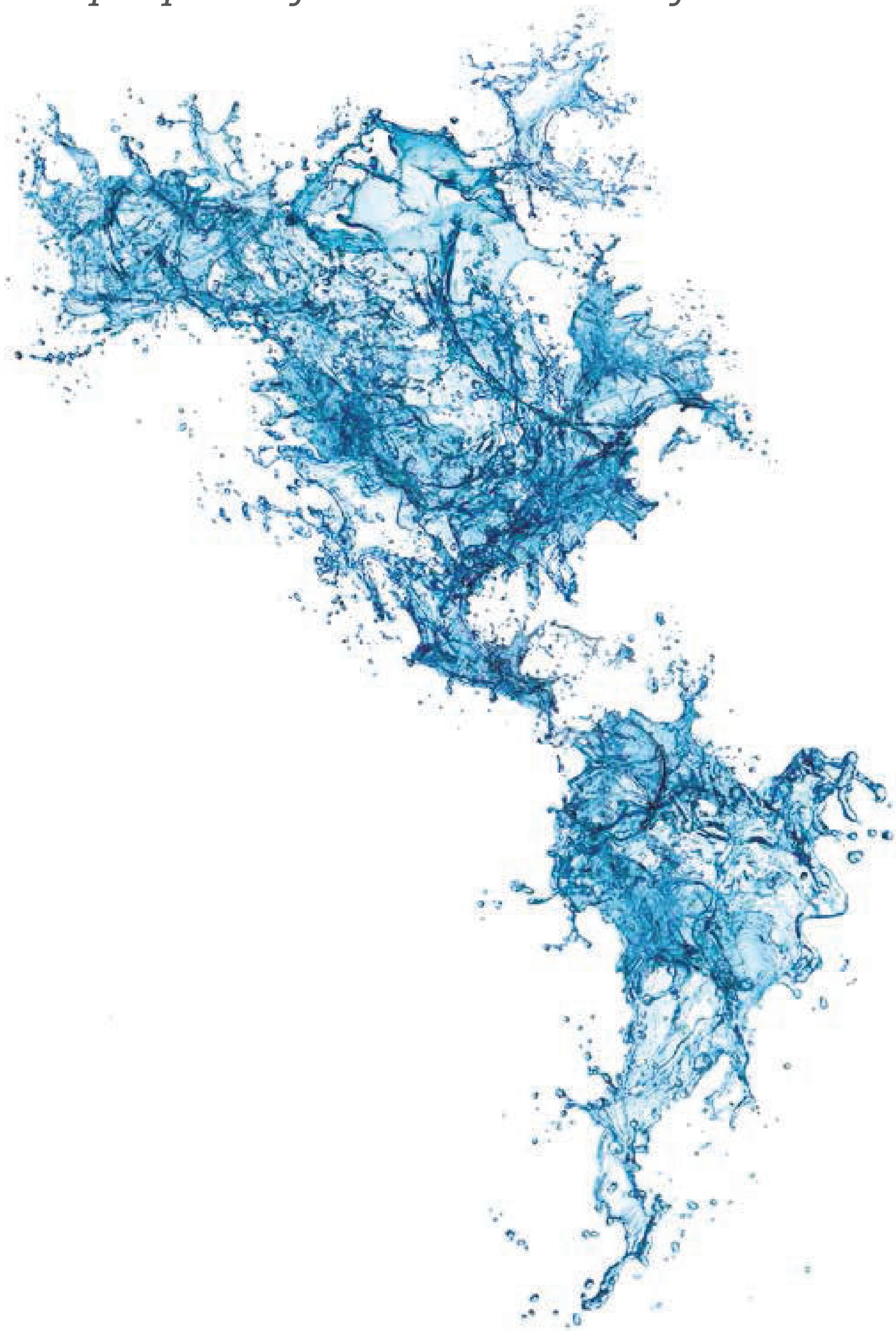
URBAN WATER
CHALLENGES IN THE AMERICAS

A perspective from the Academies of Sciences



United Nations Educational, Scientific and Cultural Organization

International Hydrological Programme

50 years

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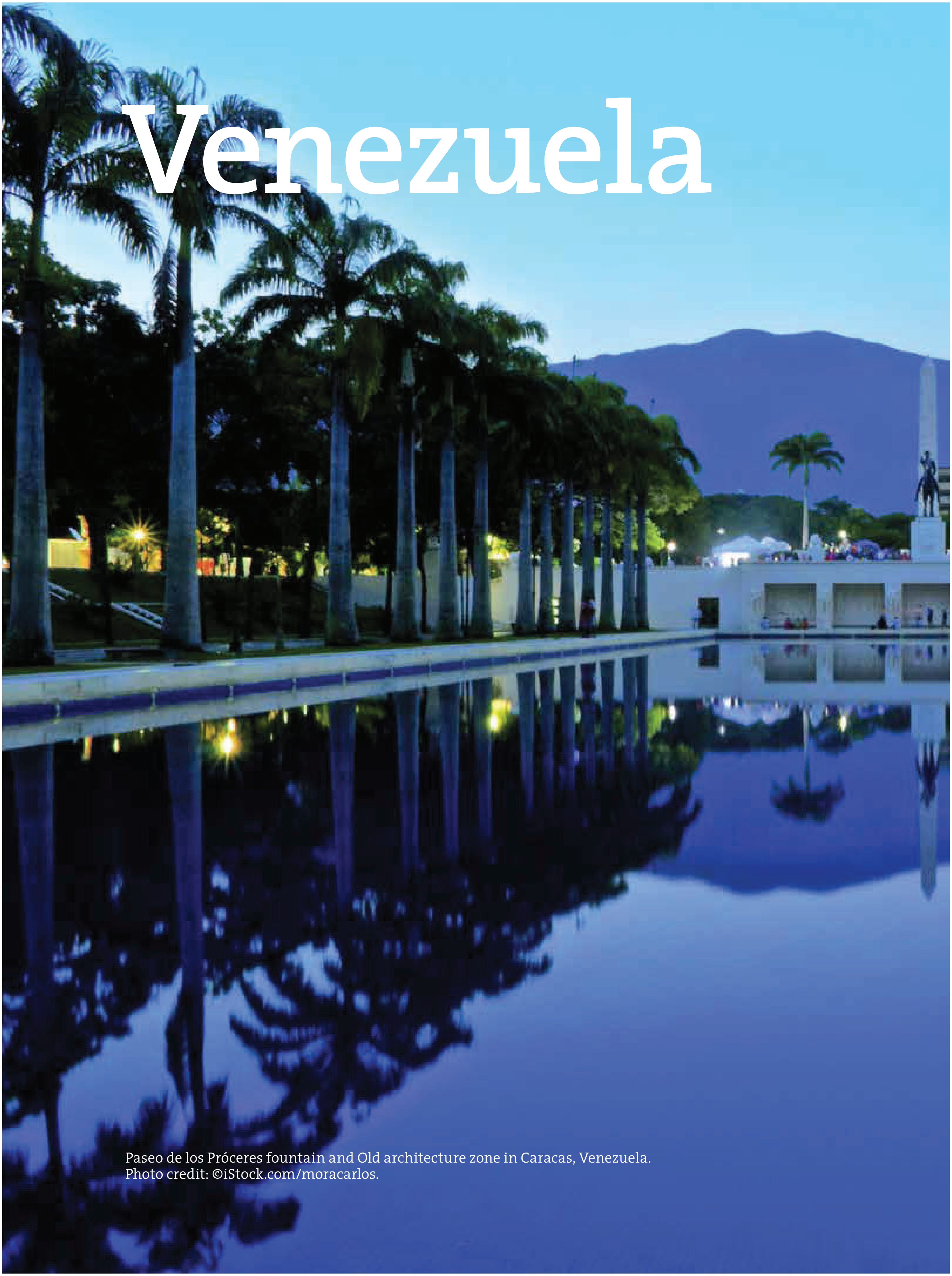
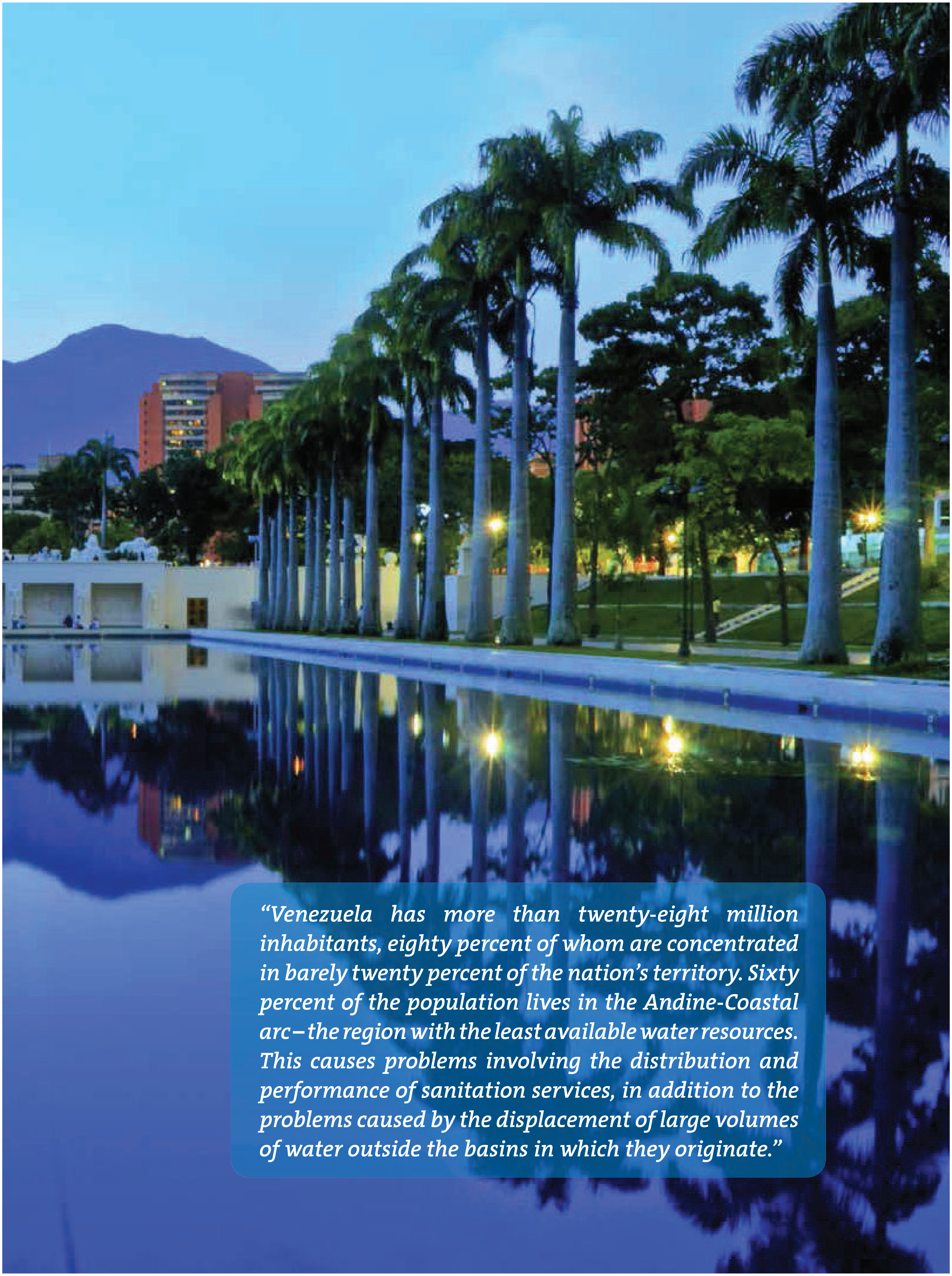
Venezuela



Paseo de los Próceres fountain and Old architecture zone in Caracas, Venezuela.
Photo credit: ©iStock.com/moracarlos.



"Venezuela has more than twenty-eight million inhabitants, eighty percent of whom are concentrated in barely twenty percent of the nation's territory. Sixty percent of the population lives in the Andine-Coastal arc–the region with the least available water resources. This causes problems involving the distribution and performance of sanitation services, in addition to the problems caused by the displacement of large volumes of water outside the basins in which they originate."

Urban Water Venezuela

Ernesto José González, María Leny Matos, Eduardo Buroz, José Ochoa-Iturbe, Antonio Machado-Allison, Róger Martínez, and Ramón Montero

Summary

Venezuela has more than twenty-eight million inhabitants, eighty percent of whom are concentrated in barely twenty percent of the nation's territory. Sixty percent of the population lives in the Andine-Coastal arc – the region with the least available water resources. This causes problems involving the distribution and performance of sanitation services, in addition to the problems caused by the displacement of large volumes of water outside the basins in which they originate. There are nine (9) regional hydrological companies and eight (8) decentralized companies nationwide that offer drinking water and sanitation services. The supply of drinking water in the largest cities depends mainly on surface water (reservoirs), which cover over ninety percent of the urban population and more than eighty percent of the sewage collection, but with less than fifty percent of these waters being treated. At present, several sanitation and sewage treatment projects are underway. Regarding the relationship between available urban water and health, in Venezuela there have been many cases of waterborne diseases. Prominent among these are diarrhea, amoebas, malaria and dengue, with the highest rates occurring among the poorest strata of the population. This chapter also offers an approach to environmental health from the space inside housing projects and homes, with observations about indications and indices aimed at gauging the interaction between water and environmental health. There are also observations concerning the high vulnerability of the nation's water regime. Accordingly, it is of vital importance to monitor the effect of climate change on the sundry water supply sources, since most of the adverse effects are tied to the availability of water. There have occurred such phenomena as extreme drought and flooding in the country's largest cities, all of them with negative effects on the urban population. Therefore, there is emphasis on the importance of timely population planning (master plans) in order to

prevent future personal and property damage. Also prominently mentioned are the structural and non-structural measures intended to mitigate the effects of flooding on the cities. The conclusion is that plans must be implemented for water resources management, which are the result of a well-planned and conceived interaction among the available technology, society, the economy and –given the occurrence of extreme water related events– the existing institutions, with a view to balancing the supply and demand of this resource. Furthermore, the plans for managing water resources and the mitigation of problems linked with the water availability cycle in urban areas must involve the participation of organized communities.

1. Introduction

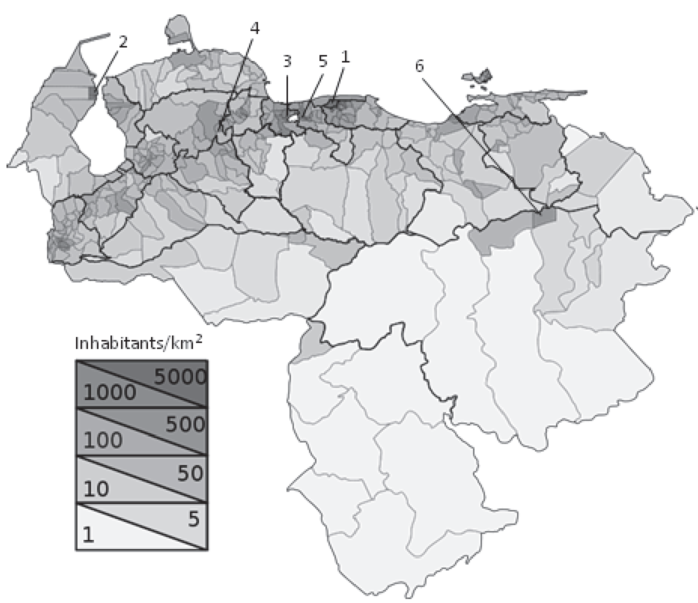
Venezuela has approximately twenty-eight million inhabitants, spread over 916,445 square kilometers of territory. According to the 2011 National Census, the population density is 29.6 inhabitants per square kilometer, with more than eighty-seven percent of the population living in urban areas, and about twelve percent in rural areas (INE, 2013).

Eighty percent of Venezuela's population is concentrated in twenty percent of the nation's territory. Of this, more than sixty percent live in the Andine-Coastal arc –specifically in forty percent of the country's largest cities, such as Caracas, Maracaibo, Valencia, Barquisimeto, Maracay and Ciudad Guayana, which have the greatest water availability (Figure 1).

Considering that the largest percentage of the population lives in the area with the greatest water supply, it is evident that problems may arise in its distribution and in the performance of services requiring water, such as sanitation, and others caused by the displacement of large volumes of water outside their original basins. All of this requires the characterization of the urban water cycle in order to guarantee drinking water and sanitation services, and to address the different problems in securing proposals looking toward their mitigation.

This chapter will present a summary of the main aspects concerning water in Venezuela's urban areas, especially in the country's largest cities –such as the supply of drinking water and sanitation services, water treatment, the health aspects and subjects related to their possible effects on climate change.

Figure 1. Population concentration in Venezuela.
Cities: 1) Caracas, 2) Maracaibo, 3) Valencia, 4) Barquisimeto, 5) Maracay and 6) Ciudad Guayana.



Source: Modified from INE (2013).

