seas and other waterbodies. They must also achieve the quality established for the receiving body, according to its current and potential use.

The regulation establishes the obligation of polluters to treat wastewater and prepare operational reports. The universal and complementary physical-chemical parameters to be measured are mandatory. Universals include the following: flow rate, biochemical oxygen demand, chemical oxygen demand, hydrogen potential, fats and oils, settleable solids, total suspended solids, methylene blue active substances and temperature. Complementary parameters required in particular applications include: total nitrogen, phosphates, heavy metals, cyanide, phenols, hydrocarbons, sulfides, fecal coliforms and color. Tables are included with the maximum limits allowed for universal and complementary parameters.

There is one chapter on the conditions and classification of wastewater reuse and another that describes the regulations related to sampling and analysis. There is also a standard for the content, procedure, preparation and signing of operational reports.

Regulation for the Evaluation and Classification of Surface Waterbodies (Decree No. 33903, MINAE-S, 2007): This decree proposes the technical tools for evaluating the quality of the surface waterbodies in the country, with an emphasis on lotic bodies (rivers and streams or streams), based on the measurement of physical-chemical parameters and the analysis of benthic macroinvertebrates, using the Dutch index and the BMWP-CR, respectively. It establishes the methodological details for taking samples, analyzing them, and calculating the indices and the ranges for the classification of water quality. It also defines the complementary parameters to be measured and the various classes according to the ranges obtained, as well as the potential uses for each of the five possible classes. The entity responsible for its implementation is the Ministry of Environment and Energy (MINAE), through its Water Directorate, and the Ministry of Health (MS) (MINAE/MS, 2007).

Regulation of the Environmental Fee for Discharges (Decree No. 34431, MINAE-S, 2008): In Article 4 of this decree, this fee is defined as "*an economic instrument for environmental regulation, based on the 'polluter pays' principle, which seeks the social objective of achieving a healthy, ecologically balanced environment, in accordance with the provisions of Article 50 of the Political Constitution, through the payment of a fee in cash, to those who use the environmental service of waterbodies, a public good, for the transport, and elimination of liquid waste originating at the point of discharge, which can cause harmful effects on water, related ecosystems, human health and productive activities*". The decree defines all the details related to the procedures for enforcement of the fee, and states that the resources derived from it will be administered by the MINAE and implemented, after consulting a Board of Directors, taking into account environmental and sanitation priorities.

Regulation for Drinking Water Quality (Decree No. 38924-S, 2015): This decree is designed "*to establish the maximum levels of components or characteristics of water that may pose a risk to the health of the community and problems for the preservation of water supply systems for the benefit of public health*". To achieve this objective, the recommended and maximum admissible values are established for the various physical, chemical, biological and microbiological parameters in their aesthetic, organoleptic aspects as well as their significance for health. The minimum frequency of analysis and the number of samples, as well as the doses for disinfection are also indicated.

2.2 Public institutions

Costa Rica has a series of institutions that govern the administration and control of water resources:

The person responsible for water in Costa Rica is the Minister of Environment and Energy (MINAE), since his brief includes the planning and execution of natural resource and environmental protection policies of the government, as well as direction, control, supervision, promotion and development in this field, specifically as regards surface and underground water. This is based on Law 7152 of the Constitution, issued in 1990. Through the Vice-Ministry of Water and the Water Directorate, this ministry allocates water concessions for various uses, charges for water use and discharges and supervises the quality of surface and groundwater bodies. The mission of the Directorate of Environmental Quality Management of MINAE is to "*design and implement the conceptual, technical and legal tools for the definition of strategies and public policies regarding environmental quality that promote the prevention, mitigation and reversal of the degradation of water, air and soil. It also establishes the monitoring and control mechanisms that guarantee compliance with the latter*".

The person responsible for ensuring the quality of water for human consumption and the quality of wastewater discharges is the Minister of Health, according to the Organic Law No. 5412 of the Ministry of Health, 1973. This is due to the fact that his attributions include everything related to the policies and technical norms and exercising jurisdiction and technical control, as well as undertaking the actions and activities to ensure public and environmental health. This is achieved through the Directorate of Protection of the Human Environment.

The AyA, in accordance with its constitutive Law, is the technical governing body responsible for drinking water supply and wastewater sanitation services as well as their operator. Its mission is to "*ensure universal access to drinking water and sanitation in a manner that is committed to health, the sustainability of water resources and the economic and social development of the country*". Wastewater collection and treatment is the responsibility of the AyA, in places where it provides water supply service. Its Constitutive Law stipulates that the AyA is responsible for: the collection, evacuation, treatment and disposal of domestic liquid waste; defining the sanitary sewer system as collection networks, collectors, treatment plants and everything required to receive, transport and treat sewage produced in households or workplaces.

In addition to the AyA, there are three types of entities responsible for drinking water supply and wastewater treatment services: 1) the Heredia Public Services Company (ESPH), 2) the Administrative Associations of Water Supply Systems and Communal Sewers (ASADAS), also known as Committees and/or Administrative Associations of Rural Aqueducts (CAARs), and 3) Municipalities. AyA is responsible for most of the distribution and sanitation in urban areas (approximately 50% of the population). The AyA also has a Sub-Department responsible for overseeing and supervising the management of ASADAS, entities created by the Law of Associations, which provide public service. They are non-profits, and apply the rate established by the Public Service Regulating Authority (ARESEP). The mission of the ESPH is to "*to provide quality services in the water, energy, sanitation, infocommunications and other sectors, which contributes value and development for society through the continuous improvement of their management*". In its current state, the ESPH is a legal hybrid: a municipal company in the province of Heredia which manages public resources and whose assets comprise all the aqueducts in the associated municipalities.

The National Service of Groundwater, Irrigation and Drainage (SENARA) was conceived from its outset as an institution with a strategic role in water management, both at the level of its direct participation and in coordination with other institutions in the agricultural and environmental sectors. It promotes agricultural development in the country, helps implement agricultural development projects, and attempts to create the rational, democratic modification of land ownership through the creation of irrigation districts. With regard to groundwater, SENARA is the technical-scientific body that researches, defines and protects aquifers and their recharge zones at the country level.

Other institutions related to water resources in Costa Rica include the Costa Rican Electricity Institute, the Climate Change Directorate, the National Meteorological Institute, the Ministry of Agriculture and Livestock and the Public Services Regulatory Authority.

