Chapter 22
Water Quality Management in San Luis Potosi, Mexico

Candy Carranza-Álvarez, Nahúm Andrés Medellín-Castillo, Juan José Maldonado-Miranda and María Catalina Alfaro-de-la-Torre

Abstract Several countries have adopted water as a human right which implies access to safe water sources for human consumption, among other conditions. Mexico has adopted this human right as well; however, there are still many actions that must be implemented before achieving drinking water and sanitation coverage as stated in the sustainable development objectives. In this paper, the situation related to access to safe water sources for human use and consumption was analyzed for the state of San Luis Potosi in its four geographic regions: Altiplano, Center, Media, and Huasteca. Each of these regions has unique characteristics, for example, the Altiplano region is arid and its water sources are mostly groundwater, while Huasteca is a humid region and its sources are mostly surface water. For this work, each municipality of the state was visited, users and authorities were interviewed, documentary information was collected, and an analysis of this information was carried out to identify the problems most frequently encountered in each region, which are highlighted in this document. It was concluded that it is necessary to encourage a regionalized management plan in the state of San Luis Potosi for this resource in order to minimize the main problems related to the quality of water supply to protect the health of the population.

C. Carranza-Álvarez · J. J. Maldonado-Miranda
Unidad Académica Multidisciplinaria Zona Huasteca, Universidad Autónoma de San Luis Potosí, Romualdo del Campo no. 501, Fracc. Rafael Curiel, C.P. 79060 Ciudad Valles, San Luis Potosí, Mexico
e-mail: candy.carranza@uaslp.mx

J. J. Maldonado-Miranda
e-mail: juan.maldonado@uaslp.mx

N. A. Medellín-Castillo (✉) · M. C. Alfaro-de-la-Torre
Facultad de Ingeniería, Universidad Autónoma de San Luis Potosí, Av. Salvador Nava no. 8, Zona Universitaria, C.P. 78290 San Luis Potosí, Mexico
e-mail: nahum.medellin@uaslp.mx

M. C. Alfaro-de-la-Torre
e-mail: alfaroca@uaslp.mx

M. C. Alfaro-de-la-Torre
Facultad de Ciencias Químicas, Universidad Autónoma de San Luis Potosí, Av. Salvador Nava no. 6, Zona Universitaria, C.P. 78210 San Luis Potosí, Mexico

E. M. Otazo-Sánchez et al. (eds.), *Water Availability and Management in Mexico*,
Water Science and Technology Library 88,
https://doi.org/10.1007/978-3-030-24962-5_22

Keywords Water quality management · Water management plan · Water supply

22.1 Introduction

Water is an essential resource that plays a central part in all economic activities; therefore, its use must be sustainable (Kunz and Moran 2014). The provision of safe drinking water is a crucial component for the world to eradicate poverty and improve public health services.

Around 3 out of 10 people worldwide, or 2.1 billion people, lack access to safe drinking water at home, more than twice as many lack safe sanitation. The WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation, and Hygiene (JMP) estimated that in 2015, 29% of the global population (2.1 billion people) lacked "safely managed to drink water"—meaning water at home, available, and safe. 61% of the global population (4.5 billion people) lacked "safely managed sanitation"—meaning access to a toilet or latrine that leads to a treatment or safe disposal of excreta. The world remains off track in meeting the sanitation target, which requires reducing the proportion of people without access to drinking water (WHO, JMP, UNICEF 2017).

Mexico is considered a regional economic and political powerhouse because of the size of its economy. However, due to its growth, management and governance failures are causing several water crises across the country (Godinez Madrigal et al. 2018).

Deforestation and the lack of a land-use plan are the main problems in the state of San Luis Potosi and in watersheds that supply water to the State. In addition to that, incomplete infrastructure of rural and urban sanitation, resulting in environmental pollution that affects mainly underground and surface sources, and mostly affects the population and water quality.

In this chapter, a diagnosis of water problems was carried out in the four geographical regions of the state of San Luis Potosi in México. For this, the main municipalities of the state were visited to obtain information and register the current situation of the access to drinking water of quality. Case studies highlight the problematic and possible solutions in these regions.

22.2 Organizations Responsible for Water Supply and Treatment in Mexico

In Mexico, the supply of drinking water to the population is primarily the responsibility of the municipal authority. Although the administration of water, as a national resource, is in charge of the Ministry of the Environment through the Secretariat of Natural Resources and Environment (SEMARNAT) through the National Water Commission (CONAGUA). The latter is in charge of the administration of water

resources and is responsible for authorizing the municipalities to use water sources for their purification and supply to the population. Nonetheless, the municipality is the state entity that has the fewest resources to meet all the demand for drinking water in its jurisdiction and frequently faces a problematic of drinking water availability that has several origins and different consequences.