2. Drinking water service in urban areas

The supply of water in Venezuela comes, in large part, from surface sources. According to González Landazábal (2001), the space distribution of surface water runoff in Venezuela is characterized by the following aspects:

- The average annual rain-generated water runoff in Venezuela, excluding Guayana Esequiba, is estimated at seven-hundred and five million cubic meters.
- The river basins in the states of Amazonas and Bolívar, which are tributaries on the right bank of the Orinoco River, produce about eighty-two percent of the aforementioned volume.
- The part of the country to the north of the Orinoco River produces the remaining eighteen percent. Of this, nine percent is contributed by the tributaries, on the West Central Lowlands, with another nine percent from Lake Maracaibo, the slope of the Caribbean, the Lake Valencia basin and the Gulf of Paria.

Beginning in 1990, Venezuela began restructuring the organisms responsible for providing drinking water and sanitation services, with the purpose of moving from a centralized supply scheme to a model which would take into account the principles of joint responsibility and the participation of every inhabitant of Venezuela, as guaranteed in Articles 60, 70 and 184 of the Constitution of Venezuela as a point of departure from which to incorporate them legally into the design of the water and sanitation policies, plans and projects related with their community and environment, thus contributing to People's Power and an interchange of know-how, among other skills. To this end, HIDROVEN was created as a main office for the drinking water and sanitation sector, with steering and supervisory functions, with ten (currently nine) affiliated regional hydrological companies, with the purpose of preventing the privatization of the water supply industry and the decentralization of its administration, thus achieving the operation of the affiliated companies with their own income and resources from the cancellation of the rate payable, in addition to contributions from the national government through economic subsidies.

The federal government will continue to own the shares of the Regional Hydrological Systems, since its only stockholder is HIDROVEN, which serves as the main office for these companies and in turn, the People's Ministry of the Environment (MINAMB). This latter owns ninety-five percent of HIDROVEN's shares. The remaining five percent is also owned by another governmental agency. In the case of the states of Amazonas and Delta Amacuro, which belong to the Guayana region, this service is also furnished by a governmental agency, which is the Venezuelan Corporation of Guayana (CVG).

The distribution of the Regional Water Companies (see Figure 2) is as follows (HIDROVEN, 2008):

- HIDROCAPITAL: The Metropolitan Aqueduct of Caracas and the Vargas and Miranda States.
- HIDROCENTRO: Aragua, Carabobo and Cojedes States.
- HIDROLAGO: Zulia State.
- HIDROFALCÓN: Falcón State.
- HIDROSUROESTE: Táchira State and the Ezequiel Zamora District of Barinas State.
- HIDROANDES: Trujillo and Barinas States (except the Ezequiel Zamora District).
- HIDROPÁEZ: Guárico State.
- HIDROCARIBE: Sucre, Nueva Esparta and Anzoátegui States.
- HIDROLLANOS: Apure State.

There is also a series of Decentralized Companies which provide drinking water and sanitation services with the participation of the federal and municipal governments and that of the Venezuelan Corporation of Guayana (CVG), which oversees the Sanitation Services and Water Management (GOSH) for Amazon and Delta Amacuro states.

The Steering Committee is elected by the Shareholders' Assembly and is independent of the Federal Government. Its members are usually from the state sphere and are concerned with the management and operation of drinking water and sanitation services. At present, the following decentralized companies are operating in the country:

- HIDROLARA: Lara State.
- AGUAS DE MONAGAS: Monagas State.
- AGUAS DE MÉRIDA: Mérida State.

- HIDROS PORTUGUESA: Portuguesa State.
- AGUAS DE YARACUY: Yaracuy State.
- HIDROBOLÍVAR: Bolívar State.
- CVG-GOSH: Amazonas and Delta Amacuro States.
- AGUAS DE EJIDO: Ejido District, Mérida State.

The sources of water for supply in the nation's largest cities come from reservoirs built for this purpose (Table 1).

According to HIDROVEN (2008), the supply of drinking water for the urban population has been increasing in recent years, attaining a coverage of ninety-one percent (Table 2), while the rural population coverage has reached seventy-nine percent. In addition, wastewater recovery has reached 82.41%. However, only 25.91% of wastewaters are treated (through secondary treatment).

Figure 2. Distribution of Regional Water Companies in Venezuela

Source: HIDROVEN.

Table 1. Reservoirs furnishing water to the main cities of Venezuela

City	Reservoirs	Total Volume M³
Caracas	Camatagua, La Mariposa, La Pereza, Taguaza, Taguacita, Lagartijo, Quebrada Seca, Macarao, Cuira (under construction)	1,975.6 x10^{6}
Maracaibo	Tulé, Socuy, Tres Ríos	659.4 x10^{6}
Valencia	Pao-Cachinche, Guataparo, Pao-La Balsa	615.7 x10^{6}
Barquisimeto	Dos Cerritos, Dos Bocas (under construction)	127.4 x10^{6}
Maracay	Pao-Cachinche, Pao-La Balsa	196.7 x10^{6}
Ciudad Guayana	Guri, Macagua (I, II and III)	111,467 x10^{6}

In-house document based on data from Castillo et al., (1973).

Table 2. Progress in the supply of drinking water supply and in wastewater recovery

Year	Drinking water supply (% of population)	Wastewater recovery (% of population)
1998	81.57	63.77
1999	83.66	64.38
2000	85.15	66.96
2001	86.37	68.15
2002	87.65	71,27
2003	89.27	71.69
2007	91.70	82.41

Sources: Arconada, 2005; HIDROVEN, 2008).

2.1 Groundwater in the Cities

Freshwater from rivers and lakes is the natural resource most extensively used by society since time immemorial. However, in recent decades the use of groundwater has increased as the result of the gradual deterioration of the sources of surface water. In many cases, groundwater is the main source of water for human consumption and for agricultural, livestock and industrial activities. Large quantities of water are also required as a secondary demand in gardening and recreational activities (Demirel and Güler, 2006).

Groundwater is the product of the seepage of rainwater through rock formations with such favorable physical characteristics as porosity and permeability, which facilitate its transportation, storage and use, whether natural or artificial, through the construction of wells using pumps or by manual extraction. In this sense, the factors affecting the availability, accumulation and type of groundwater are climate, lithology, bedrock geomorphology and time (the age of the water). Meanwhile, the geological environment within these factors includes strategic relationships and geological structures, the direction and variability of the flow of the groundwater, the location of the water recharge and discharge areas and its composition. These factors have been thoroughly documented and studied by Hem (1985), Domenico and Schwartz (1990), Custodio (1996), Ettazarini (2004), Rajmohan and Elango (2004), Van der Hoven et al., (2005) and Rao (2006).

Another factor which controls the accumulation and composition of groundwater is tectonic activity (Hendry and Schwartz, 1990; Van der Hoven et al., 2005). Its importance lies in the fact that during periods of orogeny there occur not only the creation of large mountain ranges but also the formation of sedimentary basins which can later serve as major hydrocarbon and water reservoirs in the intramountain regions (Hidalgo and Cruz-Sanjulián, 2001).

Likewise, human activities carried out in urban areas have a major impact on the final condition of the water. Thus, solutes may be incorporated directly into the groundwater through domestic wastewater, industrial waste, sanitary landfills, agricultural and cattle-raising activities, oil spills, gasoline leaks from storage tanks and the overworking of wells (Hem, 1985; Navarro et al., 1988; Domenico and Schwartz, 1990; Custodio, 1996; Magrinho et al., 2006).

Venezuela's geological history was characterized by a high degree of dynamics associated with the most important orogenic activity both worldwide and regional (Villamil, 1999). This had as a consequence that, throughout Venezuela, there are conditions that lend themselves to the accumulation of large volumes of water, associated with a wide variety of geological structures, especially in large and small sedimentary basins which contain quaternary rock formations. Decarli (2009) points out that nearly fifty-five percent of the surface of the country is covered by poorly consolidated or unconsolidated sediment and consolidated rocks with characteristics favorable to the formation of aquifer units. The seepage of rainwater and its migration through these aquifers produced significant variations in the chemical composition of their waters, due to the chemical weathering processes during the water-rock interaction.

In Venezuela, the zones with the highest groundwater and aquifer availability are mainly in the Central Region, in the South and the Lake Maracaibo plains, the Andine foothills region of the Central and Western Lowlands, on the Guanipa Plateau, in the central part of Anzoátegui state and in some sections of the coastal aquifers. Figure 3 shows the relative location of Venezuela's main aquifers.

During the development of the large cities, the potential recharging areas located at the foothills of the mountainous regions surrounding them are vulnerable or eliminated. This is the result of the construction of large urban developments and the clearing of major forests. In addition, the construction and paving of access roads and highways can lead to a limitation of the local recharging of groundwater. This, in turn, as regards the water balance, means that the only consequence is a deep infiltration, produced by the regional flow regimen. This means that, as far as this equilibrium is concerned, there is a water deficit. Thus, during rainy periods, large volumes of water appear as surface runoffs, while the underground runoffs are less dominant.

In this sense it is supposed that, given the increasing population and economic growth, the groundwaters have been subjected to a continuous waning in their availability and quality –especially to the urban areas in the northern and central regions of the country, and in those zones with significant economic activity, such as cattle-raising, agriculture, mining and hydrocarbon exploration and operations. The country's renewable groundwater reserves are spread over twenty-two billion, three-hundred and twelve million cubic meters. It is estimated that about fifty percent of this is used for drinking, industry and irrigation over a network of waterworks comprising one-hundred thousand wells (FUNDAMBIENTE, 2006; Decarli, 2009; Durán, 2011).

An example of the use of groundwater in cities is the Caracas Valley –a major region in northern Venezuela with an area of seventy-six square kilometers, measuring fourteen kilometers east-to-west between the residential area known as Propatria and Parroquia de Petare, widening by four kilometers from the San Bernardino residential complex to the El Paraíso complex. This valley comprises water-saturated sediments from the quaternary period, comprising layers of sand and gravel capable of providing a useful supply of water, enabling the construction of prominent aquifer units.

During the last forty years little attention has been paid to Caracas' groundwater. Among the most prominent hydrogeological studies, one can mention those of Delaware (1950), Gomes (1997, 1999) and TAHAL (2002). This latter carried out a study for the placement of new wells throughout the entire valley. Freile (1960), for his part, carried out a hydro-geochemical classification of Caracas' groundwater. Singer (1977a, 1977b), Rocabado (2000) and Kantak (2001) studied the soil cover of the Caracas Valley.

Of all the drinking water consumed in the city of Caracas, over eighty percent comes from the Tuy I, Tuy II and Tuy III aqueducts, which are fed from the watershed basins of the Tuy and Camatagua rivers. These basins have been undermined in recent years by long droughts, combined with short rainy seasons and a greater demand for water supply due to the increased population of the nation's capital.

The available data (Decarli, 2009), indicate that the city of Caracas consumes about eighteen thousand liters per second (lps). Of this, about twelve-hundred liters come from the more than five-hundred groundwater extraction wells in existence. While the sum total of groundwater at the different aquifers in the Caracas Valley is incapable of meeting the requirements of the entire population, it can serve as an alternate source of supply for the zones that require it. It is, therefore, important to evaluate it in terms of the characteristics of its aquifers, flows, direction of flow, of the identification of recharge areas, composition and types of water available, to conduct an inventory and determine the location of the most productive wells.

In this regard, the use of the aquifer was recently estimated in approximately 1.5 m^3/second. The principal pumping centers are in such sectors as El Paraíso, the entrance to El Valle and Miranda state. The most abundant flows are found in the El Paraíso sector, with wells offering from 20 lps to over 40 lps (Gomes, 1997). The piezometric maps prepared by the Ministry of the Environment (MINAMB) show that the flow in the valley follows the mountains (lateral recharge zones), to the main pumping centers and on to the Guaire River (discharges from the aquifer system).

According to MINAMB, the transmissivities (or measures of the distance that water can be transmitted horizontally through a unit under

Figure 3. Location of Venezuela's aquifers. 1) Río Motatán Basin, 2) Río Guárico irrigation system, 3) Caracas Valley, 4) Guanipa Plateau, 5) Quíbor Valley, 6) Eastern Lowlands, 7) Coro aquifer, 8) Western Lowlands, 9) the Barlovento aquifer, and 10) the Paraguaná aquifer.

Source: Modified from Rojas and Serrano (2007).

the influence of a hydraulic gradient), varies from sixty to one-hundred and twenty square meters per day, averaging ninety square meters per day. The average permeability obtained by dividing the transmissivity into the saturated thickness varies from 2.6 meters per day (the geometrical average) to 7.0 (the arithmetical average), while the horizontal water conductivity varies between one and forty meters per day.

The recharge zone of the Caracas Valley aquifer comes from the mountains, mainly through the main ravines which empty into it. In addition, another major water inlet to this aquifer comes from the losses sustained by the HIDROCAPITAL drinking water system which according to Seiler (1996), are on the order of one to two m^3/second.

Another example which should be mentioned is the project aimed at combining the operation of groundwater with that of surface water in western central Venezuela in order to transfer water resources from the Río Yacambú basin (in Lara state), with the following objectives: (a) increasing the agricultural area under irrigation in the Quibor Valley, which is a highly productive area, (b) through the joint use of surface water and groundwater, restoring the Quibor Valley aquifer (the area identified as Number 5 in Figure 3), the availability and quality of whose water have deteriorated considerably due to overuse, and (c) offering an additional, massive water supply to HIDROLARA, the region's public drinking water and sanitation service company (Garduño and Nanni, 2003). According to these authors, the experience with this project made possible the recommendation to include aquifers in the definition of "basin" in the Water Law passed in 2007, among other recommendations.

Groundwater represents a specific alternative to boost the supply in some sectors supplying water to cities. According to Escalona et al., (2009), in view of the high degree of chemical treatment the treatment of surface water is more costly than the treatment of groundwater. Groundwater is cheaper to produce, since by passing through the different subsoil strata or configurations it receives natural filtration. This reduces residues and obviates chemical treatment since only chlorine is used in its disinfection. It is, however, wont to contain, generally, high concentrations of such metals as iron and manganese, and a high degree of hardness, which can complicate and increase multifold the cost of its treatment. It is, therefore, important to evaluate it in terms of the characteristics of its aquifers, flows, the direction of flow, the identification of the recharge areas, the composition and types of water present, and to conduct an inventory of and to locate the most productive wells.

Box 14

Drinking water and sanitary services for the city of Caracas

The present situation and prospects for the management of drinking water and sanitation services for the Caracas Metropolitan Area.

The drinking water supply for the Caracas Metropolitan Area (AMC) was established in 1950 as a regional system. This implied the collection and transfer of large volumes of water from the Tuy and Guárico river basins, and the incorporation of small contributions from the Rio Guaire basin. After different incorporations and adjustments, the Caracas Metropolitan Region (RMC) was established, comprising five systems which in 2011 produced and distributed nearly twenty-six thousand liters per second (lps) over all. These are the Metropolitan, Litoral, Fajardo, Losada-Ocumarito and Pan-American systems (Martínez, 2012). A sixth system, Barlovento, supplies the region of the same name and completes the group of systems managed by the Hydrological Company HIDROCAPITAL. For the AMC, the production of drinking water for the Metropolitan System is 17.7 m^3/second, offering an average supply loosely calculated at 470 liters per person per day (Martínez, 2012).

The fact that half the population lives in unplanned neighborhoods, with high altitude service sources, limited water storage, pumping and distribution systems implies that the supply of 470 lpd

Box 14

does not benefit all the inhabitants residents uniformly (IMUTC, 2012). There are no known recent, overall studies to ascertain the actual drinking water supply in the AMC's informal neighborhoods. However, partial studies carried out in a number of neighborhoods show rationing that lasts for several days, and a supply less than that recommended by the health standards (Martínez, 2012). Another weakness of the distribution network, which is increasingly evident, consists in broken pipes and the difficulty in replacing them. A large part of the distribution system is over fifty years old. Therefore, its useful life has expired, making it necessary to replace them completely. The losses from leaks in the distribution system total 5.4 m^3/second. Individual readings reached only fourteen percent of the subscribers (IMUTC, 2012) while the amount of uninvoiced water has been at sixty percent for several years (HIDROCAPITAL, 2002).

With regard to the sanitation sewage system, from the technical standpoint, the system should collect wastewater and rainwater separately, discharging them in collectors running along the banks of the ravines that flow to the Guaire River. Their left bank and right bank collectors should collect all the wastewater. At times of excess flow due to the influx of rainwater to the sewers, relief ducts, installed at the junction between the collectors on the banks of the ravines and those of the Guaire River, should evacuate the excess, now highly diluted, to the Guaire River. Although before 1930, under the Public Works Ministry's Overall Sewage Duct Plan, it had been contemplated that the Guaire River would not receive wastewater and that it would be purged prior to discharge, ninety years later this still has not been achieved (Martínez, 2012).

At the end of the 'fifties, new riverbank collectors were designed which, over all, are capable of handling a flow of up to 60 m^3/second – more than three times the current average flow of the aqueduct (Pérez Lecuna, 2005). Despite the fact that these riverbank collectors have been completed since the 'seventies, they do not work properly due to lack of maintenance of the system, to urban sprawl and weaknesses in following up on collection and treatment plans, including the more recent Rio Guaire Sanitation Project. With regard to the collectors in outlying, unplanned neighborhoods, these have been built thanks mainly to the participation of the communities themselves, without observing the technical standards. Accordingly, they work poorly and lead to seepage into the soil and discharges into the natural drainage structure.