2.3 Relations with NGOs and universities (scientific research)

In Costa Rica, most scientific research is conducted at three public universities: the Universidad de Costa Rica (UCR), the Universidad Nacional (UNA) and the Tecnológico de Costa Rica (TEC, formerly ITCR). Each of the latter have research centers, institutes and laboratories that undertake research projects related to the country's water resources. The analytical laboratories of CICA (Center for Research in Environmental Pollution, UCR), CEQUIATEC (Center for Research and Chemical and Microbiological Services, TEC), IRET (Regional Institute for Studies on Toxic Substances, UNA), and LASEQ (Analysis and Chemical Services Laboratory, UNA) and LAA (Laboratory of Environmental Analysis, UNA), have the respective accreditations of the Costa Rican Accreditation Entity (ECA) for various tests related to water quality analysis for different uses. Research on water issues is also conducted at other private universities, such as the Universidad EARTH (School of Agriculture of the Humid Tropical Region) and CATIE (Tropical Agricultural Research and Teaching Center).

Research conducted in the field of water is mainly related to the quality of surface waterbodies, especially in the Greater Metropolitan Area (e.g. Herrera *et al.*, 2013; Mena-Rivera *et al.*, 2017). Other studies have been carried out on the effect of pesticide use on different types of plantations (e.g. Castillo *et al.*, 2000, 2006; Echeverría *et al.*, 2012; Pérez-Castillo *et al.*, 2013; Rasmussen *et al.*, 2016, Carazo-Rojas *et al.*, 2018) and the use of biological indicators in the evaluation and monitoring of the quality of surface waterbodies, both rivers and lakes (e.g. Mafla, 2005; Michels *et al.*, 2006; Fernández and Springer, 2008; Stein *et al.*, 2008; Sedeño-Días *et al.*, 2012; Rizo-Patrón *et al.*, 2013, Gutiérrez-Fonseca and Lorion, 2014; Umaña-Villalobos, 2014; Céspedes-Vargas *et al.*, 2016; Kohlmann *et al.*, 2015; Svensson *et al.*, 2017; Umaña-Villalobos and Farah-Pérez, 2018).

Researchers with extensive experience from various universities collaborate regularly with central government and local governments, as well as certain Non-Government Organizations (NGOs) in the formulation, review and implementation of initiatives related to water resource management.

2.4 Monitoring and database

Given that most of the initiatives to evaluate the quality of inland waters in the country have been isolated efforts and specific studies for short periods, the need to establish a National Monitoring Program that includes the periodic evaluation of surface and groundwater quality was identified.

The National Plan for Quality Monitoring of the Surface Waterbodies of Costa Rica was prepared with the support of a group of professionals and academics specializing in water resources issues, from public universities and state institutions. This Plan defines the monitoring sites and establishes the frequency of the samplings, as well as the parameters to be measured in each of them, based on Decree 33903-MINAE for the Regulation of Evaluation and Classification of Surface Waterbody Quality. It began to be implemented in 2015, with the support of the three public universities (TEC, UCR and UNA), which undertake sampling and analysis of samples for a five-year period.

Their implementation is expected to generate baseline information (national database) to classify water quality in each of the country's 34 basins and thereby regulate the appropriate use of water resources. To ensure public access to the data generated from these monitoring, maps are being drawn up on the DA website (http://www.da.go.cr/), where the results for each of the sites included in the Plan will be available for consultation.

3. Main problems impacting water quality in the country

The main point of determining the quality of mainland waters continues to be the impact on human health, since it is mostly these sources that are used to supply the country's population. Potability criteria prevail when chemical analyses are conducted of potential sources of use (Executive Decree No. 38924-S, 2015). The cases where official entities have identified and quantified other possible sources of contamination in waterbodies are those in which human health has been compromised, as happened in Aguas Zarcas, in the northern zone of the country, due to the natural occurrence of arsenic in groundwater (Mollinedo, 2013).

Since September 2015, the country has had an updated regulation for drinking water quality (Executive Decree No. 38924-S, 2015). This regulation clearly defines the variables that must be quantified in water sources, both surface and ground, as long as they are intended for human consumption or in processes whose recipient is human beings. Costa Rica also has a Regulation for Wastewater Discharge and Reuse, the latest version of which was published in 2017. This regulation details the variables that must be quantified and the maximum limits allowed for the different types of wastewater according to the use they have had and the type of receiving body.

3.1 Urban waste

As regards surface waterbodies, there are differences between the rivers that run through urban areas and those that occur in rural areas. There are differences in terms of the contaminants with greatest visibility, which attract most media attention, such as solid waste of human origin: plastics, pieces of domestic materials, fragments of automotive vehicles and the remains of building materials, the most obvious example being what happens in the basin of the Río Grande de Tárcoles, since most of its tributaries run through the Greater Metropolitan Area (Soto, 2012; Gutiérrez Wa-Chong, 2018).

These rivers or small urban streams have been used for decades as landfills that receive much of the waste from the Metropolitan Area, which exemplifies the poor management of solid waste throughout the country, as well as the lack of a proper wastewater collection and treatment system. This situation is also affected by poor urban planning, which has permitted the existence of houses on the edges of these waterbodies. These homes, the vast majority of which are illegal, lack waste collection systems, as a result of which waste is directly dumped into rivers.

3.2 Fecal contamination

It is common for unpleasant odors to increase in rivers in the urban area during the dry season, due to the illegal dumping of wastewater with a high content of organic matter, in many cases with fecal material of human origin. In this regard, the National Water Laboratory of the AyA has issued reports in which it reports the quality of waters in various basins in the country, showing the high content of fecal coliforms in many of the sites sampled. For example, in the Tempisque River, discharge from the Liberia, Cañas and Bebedero rivers contributes a significant amount of fecal matter into its basin (Mora-Alvarado *et al*., 2002). Mora-Alvarado (2004) also reported a high concentration of fecal coliforms in the Río Grande de Tárcoles basin. Samplings in estuaries throughout the country were included in this study. In just under half of them, fecal coliforms were identified in high quantities, and samples were taken in reservoirs and lakes, the latter two being the sites with the best microbiological quality in the study. Other published studies, such as those by Calvo-Brenes and Mora-Molina (2012) and Barrantes *et al*., (2013) corroborated the high level of fecal contamination in many rivers in the Greater Metropolitan Area, particularly the María Aguilar and Torres Rivers.

3.3 Oil hydrocarbon pollution

As a result of human activities related to navigation and electric power generation, the presence of hydrocarbons in coastal sites has been reported, such as the Moín channels in the Caribbean and Estero de Puntarenas in the Pacific (Acuña *et al*. al., 2004). Although this is not desirable, it is expected in areas with high movement of vessels, to transport both passengers and raw materials. The presence of hydrocarbons has also been reported in surface and groundwater sources (Mora-Alvarado and Portuguez, 2010). These cases have been associated with human error and even negligence. Sites where hydrocarbons have been quantified include the Quebradas River in Pérez Zeledón, near the Moravia Sites, the Llano reservoir in Orosi, San Ignacio de Acosta, and the aquifer supervised by the Public Services Company of Heredia, contaminated with gasoline and diesel, which attracted a great deal of media attention. The majority of these cases have been point pollution events.