CONAGUA is also in charge of operating federal government financing programs for the construction of the necessary infrastructure for water provision and sanitation; among them, the Program for the Sustainability of the Drinking Water and Sanitation Services in Rural Zones (PROSSAPYS). This program partially supports the states by financing the infrastructure needed for water and sanitation services in rural communities. Funding is distributed to the states through their State Water and Sanitation Commissions (CEA) based on the necessities manifested by the municipalities, or their water committees in the rural communities. Funds are provided to the Mexican Government by the Inter-American Development Bank (IDB) to promote the sustainability of water resources in the countries. PROSSAPYS provides funds to those communities considered in the range of high and very high marginalization levels. CONAGUA (2009) through the CEA in San Luis Potosi funded twelve projects for drinking water supply (new or rehabilitated systems) in communities of rural or periurban characteristics in all the regions of the State (Altiplano, Center, Media, and Huasteca) in the period 2008–2011.

22.3 Geopolitics of San Luis Potosi

22.3.1 Land Productivity

In recent years, the agricultural sector has shown a downward trend in their contribution of the national and state domestic gross product, due to the obsolete production systems, lack of phytosanitary controls, inefficient marketing systems, the absence of schemes for producers' organization and integration of manufacturing processes. Those factors should be amended to add value to production and develop the productive potential of each region of the state. Today, agricultural activities employ 29.3% of the employed population of the state, mostly in rural areas. The state has a total agricultural area of 682.382 ha, of which 84% are rainfed agriculture areas with low productivity.

There are 104 water storage dams and 30 diversion dams in the state of San Luis Potosi. However, this infrastructure is inadequate to meet the demand for the development of agricultural activities. This situation has forced the State workforce to migrate to urban areas, where there are industrial and commercial activities, in search of better opportunities for productive employment and income.

It is essential to address agricultural and forestry development of the state with responsibility and commitment under the principle of sustainability, preserving and taking care of natural resources. It is of utmost importance to get the training and

technology in two ways, one aimed at enhancing the level of productivity and competitiveness of the agricultural sector—the other intended to raise the standard of living and income of the employed population in agriculture, mainly in municipalities with high levels of marginalization, where agriculture currently represents more than an economic activity, a subsistence work (INEGI 2015).

22.3.2 San Luis Potosi State Population

In 2008, the country had a population of 107.1 million inhabitants. From 1950 to 2005, the country's population quadrupled and went from being predominantly rural (57.4%) to mostly urban (76.5%). The metropolitan area of San Luis Potosi is classified as a place with a population of 2,717,820 inhabitants, and it is considered that by 2030, over 70% of the population will be concentrated mainly in urban areas, having, therefore, the problem of water supply and design of new hydraulic infrastructure (INEGI 2015).

22.3.3 General Relevant Issues

The discharge of municipal and industrial sewage represents a source of pollution in many of the municipalities; only 10 of the 58 municipalities in the state have water treatment plants. Even though in some municipalities new water treatment plans have been constructed, some of these plants are not operating due to a lack of funds and trained staff. As a result, other treatment plants do not have vigilance or supervision.

The information on water, which each municipality has, depends mostly on the legal status of each operating agency. Around 70.7% of the municipalities visited, Matehuala, Cedral, San Luis Potosi capital, Rioverde, San Fernando, Ciudad del Maiz, and Ciudad Valles, have decentralized agencies, i.e., 12.1% of the municipalities in the state, and 87.9% of the municipalities have agencies that cooperate for the public administration without being part of it.

It is important to note that operating agencies provide safe drinking water mainly to the head-city of the municipality and the surrounding communities. However, the most remote communities do not receive drinking water of quality, and they are supplied with alternative or intermittent sources that sometimes do not receive any chemical treatment. All the municipalities visited, have minimal water coverage to their communities, being 25% for the Altiplano region (the arid region of the state), 15% for the Center region, 18% for the Media region and 10% for the Huasteca region.

22.4 General Situations of Each Region of the State of San Luis Potosi

San Luis Potosi is divided into 58 municipalities grouped into four regions. Each municipality has inequalities in population composition that result in essential restrictions for their development. Of all the state municipalities, 22 are predominantly rural with 596.009 inhabitants; 17 are rural with 223.833 inhabitants, 12 are semi-urban with 227.990 inhabitants, and seven are urban with 1,362.582 inhabitants. The geographical location of San Luis Potosi State is shown in Fig. 22.1.

In rural and predominantly rural municipalities, the infrastructure of services like electricity and water supply is limited, roads still show significant lags, and the economically active population works in agricultural activities. In semi-urban and urban municipalities, employment structure is more diversified, as well as labor offer, and consumption possibilities. In the majority, industrial and manufacturing development is present, reflecting further diversification of employment in the tertiary sector, with the presence of micro-businesses, mainly shops, and informal employment. The main economic activities depend on each geographical region (agriculture, mining, tourism, industry, etc.).