The social and environmental conditions of poor drinking water and sanitation management in the AMC. Future prospects

As the result of the current management of drinking water and sanitation systems, there still persist some social, economic and environmental problems. With regard to the social problems, the morbidity statistics for 2012 (Martínez, 2013) indicate the greatest incidence of water-transmitted diseases in those parishes of the Libertador District which lack water and sanitation systems and where the poorest population is concentrated.

With regard to the economic problems, it may be said that the limited access to drinking water and sanitation has a negative impact on the family income of the population with the least economic resources, who have to buy water at the highest price from private tank truck operators who are not subject to proper supervision and do not guarantee the supply of "safe" drinking water (Jouravlev, 2004). Another economic consequence of the lack of sanitation networks which has major repercussions on vital statistics, concerns the increased vulnerability of the informal neighborhoods. The deficiency of the existing water and sewage networks generally leads to seepage into the ground, weakening its ability to support buildings, causing massive landslides and increased vulnerability in the event of earthquakes. According to Civil Protection reports, massive landslides in the Capital

Box 14

District account for seventy two percent of the total occurrences, while the remaining twenty-eight percent are due to collapses, flooding, earth settling and other phenomena (Grases, 2006).

Finally, from the environmental impact standpoint, the construction of unplanned sewage networks implies the discharge of untreated wastewaters into the ravines. However, even if the problem of collecting all the effluents in their riverbank collectors along the Guaire were resolved, neither has overall treatment been achieved. This means that raw wastewater is still discharged into that river and, consequently into the Tuy River and the Caribbean Ocean, causing serious eutrophication and contamination problems. In addition, the nonexistence of a water rate policy that promotes saving implies a lack of rationalization in drinking water consumption. This leads to excessive use of water from fresh water bodies, which has irreversible environmental effects.

If in the next two decades there emerge no measures tending to rationalize water consumption and recycle wastewater, then water consumption in the AMC for the year 2031 could reach 21.3 m^3/second, while in the RMC it could reach 34.2 m^3/second. This will require the use of the Tuy I to IV systems, with no possibility of relieving the operation of the water supply systems (Martínez et al., 2013). With regard to the generation of wastewater, if measures are not taken to rationalize their usage to separate rainwater and to recycle wastewater, the production for the AMC by the year 2031 could reach 34.5 m^3/second, while for the RMC it could reach 57.5 m^3/second. In addition, if the treatment problem is not resolved, the contamination of natural water streams will continue, with harmful and irreparable effects on the underground ecosystems affected by the discharge of the Tuy River, whose basin is that which has the most serious harmful impact on the Caribbean Sea (Martínez et al., 2013).

The proposed policy

A desirable evolution of water management would have to bring together the participation of the institutional players at the different levels of government (federal, regional and local), preserving the incorporation of the organized communities, which is an international trend (WSP, 2008), but within a scheme that does not relieve the government of its responsibilities. According to the analyses carried out for the different supply systems which today comprise HIDROCAPITAL, there will apparently be, worldwide, enough water from the current sources – with the imminent incorporation of the Tuy IV System – to sustain the growth of the entire Metropolitan Region. It is, however, necessary to rationalize consumption in order to reduce the per capita provision. This is a task which necessarily implies joining forces with the districts (Martínez et al., 2013). The replacement of distribution pipes in order to prevent leaks, the regularization of clandestine taps, the micromeasurement and collection for services performed, tending toward a reasonable consumption that facilitates financial balance for the performance of services, is a task which could well be undertaken by local entities.

A new institutional arrangement must be adopted, in which the seventeen districts of the Metropolitan Region – either individually or jointly – can administer the components of the drinking water and sanitation systems closest to the end user. That is, for the aqueduct, the local drinking water distribution networks; for the sewage system, the embedded elements and secondary wastewater collection systems and, for drainage, the secondary and tertiary urban drainage systems.

Underlying all of these lines is the notion that in order to achieve a sustainable water administration, public policy must have an urbanization counterpart. This subject requires interdisciplinary approximations which bring together contributions from the sociological, economic, political, legal, engineering and other spheres, making it possible to recognize the problems and propose changes that lead to decision-making.

Box 14

Description of the supply of water to the city of Caracas

With regard to the supply of water for distribution, the city of Caracas depends on surface sources (reservoirs) located in remote regions and at altitudes much lower than those of the city. Water reaches the city through a complex of fittings and ducts known as the "Tuy System" (Figures 4 and 5), comprising the following subsystems:

- Tuy System I: Fed by the Lagartijo reservoir (80 $x10^6$ m^3). It transfers to the La Mariposa reservoir and supplies water to the parts of the city at lowest altitudes (3 m^3/second).
- Tuy System II: Fed by the Taguaza reservoir (184 $x10^6$ m^3). Supplies water to the southeastern zones and intermediate altitude sections of the city (7.2 m^3/second).
- Tuy System III (the most important): Fed by the Camatagua reservoir (1,550 $x10^6$ m^3). Supplies water to the rest of the city and other cities in other states (9 m^3/second).
- Tuy System IV (under construction): Fed by the reservoir to be built on the Cuira River. Will furnish 12 m^3/second and may furnish up to 21 m^3/second.

The water is routed from the reservoirs, usually at less than 400 meters above sea level, through pumping stations to carry the water to the city, which is over 900 meters above sea level.

As may be seen, the supply of drinking water to the Venezuelan capital proves quite complicated, in addition to the problems involved in the translocation of water from other drainage basins to the city, as will be described later in this treatise.

Figure 4. Tuy System. Modified from HIDROCAPITAL.

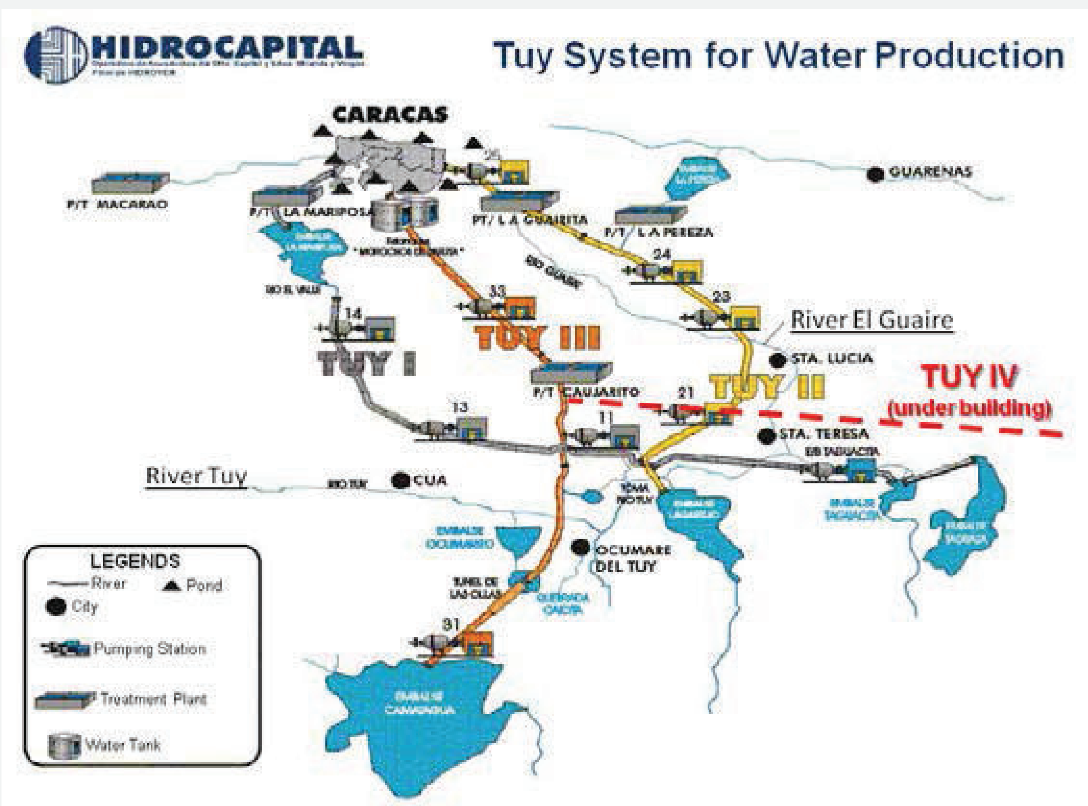
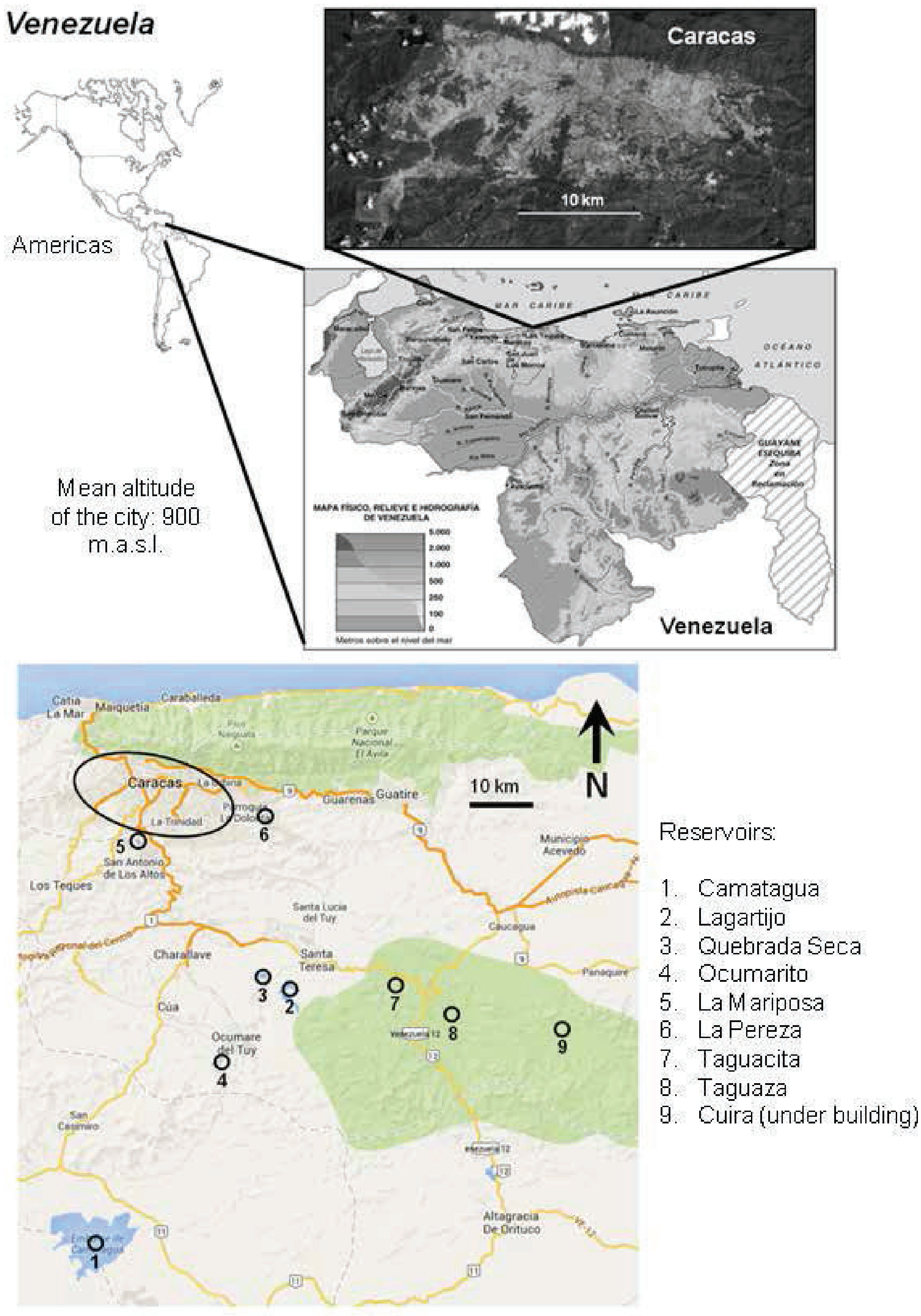


Figure 5. Relative location of the city of Caracas and the reservoirs supplying drinking water



Source: In-house document based on Google Earth images.

2.2 Drinking Water and Sanitation Service Rate Structure

The cost structure for the supply of drinking water and sanitation services dates from 2011, established pursuant to Transitional Provision Nine of the Organic Law for the Supply of Drinking Water and Sanitation Services Law published in the *Official Gazette of the Republic of Venezuela* under Number 39,788, dated October 28, 2011 (GORBV, 2011). This Administrative Ruling establishes the methodology, formulas, model and technical criteria that regulate the rates for the drinking water and sanitary services rendered by the Regional Hydrological Companies affiliated with the Compañía Anónima Hidrológica Venezolana, or HIDROVEN, C.A.

The use made of the water is as follows:

- Business Use "A": Establishments where water is an essential and main input for carrying out business activities or performing services, such as clinics, hotels, boarding houses, carwashes, laundries and/or dry cleaners, nurseries, barber shops, butcher shops, fish markets, shopping centers, restaurants and others.
- Business Use "B": Those establishments in which water is not an essential, main input for the conduct of business activities or the performance of services.
- Industrial "A": Those establishments where water is an essential and main input for the performance of industrial activities.
- Industrial B: Those establishments where water is not an essential and main input for the performance of industrial activities
- Residential: Refers to all real property intended exclusively for housing or family residence.

Residential use is classified as follows: Social, 1, 2, 3 and 4. In order to classify a subscriber as belonging to one or another of the residential categories, the drinking water and sanitation service provider follows a methodology which takes into consideration the key variables related to the residential zone or geographical location where the property is located, the cost of the property, the nature of the housing, its services and facilities (gardens, swimming pool, cable television, etc.).

Table 3 presents a rate structure for business and industrial use, while Table 4 presents a structure for residential use. In addition, the Average Reference Price is determined by the geographical location of the property (Table 5). The prices are in Venezuelan Bolivars (Bs) and, for purposes of reference, the value in American dollars (US$) is shown at the official rate of exchange.

This Administrative Ruling also provides that in those systems or population centers in which, apart from the wastewater collection process, the treatment and final disposal of wastewater are also carried out, an ad valorem charge of 25% will be added to the public drinking water and wastewater collection service invoiced.

WSP (2007) has estimated that the providers do not issue invoices to thirty-five percent of the low income population, while sixteen percent of the remaining sixty-five percent are considered subscribers offering services to society. Accordingly, they are charged about twenty percent of the actual applicable rate. This maintains a relationship with the principle of solidarity and recognition of the social obligation in the policies of each sector.

Table 3. Rate structure for industrial and business use. PR= Average Reference Rate

Uses	Fixed rate (1/6 of the allowance is calculated, and a minimum rate established for each use)	Variable rate (up to amount of the allowance)	Excess Use 1 (from the allowance up to 1.5 times the amount of the supply)	Excess Use 2 (from 1.5 times the allowance up)
Industrial A	Minimum of 50 m^3/month (2.50 or 3.00) x PR	(2.50 or 3.00) x PR	4.00 x PR	7.00 x PR
Industrial B	Minimum of 40 m^3/month (2.25 or 2.50) x PR	(2.25 or 2.50) x PR	4.00 x PR	7.00 x PR
Business A	Minimum 30 m^3/month (2.00 or 2.25) x PR	(2.00 or 2.25) x PR	4.00 x PR	7.00 x PR
Business B	Minimum 20 m^3/month (1.50 or 2.00) x PR	(1.50 or 2.00) x PR	4.00 x PR	7.00 x PR

Sources: *Official Gazette of the Republic of Venezuela* (2011).

Table 4. Rate structure for residential use. PR= Average Reference Rate

Uses	Fixed rate (1/6 of the allowance and the minimum rate considered will be 15 m³/month)	Variable rate (between 15 and 40 m³/month)	Excess 1 (between 40 and 100 m³/month)	Excess 2 (over 100 m³/month)
Lodging	(0.50) x 0.50 x PR	(0.50) x 0.75 x PR	3.50 x PR	5.00 x PR
Residential 1	0.75 x PR	0.75 x PR	3.50 x PR	5.00 x PR
Residential 2	1.00 x PR	1.00 x PR	3.50 x PR	5.00 x PR
Residential 3	1.50 x PR	1.50 x PR	3.50 x PR	5.00 x PR
Residential 4	2.00 x PR	2.00 x PR	3.50 x PR	5.00 x PR

Source: *Official Gazette of the Republic of Venezuela* (2011).

Table 5. Average Reference Rate (PR) according to use and water company

Companies	Residential PR (Bs/m³ – US$/m³)	Business and industrial PR (Bs/m³ – US$/m³)
HIDROANDES	1.00 – 0.091	1.90 – 0.173
HIDROCENTRO	1.55 – 0.141	1.90 – 0.173
HIDROCARIBE	1.55 – 0.141	1.90 – 0.173
HIDROCAPITAL	1.55 – 0.141	1.90 – 0.173
HIDROFALCÓN	1.55 – 0.141	1.90 – 0.173
HIDROLAGO	1.55 – 0.141	1.90 – 0.173
HIDROLLANOS	1.00 – 0.091	1.90 – 0.173
HIDROPÁEZ	1.00 – 0.091	1.90 – 0.173
HIDROSUROESTE	1.25 – 0.114	1.90 – 0.173

Source: *Official Gazette of the Republic of Venezuela* (2011). The official rate of exchange of 11 Bs to 1 U.S. dollar (as of February 28, 2014) has been taken as a reference.