3.4 Rural zones

With regard to water sources in rural areas, the situation of solid waste is less dramatic, due to the simple fact of having a lower population density, but here the problem lies in the fact that many of these sources are primarily for agricultural use. This competition for water makes it necessary to resort to groundwater sources in these areas. Extensive crops in the area, which nonetheless are intensively produced, such as sugarcane, banana, oil palm or pineapple, are activities that require the use of an abundance of fertilizers and pesticides. In the case of fertilizers, their presence in surface waters has rarely been studied, for methodological reasons linked to the high solubility in water of the compounds used. These chemical substances (nitrogenous and phosphorous) are easily transported by runoff, especially in areas with high precipitation, which turns nearby rivers and reservoirs in the recipients of these substances. It is therefore not easy to demonstrate the presence of these sources of pollution in surface waters, unless the characteristics of the waterbody enable their main effect to be seen: eutrophication, the excessive increase of nutrients in water (mainly nitrate, ammonium and phosphate) and consequently the growth of aquatic plant species. These conditions may be the best indications of alterations in the natural concentration of these nutrient substances in water, while seasonal monitoring is the best way to record these variations (Jones *et al*., 1993, Umaña *et al*., 1999).

Despite this difficulty, for the State of the Nation report, Castillo *et al*. (2012) compiled the most relevant information on the quantification of nitrate, presumably of agricultural origin, in various bodies of surface and groundwater. The presence of nitrate was reported in wells in areas devoted to agriculture in both the Caribbean region and in Chorotega (Guanacaste). In terms of surface water, the anomalous presence of this nutrient was also measured in rivers and streams in Cartago, Guanacaste and Limón. Guevara and Herrera (2014) reported high concentrations of nutrients in some streams and rivers in the canton of San José, although because they are rivers located in the urban area, the mismanagement of domestic wastewater may be altering the natural concentration of these substances rather than agricultural activities.

3.5 Arsenic, an important case in public health

Due to the geological context of the country, characterized by volcanism and active faulting, arsenic of natural origin exists in the groundwater in certain regions in the north. The origin of arsenic has been studied by Alpízar and Vargas (2017) in a research project undertaken at the University of Costa Rica, through the Specific Agreement on Technical Cooperation with the AyA (2013-2016). This project characterizes the zones of Aguas Zarcas, in the province of Alajuela; Cañas, Bagaces, Los Chiles and La Cruz, in Guanacaste. This element is highly toxic, both cumulatively and specifically. According to the World Health Organization and the Drinking Water Regulation of Costa Rica, the maximum limit allowed for water for human consumption is 10 micrograms per liter. By 2013, 24 populations affected by the presence of this element had been identified, in both wells and surface sources. The communities are located in the provinces of Guanacaste and Alajuela: and include Aguas Zarcas, Cañas, Bagaces and La Cruz (Mollinedo, 2013). Arsenic appears naturally in a section of the Aguas Zarcas River in Lomas, three kilometers north of the town of Aguas Zarcas, where there is a fault zone eroded by water from this river. The findings regarding groundwater will be discussed in section h. of this document. Since the discovery of this pollutant, the main concern of state entities has been to ensure arsenic-free drinking water or, at least, with limits below the maximum allowed. To this end, the AyA has embarked on the task of finding new areas to drill wells where groundwater is free of the element, supply the affected communities with nearby aqueduct waters and dilute drinking water to bring the concentration below the maximum allowed (Mora-Alvarado, 2011, Córdoba, 2017).

In recent years, the effort to resolve this situation has not only focused on designing new aqueducts, such as the new aqueducts Cañas-Bebedero and Bagaces. In addition, six specialized plants were built for the removal of arsenic in La Cruz, Cañas and Bagaces, among other projects developed by the AyA. The AyA has also embarked on the search for technologies that can remove arsenic from the ground sources used, in association with state universities. For example, in the Vice-Rector's Office for Research of the University of Costa Rica, there are at least three registered projects related to the subject (Vicerrectoría de Investigación HYPERLINK "http://www.vinv.ucr.ac.cr/sigpro/web/").

3.6 Presence of pesticides

This issue has been important in recent years, since evidence has been found of the contamination of aquifers in crop areas, specifically in the communities of Milano, Cairo, La Francia and Luisiana, in the canton of Siquirres. This aquifer was contaminated by bromacil, a herbicide used in the cultivation of pineapple. Due to the high dilution power of this herbicide and its toxicity, its use was prohibited in the country in June 2017. This contamination obliged the AyA to supply drinking water to the population with tankers and to build a new aqueduct for them, capturing more distant sources of water without risk of contamination from the cultivation of pineapple.

For The State of the Nation report, Ruepert (2011) compiled the existing information on the incidence of pesticides in surface water until 2010, all in the Caribbean zone of the country. According to this study, in a project on the quality of surface water and sediments in rivers, conducted between 2008 and 2011, the presence of substances such as bromacil, chlorpyrifos, diuron, fenbuconazole and endosulfan, compounds related to the cultivation of the pineapple and banana, was detected. The same report indicated that in monitoring conducted between 2009 and 2011 of the Jiménez River, Limón, the presence of the ametryn and diuron was found in surface waters, both pesticides being linked to pineapple crops, whereas in the Madre de Dios River, also in the Caribbean, between 2010 and 2013, the presence of seven pesticides related to the cultivation of pineapple, rice and bananas was identified. Their incidence was also recorded in several parts of the country (Matina, Bagaces, Puntarenas, and Caletas-Ario), where the mortality of aquatic organisms or intoxication of humans was demonstrated, all of which are related to the presence of pesticides. The information compiled by Ruepert (2011) was subsequently added to by Castillo and collaborators (2012), since more data from other studies was presented in which the presence of a large amount of pesticides in various bodies of surface water in the country was identified.

In June 2018, within the framework of the Good Agricultural Practices in Pineapple Production in the North Zone project, implemented by the Center for Research in Environmental Pollution (CICA) of the University of Costa Rica (UCR) and the Phytosanitary Service of the State (SFE) of the Ministry of Agriculture and Livestock (MAG), the presence of pesticides was reported in the Pital, Aguas Zarcas and Venecia de San Carlos water sources. In this project, 22 surface water samples and 10 well water samples were collected between 2015 and 2017. Bromacil, ametryne and diuron were the most frequently reported substances, although metalaxyl, carbendazim and hexazinone were also detected (O'neal Coto, 2018). Through CICA, that same university had detected the presence of bromacil and ametryne residue in the waters and sediment of Térraba-Sierpe Wetland, an area strongly influenced by the cultivation of pineapple and rice (O'neal Coto, 2017).