It was necessary to compile existing information on quality, quantity, extraction, recharge, and primary uses of water, identified by watersheds, using the various reports, studies, and dissertations, in the Secretary of State, in the municipalities

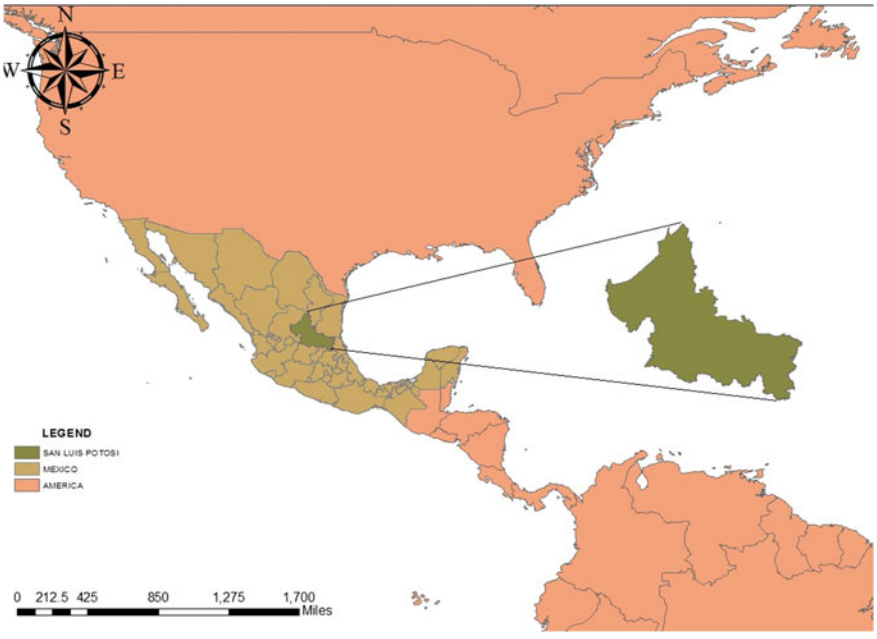

Fig. 22.1 Geographical location of San Luis Potosi State

and institutions of education. Also, focus groups were organized to review, analyze, discuss, and compile the information obtained in fundamental aspects.

The sample size was determined using a standard normal distribution. Before beginning the interviews, consent was obtained to collect the information. Interviews were conducted using a semi-structured questionnaire.

22.4.1 Altiplano Region

Observations on water held in the municipalities of the Altiplano region pointed out that the municipalities in this region have adequate organization and management of the resource. Culturally, the inhabitants take care of the resource because it is scarce, and people are prepared for times of drought. Rural communities have an adequate water management program, and even some communities have alternative energy sources to extract water at a low cost, as is the case of the municipality of Charcas. This municipality has a program to improve renewable energy, both for the extraction of water through the use of extraction mills, as for domestic use with solar cells.

The problems identified in the Altiplano region (Fig. 22.2) are represented by importing water from other municipalities as in the case of Matehuala, lack of geological studies for the opening of new wells, and the presence of pollution sources (municipal waste) near wells as in the case of Real de Catorce. About infrastructure, the problems are very similar in all municipalities of this region; the pipeline is obsolete, the pumping system is weak, a lack of automatic hypochlorinators equipment, and a lack of storage stacks of distribution and replacement material for contingency situations. In some communities, the deficiencies are even more substantial, as in the case of the community of Guadalupe Victoria in Charcas, where it was found that the primary deficiency is the design of efficient and economical construction works for the extraction of water. To date, it has not been put into operation due to the lack of financial resources for infrastructure projects of this type. Another frequent problem is the flooding in the rainy season due to the lack of adequate storm sewers, which results in flooding of agricultural and livestock land, and therefore, infiltration to groundwater wells.

Therefore, the supply of drinking water does not have a cost, because most of the time the resource is deficient for the population. Sometimes people go directly to the storage stack with buckets to carry water to their homes and cover their basic need. Regarding water quality, in some municipalities, storage stacks do not have adequate facilities for maintaining the resource under appropriate conditions, especially lack of staff and financial resources to clean them. The main quality issues in other municipalities are the high concentration of salts where water has high hardness and an unpleasant taste and even causes pipeline rupture. In addition, studies by Ortíz-Pérez (2011) indicated concentrations of fluoride above 1.5 mg/L which is the maximum permissible value specified in the Official Mexican Standard (Diario Oficial de la Federacion 2000), in most of the wells and distribution cells of the municipalities in this area, and in some cases arsenic was also detected. Among the