Box 15

Technical Roundtables of Water

Community participation in the administration of the supply of drinking water and sanitation services

Within the framework of the new structure of the Venezuelan nation established in the Constitution of Venezuela, HIDROVEN and its Regional Water Companies promote the formation of Technical Roundtables of Water.

Both the Constitution of Venezuela and the Organic Law for the Performance of Drinking Water and Sanitation Services (LOPSAPS, passed in 2001), establish the legal framework and the mechanisms for transferring the administration of water services from the water companies to the districts.

Since 1999, it has comprised Urban-Rural Area based community organizations known as Technical Roundtables of Water (MTAs), are dedicated to improving the supply, maintenance and operation of the drinking water and sanitation services.

These organizations contribute to citizen participation in the Drinking Water and Sanitation Sector (LOSAPS) and have been transformed into a basic mechanism for community participation, for the policies governing the rendering of services and, above all, for the organization of the service companies, since they have transcended their initial objectives and now participate directly in the administration of these companies.

The application of these principals to the development of LOSAPS has given rise to major changes, which may be summarized as two major processes underway. One is the incorporation of community

Box 15

participation in the administration of the service and the development of a new water culture; the other is the expansion of the service, with greater equity, in the framework of a new vision of the public water company which includes, in each such company, the creation of Community Management Committees.

The MTAs channel community participation in order to obtain, improve, maintain and oversee the water and sanitation services for their communities, and to mold a water-conscious culture which values and safeguards this resource.

The relationship of the MTAs with the water companies is predicated on a vision of shared responsibility and identification with the service, since community participation in the initial diagnosis has been achieved. They prepare and carry out projects and perform controlling functions. In addition, as an additional task, these communities are simultaneously building a network of relationships and values which constitute citizenship participation.

From the beginning, the Technical Water Committee program has offered the communities direct participation in the solution of drinking water supply and wastewater treatment problems.

With the creation of the Community Project Financing Fund, the Technical Roundtables of Water have become pioneering community experiences in the direct management of the economic resources required for the execution of water and sanitation projects, designed as well by the communities themselves. By early 2014, there were more than nine Technical Roundtables of Water nationwide.

As of January 2011, the Technical Roundtables of Water had been allocated a total of 481,052,043 Bolivars (US$ 111,872,568.14, at the official rate of exchange on that date, calculated at 4.30 bolivars to the dollar), for the performance of 1,556 Drinking Water and Sanitation Projects. Of these, 1,497 million had been finished with 459 still in progress, benefitting a population of 1,526,329 inhabitants with the projects finished, with an estimated total of 2,975,835 inhabitants who will benefit from the entirety of these Projects.

The Community Water Committees, comprising the Technical Roundtables of specific sectors, are entities organized by regions and water supply cycles throughout the nation.

The Technical Roundtables of Water program thus represents an overall effort to bring quality of life to the population and to empower the communities, which recognize the effort made and feel satisfied with the gains made, since they now participate in the solution of their problems.

This participative strategy has contributed decidedly to the overall objective of broadening the people's access to drinking water or sanitation, so that by 2005, Venezuela had met its Goals for the Millennium which had been foreseen for attainment by 2010. In addition, the MTAs have had a positive impact in strengthening the fiber of the community, forging a socially aware citizenry, constructing a new institutionality such as the creation of a new of Community-Government relations network and the forging of a new water culture.

3. Water Treatment in the Cities

In order for it to be distributed and consumed in the country, the water must meet the Drinking Water Quality Standards established by the Ministry of Health and Social Welfare (now the People's Ministry of Health) in the *Official Gazette of the Republic of Venezuela* under No. 36,395, dated February 13, 1998, as the steering committee for sanitary water oversight. These establish the maximum values of the regulated parameters which the water must meet in order to be considered potable. During the process of the water companies' transporting the water to the distribution networks, the first step is the implementation of these standards. The potability parameters establish the following: that the water shall be odorless, colorless and tasteless. In addition, it shall be tested to determine the presence of lead (with a maximum accepted value of 0.01 mg/l.) On its discharge from the different plants, the water will be chlorinated in order to disinfect it and eliminate bacteria, and to ensure a residual chlorine concentration, thus insuring the microbiological quality of the water in the distribution networks in compliance with the Standards.

The water treatment begins with the application of coagulants such as aluminum sulfate and such polymers as aluminum polychloride, among others, in either the quick mix stage or the coagulation stage. This enables the elimination of the suspended or dissolved solids and solids subject to sedimentation which color and cloud the water.

The floccules formed are subsequently fed through sedimentation tanks, where they are precipitated and settled. A continuous analysis is made of the control parameters to be eliminated in the process of purification when they enter the treatment plants. These include turbidity, apparent and true color, pH, hardness, total alkalinity, metal content, total coliform and fecal bacteria, among the main control parameters.

The purification process ends when the water enters the filters, where the smallest particles and tiny organisms are captured, which could not be captured during sedimentation. These filters use filtration beds comprising gravel and sand of different graduations, and a layer of anthracite.

Chlorine (usually as a gas) is applied during the final treatment stage in order to ensure that the water distributed to the network contains only a residual concentration of this element when it reaches the users' homes pursuant to the provisions of the Drinking Water Quality Standards. Due to the prolonged effect of this element in eliminating microorganisms, this concentration is between 0.3 and 0.5 mg/liter.

According to González Landazábal (2001), 119 water purification plants are in operation in Venezuela, with a total installed capacity of 132,390 liters per second. The existing plants are basically standard, with traditional type units; they are conventional, offering a thorough treatment, which includes flocculation, sedimentation, filtration and disinfection – conventional with partial treatment and unconventional with modular, accelerated, compact and combined design partial treatment. Compliance with the existing standards for bacteriological quality and organoleptic quality is between 85% and 83%, respectively for water receiving only chlorination, and 91% and 85%, respectively, for water subject to conventional treatment.

With regard to wastewater coverage, disposal and treatment, while considerable progress has been made, this last mentioned is still one of the major environmental problems faced by Venezuela (Páez-Pumar, 2010).

Percentage-wise, wastewater cleansing is insufficient (González Landazábal, 2001). The types of treatment generally employed are stabilization or oxidation ponds and prolonged aeration for urban areas, and septic-filter wells and septic drain fields for absorption in a number of rural cities. In general, given the large cities' proximity to the sea, or to the fact that they are discharged directly in rivers which empty into the sea, and most of the untreated effluents contaminate the coast. In the major tourist developments, such as Margarita Island (in Nueva Esparta state), some areas of Falcon state (the city of Coro and the Paraguaná peninsula) and Anzoátegui (the Barcelona-Puerto la Cruz-Guanta axis) and, more recently, the city of Maracaibo, wastewater treatment systems are being implemented (González Landazábal, 2001; Rosillo, 2001). Wastewater treatment systems are also being installed in the cities of Cumaná and Carúpano on the Sucre coast. For Caracas –the city with the largest urban concentration– there is no type of wastewater treatment, and it is discharged in the Tuy River basin and from there into the Caribbean Ocean.

As additional information, the city of Caracas has the experimental type wastewater plant at the Faculty of Engineering of the Central University of Venezuela (Experimental Water Treatment Plant – PETA) and with one of the food distribution companies (POLAR Group).

There are also plants in the north central part of Venezuela, which is the industrial heart of the nation. In this region, private companies generally have their own wastewater treatment plants in order to comply with the established discharge values for the parameters regulated under Decree No. 883 regarding the Standards for the Classification and Quality Control of Waterbodies and Discharges or Liquid Effluents (*Official Gazette of the Republic* *of Venezuela, under extraordinary decree No.* 5,021 dated December 18, 1995. The treatment plants at Los Guayos and La Mariposa in Carabobo state, treat two-thousand and two-thousand four-hundred liters per second respectively, while the treatment plant in Taiguaiguay, in Aragua state, treats three-thousand liters per second (MINAMB, 2006).

According to Páez-Pumar (2010), there is sewer coverage of eighty-one percent in Venezuela. However, as the result of the scant existing infrastructure, the wastewater treatment situation is much less. The lack of these services has an impact on the increase of waterborne diseases, a number of which have reemerged in areas where they had previously been eradicated. At present, the districts are in the process of reviewing the management models in order to incorporate new forms of community participation (community committees, technical agencies) and to improve the efficiency of these services (WSP, 2007).

According to WSP (2007), at the beginning of 2007 wastewater treatment coverage was barely 20.2% and, with an investment of three-hundred million dollars, it is expected that a nationwide coverage of 27% will be attained by the end of this year, with the coverage reaching 40% in 2010 and 60% in 2015. In order to achieve this, a total investment of three-billion, six-hundred and twenty-million dollars will be required.

Apart from the waterborne diseases and their foul smell, untreated effluents from factories, swine farms and wastewater in urban centers contaminate rivers, seacoasts, lakes, reservoirs and other water ecosystems, possibly giving rise to changes in the concentration of dissolved oxygen, nitrogen, phosphorous, bio-oxygen demand and chemical-oxygen demand, among other parameters. Such heavy metals as manganese, zinc, iron and copper may accumulate in them, and have other negative environmental impacts such as high temperature, change in salinity, a reduction of the dissolved oxygen concentration, among other conditions.

Prominent among the major sanitation investment projects is the Rio Guaire Sanitation Project, which crosses the city of Caracas west to east. This project (MINAMB, 2012b) is seventy-two kilometers long and is the city's main river, with a basin of 655 square kilometers (Pérez Lecuna, 2005). It also represents Caracas' main wastewater collector. The Guaire River is one of the main tributaries of the Tuy River, in whose basin are located most of the reservoirs which supply the city's drinking water. The sanitation plan for this river is summarized below.

- First Phase (2005–2006): Cleaning and dredging the Guaire river and its tributaries. This phase contemplates hydraulic engineering and sanitary engineering works, with the objective of raising to 75% the collection of wastewaters in the riverbank collectors already in service. It contemplates the construction of 1,500 hectares of collectors, the rehabilitation of the riverbank collectors along several main tributaries of the Guaire River: the San Pedro, Macarao, Caricuao, Mamera, Antímano, Carapita, La Vega, Bella Vista, La Yaguara, San Martín, El Guarataro, Caroata, Catuche and Arauco creeks, and the construction of a treatment plant. The approximate cost is seventy-five million dollars. This phase has been concluded.
- Second phase (2007–2014): The continuation of the hydraulic engineering and sanitation works required to intercept up to 95% of the wastewater in the riverbank collectors, and for the sanitation of 1,500 hectares of collectors in urban areas. The riverbank collectors in the following tributaries will be rehabilitated: El Valle, Chacaíto, Baruta, Tocoma, Agua de Maíz and Quebrada Grande de El Hatillo. This phase will end with the canalization of the Guaire River and the construction of riverbank collectors. Its cost is approximately four-hundred and fifty million dollars, and community participation will play a vital role in this plan. It is anticipated that the river banks can be used as recreational areas once the plan is concluded. This second phase is still unfinished.

Another major sanitation project is the Overall Project for the Sanitation and Control of the Level of the Lake Valencia Basin. This consists in the construction of collectors in Aragua and Carabobo states, with the purpose of transporting wastewater to the wastewater treatment plants in Carabobo state (La Mariposa and Los Guayos) and Aragua state (Taiguaiguay), so they can be treated in order to contribute to the sanitation of the Lake Valencia basin (MINAMB, 2006).

In addition to the construction of collectors, the expansion of the La Mariposa wastewater treatment is underway, with the purpose of increasing to 5,200 liters per second the flow entering the plant, based on the requirements of an increased population in Carabobo state.

This also contemplates the construction of wastewater treatment systems in La Victoria and Tocorón (in Aragua state), and wastewater treatment systems in Güigue, Mariara and San Joaquín (in Carabobo state), in addition to the construction of a dam to protect the cities of La Punta and Mata Redonda in Aragua state against floods caused by the overflowing of Lake Valencia.

This project also includes the Environmental Education Program, whose purpose is to form and organize the communities with regard to their social, economic, environmental, civil, political, cultural and educational rights, thus developing their capabilities and potentialities in order to promote and consolidate an inherent and sustainable development of the Lake Valencia basin. In the western part of the country, the Lake Maracaibo Sanitation Project is under development. Its purpose is to use treatment plants, main collectors, wastewater plants in many districts of the state, torrent control and dredging of the lake basin in order to clean the wastewaters reaching the lake (GeoVenezuela, 2010). In this regard, in 2007 construction began on a 130.2 kilometer aqueduct from the Tres Ríos reservoir to the Maracaibo district, for the supply of drinking water to the Maracai¬bo, San Francisco, Jesús Enrique Lozada, La Cañada de Urdaneta and Mara districts in Zulia state. According to official information from the Ministry of the environment, work on this project was finished in September 2007.

4. Water and Health in the Cities

It is well known that wastewater harbors microorganisms (pathogens) which cause diseases. These include viruses, protozoa and bacteria (Reynolds, 2002). Pathogenic organisms can originate in infected persons, or in domestic or wild animals, which may or may not show signs of disease. Diarrhea and gastroenteritis are among the three main causes of death in the world, and in Latin America. Unsafe drinking water and contamination through improper disposal of sewage are responsible for the vast majority of these deaths.

From the public health standpoint, an inadequate supply of drinking water and of effluent collection services, added to conditions of poverty, involve the appearance of such water-transmitted diseases as amebiasis, diarrhea (mainly in children), giardiasis, helminhtiasis and acute Type A hepatitis (Martínez, 2013).

According to Martínez (2013), in the Capital District over thirty-thousand cases of waterborne diseases were reported during 2012. This represents an index of 15.5 cases per thousand inhabitants. In this index, 42.64% of the cases occurred in among the poorest levels of the population. However, in breaking them down by parishes according to the highest incidence of these cases, we may observe: (1) that in the city's relatively healthy parishes, where twelve or fewer cases of waterborne diseases per thousand inhabitants were recorded, formal aqueducts and sewers are the rule, whereas the average percentage of poor inhabitants is relatively lower (36.48%); (2) in those parishes in which there are between twelve and thirty cases per thousand inhabitants, informal urban settlements are predominant, the networks of some of their sectors are highly precarious and the average percentage of poor population is 43.11%; (3) finally, where the concentration of these cases is over thirty per one thousand inhabitants, overcrowded, informal dwellings and deficient water and sanitation services are relevant factors, and the average percentage of poor population is high (48.95%).

To these results should be added the fact that inadequate water storage in open vessels to compensate for rationing fosters the propagation of such diseases as dengue and malaria, and they may have a geography related distribution. There also tend to be present a number of structures, such as, for example, old automobile tires, which can accumulate water, thus providing ideal habitats for the vehicles which spread some of these diseases.

According to the People's Ministry of Health (MPPS, 2008, 2009, 2010, 2011, 2012, 2013), in Venezuela many cases of waterborne diseases have occurred. Below are a number of instances:

- Diarrhea: Most of the waterborne infectious diseases are diarrheal diseases, caused by microorganisms (bacteria, virus, worm or protozoa eggs), discharged by human or animal excretions. The carriers of these diseases may be found in untreated, contaminated water containing excretions, or persist due to the lack of available water. The most vulnerable sector of the population are children under five years old, and the documented cases number in many hundreds of thousands per year in Venezuela (Figure 6).

- Amebiasis: A parasitic illness caused by amoebas *Entamoeba histolytica, E. dispar* and *E. moshkovskii*. Its incidence is high in areas with deficient environmental sanitation. From 2008 forward a decline in the number of cases has been noted. However, the incidence is still high (Figure 7). As with diarrhea, the most vulnerable population group are children under five years old.
- Malaria (or yellow fever): There are four species of parasites (*Plasmodium vivax, Plasmodium ovale, Plasmodium falciparum* and *Plasmodium malariae*) which may infect humans and cause this disease. Their carriers are several species of mosquitos (*Anopheles*), whose larval phases develop in water. In Venezuela tens of thousands of cases are recorded annually, with a notorious increase in 2013 (Figure 8a); its incidence was high during almost every month of that year (Figure 8b); the greatest number of cases normally appears in the southern region of the country, which is the one with the greatest water availability.

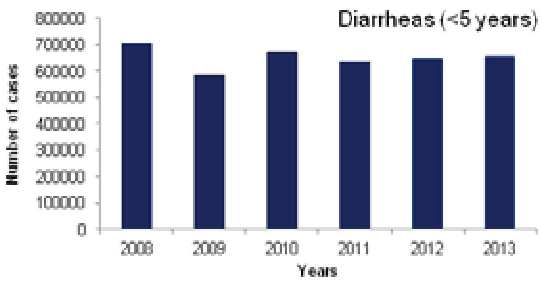
  Delgado Petrocelli et al., (2011) also noted a high incidence of this disease in the Nor-Oriental region of Venezuela, specifically in Sucre state. These researchers found an active malaria epidemic corridor in this region, aligned along communication channels, which is associated with highly concentrated populations living near the habitats of the pre-adult stages of the carrier, low altitudes, gradually sloping terrain and proximity to mangroves and forests, in addition to their relationship to the rainfall patterns (Rodríguez et al., 2013).
- Dengue: This is a disease caused by viruses, whose carriers are mosquitos *Aedes aegypti* and *Aedes albopictus*. In recent years its transmission has increased mainly in urban and semiurban zones and has become a major public health problem. It is estimated that Venezuela accounts for over seventy percent of all known cases in the Americas. In Venezuela, dengue has become a serious public health problem nationwide. According to Barrera et al., (2000) in our country, control of the carrier *Aedes aegypti* is difficult not only because of limited resources but also because of the great expanse and heterogeneous nature of the urban zones, and the lack of sanitation resources such as solid waste collection, drinking water supply and medical attention. Tens of thousands of cases are reported every year (Figure 9a) and the greatest incidence normally occurs during the last few weeks of the year (Figure 9b). These Figures show the total cases of dengue (both classic and hemorrhagic) reported. At present, the greatest incidence of cases of dengue is found mainly on the Andine-Coastal arc, where the highest percentage of the country's urban population is concentrated (MPPS, 2013).