Problems related to the presence of pesticides in both surface and groundwater sources are exacerbated by the fact that many of the substances remain in the environment for a very short time, making it difficult to determine them by conventional analytics, which are based on the collection of samples that do not reflect the immediate or specific situation, but rather the cumulative nature of some of these chemical substances. Another factor that conspires against an adequate response to the presence of these substances is that there is no state entity that systematically quantifies all these products. The technology used to identify it is extremely costly and it is only as a result of the collaboration between the state and public universities that these important findings have come to light.

3.7 Emerging contaminants

Emerging contaminants are defined as such because of the recent interest they have elicited in the international scientific community. They are mostly substances on which research had not focused, because they exist in very low concentrations, below micrograms or even nanograms per liter. It is only the advance of analytical techniques that has made it possible to focus on them. This analytical interest has been accompanied by the interest in determining their effect on human health and other organisms that are in contact with them, mainly aquatic organisms.

These substances comprise a broad spectrum of chemical compounds: personal care products, disinfectants, perfumes, hormones, bactericides, surfactants, fire retardants and antibiotics. There are no regulations in the country on the presence of these substances in water bodies. Moreover, their detection is expensive and their identification has been due to initiatives in academia, since state entities lack the technological capacity to quantify them, even though they are a substance that is widely distributed in the environment.

There are very few publications in Costa Rica on this subject. In a study by Spongberg *et al*. (2011) 86 samples of surface water, both fresh and brackish, were collected throughout the country. Doxycycline was found in 77% of the samples, sulfadimethoxine in 43%, acetylsalicylic acid in 41%, triclosan in 34% and caffeine in 29%. Caffeine was the substance found was in the highest concentration (1.1 milligram per liter), followed by doxycycline, ibuprofen, gemfibrosil, acetaminophen and ketoprofen, in order of micrograms per liter. The highest incidence of these substances occurred in effluents near the Golfito Hospital, the treatment plant in Liberia, near the Manuel Antonio National Park and the Río Grande de Tárcoles. The actual effect of these substances on human health and whether they are also present in drinking water is still unknown in the country. What is known is that academic initiatives exist to increase the number of sampling sites, substances and regions in the country, in order to have a clearer picture of what is really happening with these chemical compounds that are discharged into water bodies.

3.8 Groundwater pollution

In Costa Rica, as in other parts of the world, groundwater is used for different purposes, such as public water supply, crop irrigation, tourism and industry. According to the MINAE, 80% of the water used for human consumption in the country is groundwater, obtained from springs and wells.

The study of groundwater quality in the country has focused mainly on determining the potability of water intended for human consumption. This work is undertaken by the entities that administer public supply systems. AyA is the entity that supplies 50% of the national population, ASADASs cover 30%, municipalities 15% and the ESPH 5%. Although it is true that Decree 33903, MINAE-S, 2007 for monitoring water quality in surface water bodies seeks to establish a baseline in different parts of the country, a legal loophole exists regarding the monitoring of groundwater quality. There has been very little research on this issue due to the high cost of chemical analysis. The relationship between surface and groundwater should be studied in detail, because pollution in rivers is increasing on a daily basis due to the inadequate disposal of solid and liquid waste, which can reach aquifers when rivers are influent (hydraulically connected to groundwater). The study by SENARA-BGS (1985) notes that there are influent sectors of the Virilla River, a condition that encourages the vertical migration of pollutants into groundwater, which calls for permanent control of the possible adverse effects this could cause. Although efforts are being made to collect wastewater in the metropolitan area through the sanitary sewer system and to improve its treatment, its disposal remains inadequate.

Sources of groundwater contamination are both point and non-point. Pollution by type of compound can be classified as follows:

1. Bacteriological contamination: total and fecal coliforms have been detected in excavated or artisanal wells that capture shallow aquifers in rural areas, since these are often located near the septic tanks of houses, in addition to being prone to flooding, and are often abandoned and used as dumps.
2. Contamination from inorganic substances: nitrates have been reported in the La Libertad spring by SENARA-BGS (1988) and by Losilla *et al*. (2001), and in the Barva aquifer (Reynolds *et al*., 2006). Pesticides in agricultural areas of the Atlantic zone (Ruepert *et al*., 2005) and the North zone of the country are undoubtedly one of the most common non-point sources, while bromacil is one of the main compounds in Cairo and Milano in Siquirres, in Veracruz in Pital de San Carlos and in Río Cuarto de Grecia. All these pollutants are associated with anthropogenic activities. Certain other chemical elements have been reported as anomalous in groundwater, such as manganese and iron, mainly occurring on the Caribbean slope and northern subslope; these elements appear naturally due to the reducing conditions found in the aquifers of these regions.

   Mollinedo (2013) and Araya (2018) determined the origin of arsenic from hydrogeochemical and hydrogeological information in the Aguas Zarcas and Los Chiles, Alajuela regions respectively. Arsenic in the areas of Bagaces and Cañas, in Guanacaste, has been studied by Ramos *et al*. (2014). Other types of contamination have been reported since the early 21st century, such as salinization due to saline intrusion problems in several North Pacific beaches (Arellano and Vargas, 2001, Arias-Salguero and Vargas, 2003). Another case is Tamarindo, Guanacaste, where increases in electrical conductivity and chloride levels in water have been detected, due to excessive extraction of groundwater by pumping wells near the coast (Astorga, 2018, personal communication).
3. Contamination by organic compounds: Point pollution by hydrocarbons has also been found in two places; the AB-1089 well, belonging to the ESPH, located in Barrial de Heredia near a gas station that had had a spill, which is why the well was disconnected from the system in 2005. Another case is the Moín aquifer, in the RECOPE site in Limón studied by Guzmán (2006). Both sites have had to be intervened with remediation processes. Although it is impossible to rule out the existence of other contaminated sites in the country, they have not been detected due to the lack of groundwater monitoring. Studies

on the chemical composition of water in specific aquifers, include the SENARA-BGS study (1985) undertaken in Valle Central, where the waters of the Barva and Colima aquifers were characterized chemically and isotopically. Gómez and Arredondo (1994) and Vargas (2015) studied the hydrogeochemical characteristics of the Tempisque aquifer; while Vargas (2017) explored the hydrogeochemical features of groundwater in the Rio Grande basin. The quality of the groundwater in other aquifers has been sporadically studied through graduate and postgraduate theses on geology. However, more research is required and projects for the adequate instrumentation and permanent monitoring of groundwater quality must be considered at the country level to prevent and detect contamination that may affect the groundwater sources used in public supply in an early stage.

SENARA is currently developing Sustainable Supply Plans (PAS), in which users requests support from to conduct research on selected aquifers and begin a continuous process for water resource management. Two projects of this nature have already been carried out: one in the Parrita region in the Central Pacific and another in Santa Cruz Guanacaste, in which the quality of groundwater is characterized (Ramírez, 2018, personal communication).