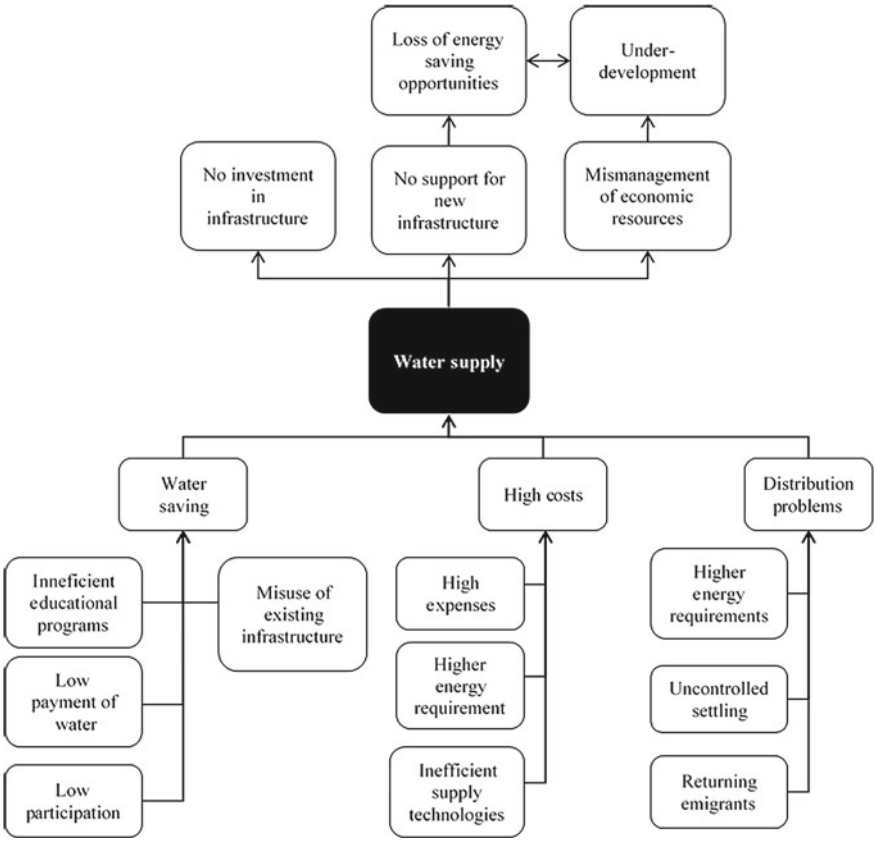

Fig. 22.2 Main problems and consequences of water supply in the Altiplano and Center regions

most common diseases in this region because of the intake of poor quality water is the dental fluorosis and often, allergies and hepatitis, although the source of the last one is not precisely known. The problems are summarized in Fig. 22.2.

22.4.2 Center Region

The situation of the municipalities in the Center region is very different from that observed in the rest of the state. Except for the metropolitan area of San Luis Potosi, Soledad de Graciano Sanchez, and other neighboring municipalities, there is a considerable backlog in infrastructure and information management. In the municipality of Villa de Arriaga, for example, water was not chlorinated because of the low availability of water (0.5–1.0 L/s), and they receive few economic resources for these requirements. These actions will further limit the development of new infrastructure

in this municipality. As a result of water shortages, residents of some communities of the municipalities of the Center region consume water from troughs and ponds which also supply brick factories in the region. Consequently, mass poisonings have occurred in the population.

Also, municipalities have an enormous backlog in works to the distribution network system and water coverage. In these municipalities, there is no drinking water in the downtown area, or higher areas. The executives of the operating agencies of most municipalities in the Center region agree that there is inattention because resources are generally concentrated in the capital and other regions of the state. Regarding water quality, all the municipalities surrounding the capital only have bacteriological, and chlorine residual studies and they are unaware of other studies in their area. The study by Ortíz-Pérez (2011), reflects in detail the concentration of fluoride and arsenic in some wells of the municipalities in this area. In Fig. 22.3, a problem tree graph constructed with the analysis performed on the main problems of distribution, use, and accessibility of water is shown.

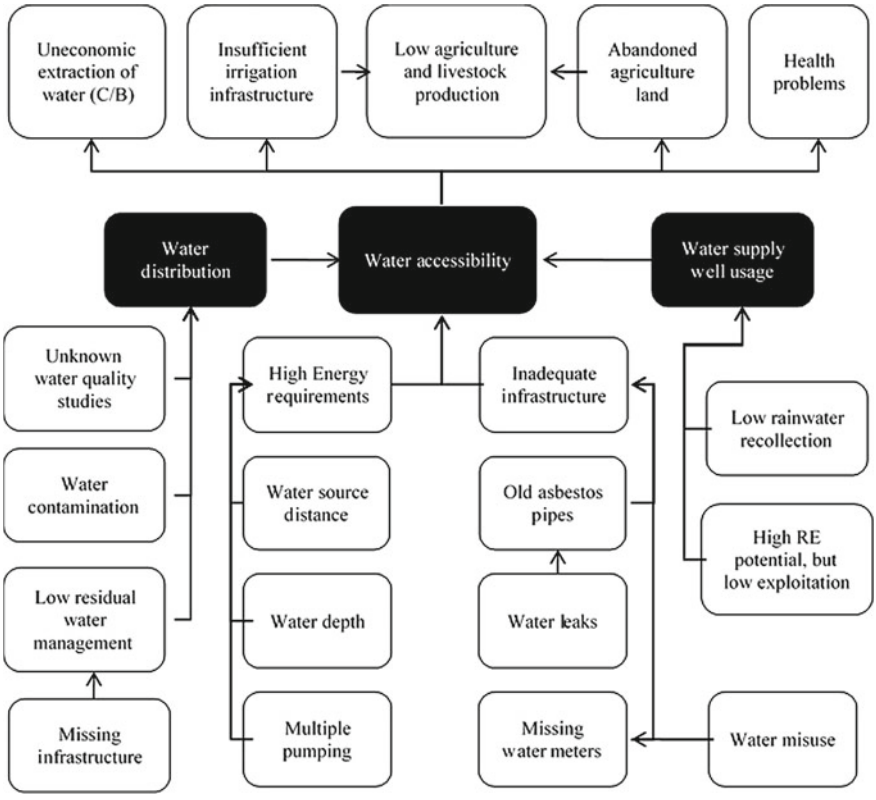

Fig. 22.3 Main problems of distribution, access, and use of water in the Center region