In the Capital District, which has the nation's highest urban population, the prevalence of dengue has been very high (Figure 10a), especially in 2010, when more than ten-thousand cases were reported. The Capital District also reported a higher rate of cases of dengue during the last few weeks of 2013 (Figure 10b).

According to Delgado Petrocelli et al., (2013), dengue in Venezuela has rebounded significantly, especially in the central region of the country, in Aragua state, since Maracay, its capital, has been classified since the first decade of this century as hyperendemic. In addition, the western region, especially Mérida state (in the Venezuelan Andes) has not escaped its impact (Marichal, 2011). There is a relationship between dengue and cultural patterns, both in mobility and in water storage practices. This, in turn, is linked with the shortage of water, caused by a seasonal drought or by the alteration of the weather change patterns due to such weather phenomena as El Niño and Southern Oscillation (ENSO). An epidemic corridor associated with the Transandes highway has also been detected.

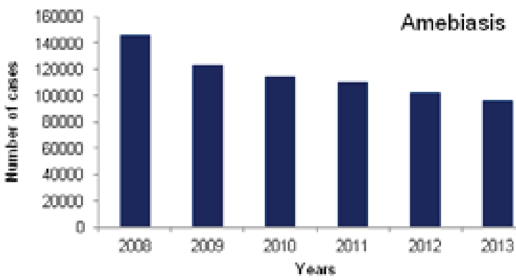
As may be seen, greater wastewater disposal and treatment is necessary in the urban areas specifically, and nationwide generally. Waterborne

Figure 6. The number of cases of diarrhea in children under five years (2008-2013)



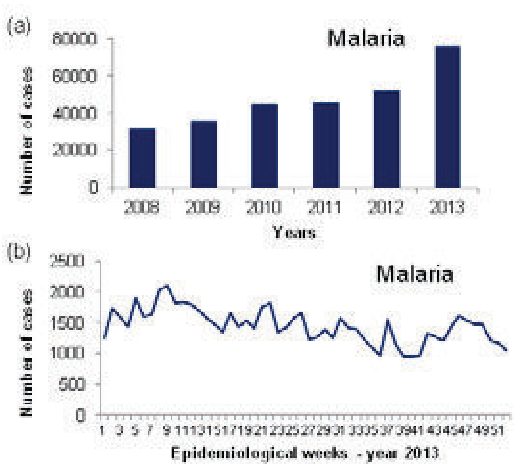
Source: In-house document based on MPPS data (2008, 2009, 2010, 2011, 2012, 2013).

Figure 7. The number of cases of amebiasis (2008-2013)



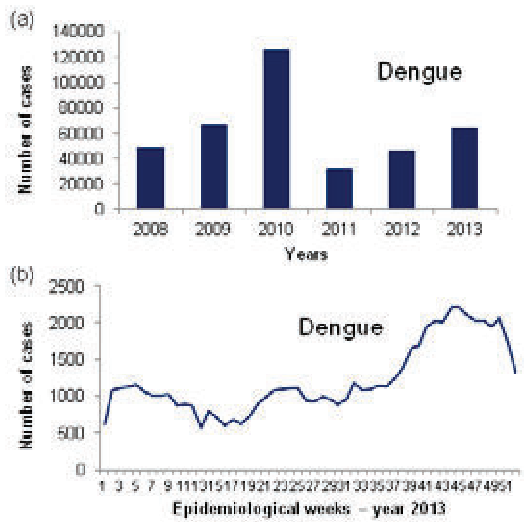
Source: In-house document based on MPPS data (2008, 2009, 2010, 2011, 2012, 2013).

Figure 8. Number of cases of malaria: (a) From 2008-2013, b) for 2013



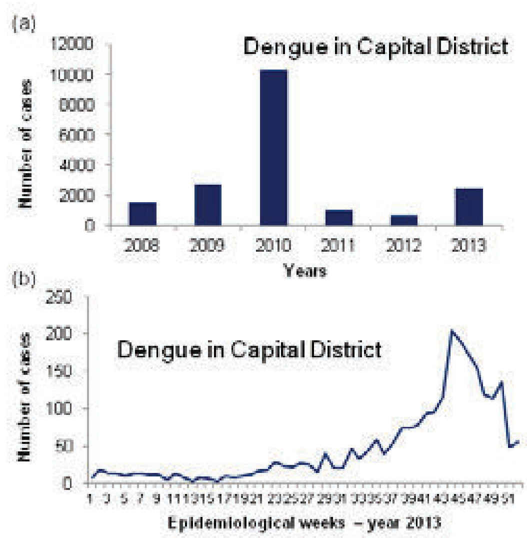
Source: In-house document based on MPPS data (2008, 2009, 2010, 2011, 2012, 2013).

Figure 9. Number of cases of dengue: (a) From 2008-2013, b) for 2013



Source: In-house document based on MPPS data (2008, 2009, 2010, 2011, 2012, 2013).

Figure 10. Number of cases of dengue reported in the Federal District. (a) From 2008-2013, b) for 2013



Source: In-house document based on MPPS data (2008, 2009, 2010, 2011, 2012, 2013).

diseases are more usually found among the poorest strata of the population. Several authors (Faría, 2006; Pineda, 2006; Martínez et al., 2013) state that organized community participation (for example, the Technical Roundtables of Water) and education of the people are key elements in mitigating the incidence of these diseases, as is the necessary public investment in the sanitation of rivers and ravines.

4.1 Another Ddimension of "Water and Health": Gauging Environmental Health in Housing and Public Buildings, and their Relationship with Water

The World Health Organization ("WHO") affirms that environmental health is related to all of a person's external physical, chemical and biological factors (OMS, 2013). Consideration of the environment where humans live goes from rural communities to the large cities and their outlying areas; from the suburbs comprised by single-family houses to the neighborhoods surrounding many of Venezuela's cities. These may be villages, towns, cities or the urban fringe. In the final analysis, in each of them there are dwellings and, perhaps, several homes within these dwellings. Hence, this approximation of environmental health from within dwellings and households, with observations regarding the indicators and indices intended to measure the water-environmental health interaction.

The measurement of environmental health in housing and homes must be related to the basic environmental health indicators, with regard to the drinking water supply, disposal of sewage, domestic hygiene, domestic garbage handling and collection, control of plagues (insects and rodents) in dwelling, in addition to the physical conditions in the residences themselves (roofing, floors, walls and friezes).

4.2 General Information, Indicators and Indices Regarding Environmental Health in the Housing Available in Venezuela

The censuses constitute the national inventory of housing in Venezuela. From the available housing data, three of these are tied to environmental health and water. These are:

a. The drinking water supply: An effort has been made to determine how drinking water is supplied to dwellings. The first option is an aqueduct or piping, which involves a continuous, public supply of drinking water of the quality required by the sanitation standards and in sufficient quantity, with a predetermined daily supply and at a pressure adequate for faucets and sanitary facilities to operate properly. The second option involves tank trucks, which offer irregular service, requiring storage in the home where the potability of the water supplied makes it desirable to have a home disinfection system. It is, therefore, important to discern the quality of the serviced rendered, beyond the simple connection to the aqueduct. An early approximation involves the means of supply. Table 6 offers relevant information in this regard. It shows the high percentage of incorporation of aqueduct systems as a means of receiving an allowance of drinking water. This is a favorable and significant circumstance; however, as mentioned before, it is necessary to ensure the continuity of the service performed. Since Venezuela is a basically urban country, the charts showing the analysis refer to fifty-seven parishes of some of the cities with the largest population: Caracas, Barcelona, Puerto Ordaz, Valencia and Maracaibo. In addition, it must be mentioned that Venezuela has in place a successful rural aqueduct construction program. Accordingly, the figures for rural aqueduct service coverage in that geographical area are high.
b. Frequency of supply: The 2011 Census, aware of the importance of this information in classifying the quality of the water supply service, asked the users about the frequency of the supply of water to their homes: every day, every two or three days, once a week or once every two weeks. Table 7 shows the results for the five cities compared. It may be seen that, despite the high degree of aqueduct connections, the quality of the service with regard to continuity is significantly lower in such cities as Maracaibo, where barely 37.3% of the residences have a permanent supply. In general, the percentage of permanent water supply is around 79% except for the anomalous situation in Maracaibo. In any event, the population receiving water at different frequencies – from every other day to once every two weeks – represents about 20% of

all residences. Interruptions in the supply may cause personal hygiene deficiencies, improper handling of sewage, improper handling of food and kitchen utensils, all of which can cause health problems. These matters require investigation.

c. Home treatment of water: Considering that water is supplied infrequently to homes and, in general, is subject to storage prior to use, the 2011 Census included a question about water treatment carried out at home, prior to use. The options include filtration, boiling, filtration and boiling, chlorination, the use of bottled water as a beverage, or no treatment. Table 8 offers an appreciation of the number of users per type of prior water treatment. These data enable us to have an idea of the degree of confidence in the quality of the water furnished. Valencia shows the highest percentage of bottled water, while in Caracas and Maracaibo, a third of all homes boil their water before using it. In all the cities, twenty percent filter their water; the same percentage applies to those who drink water directly from the tap with no additional treatment. In Caracas and Valencia direct consumption comes down to 15% and 12%, respectively. These figures reveal an awareness, on the part of the population, of the relationship between health and water disinfection, while the variations from city to city offer an idea of the implications of storage as a means of having available water.

d. Means of sewage disposal: Complementing the data regarding living conditions as related to environmental health and water, the 2011 Population and Residence Census obtained information on the disposal of sewage, inquiring about the options shown in Table 9. The "bathroom with no sewer or septic tank connection" is alarming from the environmental health standpoint, since it presupposes discharges into waterways, artificial or open air discharge, which can lead to the accumulation of septic material, foul odors and miasmas serving as hosts for parasites and microbes which can cause diseases in the event of their eventual contact with humans and domestic animals. The figures for the cities selected show a high percentage of toilets connected to sewers or septic tanks. This leads one to contemplate two basic aspects to ensure urban health: (1) control of the quality of drinking water by using water from below these discharge points which, in turn, are related to the design of treatment of water to make it potable, and (2) the need to treat wastewater collected by the sewer systems in order to safeguard the quality of water at the river banks and their use downstream of the points of discharge. Despite the scant rural population in Venezuela and the systematic implementation of basic environmental sanitation in the rural areas, it is possible that there may still be open air discharges in the most isolated communities, giving rise to the transmission of parasitic diseases.

e. Use of communal showers.. For homes, the 2011 Population and Residence Census prepared a question about the matter of environmental

Table 6. Venezuelan cities: Caracas, Barcelona, Puerto Ordaz, Valencia, Maracaibo. Population supplied by aqueduct and tank trucks.

Cities, districts	Population of district	Supplied by aqueduct		Supplied by tank truck	
		Population	%	Population	%
Caracas, Libertador District	1,828,956	1,821,211	99.57	7,745	0.43
Barcelona, Simón Bolívar District	371,702	357,936	96.29	13,766	3.71
Puerto Ordaz, Caroní District	656,386	639,864	97.48	16,522	2.52
Valencia, Valencia District	754,329	739,563	98.04	14,766	1.96
Maracaibo, Maracaibo District	1,385,463	1,336,550	96.47	48,913	3.53
All cities selected	4,996,836	4,895,124	97.96	101,712	2.04

Source: Fourteenth National Population and Housing Census for 2011 (INE, 2013).

Table 7. Frequency of water supply to dwellings

Cities, districts	Dwellings	Continuous supply (every day)		Intermittent supply (every two or three days)		Weekly Supply		Biweekly supply	
		Dwellings	%	Dwellings	%	Dwellings	%	Dwellings	%
Caracas, Libertador District	521,326	384,512	73.8	67,178	12.9	38,151	7.3	31,485	6.0
Barcelona, Simón Bolívar District	93,179	72,328	77.6	16,603	17.8	2,741	2.9	1,507	1.6
Puerto Ordaz, Caroni District	165,424	138,408	83.7	19,344	11.7	5,601	3.4	2,071	1.3
Valencia, Valencia District	202,105	167,283	82.8	31,001	15.3	2,668	1.3	1,153	0.6
Maracaibo, Maracaibo District	329,122	122,606	37.3	195,864	59.5	7,812	2.4	2,840	0.9
All cities selected	1,311,156	885,137	67.5	329,990	25.2	56,973	4.3	39,056	3.0

Source: Fourteenth National Population and Housing Census for 2011 (INE, 2013).

Table 8. Home water treatment

Caracas, Libertador District		
Water used for drinking	Cases	%
Boiled	168,964	31.0
Filtered	151,515	27.8
Filtered and boiled	46,375	8.5
Chlorinated	13,004	2.4
Purchase of bottled water	85,937	15.7
No treatment	79,996	14.7
Total	545,791	100.0

Barcelona, Simón Bolívar District		
Water used for drinking	Cases	%
Boiled	9,467	9.5
Filtered	34,995	35.1
Filtered and boiled	3,887	3.9
Chlorinated	6,403	6.4
Purchase of bottled water	15,188	15.2
No treatment	29,791	29.9
Total	99,731	100.0

Puerto Ordaz, Caroní District		
Water used for drinking	Cases	%
Boiled	10,114	5.8
Filtered	37,267	21.5
Filtered and boiled	5,042	2.9
Chlorinated	8,139	4.7
Purchase of bottled water	56,868	32.8
No treatment	56,038	32.3
Total	173,468	100.0

Valencia, Valencia District		
Water used for drinking	Cases	%
Boiled	11,043	4.8
Filtered	25,951	11.4
Filtered and boiled	5,766	2.5
Chlorinated	3,452	1.5
Purchase of bottled water	155,660	68.2
No treatment	26,472	11.6
Total	228,344	100.0

Maracaibo, Maracaibo District		
Drinking water used	Cases	%
Boiled	141,010	40.6
Filtered	49,282	14.2
Filtered and boiled	28,890	8.3
Chlorinated	5,269	1.5
Purchase of bottled water	50,611	14.6
No treatment	71,907	20.7
Total	346,969	100.0

All cities selected		
Drinking water used	Cases	%
Boiled	340,598	24.4
Filtered	299,010	21.4
Filtered and boiled	89,960	6.5
Chlorinated	36,267	2.6
Purchase of bottled water	364,264	26.1
No treatment	264,204	18.9
Total	1,394,303	100.0

Source: XIV National Population and Residence Census, 2011 (INE, 2013).

health and its relation to the use of communal showers. This is related with the greater possibility of skin diseases and the control of molds producing allergies and respiratory tract diseases. In general, the problem arising from the use of communal showers in homes involves responsibility for cleanliness of the shower room. The possibility of contracting diseases is similar in either an improperly cleaned individual shower room or communal shower room. The percentage of homes with no shower in the bathroom is still around 5%, except in the case of Barcelona, where it climbs to 16.2% (Table 10). The circumstances of living in a home with a showerless bathroom involves sharing showers and assuming joint responsibility for the cleanliness of the facilities. The percentage of bathrooms with showers is significantly higher in the large cities other than Caracas. Maracaibo, in turn –perhaps due to the influence of the weather (high temperatures)– shows the greatest percentage of three or more bathrooms with showers. The information regarding the extremes indicated offers food for thought about the desirability of correlating skin diseases with the situation of several families using the same bathroom, and taking note of whether a greater of number of bathrooms with showers is related to higher water consumption.

Table 9. Sewage disposal services

Cities, districts	Dwellings	Drainage tank connected to sewer		Drainage tank connected to septic tank		Drainage tank with no connection		Hole, or outhouse latrine		No tank or toilet	
		Dwelling	%	Dwelling	%	Dwelling	%	Dwelling	%	Dwelling	%
Caracas, Libertador District	530,694	520,359	98.1	7,745	1.5	1,109	0.2	200	0.0	1,281	0.2
Barcelona, Simón Bolívar District	95,625	64,372	67.3	26,771	28.0	1,055	1.1	829	0.9	2,598	2.7
Puerto Ordaz, Caroni District	168,746	129,733	76.9	35,606	21.1	1,228	0.7	566	0.3	1,613	1.0
Valencia, Valencia District	218,166	198,293	90.9	15,901	7.3	944	0.4	530	0.2	2,498	1.1
Maracaibo, Maracaibo District	335,352	262,967	78.4	57,703	17.2	2,352	0.7	6,596	2.0	5,734	1.7
All cities selected	1,348,583	1,175,724	87.2	143,726	10.7	6,688	0.5	8,721	0.6	13,724	1.0

Fourteenth National Census of the National Statistics Institute for 2011 (INE, 2013).