4. Social and economic aspects

4.1 Health

The World Health Organization (WHO) has suggested that diarrhea is a symptom of infectious diseases, usually spread by water pollution (WHO, 2000). Factors that can contribute to reducing the number of diarrhea cases include access to water for human consumption, improvements in the health system, good personal and food hygiene, and health education on how diseases are transmitted (WHO, 2000). Diarrhea deaths are common among the poor, especially in developing countries. Every year, there are approximately four billion cases of diarrhea in the world (WHO, 2000).

Costa Rica has achieved extremely satisfactory levels in terms of drainking water coverage, reaching 98% coverage of water from indoor pipes and 99% with improved drinking water sources in 2012 (Hidalgo-León *et al*., 2015). One of the most pressing problems in terms of water quality in Costa Rica, identified in previous studies (Hidalgo-León *et al*., 2015), is the problem of low coverage of sanitary systems for sewage and gray water treatment in metropolitan areas. It is worth noting that in 2016, a positive step was achieved in sanitary sewer coverage, with wastewater treatment increasing from 4.2% in 2014 to 14.4% in 2018 (AyA, 2018).

Although wastewater treatment coverage must be greatly improved, good coverage in terms of access to drinking water and the basic health system mean that the incidence of diarrheal diseases, particularly of diarrhea-related mortality, is still relatively low with respect to other countries in the region (Hidalgo-León *et al*., 2015). The percentage of causes of death in infants due to infectious and parasitic diseases is 1.6%, while for respiratory causes it is 4.3% (INEC, 2013). It should be noted that diseases of the digestive system in Costa Rica are rarely fatal in childhood. For example, in 2011, the percentage of deaths of children under 5 from these causes was 0.01 per thousand, compared with the death rate of 2.21 per thousand obtained by adding all the causes of death for this age range (Ministry of Health, 2011, Hidalgo-León *et al*., 2015). In fact, neither diarrhea nor hepatitis feature among the ten leading causes of death in children under 5 in any of the years from 2012 to 2015 evaluated in INEC (2015, see Table 7.12). The incidence of other types of diseases associated with water is shown in Hidalgo-León *et al*. (2015). In Costa Rica, the mortality rates of the first five sources of death have remained relatively constant over time. Deaths from diseases of the digestive system (a fraction of which may be related to water quality) amount to a third of the diseases due to the leading cause of death in the country (problems of the circulatory system). For reference, the average mortality rate for those years due to certain infectious and parasitic diseases is 0.81 deaths per 10 000 inhabitants (INEC, 2015) and it does not figure among the ten leading causes of death in the country. For the case of diarrhea in particular, the average mortality rate from 2008 to 2015 is 0.1 deaths per 10 000 inhabitants, the great majority of whom are over 75 (Ministry of Health, 2016).

4.2 Poverty

In terms of poverty, the average percentages for the period 2012-2015 of the population living in non extreme, extreme and total poverty are 16.4%, 7.3% and 23.7% respectively (INEC, 2015). This in itself poses a social challenge in many respects, but although the country faces an increasing number of challenges to maintain its basic services, no study has shown that the limitations of the lowest socioeconomic group regarding access to drinking water, basic hygiene education or basic health systems have been sufficiently influential to clearly identify correlations between social stratum and the prevalence of disease outbreaks related to water quality. For example, in the case of diarrhea, there does not seem to be a correlation between the index of social development and the rate of diarrhea (Table 19 of the Ministry of Health, 2016). Other diseases related to the quantity of water available and the presence of breeding grounds for vectors transmitting diseases such as Dengue, Zika and Chikunguña, do seem to have a tendency to produce significant outbreaks in rural municipalities (Ministry of Health, 2018). In these communities, the quality of support services is usually more limited and the population living in poverty may be more socially vulnerable. With respect to indigenous populations (accounting for 2.4% of the total population of the country in the 2011 census), according to the Unsatisfied Basic Needs method, "*only 7.6% of indigenous people have no shortcomings. The main shortcomings are related to productive development, food security, marketing possibilities, access to drinking water, basic services and all kinds of infrastructure development (health, education, production and social). In indigenous populations, the concepts of poverty and vulnerability differ substantially from those use for the non-indigenous population*" (PND, 2014)

4.3 Educational attainment in communities. Education programs and curricula

The National Development Plan (NDP) 2015-2018 includes, among many other goals, the strengthening of community water management, as well as the increase in wastewater collection and treatment (PND, 2014). The need to address the vulnerability of the road, energy and public service systems (water, sanitation, health) to natural, socio-natural and industrial threats is also mentioned. In order to achieve sustainable development, the country needs to improve many aspects, such as the following: the conservation of water resources, the rational exploitation of marine resources, waste management, adaptation and mitigation mechanisms in the face of climate change, land use planning, clean energy use to reduce dependence on fossil fuels and strengthen culture and environmental education (PND, 2014). "*It will also be a major challenge to enforce the Law and ensure that the institutional framework achieves better environmental management, in which the link between environmental sustainability and economic and social development is a central aspect*" (PND, 2014). Environmental education has been mentioned among other priority services that must be evaluated at schools so that they can be improved and thus promote better education and the permanence of students in educational centers. In fact, environmental education (from elementary school to diversified education) is regarded as the core of the curriculum and institutional management to strengthen education for life that will encourage creativity and innovation to enhance human development (PND , 2014).

4.4 Gender

Gender issues have been associated with water supply in certain cases. For example, Rico (1998) notes that women in Costa Rica have traditionally participated in the construction of aqueducts, yet are relegated in terms of the percentage who participate in project administration. The health statistics related to various diseases are differentiated by sex in the information provided by the Ministry of Health, but to our knowledge, no statistical analysis has been undertaken of the incidence of all kinds of diseases for men and women separately in order to determine the causes of the possible differences (there is an analysis of the incidence of hepatitis B, dengue and malaria by sex in INEC *et al*., 2010). In Costa Rica, the National Institute for Women (INAMU) is responsible for ensuring equal conditions for women, although significant gaps exist in some respects, such as access to employment (INEC *et al*., 2010).

4.5 Rural and urban areas

In Costa Rica, excreta disposal systems are based on the use of septic tanks (76.9%) and treated and untreated sewage (21.1%). Most urban services are provided by the AyA (although it is also present in rural regions) and to a lesser extent by the ESPH and municipalities, while ASADAS usually serve rural regions. Of the 21 wastewater treatment systems administered by AyA, nine fail to comply with the Wastewater Discharge and Reuse Regulations, specifically in the determination of total BOD. For its part, the ESPH administers five treatment systems, four of which comply with the total BOD. Information is unavailable on the 32 systems operated by municipalities and ASADAS (Mora-Alvarado *et al*., 2016). Information for the period from November 1, 2012 to October 31, 2015, indicates that urban treatment systems for water supply have an average of 5.4% of treatment compared to 1.3% in rural systems. Likewise, urban systems have 94% of installations with disinfection compared to 38.8% in rural systems (Mora-Alvarado *et al*., 2016). Within the episodes of contamination in the country, there have been cases of anthropic chemical contamination (especially with hydrocarbons) and natural chemical contamination (particularly arsenic). A list of the occurrence of these incidents is available in Mora-Alvarado *et al*. (2016).