The existence of a regulatory framework that applies state-wide is of utmost importance for the prevention and control of pollution. At the state level, each municipal entity should have their Ecological Balance Law or equivalent, which clearly defines the tasks involved in prevention and control of pollution, integrated waste management, regulations and laws of water and wastewater. They would provide authority and power to the drinking water operating agencies. In turn, the policy could be implemented by the relevant government departments. It is also necessary, as demonstrated in the other three regions of the state, to work on the decentralization of the granting and management of water bodies of the state.

22.4.3 Media Region

In the Media region of the state, the scenario is similar in the topic of infrastructure. However, municipalities such as Rioverde, San Fernando, San Ciro de Acosta, Rayon, and Ciudad del Maiz present significant advances in the management and allocation of the resource. The water distribution system is efficient for the public, and executives of operating agencies are better informed of the current water situation and the problems of the region. Currently, these municipalities are developing executive projects to apply to state and federal support. However, due to the increase and concentration of population in urban areas in recent years, a scheduled supply system had to be implemented where water is only supplied to specific areas of the cities two or three days a week and other areas on the remaining days. The schedule cares the sectors located in the highest part of the municipality would not receive water otherwise due to the deficiency in the pumping system. Therefore, the requirements regarding the acquisition of larger pumping equipment, pipes for water distribution and pipe change, have become a primary necessity.

Regarding water quality, the municipalities of Rioverde, Ciudad Fernandez, and the community of Refugio in San Fernando perform routine studies with the Universidad Autonoma de San Luis Potosi (UASLP), in order to monitor the physicochemical characteristics and the presence of fluoride in the main wells. One of the main problems is the location of the wells supplying water to the population in agricultural areas, especially between maize and tomato. Regarding infrastructure, the greatest need is the lack of technical support to find other sources of safe water supply, since the pursuit of this resource is still performed by the traditional method of shaking. Also, automatic hypochlorinators equipment and more efficient pumping systems are required. The problems observed are presented in Fig. 22.4.

22.4.4 Huasteca Region

The water situation in the Huasteca of San Luis Potosi highly contrasts with the other three areas of the state. The municipalities of this region are supplied by surface

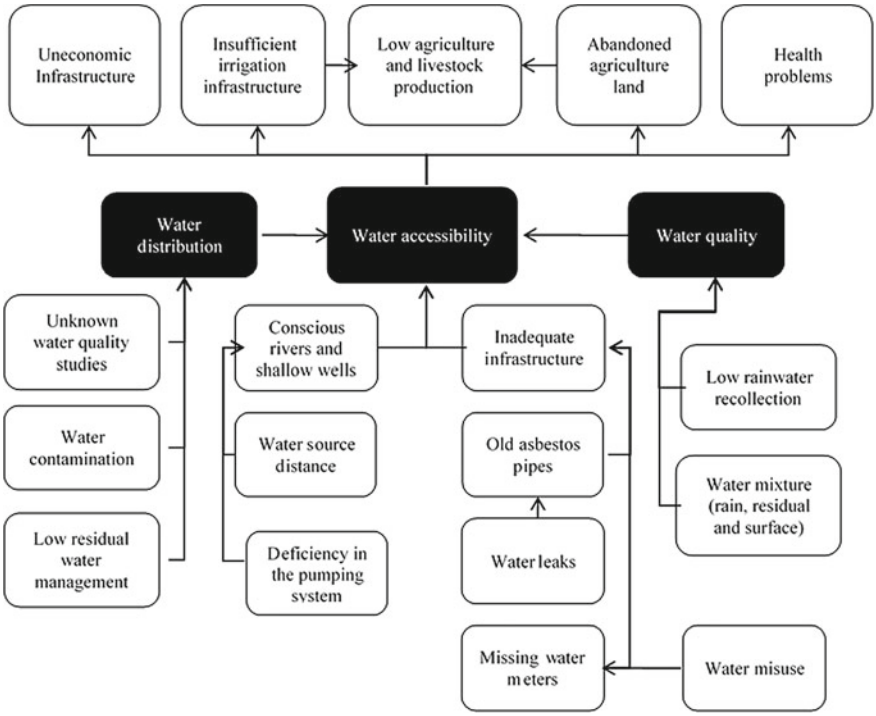

Fig. 22.4 Main problems of water in the Media and Huasteca regions

water, including rivers and permanent or intermittent streams. However, some rural communities do not receive drinking water, and their water supply is from treadmills that receive no treatment. Although rivers cross most municipalities, communities do not have access to it, even if the people live across the river shorelines, as is the case of the communities surrounding the Pujal Coy. In other municipalities such as Xilitla, the water shortage is so prominent in hot weather, that people must cover their daily needs with water bottles, which dramatically affects their economy because of the cost of each bottle. Besides this, it is widespread to find the distribution of water in trucks, especially in Ciudad Valles and Tamuin, which is the result of the lack of planning and unsuitable land organization for population growth.