Table 10. The number of bathrooms with showers per home

Cities, districts	Homes	Zero bathrooms with shower		One bathroom with shower		Two bathrooms with shower		Three or more bathrooms with shower	
		Homes	%	Homes	%	Homes	%	Homes	%
Caracas, Libertador District	545,791	16,257	3.0	431,990	79.1	84,611	15.5	12,933	2.4
Barcelona, Simón Bolívar District	99,731	16,151	16.2	59,938	60.1	21,124	21.2	2,518	2.5
Puerto Ordaz, Caroní District	173,468	8,299	4.8	121,562	70.1	36,231	20.9	7,376	4.2
Valencia, Valencia District	228,344	8,131	3.6	158,885	69.6	50,477	22.1	10,851	4.7
Maracaibo, Maracaibo District	346,969	23,946	6.9	211,670	61.0	86,746	25.0	24,607	7.1
All cities selected	1,394,303	72,784	5.2	984,045	70.6	279,189	20.0	58,286	4.2

Source: Fourteenth National Census of the National Statistics Institute for 2011 (INE, 2013).

4.3 Information Regarding "Poverty due to Unsatisfied Basic Needs" (INE, 2013)

The data regarding Unsatisfied Basic Needs reveals three important data required to determine the environmental health status of the dwellings and households in Venezuela. These are:

- Overcrowding: this refers to the number of homes with more than three persons using the same bedroom. Nationwide, the Fourteenth National Census of the National Statistics Institute for 2011 shows this condition in 15.12% percent of all homes.
- Inadequate living quarters: that is, dwellings classified as farms, tenements, tents, containers and others similar. This figure comprises 9.38% of all dwellings.
- Lack of basic services: the lack of drinking water or sewage disposal services. This means that the figures embrace either one of these two services and, in the case of elimination of sewage, it is described as follows: dwellings with no sewer installed. This figure comprises 14.79% of all dwellings, many of which are connected to septic tanks. This is an acceptable sanitation practice provided that there is an awareness that they require periodic maintenance.

4.4 GeoVenezuela 2010 (GV-2010)

GeoVenezuela (2010), a summary of the state of the environment published by the People's Ministry of the Environment, the Latin American Forest Institute and the United Nations pro-Environment Program, presents information of various kinds regarding cities. However, its degree of diversity does not take in housing and homes. The indications used in the reports on "The State of the Environment", published in 1995 and 1996, report only the following in this new evaluation:

- Mortality, showing the rate per thousand (‰) for the censuses from 1990 to 1994.
- Drinking water and sewage disposal service availability. The following indicators are described and quantified:
  - The percentage of the population with access to drinking water storage. In this regard, it indicates that Venezuela has an installed drinking water infrastructure to supply water to 86% of the population. The figure reported in the Environmental Balance for 1995, carried out by the Ministry of the Environment and Renewal Natural Resources, was 83%.
  - The percentage of the population with wastewater collection services. In this case, GV-2010 reports the state-by-state characterization of sewer coverage. Based on those data it has been determined that the state with the highest coverage is Carabobo, with 91%, while the state with the lowest coverage is Mérida, with 18.85%. The average nationwide coverage is given as 56.9%. However, it is also apparent from the text that the coverage is 63.64% in states on the Caribbean and Atlantic Ocean coasts, and 65.20% in noncoastal states. The figure shown in the 1995 Environmental Balance for Venezuela was 62%.

4.5 The National Indicator and Statistics System for Environmental Management (SIENAGA)

With regard to public health, the Ministry of the Environment (MINAMB)'s National Indicator and Statistics System for Environmental Management contains a series of indicators aggregated either nationwide or by cities. None of them is broken down in accordance with homes and dwellings. These indicators are as follows:

- The percentage of wastewater treated.
- Proper urban generated garbage disposal.
- Final disposal sites of garbage.
- The percentage of the population with access to improved sources of urban water supply.
- The percentage of the population with access to improved sanitation services.
- The percentage of the population with access to garbage collection services.
- The morbidity rate attributable to acute respiratory diseases.
- The morbidity rate attributable to waterborne diseases.

Some of these allow inferences regarding the status of environmental health in dwellings and households. This is the case with the following:

a) The percentage of the population with access to improved sources of urban water supply.

Using data gathered by the National Statistics Institute and processed by HIDROVEN, it is reported that as of 2008, the total population with access to improved drinking water sources was 94.0%. With regard to the urban population, this percentage was 96.0%. SIENAGA states that these data reflect a population with household connections as an improved source of drinking water.

With regard to the proper way to interpret the information gathered by the National Statistics Institute, SIENAGA reports that the criteria of the Joint Monitoring Program (OMS-UNICEF) have been taken into account. These define the access to water supply services, such as the availability of at least twenty liters per person per day from an "improved" source within a kilometer from the user's home. "Improved sources" means all of those which commonly provide healthy water. The following are defined as "improved" water supply sources: household connections, public sources, drilled wells, wells drilled and protected, protected springs and gathered rainwater. The term "Unimproved sources" refers to unprotected wells, unprotected springs, water furnished by vendors, bottled water (based on considerations related on the amount, not the quality, of the water supplied) and water furnished by tank trucks.

b) The percentage of the population with access to improved sanitation services.

From data gathered by the National Statistics Institute and processed by HIDROVEN, it is reported that as of 2008, the total population with access to improved sanitation services was 83.9%. For the urban population, the percentage was 85.5% SIENAGA reports that these data reflect the population with connections to public sewers as an improved sanitation service.

With regard to the interpretation of the information gathered by the National Statistics Institute, SIENAGA reports that the category of improved sanitation includes connections to public sewers, connections to a septic sanitation system, a flush toilet, a single well toilet and a ventilated pit toilet. On the other hand, "unimproved sanitation facilities" refers to a public or shared toilet, an open-pit latrine or bucket latrines. It clarifies, however, that as indicated, only those dwellings with connections to public sewage systems have been taken into account.

c) The morbidity rate attributable to waterborne diseases.

With the morbidity data obtained from the People's Ministry of Health, and population data from the National Statistics Institute, SIENAGA calculates the morbidity rate attributable to waterborne diseases as the number of cases per hundred-thousand inhabitants. The analysis performed is of the tendency behavior for the period from 2002 to 2007. The diseases contemplated in calculating the indicator were typhoid fever, diarrhea in infants less than a year old, diarrhea in children from one to four years old, diarrhea in infants over five years old and type "A" hepatitis.

4.6 Considerations on the Water-Health-Dwelling Relationship

Information concerning indicators and indices designed to define the condition of a healthy environment or the environmental health in dwellings and households, comes from sundry sources and is presented in random order. It is, however, possible to combine the information available in order to produce a reasonably satisfactory system concerning water-related environmental health in dwellings and households. It should look toward accomplishing the task of establishing a basic group of indicators and indices to enable the gathering of information, with the purpose of evaluating the right to a healthy environment in homes and dwellings. A minimum approximation may be, among other criteria, a consideration of the elements which comprise basic environmental sanitation.

In order to combine the available information so as to produce a reasonably satisfactory system with regard to the status of environmental health as it concerns water in homes and dwellings, the country has available diverse official sources of information, as may be seen from the preceding sections. These organizations produce their figures according to different data-gathering criteria, for different dates and using different data gathering processes. This aspect is important, to serve as a warning of the need to stipulate, in each case, not simply the source used but information regarding the date that the data was captured, how it was processed, the criteria used in assembling it and, in general, any inquiries required to interpret the data and compare it with the data from other sources.

5. Climate Variability and Change – its Impact on Water Resources in the Cities

In Venezuela, the First National Communiqué on Climate Change states that the potential impacts which could be felt in the country are an increase in from one to two degrees Celsius in the average temperature by the year 2060, a reduction in rainfall and the change in weather patterns, among others (Martelo, 2004). While the studies indicate that there will be global warming and a trend toward less rainfall in the future, there are major regional differences. The southern part of the country could be the one most affected, while in the Andine and north-central regions –that is, the country's main mountainous zones, there is greater uncertainty.

In general, the country is highly vulnerable due to the population concentration to the north, where water is more scarce. In fact, even slight reductions in rainfall or slight increases in water outlets (as, for example, evapotranspiration, or "ETP") could have serious consequences, especially in the semiarid and sub-humid, dry regions (Martelo, 2004). Therefore, it is vitally important to monitor the effect of climate change on the different sources employed for its supply, since most of the adverse effects are related to the availability of water.

According to Andressen (2005), the impacts of climate change on water resources will depend on the conditions taken as a base for the water systems themselves and of the skill employed in administering those systems in order to respond not only to climate change but also to the growth of the population and their demands, improvements in technology and changes in social and economic conditions, and in legislation. It must be borne in mind that if the there is a decreased availability of water it will increase pressure on it and have a negative impact on its quality.

The adoption of adequate adaptation and mitigation measures in the face of climate change can ensure that population and economic growth in the coming decades can be brought into harmony with the limitations might occur in the water supply (Andressen, 2005). In this sense, projects resulting from a well-planned and conceived interaction among ecology, society, the economy and the existing institutions, must be implemented to manage the water resources, with a view to balancing the supply and demand of this resource when faced with extreme water occurrences.

In November 2013, Venezuela's First National Climate Change Symposium was held, with the purposes of (1) making known to the governmental and non-governmental sectors, the industrial sector and the public in general, the state of the art in activities and research being carried out nationwide to determine the impacts of climate change in Venezuela; (2) to identify the climate change mitigation and adaptation measures which have already been taken in the country, and (3) to detect the existing voids in this area, as well as future requirements. The impact of climate change on water resources was one of the subjects discussed, giving rise to proposals for the use of urban elements as mitigating factors (for example, the use of vegetation on the roofs of dwellings, known as "green roofs") (Bolívar and Cegarra, 2013).

The First National Climate Change Symposium culminated in the "Caracas Declaration", which expressly set forth the following commitments (Scientific Committee of the First National Climate Change Symposium, 2013):

1. To promote and support joint efforts among the nation's public and private institutions for the generation and widespread dissemination of knowledge about climate change.
2. To promote the multidisciplinary study of climate change.
3. To promote and support the creation of a National Climate Change Observatory as a monitor of the needs for research, analysis and preparation of this problem as a platform for the identification of viable options for adaptations to the realities in the country, and as a critical observer and alerting factor to the nation's commitment to the United Nations' Framework Convention on Climate Change.
4. To promote a rapprochement between the Government and all the nation's knowledge generation centers as a natural channel for the effective, overall attention to the problem of climate change.

Box 16

Lakes and reservoirs as sentinels of climate change

Lakes and reservoirs may be considered sentinels for climate change because they respond quickly to changes in solar radiation, rain, wind, hydrology and in a wide variety of changes from both the atmosphere and the earth (Williamson et al., 2009). These waterbodies embody climate change since they store the signs of change in their sediment, incorporating changes not only in the waterway system but also in the surrounding earth ecosystems. They also serve as regulators of climatic change inasmuch as they (1) receive, process and store large quantities of carbon from the surrounding slopes, and from the productivity of water along their coastlines; (2) they are involved in the active interchange of greenhouse effect gases and the atmosphere beneath them, and (3) they can change the regional climate by changing the patterns of sunlight, the formation of clouds, rainfall and evaporation.

Venezuela has more than one hundred reservoirs (Ginez and Olivo, 1984), but there is limnological information available for only about twenty percent of them (González et al., 2004), and for only a few of these is there a historical sequence enabling comparisons with recent events.

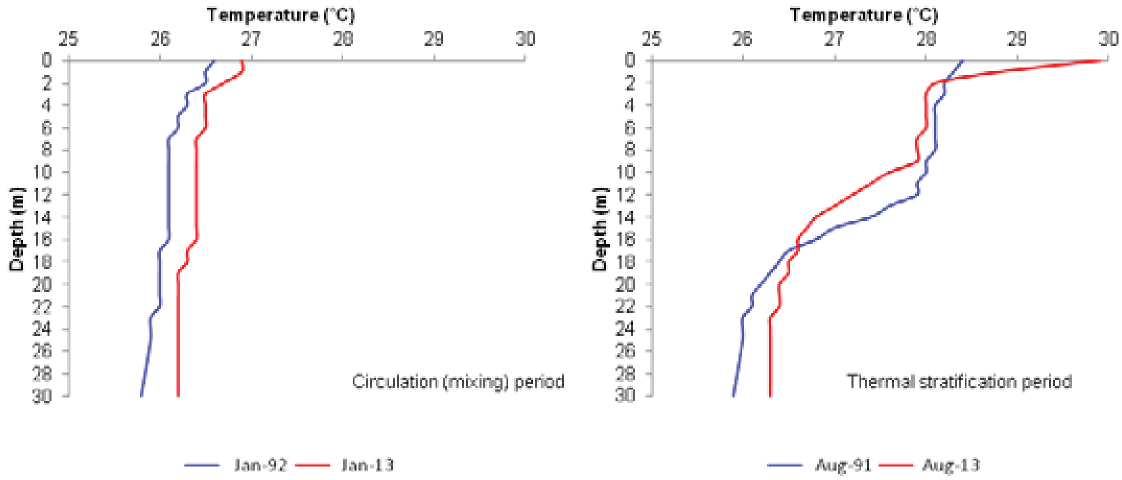
The Camatagua reservoir (in Aragua state), the main water supply reservoir for the city of Caracas, is one of the few reservoirs for which we have information for more than the last twenty years (Infante et al., 1992), and with recent data from projects carried out in the Limnology Laboratory of the Central University of Venezuela (González et al., 2013). This reservoir, being a deep system which develops a stable heat stratification during the rainy season, may serve as a monitor of climate change by measuring the temperature of its waters.

The Camatagua reservoir is more than thirty meters deep at the part nearest the dam. During the rainy season (May to October), when the wind speed is lower, the reservoir's thermoclines are stable. On the other hand, during the dry season (November to April), when the wind velocity increases, it promotes a full circulation of its water and, therefore, a uniform heating. It has, therefore, been classified as a warm monomictic system since there is one period of complete circulation of its waters each year.

Comparing the studies of Infante et al., (1992) and those of González et al., (2013), it may be said that at present, at depths below thirty meters, the temperatures are currently from 0.1 to 0.6°C higher than those recorded over twenty years ago (Figure 11). The increase in temperature raises the thermal stability, reducing the mixing and circulation periods of the waters. All of this may lead to a deterioration in the quality of the water due to the depletion of its oxygen and the formation of hypoxic and anoxic strata, the regeneration of limiting nutrients such as phosphorous, which can foster the growth of cyanobacterias and the release of greenhouse gases from the bottom of these waterbodies (Williamson et al., 2009).

While the data presented are not conclusive as to their effect on climate change in the Camatagua reservoir (since the human-induced effects may overlap those of global warming) it is also true that water temperature is a parameter offering relevant information, which could well be easily and permanently monitored in order to follow the possible effects of climate change, and predict well in advance its consequences on the quality of water which requires treatment before distribution for supply to the city of Caracas, in order to take the measures required to confront and mitigate them.

Figure 11. Profiles of water temperatures in the Camatagua reservoir during the periods of heat circulation and stratification for the years 1991-1992 and 2013



Source: In-house document based on data from Infante et al., (1992) and González et al., (2013).

5.1 Periods of Extreme Drought

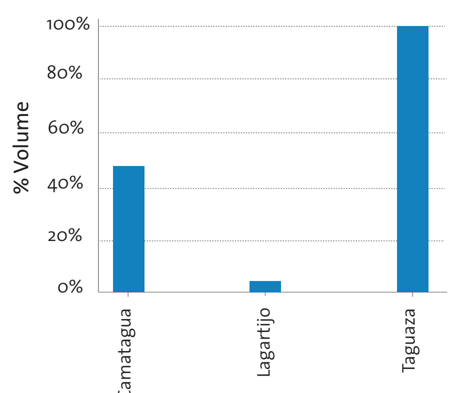
During 2009 and until halfway through 2010, Venezuela suffered one of the most severe droughts of the last few years as the result of the El Niño and Southern Oscillation (ENSO) phenomena.

Over seventy percent of the nation's electric energy (hydroelectric energy) comes from the Guri reservoir, located in Bolívar state in southern Venezuela. The reduction of its volume (a drop to more than twenty meters below its normal operating level), as the result of the drought, had an effect on the electricity supply in nearly the entire country. Electricity had to be rationed to prevent it from collapsing. Among the measures taken was a 900 megawatt energy saving plan, the reduction of working hours in public institutions (with working hours from 8:00 a.m. to 1:00 p.m.), and an electric energy blackout system during given hours in different cities. This emergency situation lasted from the end of 2009 until June 2010.

The water supply was also affected, since a large number of the sources of supply come from reservoirs (surface waters). For the city of Caracas, the situation of the reservoirs at the beginning of the drought, in 2009 is shown in Figure 12, where the water deficits in these reservoirs may be appreciated.

In order to deal with the severe drought, the water company (HIDROCAPITAL) proposed to reduce water consumption in one-hundred liters daily. To do this, it prepared a rationing plan applied to different parts of the city effective November 2, 2009, which was gradually rescinded as the water levels rose in the reservoirs which supply the capital (which was not until about August 2010). This plan was known as the "Special Caracas Water Supply" Plan. The water rationing plan remained in effect until August 2010 and, according to the water company itself, enabled the saving of more than 230 million cubic meters of water, which meant that this plan could be considered a success.