4.6 Investment in water quality programs

For over 90 years, basic sanitation has managed to separate fecal matter from direct contact with people. However, although the basic system reached rates of 97% in 2017, approximately 70% are covered by septic tanks which in many regions is unsuitable and creates an enormous risk of contamination of surface waters and underground layers (AyA, 2017a). As a result, many rivers and streams carry soapy or wastewater, due to direct disposal from nearby houses or the poor drainage of septic tanks (AyA, 2017a).

In Costa Rica, wastewater treatment and project implementation is the responsibility of following operators: AyA, ESPH, ASADAS and municipalities. However, the high design and investment costs of the sanitary sewer infrastructure and wastewater treatment plants, mean that they must be covered by the central government budget. The cost of maintenance and operation of these systems is covered by utility rates (AyA, 2017a). Accordingly, the country created a National Investment Plan in the short and medium term, in response to the Public Policy for Wastewater Sanitation, which will allow the development of the improvement projects and new systems required. "*The AyA has spent nearly eight years investing in the environmental improvement of the cantons in the Greater Metropolitan Area, through a loan of more than $300 million USD from the central government, the Japanese Bank and the Inter-American Development Bank*" (AyA, 2017a). The goals are as follows: by 2036 it is hoped to have urban sanitary sewage and wastewater treatment in the priority cities covered and by 2045, rural sanitation and wastewater treatment in the remainder of the urban area (AyA, 2017a). By 2030 it is hoped to invest $1082 million to benefit more than 580 000 people in the Greater Metropolitan Area, $127 million will be invested in the coastal tourism region, benefiting more than 69 000 people, while $435 million will be invested to repair current systems to benefit more than 235 000 people (AyA, 2017a). The entire national investment plan for 2045 will total $6.224 billion, including $3.654 billion for wastewater treatment in urban areas and $2.569 billion for the expansion and implementation of wastewater treatment in rural areas (AyA, 2017a).

5. Meeting Sustainable Development Goals (Goal 6: Ensure water availability and its sustainable management and sanitation for all)

5.1 Compliance with SDG

Costa Rica has made significant efforts to meet not only the Millennium Development Goals (MDGs), but also the Sustainable Development Goals (SDGs). Targets 6.1 and 6.2 of Goal 6 refer to drinking water provision, sanitation and hygiene, with the SDGs being much more precise and having more variables. SDGs promote universal, equitable access for all, promoting the elimination of inequalities in service levels. Hygiene is also included, which had not been considered in the MDGs, while drinking water supply service is conceptualized as safe, affordable water and sanitation is conceptualized as adequate, eliminating open fecalism and paying particular attention to the needs of women and girls and people in situations of vulnerability.

The processes and systems to monitor and review SDG6 trends are being coordinated by the Secretariat of Sectoral Planning of the Environment, in which the National Center for Geoenvironmental Information (CENIGA) and the National Institute of Statistics and Censuses (INEC) provide the inputs. This Secretariat has the technical support of the MINAE Water Directorate, the Ministry of Health, the AyA and the Interinstitutional Technical Committee comprising MINAE, AyA and SENARA.

5.2 Drinking water supply

In Costa Rica, drinking water has been defined as the priority use among other uses, in addition to the recognition of access to drinking water and sanitation as a Fundamental Human Right, as stipulated by the United Nations in 2010. Since 1961, the water supply service as a public rather than a private service has been conceptualized and framed in various laws and, above all, in the constitution of the AyA, which has been given the authority and responsibility to "provide the inhabitants of the country with drinking water, and sewage and liquid industrial waste collection and disposal services". This mission complements it for the entire national population with the work of the ASADAS, the ESPH and the Municipalities.

The Law Establishing the AyA stipulates that, "Rate setting should be based on distributive social justice criteria, taking into account the social strata and the area to which users belong, so that those with the greatest capacity to pay subsidize those with less capacity". Moreover, the service must be at cost through an affordable rate for families.

This public service model implemented in Costa Rica achieved the universalization of water supply services, increasing coverage from 70% in 2000 to 94.5% in 2017. The AyA covers 47%, ASADAS 29% , Municipalities 14%, ESPH 5% and other entities 5%. Indoor coverage is 97.6%, corresponding to 91.8% of the population that receives totally safe drinking water, free of microorganisms and dangerous chemical elements (AyA, 2018).

Water supply service in Costa Rica has generally high coverage, with continuous equitable service. In order to ensure this management model of public water supply services, the National Policy for the Potable Water Sub-sector 2017-2030 (AyA *et al.*, 2018) was constructed and launched, with the aim of "achieving access to drinking water through the protection of water resources and the strengthening of the capacities of the actors related to the provision of the service, to contribute to the health, welfare and development of the country". The strategic axes of this Policy are: water culture, governance of the potable water sector, investment in infrastructure and service and environmental management in the drinking water sector. A National Program for the Improvement of the Quality of Drinking Water Services 2017-2030 (AyA/MINAE/MS, 2018) is also in place.

5.3 Basic sanitation

Basic sanitation in the country was promoted through the 1973 General Health Law. By 2017, 70% of the population had a septic tank, 14.4% with sanitary sewerage and a water treatment plant, 13.4% with sanitary sewage without treatment plants, 1.6% with latrines and just 0.5% without toilets. This means that the country has achieve Goal 6 of the SDGs, where the proportion of people who practice open fecalism is almost nil (AyA/MINAE/MS, 2016).

Moreover, in order to promote advanced sanitation for major cities and coastal areas with a high influx of tourists, the National Wastewater Sanitation Policy was constructed in a participatory manner (AyA/MINAE/MS, 2016), with five axes: 1. Institutional and regulatory strengthening, 2. Integrated sanitation management, 3. Infrastructure and investment, 4. Financial sustainability and tariff model and 5. Citizen participation. This policy is complemented by the National Plan of Investments in Sanitation for the period 2017-2045, in which an investment of $6.224.000.000 has been calculated to capture and treat wastewater from cities through sewerage and treatment plants, and wastewater in rural areas through septic tanks or another type of alternative technology.

The Communal Associations for water supply and sanitation are official organizations, which have the AyA delegation to provide these services. In order to strengthen these organizations, the Policy for the Organization and Strengthening of Community Management of Drinking Water and Sanitation Services was launched, which has a digital unified instrument (ASADAS-SAGA Management Support System), which is collecting information on the status of ASADAS aqueducts, as well as the risk level of the systems and sources used. ASADAS capacities are being built by the National Continuous Training Plan.