The municipality of Ciudad Valles is the only one with a decentralized operating agency that works efficiently, and has the entire infrastructure for routine analysis, and addresses all matters relating to the management and resource management. This agency called the Department of Drinking Water, and Sewerage (DAPA) has a database of all the volumes of water extracted and chlorinated monthly and analyzes other organic and inorganic pollutants in certified laboratories.

Regarding water quality, pollution of surface waters by various factors is a severe problem, especially for the municipalities of the Huasteca region, where rivers are the only source of supply. The problem of river pollution is the result of the lack of

land organization for the development of population centers, both structurally and functionally. As a consequence, there is a lack of drainage, sewers, and treatment plants designed for population growth. Also, although some municipalities have treatment plants, they are not operating correctly, as in the case of Tamuin and plant Birmania in Ciudad Valles. The financial resources provided by the state and the federation do not cover all the design (power supply, transmission, purification, water treatment, sewage treatment) so that it is sometimes only available for a given stage without fully considering the whole design. In addition, there is not a proper record of downloads which can be reliable or updated.

Figure 22.4 shows an overview of the current situation regarding infrastructure and water quality in the Huasteca region. There are two critical aspects that affect the quality of surface water in the Huasteca region: (1) the combination of wastewater and stormwater, which often affect the efficiency of wastewater treatment plants, and untreated overflow is discharged into rivers; (2) diffuse pollution, urban runoff flowing without any quality control, dragging the sediment, trash, grease and oils to streams, impacting them severely. It is, therefore, necessary to implement and create regulations on urban development when it comes to express the environmental impact in any municipality in the present or future. Although there are environmental laws, in most cases there is a lack of regulations to facilitate their implementation.

22.5 General Considerations

The diagnostic of the quality and availability of water for different uses in the major watersheds in the state of San Luis Potosi is necessary to achieve sustainable management and identify priority areas of study for the rehabilitation, operation, management and distribution, water disposal, and reuse.

These studies should go parallel to a concurrent understanding of the patterns and geohydrological processes in each area of the state. The water flowing into the aquifers and the one used on the surface depends on the quality and quantity attributes of watershed health. This perspective of study, because of its inherent complexity, necessarily requires the establishment of a multidisciplinary team.

22.5.1 The Public Management of Water

As mentioned above, being water an essential resource central to all economic activities, its use must be sustainable (Kunz and Moran 2014). Water management strategies are required to be effective despite variability in climate and geography conditions. To make better-informed management strategies, managers need to understand the dynamics of heterogeneous water systems under extreme climatic variability (Barrett et al. 2014) and understand those factors within a system which are most influential on system behavior. Managers also need to understand how these influen-

tial factors change under different climatic conditions and between sites (Giordano and Shah 2014).

Water management reforms can fail for multiple broader socioeconomic factors like lack of funding, political instability or the interference of global drivers like trade policies or droughts (Warner et al. 2015). The provision of safe drinking water is a crucial component for the world to eradicate poverty and improve public health. As part of the Millennium Development Goal (MDG) 7, halving the proportion of people without sustainable access to safe drinking water, and basic sanitation by 2015 was one of the targets (United Nations 2011, 2013). Although it was declared that the drinking water part of the goal was met (WHO and UNICEF 2014), this is not true globally as some regions still lag (WHO and UNICEF 2015).

Despite disparities in water access, it is also worthwhile to note that the declaration of success ignores two critical components of water supply, which are the provision of safe water and maintaining sustainable supply systems (Alexander et al. 2015). It was noted that development practitioners in the sector were paying more attention to building new facilities to meet the drinking water as part of the goal than ensuring their sustainability, (Kunz and Moran 2014).

In this way, the Management of Water Resources was established as an alternative solution to this problem. Due to this, it is essential to start from a socio-environmental and holistic analysis, considering the values that are attributed to water. This management is based on three pillars: economic efficiency, equity, and environmental sustainability. To achieve adequate management of water, managerial instruments which allow evaluating it are required. An enabling environment is needed through the creation of policies and legislation, and the institutional framework at different levels so that that water can be had for both human being activities as for the environment (Gil Antonio and Reyes Hernández 2015).

Many methods and techniques can be used to water management, including water conservation, reuse and wastewater management. Likewise, it is necessary to create a legal and institutional framework that establishes principles accompanied by work tools and methodologies for its application (Sánchez and Sánchez 2004).

The transversality of public policies is an essential issue of water management, defined as the combined efforts of the federal, state, and municipal public administration agencies to exert joint actions for solving problems linked to the same area and contribute to solving others (Vargas et al. 2004).

One of the principles of water management is the participatory approach of all the actors involved in water management. In San Luis Potosi, despite the efforts made so far, water management has not been achieved due to the lack of mechanisms that facilitate the participation of all the actors involved in the water distribution and use, especially in rural communities where the inhabitants have to manage and provide themselves with poor quality water.