Figure 12. The situation (in blue) of the main reservoirs furnishing drinking water to the city of Caracas at the beginning of the drought in 2009



Source: HIDROCAPITAL (2009).

5.2 Flooding in the Cities

Population growth, with its obligatory occupation of areas whose characteristics are not ideal for the performance of common, routine activities, sometimes requires costly investments in order to adapt these spaces to human requirements. Even worse, the occupation of areas with high risk to the poorest elements of the population and no improvements that would guarantee even a minimal safety of life, has caused a great deal of concern on the part of governments, to the United Nations and to Multilateral Agencies regarding the vulnerability of the people who inhabit these zones (whether or not controlled), and the risk management required to lessen the potential harm to these persons and their property.

In Venezuela, as in many countries, the occupation of floodplains, unstable hillsides and areas below sea level represents a matter for study. These circumstances were viewed with greater emphasis as the result of the landslides which occurred in 1999 over more than three hundred kilometers of the country's waterfront and took a heavy toll in both lives and property damage.

In the majority of cases the origin of many floods is, of course, an extraordinarily heavy rain, while at other times they may be caused by events of lesser magnitude but with days or weeks of constant rains (with the soil completely saturated.)

There is also periodic flooding, usually on the floodplains of the major rivers, caused by phenomena arising from the annual change in the inclination of the planet, with its consequences for the climate. In Venezuela there are several rivers which, given the size of their basins, flood their banks every year. Perhaps the most outstanding of these is the Orinoco River, whose water level at some points climbs to sixteen meters, flooding large areas of the plains along the bank. However, since there are few cities along the river bed down to its mouth at the Atlantic Ocean, the behavior of this river receives scant mention in the public prints. It is only when it affects Ciudad Bolívar, in Bolívar state, or Tucupita, in Delta Amacuro state, that it is mentioned in the country's press. This is not the case with other cities, prominent among them being mainly Cumaná, Barcelona, Valencia and Caracas. In these cases, given their population, any behavior of the waterways receives immediate coverage.

It may, therefore, be said that the floods take on importance to the extent that they affect humans, their daily activities and their property.

A good example of this is what happens with the Guaire River –the primary and most important river in the city of Caracas. This is a small river, with a basin of some 655 square kilometers and an average annual rainfall of 1,500 millimeters a year, whose floods affect, in different ways, some six million inhabitants –about twenty percent of the country's total population.

Canalized along almost its entire length, the Guaire River frequently floods. This is due to several factors:

1. The river was canalized in the 'fifties and 'sixties when the population of the city was barely around a million inhabitants and many areas in the basin were vacant lots, small wooded areas with bushes or pasture. There were sugar cane haciendas and planted areas along its banks. While a basically very high flow was estimated, the present reality is that over the last twenty-five to fifty years its flow has been compromised by the changes in the way land is used, as pointed out by the Institute of Flow Mechanics of the Central University of Venezuela carried out in 2008.
2. The water quantifying data was (and is) scant; accordingly, the statistical series are unreliable due to the short period for which data is available. If you add to this a possible climate variability (or climate change), the possibility of more frequent flooding proves almost evident.
3. The urbanization process (and, accordingly, weatherproofing) of the upper part of the basin and the canalization of the San Pedro River accelerate the flow of the water to the river, causing higher swells and higher levels in the middle basin –precisely, in the city of Caracas.
4. Even if it can be said that these are a minor cause, the accumulation of garbage in sumps, gutters and water collectors also contributes to the flooding of streets and avenues when these projects do not operate at full capacity causing, as a minimum, vehicle traffic jams. There are also cases in which when the streets are repaved, this reduces the opening of gutters, thus reducing their capacity and efficiency.

5. Finally, drainage studies are not usually a course in our universities. There are, therefore, few professionals who can adequately analyze and solve these issues.

These problems recur, with either greater or lesser importance, in many of our cities. As the population grows and occupies the natural floodplains along the rivers, the situation set forth in this document has recurred. For this reason, timely population planning (master plans), with guidelines for the possible uses of the land and an analysis of the potential hazards in the face of extraordinary occurrences, is essential to prevent future damage to persons and property.

According to Ochoa-Iturbe (2011), the sediment found in the drainage systems is usually the result of the natural processes of erosion, decomposition in wooded areas and erosion of the riverbeds, among other causes which are due, among other factors, to such weather changes as droughts and flooding, heavy and unusual rains and seasonal fires. As the population grows, the need for more livable space has created conditions which multiply these natural phenomena many times over. Specifically, during the first stages of urban development and construction, the load of sediment multiplies hundreds of times, upsetting the characteristics of the river and ravine canals (forms and declines). This, in turn, alter their respective flow regimens. In developing countries, this circumstance is aggravated by uncontrolled development –the result of a lack of regulations or insufficient enforcement of codes and standards.

Another source of solids which affects small creeks and drainage collectors, especially in developing countries, is that due to inefficient garbage collection. The citizenry is in the habit of throwing waste into ravines and creeks (Ochoa-Iturbe, 2011). These wastes are generally carried downstream, during the first weeks of the rainy season, plugging urban drainage systems, most especially those of the smaller collectors.

Finally, another urban drainage problem is the increase of landslides caused by extreme weather occurrences, which are often provoked by human interference with the urban riverbeds. In these cases, the loss of property and of human life is sometimes alarming.

In addition, at present large volumes of water are transferred from surface sources (lakes and reservoirs) in remote basins to the cities, consequently upsetting the urban water cycle, Thus, there is the potential risk of floods and of the consequences that they could bring with them in terms of the loss of life and property.

The torrential landslides that occurred in Vargas state (in the central-northern coastal area of Venezuela) in 1999 taught the Venezuelans important lessons (López, 2005). The loss of life might have been less if a program of coordinated prevention and mitigation measures had been implemented.

In view of the above, measures have been recommended and implemented to mitigate the effect of these occurrences (López, 2005). These may be summarized as follows:

Structural measures:

- Canalization of rivers and ravines.
- Control of sediment.
- Control of riverbank erosion.

Nonstructural measures:

- Monitoring of water and weather conditions in the river basins. There are presently twenty-five monitoring stations for the city of Caracas valley and Vargas state).
- Formulation of risk charts.
- Preparation of contingency plans.
- Installation of early warning systems (for example, Doppler radar systems).

As of 2005, twenty-four sediment control dams had been built in Vargas state, shared by the Curucutí, Guanape, Piedra Azul, El Cojo, Alcantarilla, Macuto and Camurí Chico river basins, which offer a certain degree of protection to the villages downstream of these projects (López, 2005). However, it is cause for alarm that these dams quickly clog up with sediment as is the fact that, due to their insufficient storage capacity they will, in the short run, be out of service. This is aggravated by the absence of locks or discharges in some of the dams, thus preventing the passage of the sediment carried by the ordinary currents.

López (2005) states that one of the causes of the tragedy of Vargas (which occurred in 1999) was the lack of alarm systems which could have warned the village residents in advance so that they could have taken appropriate evacuation measures. The possibly of torrential landslides occurring depends on the quantity and intensity of the rain, the degree of saturation of the soil, the presence of pronounced slopes in the basin and the characteristics of the soil to provide sediment material to produce landslides. For this reason, the two most important factors in establishing an early warning system are the continuous monitoring of rain and the moisture of the soil. In order to design an early warning system, it the monitoring stations must be telemetric – that is, that must transmit real time data to a central control station at regular intervals (for example, every five or ten minutes). This system will be charged with sounding the alarm to the competent authorities. However, of the twenty-five stations spread over Vargas state (14) and Caracas (11), only nine of them are telemetric. Most of the telemetric stations are located in the San José de Galipán basin where the Flow Mechanics Institute, working together with the Department of Hydrometeorological Engineering of the Central University of Venezuela (UCV), is carrying out a research project on the generation of torrential landslides and the means of preventing them.

In addition, in 2004 the Fluid Mechanics Institute installed a Doppler meteorological radar in the Tovar section of the city. This represents a major tool in predicting rain, several hours or even days in advance. The radar enables an atmospheric sweep with a with a radius of up to 150 km. and is based on the Doppler effect, issuing waves that bounce off the raindrops from the clouds. Therefore, the amount of water they transport can be measured.

Researchers from the Fluid Mechanics Institute have developed a methodology for the creation of maps showing the threat of extreme flooding. These use mathematical models which simulate torrential flows, coupled to digital terrain models and geographical information systems (López, 2005). This methodology has been applied in nineteen basins in Vargas state and seven basins in the Caracas Valley, in a project carried out jointly with the Venezuelan Simon Bolivar Geographical Institute within the framework of the Avila Project. The results of the threat maps show that major urban areas in Vargas state and the Caracas Valley are located in the area subject to high risk of extreme flooding.

The experts recommend the intensification of efforts to implement early warning systems in Vargas state and the Caracas Valley. The installation of a monitoring and early warning network for twelve top priority basins will entail a cost on the order of 900,000 thousand dollars. The management, operation and maintenance of this network will be carried out directly by the control centers to be created at the regional level, where the affected communities are involved, in order for them to participate in these activities.

Another case related to the flooding problem, as the result of the transfer of large volumes of water, involves Lake Valencia (in Aragua and Carabobo states).

At the end of the seventies, Lake Valencia suffered a natural drying out, which was hastened by human activities, causing it to reach its minimum level (402 meters above sea level). Due to this, the water from several rivers in neighboring basins, chiefly the Cabriales River, was diverted through the main pipeline.

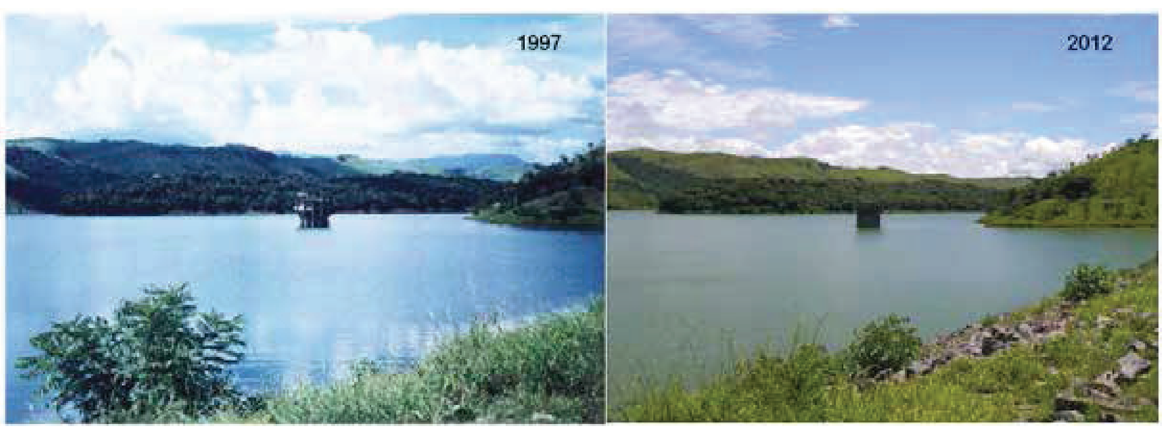
As a result of this transfer from the rivers, the water level in Lake Valencia rose, flooding farming and urban areas. Urban settlements around the lake were prohibited, but this was not enough to prevent them. At present its high-water mark is over 413 meters above sea level. This has caused serious flooding in such Aragua state urban areas as Mata Redonda, which have been widely reported by the nation's press in view of the property losses which have been widely reported in the nation's press because of the property losses they have caused.

Due to this and to the pressure brought by both the population and the press, beginning in November 2005 the Maruria and Cabriales rivers were diverted to the Pao River basin –one of the main tributaries of the Pao-Cachinche reservoir, from which drinking water is supplied to the cities of Valencia (Carabobo state), Maracay (Aragua state and San Carlos (Cojedes state). The high organic content of these rivers depleted the oxygen in the reservoir's water column, which provides drinking water o the cities of Valencia (Carabobo state), Maracay (Aragua state) and San Carlos (Cojedes state) and several outlying cities (González and Matos, 2012). The high organic content of these rivers caused the depletion of the oxygen in the reservoir's water column, reducing part of the benefits obtained. This was followed by the artificial breakdown of the layers in this reservoir beginning in 2001 (Estaba et al., 2006).

Another method used to mitigate the effects of the swelling of Lake Valencia was the extraction of water through transfers to the Pao River basin. In addition, the discharges from the Taiguaiguay water treatment plant (in Aragua state) were diverted to the Taiguaiguay reservoir. From there water is pumped o the Tucutunemo River for the construction of an irrigation system for the valleys in this zone. However, since this project has not been completely finished, a part of the effluent from this system is being emptied into the Guárico River –the main tributary of the Camatagua reservoir (in Aragua state). This has caused a deterioration of the quality of the water in this body of water, which in the last few years has gone from mesotrophic to eutrophic (González et al., 2014). Quality-wise, the change in the color of the water (from blue to green) is a clear reflection of the change in the trophic condition that the Camatagua basin has undergone following the transfer of water from low water quality sources (Figure 13).

As far as solid waste handling is concerned, Ochoa-Iturbe (2011) observed that in developing countries, the middle and upper classes in the urban areas usually have adequate garbage collection systems. However, the poorest residents have limited garbage collection systems (in some cases, once or twice weekly) and for these inhabitants the usual practice is to take their own garbage to a dump – sometimes at a distance from their homes. In some cities with high mountain slopes (as is the case with the city of Caracas), it could be easier to dump garbage in the ravines or on nearby slopes, with the knowledge that the next rains will carry them downstream. It is for this reason that the authorities must make a major effort, working along two main lines: (1) education, to teach the residents that throwing waste in ravines could produce an environmental risk, which would be counterproductive to it (an increased propagation of flies and mosquitos, among other effects), and (2) the creation of garbage collection systems to make it easier for the residents to dispose of these wastes and, in turn, to encourage them to use these systems.

Figure 13. The change in the trophic state of the Camatagua reservoir may be observed quality-wise in the change in the color of its waters



Photographs taken by Ernesto J. González in September 1997 and September 2012.

Box 17

Limnology and the management of water resources

Venezuela's limnologists have gathered abundant data concerning the physical, chemical and biological characteristics of several waterbodies. The data may be classified, thus being transformed into useful tools for prediction (González and Quirós, 2011).

A number of generalities and trends may be observed from the classification of the data from the fifteen waterbodies (Figure 14), studied by the Limnology Laboratory of the Central University of Venezuela. Most of these are used to supply drinking water.

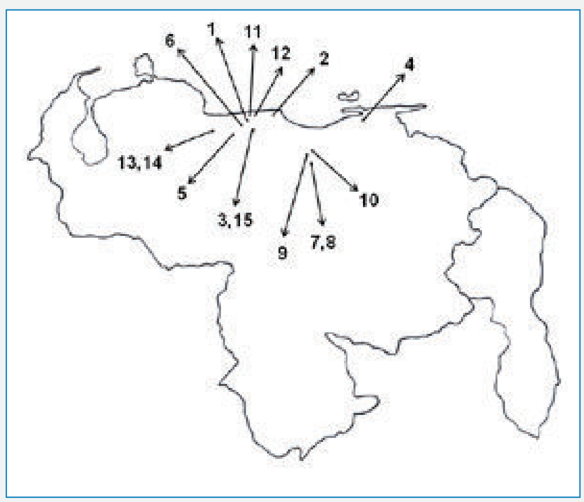
A clear linear relationship between the total phosphorous and total nitrogen, and the phytoplankton biomass (as chlorophyll-*a*) may be noted in the reservoirs studied (Figure 15).

Despite the fact that there is no apparent relationship between the variables involved, their empirical relationships make it possible to gather valuable data. At first glance, the distribution of the reservoirs according to total phosphorous and the nitrate-ammonium quotient (NO_3:NH_4) shows a high data spread (Figure 16). In this case, it is possible to identify three major groups of reservoirs. The first group comprises those reservoirs with low total phosphorous concentrations (<20 μg/l, shown in the black circles) while in the group of reservoirs with a moderate to high phosphorous concentration (>20 μg/l). Two more clearly identifiable groups may be observed: one of them (the lower, in black triangles) is represented by the reservoirs in which ammonium predominates over the nitrates, and some with relatively high residence times. In these, the cyanobacteria are dominant. The third group (at the top, in black rhombi) includes those reservoirs in which nitrates dominate over ammonium, with relatively low residence times, where the dominant groups of phytoplankton are different from the cyanobacteria – for example, diatoms, green algae or flagella. The exception would be represented by the Loma de Niquel reservoir (shown in the white circle), which is very near the total low and high phosphorous concentration limits and showed a predominance of cyanobacteria during the period under study, for which reason it has not been included in any of the three above-descried groups. Hence, the preponderance of cyanobacteria – some of them in strains which could be poisonous and cause public health problems – may be predicted when the water in the reservoirs is physically and chemically characterized.

Based on these studies it is evident that in order to control the eutrophication in these waterbodies, the input of nutrients, especially phosphorous and nitrogen, must be controlled.

Figure 14. Reservoirs studied by the Limnology Laboratory of the Central University of Venezuela:

1. Agua Fría,
2. Taguaza,
3. Lagartijo,
4. Clavellinos,
5. Tierra Blanca,
6. Loma de Níquel,
7. El Cigarrón,
8. El Pueblito,
9. El Cují,
10. El Andino,
11. La Mariposa,
12. La Pereza,
13. Pao-Cachinche (western wing),
14. Pao-Cachinche (eastern wing),
15. Quebrada Seca.