Integrated Water Resource Management is also reflected in the National Water Policy and the National Water Strategy, launched in 2009, derived from the Political Constitution, which states that, "The State shall seek the greatest welfare for all inhabitants of the country, by organizing and stimulating production and the most appropriate distribution of wealth," where, "everyone has the right to a healthy, ecologically balanced environment". The Minister of Environment and Energy is responsible for the political leadership and stewardship of water resources.

5.4 Legal Framework

With regard to the general legal-regulatory framework for integrated water management and intersectoral action in Costa Rica, there are over 15 organizations including Ministries, Autonomous Institutions and Local Governments with authority over Water Resources. Thus, there is a Water Law dating from 1942 and over 100 instruments among other laws and decrees that govern water in Costa Rica. This is why, since 2001, a bill for Integrated Water Resource Management has been promoted, which is an integrative law with a clear definition of spheres of authority. This bill has yet to be approved by the National Congress.

Water is defined as a good in the public domain, an inalienable good, which must be managed in a sustainable fashion, considering the hydrological and hydrosocial cycle. It is the responsibility of the state to use concessions or permits to authorize the use of water, which is charged through the Environmentally Adjusted Use Free by surface or ground source, according to the volume and type of use: commercial, industrial, tourist, irrigation, human consumption or hydroelectric. It also has a discharge rate which is calculated according to the volume and pollutant load discharged into a surface waterbody.

For wetland ecosystems, there is a National Wetland Policy 2017-2030, with the aim of integrally managing the wetland ecosystems of Costa Rica, in order to contribute to national development. Wetland ecosystems account for seven per cent of the country (Mora-Rodríguez, 2017).

Three of the institutions with competence in water resources comprise the Institutional Technical Committee (CTI), which conducts hydrogeological studies and monitors the country's aquifers. The aim is to determine the amount of water available and to have scientific data on the permissible volumes to be exploited, thus ensuring the sustainable management of groundwater bodies.

Although Costa Rica has undoubtedly made progress in complying with SDGs, it has yet to improve the indicators related to sanitation. The main hurdles to maintaining and even improving SDG 6 involve investing in water treatment and purification systems with chemical elements for human consumption, the protection of water sources, sustainable watershed management using participatory processes and continuing to invest in wastewater collection and treatment.

6. Recurrent Problems and Successful Experiences in Improving Water Quality

Box 1: Sustainable management of the Nimboyores aquifer, Santa Cruz, Guanacaste

By Yamileth Astorga Espeleta

As a result of a crisis caused by a project designed to capture water from the Nimboyores aquifer to supply coastal areas, there is a need to promote a participatory process with various strategic socio-institutional actors to ensure sustainable groundwater management in the Nimboyores area. This process was coordinated by institutions responsible for water resource management, such as the Costa Rican Institute of Aqueducts and Sewers (AyA), the Water Directorate of the Ministry of Environment and Energy (MINAE), the National Groundwater, Irrigation and Drainage Service (SENARA), supported by the Ministry of Health (MS), the Ministry of Agriculture and Livestock (MAG), the Institute of Rural Development (INDER), the Associations of Communal Aqueducts (ASADAS), the Integral Development Associations, local government, academia (National University) and the private sector.

The first step was to win the trust of the various actors and invite them to be part of a participatory process, since the image of public institutions has been severely discredited for various reasons. It was therefore decided to work together on several fronts, such as the measurement and monitoring of the status of the aquifer, the analysis of water balance data, the development of a sustainable management plan for the aquifer and the conceptualization of an infrastructure project to supply water to various communities. This effort culminated with the consolidation of an organization called "Commission for the Sustainable Management of the Nimboyores Aquifer and Coastal Aquifers of Santa Cruz (CONIMBOCO)", formalized by Executive Decree No. 41094-MINAE.

In this experience, the AyA signed the first public-community agreement with ASADASs on the coastal zone of Santa Cruz, where the AyA built an aqueduct using water from the Nimboyores aquifer and transporting it to 16 communities all supplied by 14 ASADAS. Water is delivered to each ASADA through a macro-meter and charged on the basis of a new tariff defined by the Public Services Regulatory Authority (ARESEP), called block water, calculated on the basis of the average cost of the service provided by each operator, while ensuring the economic sustainability of each ASADA. The commitment of each ASADAS is to ensure efficient, quality service.

CONIMBOCO seeks to restore coastal aquifers that have undergone salinization processes, by reducing or eliminating the extraction of their waters and consuming water from the Nimboyores aquifer, a non-coastal aquifer. This inter-organizational body is also responsible for implementing the management plan for the Nimboyores aquifer, where the extraction of water is limited to the flow established by the water balance study, ensuring that 60% of the water will be reserved in the aquifer, and controlling land use in areas with the greatest water recharge. This guarantees the quantity and quality of the aquifer water.

Box 2. Integrated Water Resource Management at the level of the Purires River Microbasin, El Guarco, Cartago

By Yamileth Astorga Espeleta

The University of Costa Rica promoted the Dialogue of Knowledge Project for the use of Integrated Water Resource Management as a strategy for water sustainability at the level of the Purires River Hydrographic Basin in Cartago, Costa Rica. The objective of this initiative was to contribute to the collective use of integrated water resource management as an integrating strategy for actors and communities based on the Purires River microbasin, through a process of exchanging knowledge, experiences and sustainable water use and management practices.

This project is the continuation of an earlier process, based on the mapping of strategic actors in the microbasin and the promotion and consolidation of a platform, with the representation of local actors, community organizations, and public Costa Rican state and local government institutions. The project incorporated the building of the organizational and integrated water resource management capacities of the Commission for the Purires River Microbasin (ComPurires), culminating in a formally constituted Association with legal status designed to lead and maintain the integral management process of water resources in the micro-basin.

The project also included the assessment of the vulnerability of water resources in production areas, the sources used and the discharge of wastewater from various users, such as the Administrative Associations of Aqueduct and Rural Sewerage Systems (ASADAS), household and agricultural users and, in general, the ecosystem of the Purires River and its main tributaries in the Purires River microbasin, with the active participation of members of ComPurires.

Local actors in the Commission, elementary and middle school students, were trained to take water samples from the river for the evaluation of the physical-chemical quality and macroinvertebrate samples for evaluation through biological indicators of the quality of the aquatic ecosystem. To this end, they also produced maps, guidelines and other types of educational material to continue monitoring water quality in the microbasin.

The project also incorporated continuous monitoring for approximately seven years at six points along the course of the microbasin, in keeping with the provisions of the Regulation of the Evaluation and Classification of Surface Waterbody Quality, Executive Decree No. 33903. Twice a year, samples were taken for the analysis of the physical-chemical quality of the water and the Water Quality Index (WQI) was used, which includes the percentage of oxygen saturation, Biochemical Oxygen Demand and Ammoniacal Nitrogen, in addition to other physical-chemical parameters. Macroinvertebrate samples were taken to use the BMWP-CR biological index.