22.5.2 Water Management in San Luis Potosi

Due to the excessive use of water for different human activities, in Mexico its use was regulated through several regulatory instruments, the main one being the National Water Law (NWL) of 1992. The NWL establishes that state governments are granted a more active role in water management, and they are invited to adopt their drinking water, sanitation, and sewerage management laws, and set their rates. It seems that in the legal field there is no clear definition of the instances that are responsible for defining water quality for a specific use to support those who must make decisions. However, there are legal instruments that allow monitoring of its quality. Among them, we mention "The Law of Health" which states in Article 119, that it is up to the Ministry of Health and the governments of the states in their respective areas of responsibility: to monitor and certify the quality of water for human use and consumption (CONAGUA 2009).

Also, the Water Law for the State of San Luis Potosi, in Chapter III relating to the State Water Commission (CEA) says that its assignment is to gather and update information on state waters related to the different uses, availability, and quality. Article 14 states that the CEO attributions are to command the practice on a regular and periodic basis, to perform control water sampling and analysis, to keep statistics, and take action needed to optimize water quality for the population supply as well as the sewage poured, in accordance with the applicable law (Ley de Aguas 2016; Peña 2006).

In the visits made to the different municipalities of San Luis Potosi, it was found that there is inadequate water management, which has been generated by the complexity of the associated problems and the lack of organization of water managers. Rural communities lack an adequate management program, and the inhabitants of those places are the most affected regarding access to quality water. In this sense, community management can lead to participatory sanitation; the active community can generate a process to develop waterworks, follow up, manage it, and make it work. Figure 22.5 summarizes a plan to achieve water management.

22.6 Case Studies

22.6.1 Water Supply Problems in the Altiplano Region

Recently, the Autonomous University of San Luis Potosi undertook an analysis of the water supply problem in communities between 500 and 2500 inhabitants considered as rural, in the Altiplano Region of San Luis Potosi, which is the aridest region of the state and its resources of water depend entirely on groundwater (Tejeda-González 2017). A total of 77 communities and the head-town of each one of the 15 municipalities of the Altiplano were visited. Information was obtained on the water sources available to the population, the water treatment processes used, and

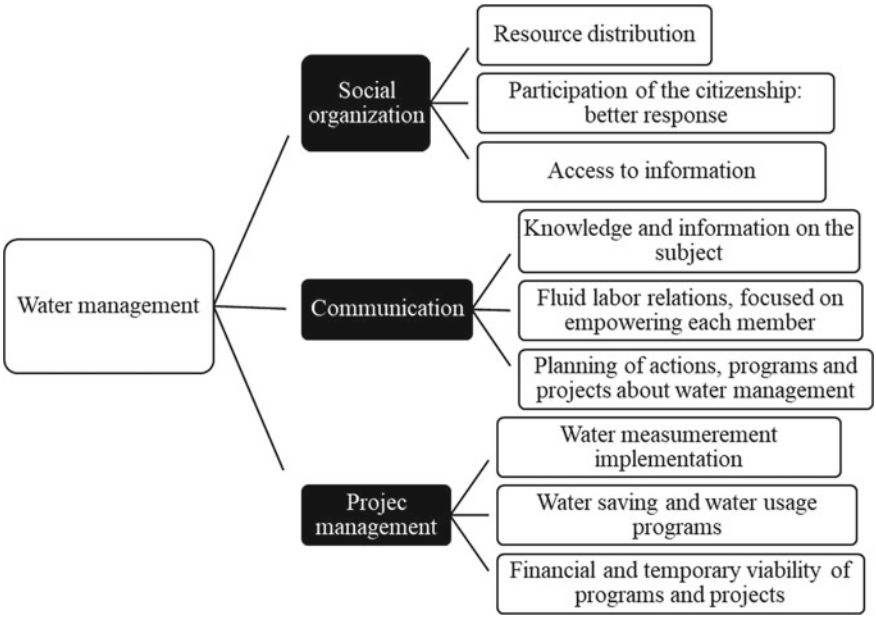

Fig. 22.5 Water management plan

on how local authorities and the population manage the water distribution to the communities. Analysis of problems was done according to the principles of the Strategic Environmental Assessment (SEA) (Fischer 2007). Evidence to support the analysis was documented through fieldwork, interviews to users and authorities for the water supply. Also, reports, governmental programs, and other documents obtained were considered in the SEA Analysis.

The following problems were documented.

1. The degree of social marginalization in the region is considered of mid-level, and it considers, among others, the access to the basic water and sanitation services in the house.
2. The drinking water services are the responsibility of the municipality that serves the head-town and the closest rural communities fundamentally; the others make their water demand assisted by several official instances.
3. In rural localities, farmers participate in "ejidal organizations" represented by a commissary and a supervisory council. The "ejidal organizations" are established in Article 27 of the Mexican Constitution. There are also "water committees" with a president, a secretary, a treasurer, and a person responsible for the operation of the water well on which the town depends. In this way, the ejido organization and the water committees make a request to the official authorities for the water resource needed in their locality.
4. The rural localities are responsible for paying the electricity needed to operate the wells pump. The electric power consumption is paid by the locality, and

the water committee oversees establishing the rates for the water services to the population based on the amount of the electricity receipt.