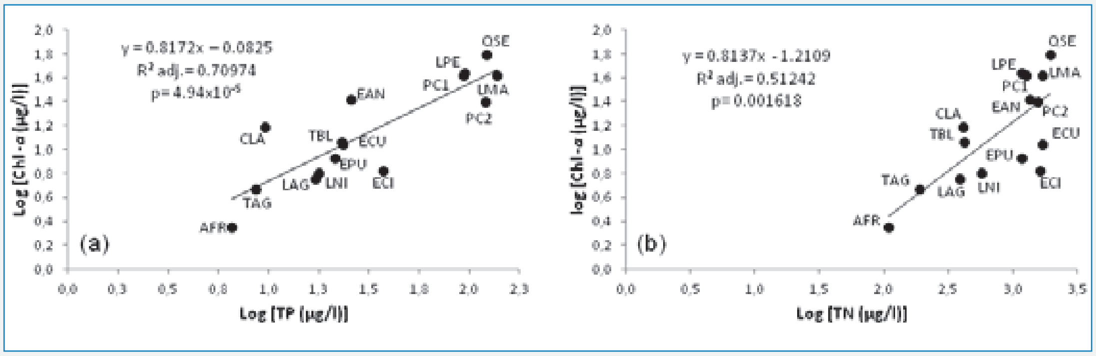


Source: González and Quirós (2011).

Box 17

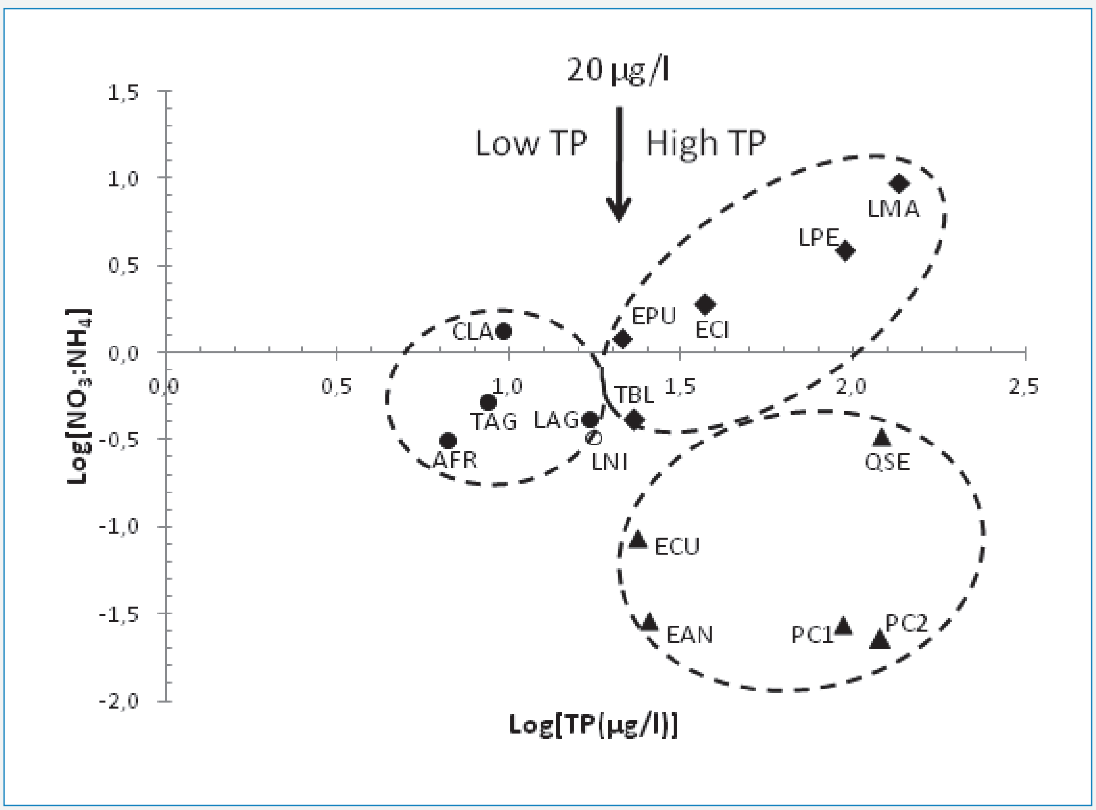
Figure 15. The relationship between (a) total phosphorous (TP) and chlorophyll-*a* (Chl-*a*) and (b) b) total nitrogen (TN) and chlorophyll in Venezuela's reservoirs

Key: AFR: Agua Fría, TAG: Taguaza, LAG: Lagartijo, CLA: Clavellinos, TBL: Tierra Blanca, LNI: Loma de Níquel, ECI: El Cigarrón, EPU: El Pueblito, ECU: El Cují, EAN: El Andino, LMA: La Mariposa, LPE: La Pereza, QSE: Quebrada Seca, PC1: Pao-Cachinche –western wing with a spillway and tower pump; PC2: Pao-Cachinche –eastern wing with no spillway.



Modified from González and Quirós (2011).

Figure 16. Relationship between total phosphorous and the NO3:NH4 quotient in Venezuela's reservoirs. Legend as per Figure 15



Modified from González and Quirós (2011).

Box 18

Factors producing changes in the water cycle and their effect on the biodiversity of the Orinico River basin and nearby basins

Scope of study

Venezuela owns (jointly with Colombia) one of the largest water basins and water reservoirs in the world. The Orinoco River basin is the third largest on the planet. Along its two-thousand kilometer course, it drains an area of about 90,000 kilometers, representing 94.44% of the total volume drained from Venezuela's water basins. It is a river of considerable size, with rapids and abundant suspended sediment (200 x 10^6 tons per year). It has a weather regimen dominated by two seasons (rainy and dry), each approximately equal: rainy (June to November) and dry (December to May). During the former, water covers substantial areas of the plain, forming shallow lagoons (estuaries) and penetrating into the forests along the banks. During the latter, there is a drastic reduction in the level of its waters, draining the plains and eliminating thousands of square kilometers of aquatic habitats. These two seasons regulate the biological cycles of the water flora and fauna (Table 11). Any change in either the weather or the water cycle could affect, wholly or in part, the system's living organisms.

Table 11. Summary of the environmental factors regulating communities

Rainy season	Dry season
Physical and chemical changes in the water; an increase of dissolved hydrogen and transparency; reduction of pH; lower temperature; nutrients.	Physical and chemical changes in the water; reduction of dissolved oxygen; reduced transparency; higher temperature, sediment and nutrient concentrations; higher pH.
Increase in aquatic habitats: rivers, ducts, lagoons, estuaries, flooded forests.	Reduced habitats and trophic levels; drying out of forests and plains; reduction or elimination of channels, estuaries, flooded forests and lagoons; reduction of volume of river flow.
Increase in primary and secondary productivity; reproduction and growth; dietary diversification; sexual preparation and maturity; preparation and sexual maturity.	High mortality rate and/or migration to canals and rivers holding water. Reduction of growth; maturation of gonads.
Processes of decomposition of the organic material deposited on the soil, in forests and plains.	Accumulation on the soil of organic material produced or transported during the prior phase.

Source: In-house document

Factors producing changes or impacts due to the use of water for human development purposes in the water cycle

Water resources are vital to human development. For millenniums, villages were established in relation to this vital liquid and its sources. We have interfered with its cycle somehow, often without taking into account how it benefits wildlife (Figure 17).

There are few research projects that can quantitatively and qualitatively document the biological impact caused by changes in the water cycle or by changes in Venezuela's continental waters. However, based on research carried out by Petts (1985; 1990a,b), governmental plans and technical reports (Rangel, 1979; Taphorn, 1980; Machado-Allison, 1990; Taphorn and García, 1991; Machado-Allison, 1994; Veillon, 1997; Machado-Allison, 1999; Marrero, 2000; Machado-Allison, 2005; Andrade and Machado-Allison, 2008; and Machado-Allison et al., 2011), the interference with the water may be classified as follows:

1. Damming of water for domestic or agricultural use. Dams built for farming or domestic use were widely built over the last fifty years, when the headwaters of nearly all the main tributaries of

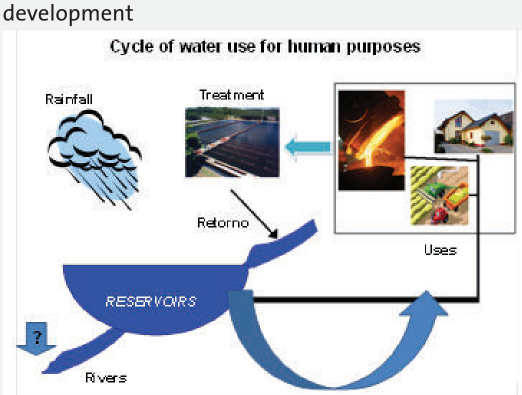
Box 18

the Orinoco River's north slope of had been dammed, as is the case with the following rivers: the Apure, Boconó, Cojedes, Guanare, Guárico, Masparro, Portuguesa and San Domingo and on the southern slope, the Caroni River (used mainly for hydroelectric power). Other rivers of lesser national importance, but still of regional importance, are the headwaters of the Manzanares, Neverí, Unare and Tuy rivers in the northern part of the country (Figure 18).

Dams (see Table 12) cause:

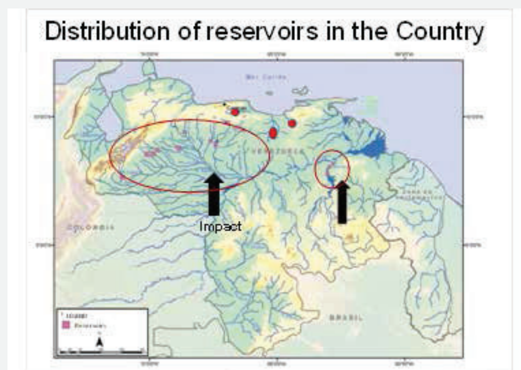
- Alteration or regulation of the annual water flow, affecting the vital cycles for the animals and plants that depend on it (for example, the migration of fish for reproduction, the flooding of riparian plains and forests).
- Contamination, through home (urban) and/or farm use. The waters used in urban and farming areas (for washing) are discharged again as wastewater. Although national regulations make their treatment obligatory, it is evident that they are not enforced. Hence, discharges of hydrocarbon-bearing waters (oils), fertilizers, insecticides and industrial waste (heavy metals) enter the aquatic environment, thus affecting the quality of the water, with physiological and biochemical impacts on the organisms which inhabit it.

Figure 17. The water cycle and its use in human development



Source: In-house document.

Figure 18. Main dams built in Venezuela



Source: Machado-Allison and collaborators (2011).

Table 12. Scheme showing activities, actions, effects and impacts on the water ecosystem

Activities	Actions	Effects	Impacts
- River closed (dammed)	- Flow blocked by construction of dikes - Variations in the hydrodynamics of the flow system, both in the main channel and its areas of influence (for example, riparian plains and forests)	- Reduction of the flow downstream or across the bed - Increase in the temperature and the reduction of dissolved oxygen - Effects on migration of species - Rise in water level on alternate routes upstream - Obstruction of passage of water organisms - Colonization and changes in the use of the land - Acidification of planted soils and loss of fertility - Deposits of and increases in sediment upstream and downstream - Elimination of threats of flooding	- Reduction of the richness of habitats and species; impact on biodiversity - Reduction in interchange of organisms; loss of biodiversity - Reduction in water transportation - Changes in the structure of the related water and land organisms

Source: In-house document

Box 18

2) Deforestation for urban or agricultural purposes: Figure 19 shows an area cleared for agricultural purposes in the Venezuelan foothills region. These areas have been extensively and intensively altered (Centeno, 1999). Deforestation has caused a reduction in rain intensity and, naturally, a substantial reduction in the flow of our rivers. In addition, solid waste (sediments) have increased due to erosion. This has caused changes in the quality of water for life-sustaining purposes (changes in temperature, pH and transparency) and the physical elimination of its microscopic inhabitants.

Figure 19. Deforestation and its effect on rivers

Source: In-house document based on "Google Earth" images

The situation of certain Venezuelan rivers

Studies and follow-up of documents prepared by the personnel in charge of environmental sanitation maintenance (http://www.monografias.com/trabajos/contamagua.shtml) have determined that there are several regions or basins in the country with serious water environmental deterioration.

Among these are:

- The Guaire and Tuy rivers in the Capital region.
- Lake Valencia and its tributary rivers.
- The Toyuco and Aroa River valleys.
- The systems of the Guárico and Portuguesa rivers.
- The Unare, Neverí, Manzanares and Guarapiche rivers and their tributaries.
- Lake Maracaibo.

The aforementioned rivers and waterbodies are located in highly populated areas. They receive contaminated urban wastewater with domestic, industrial and, in many cases, agricultural waste. When the treatment plants fail, these contaminated waters flow freely, affecting reservoirs and the cities downstream from them. Today, for example, there are serious problems due to the transfer of contaminated waters from Lake Valencia to the reservoir supplying water to the city. The same thing happens with the Guárico and Portuguesa rivers, which empty their waters into reservoirs which supply water to populated areas in the plain region and the nation's capital.

Recommendations regarding the factors producing changes in the water cycle and its impact on the biodiversity of the Rio Orinoco basin and neighboring basins

Box 18

An effort has been made to describe succinctly the natural and human-driven factors that regulate or shape the vital cycles in Venezuela's water ecosystems, with emphasis on those human activities which directly imperil the aquatic life communities. The researchers must be aware of how these ecosystems behave before they are biologically, productively, socially and culturally altered. There must be, and there is, the obligation to educate and influence those who make decisions regarding how they may be altered while causing the least possible damage and ensuring the sustainable use of this resource. The following, then are required:

- Ensuring adequate management and control of these activities.
- Compliance with the sundry national norms (Laws, Regulations and Norms governing water and the environment).
- Applying international conventions and standards regarding the use of substances (for example, pesticides, insecticides, fertilizers, etc.
- Education at all levels regarding the risks of owning contaminated water.
- Promoting scientific studies to form a basis for rigorous support and formation of adequate technical personnel.

In conclusion

Venezuela has one of the world's largest and most extensive waterway networks. For millenniums, this had led to the creation of one of the most interesting biological processes on our planet, and has turned Venezuela in a widely diverse country. The Orinico River basin represents one of the most extensive wetlands in the Neotropical region (Hamilton and Lewis, 1990; Machado-Allison, 1990), supporting thousands of species, many of them important from both an economic standpoint and as food for the villages. There is a historic responsibility to preserve them for the enjoyment of future generations.

From the Andes to the Orinoco Delta, large cities and concentrations of human population are established on the banks or in the vicinities of the major rivers, the tributaries of the Orinoco, the Caribbean Coast, Lake Maracaibo and Lake Valencia. These rivers have been dammed or have served for withdrawing water for home, agricultural or industrial use, thus guaranteeing our nation's development. However, the cost paid by the environment is enormous. Waters contaminated with detergents, oils, heavy metals, insecticides and many other contaminants flow downstream, with repercussions on rivers, oceans or lakes. This situation not only endangers the wildlife inhabiting these bodies of water; it also creates the possibility of affecting human life in the villages located outside the area where the contaminant originates. Considering that the basins are interconnected systems, the contaminants, once in one of them, affect all of them.

6. Conclusions

- The most densely populated areas of Venezuela are located in regions with the least water availability. This involves high costs in supplying water to the cities.
- Coverage of the drinking water supply and wastewater collection is increasing fast in Venezuela. However, the percentage of wastewater treated is still low.
- Major sanitation plans are being carried out, such as the Rio Guaire Sanitation Project and the Overall Sanitation and Water Level Control Project for the Lake Valencia Basin.
- There is the need to address and resolve water-related problems and diseases.
- Given the climate change, projects for the management of water resources must be implemented –projects well planned and conceived by the available technology, society, the economy and the existing institutions, with a view to balancing the supply and demand for this resource in order to confront scenarios of the occurrence of extreme hydrological events.
- It is necessary to address the problems created by the swelling of bodies of water (flooding) and its consequences. Some structural and nonstructural measures have already been taken.
- The used of limnological information can help in managing the nation's water resources.
- Plans for the management of water resources and the mitigation of the problems involved in water cycles in urban areas must involve the participation of the organized communities.

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9. Acronyms

AMC: Caracas Metropolitan Area
CVG: Venezuelan Corporation of Guayana
ENSO: El Niño and Southern Oscillation
FUNDAMBIENTE: Environmental Education Foundation
GORBV: Official Gazette of the Bolivarian Republic of Venezuela
GORV: Official Gazette of the Republic of Venezuela
GOSH: Manager of Sanitation and Water Projects
HIDROVEN: Venezuelan Hydrological Water Company
IMUTC: Metropolitan Institute of Urban Planning “Taller Caracas”
INE: National Statistics Institute
LOPSAPS: Organic Law for the Performance of Drinking Water and Sanitation Services
MINAMB: People's Ministry of the Environment
MPPS: People's Ministry of Health
MTA: Technical Roundtables of Water
OMS: World Health Organization
RMC: Caracas Metropolitan Area
SIENAGA: System of National Environmental Management Indicators and Statistics
WSP: Water and Sanitation Program.