In order to reduce the vulnerability of the water resources in the micro-watershed, solution strategies were implemented, such as the installation of collectors to harvest rain at education centers, dry leach fields and bio-digesters for wastewater treatment, the production of organic fertilizer using agricultural waste, reforestation in the areas of water recharge and riparian protection areas, solid waste collection in the river bed, environmental education, educational fairs and the use of the Ecological Blue Flag Award V Hydrographic Micro-watershed Category.

Box 3: Water problems affecting the Río Grande de Tárcoles Basin: Seeking solutions

By Édgar Meléndez

The Río Grande de Tárcoles Basin (RGT) covers five of the seven provinces in the, including the upper part of the Greater Metropolitan Area (GAM). The RGT flows into the Pacific Ocean and has been considered the most polluted river in Central America (State of the Nation, 2017).

The RGT Watershed Management Program, undertaken by the Abt Associates Inc. consultancy firm in 1999 (Abt Associates Inc. *et al*., 1999), declared that, "*This Basin has entered a downward spiral of degradation that threatens not only the sustainability of the natural resources present in it, but also the quality of life of its inhabitants and that of future generations. The logical causes of this problem include rapid, disorderly urbanization as well as the opening up of areas for agricultural and industrial purposes, which are the source of deforestation and the loss of plant cover, which reduces infiltration, thereby increasing run-off, the risk of floods and the dragging of sediment. It states that liquid [sic] effluent from sewerage is discharged untreated into the river, since only 45% of the basin population have untreated sewerage, which leads to the deterioration of the quality of the surface and groundwater in the basin, creating unhealthy conditions and contaminating the water sources. It states that this problem is a result of unplanned growth, deforestation, lack of foresight regarding the impacts of urban use and ignorance of the capacity of the storm sewer system*".

The Resolution of the (Court) Constitutional Chamber, Vote 5894-2007 of April 27, 2007 ordered that, "*the necessary actions be taken immediately to comprehensively eliminate the sources of contamination that exist throughout the basin of the Río Grande de Tárcoles*". Fulfilling this mandate required the joint efforts of a significant number of actors, in both the public and private sectors, a combination of wills aware of the severity of the problem and the continuity of long-term actions. Reversal and repair processes for the damages caused to the Basin must be initiated, through integral environmental management that emphasizes participatory and sustainability aspects. From this perspective, Integral Management of the RGT Basin must be framed in integrality, at least in two respects: 1) by encompassing the geographical totality of the Basin, in other words, the 37 cantons; 2) through Integral Management that contemplates the inclusion of all anthropic factors that generate changes or disturbances in the natural environment, whether positively or negatively.

Once the excess pollution affecting the river was determined, as a direct consequence of inadequate solid and liquid waste treatment, the implementation of all corrective measures contemplated by current laws and decrees becomes indispensable and impossible to postpone. The most obvious method for solving the problem is Integral Waste Management (IWM). Article 6 of Law 8839 defines its nature as "the coordinated, inter-related set of regulatory, operational, financial, administrative, educational, planning, monitoring and evaluation actions for waste management, from its production to final disposal". IWM means that the geographical integration with its actors as well as the different uses of the water factor must be considered with an overall vision, because they are interdependent. As pointed out, the administration of water resources will require a long time to reduce the causes of the severe pollution affecting the river and its tributaries. There are still conditions to initiate processes of reversion and repair of the damages caused to the Basin, with an integral environmental management that establishes an emphasis on participatory and sustainability aspects, which is essentially confined to the municipal sphere in terms of solid waste.

With regard to the production of sewage that affects the RGT Basin, the San José, Heredia and Alajuela sewers in the Great Metropolitan Area (GAM) have systems which only collect sewage and, in practice, dispose effluents without treatment in the rivers of the basin. It should be noted that the Los Tajos AyA Wastewater Treatment Plant, west of San José, involves primary treatment with complete sludge treatment. The recent establishment of this plant will at least partly reduce the high existing contamination rate and the deterioration of water resources in the RGT Basin.

Proposed recommendations for solving the problem include the following: 1) IWM Plans at the municipal level will be successful if these local governments ensure accurate, prompt compliance with the obligations established in Article 8 of the Law for Integral Waste Management; 2) It is advisable to explore whether, through public works concession contracts, sewage and wastewater treatment systems can be built. The costs of these works should be seen as investments rather than merely expenses because from an economic perspective, with the collection of fees for services rendered, compensation is guaranteed; 3) it is important to raise awareness to reflect on the imminent problem of water pollution, which overwhelms us today and could have serious consequences for future generations.

7. Conclusions and Recommendations

Costa Rica has historically made significant progress related to the supply of drinking water, to excreta disposal to a lesser degree and only in recent years has it made progress in the field of wastewater treatment. However, much remains be done. One of the problems is obviously the cost of investing in the infrastructure required to treat wastewater, but there is also very little environmental awareness among a certain sector of the population. Although in recent years many of us have learned to value drinking water more and avoid the waste of clean water, we are usually unconcerned about what happens to wastewater, which is why there is still a high degree of contamination by solid and liquid waste in rivers (particularly in urban basins). Awareness could be raised by the Integrated Water Resource Management in the communal committees around the basins, where the problems of specific regions are addressed. It is essential to create more of these committees throughout the country and strengthen existing ones.

The country requires more research on the subject of surface and underground water quality, so studies focused on monitoring water quality should be strengthened, for which rivers and aquifers should be equipped with devices to measure levels of water and electrical conductivity, fecal coliforms and nitrates as indicators of anthropogenic pollution.

The institutions of the national water sector must join forces to carry out studies in areas where demand has been growing and/or is expected to occur in the future. Research should be increased on issues linked to the physico-chemical characterization of water, while plans to prevent pollution should also be drawn up.

A modern Water Law is required that will adapt to the needs of the management and responsible use of water resources. New legislation should place greater importance on water and guarantee its supply, protection and quality. But a law alone is not enough to guarantee a significant change in management of water resources, since it must be accompanied by suitable mechanisms and financing for its implementation and supervision. A change is required in the way water has been managed in recent years, especially with regard to the time horizons needed for proper planning. Increases in demand, associated with population aspects, changes in household use, industries and agriculture, as well as climate variability and change, have the potential to impose restrictions and create challenges regarding the availability and quality of water resources in the short, medium and long terms. There is also a need to establish an effective mechanism to transfer technical/scientific information to decision makers. To this end, universities should include degree courses to train professional "managers" who will serve as a link between physical and social fields. Effective coordination between the various institutions related to water is also required, particularly as water becomes increasingly scarce.

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