5. At the head-town of the municipalities, drinking water services are administrated by operating organizations, water boards, municipal water departments, or the ecology department. Their budget is often insufficient, so the water supply is mainly granted to the host city of the municipal government and nearby towns. In these cases, the State and the municipality are supported with Federal Grants as those obtained by the Mexican Government from the Inter-American Bank for Development (BID) and administrated by CONAGUA. Unfortunately, funds are only allocated to those localities considered as having very high marginalization.
6. The people responsible for the water supply can change with each municipal administration and do not always have the necessary knowledge and training to operate the water service.

These situations that have been highlighted for the Altiplano region of San Luis Potosi are practically identical in the other regions of the state and other states of the country located in the central-northern region, mostly arid.

22.6.1.1 Water Quality and Treatment in the Altiplano Region

The Altiplano region of the state of San Luis Potosi is located within the Hydrological-Administrative Region of the Northern Basins (Cuencas Centrales del Norte), a region of the country mostly semi-arid in which groundwater is the primary water resource for all sectors. In this region of the country, it is well known that water has a quality problem due to the presence of arsenic and fluorides (Bocanegra-Salazar 2006; Cardona et al. 2018), two pollutants from geological origin that cause health problems through the continuous consumption of this water (Rocha-Amador et al. 2011; González-Horta et al. 2015).

Water samples were collected from all sources of water supply used by the population in the 15 municipalities of the region. These sources included wells, water pots, storage tanks, and even small reservoirs. The samples were collected in seventy-seven sources of supply; eight rural populations with less than 500 inhabitants were visited by request of the municipal authorities. At each site, water samples were collected for microbiological analysis (sterilized bags), metals (HDPE bottles with HNO_3 trace grade), and physicochemical analysis (HDPE bottles). Some parameters were measured in the field (pH, ORP, conductivity, residual chlorine). The physicochemical and bacteriological parameters established by the National Legislation for drinking waters (Diario Oficial de la Federación 2000) were determined. For the analysis of arsenic and metals, the samples were filtered (0.2 μm membrane filter, PC-Nuclepore) and acidified to pH 2 with nitric acid grade trace analysis. Spectrophotometry of Atomic Absorption did the determinations with flame or graphite furnace (Varian SpectrAA 220FS and 220Z). The results obtained allowed to determine that the contamination with fluorides and arsenic in samples from deep wells represented 19% of the analyzed supplies. The determined concentrations varied in

the range of 0.1–4.7 mg/L for fluorides (determined by the Ion Selective Method); in the case of arsenic, the concentrations varied between 0.5 and 141 μg/L (Tejeda González, 2017).

In addition to fluorides and arsenic, water showed a high content of salts (sulfates, chlorides, sodium) in nine municipalities, and presence of lead and other metals in many water sources, at concentrations higher to those recommended by the NOM-127-SSA1-1994. These results show that the problem of the quality of the water sources to which the population has access, at least in the Altiplano region is complex and requires urgent and concrete actions aimed to provide treatment even in rural areas depending on well water. Bacteriological contamination was detected only in samples from shallow wells and storage basins. For this, the responsible authorities of health (Ministry of Health) support with a permanent campaign of water disinfection, so that the population in the rural localities at least disinfects the water. Where possible, the water is made safe by using reverse osmosis systems (head-town in the municipalities and two rural localities in the Altiplano region) and disinfection, in most of the rural localities the necessary products are provided for the water disinfection of storage tanks and cisterns. In several localities, water is distributed to the population after being disinfected in the storage tanks, or there is a community water tap. Unfortunately, not all inhabitants disinfect the water because they indicate that it acquires an unpleasant taste. Also, an important sector of the population has adopted as a measure, the consumption of purified water to drink, even if they cook with untreated water.

22.6.2 Diagnosis of Water Quality and Treatment Alternative in Central Region

In this case study, a diagnosis of water quality was carried out to evaluate the contamination by fluoride and arsenic in well water for human consumption in the Center region of the state of San Luis Potosi (Torres Rodriguez 2016), based on previous work carried out by Ortíz-Pérez et al. (2006). First, the localities of each municipality were classified as urban (higher than 5000 inhabitants) and rural (less than 5000 inhabitants). Then, the percentage of the localities that have or do not have water quality studies was determined. Finally, the data was plotted to visualize the information (Fig. 22.6). With the above information, the percentages of the localities of the municipalities whose fluoride levels in the well water exceed the maximum permissible limits according to NOM-127-SSA1-1994 were determined (Fig. 22.7).

The wells chosen for this study correspond to the well in Laborcilla located in the municipality of Villa de Arriaga and the well Las Rusias located in the municipal seat of Villa de Reyes. Also, it was found in the diagnosis that in the study conducted by Ortíz-Perez et al. (2006) a fluoride concentration was reported in the Laborcilla and Villa de Reyes wells of 4.82 and 2.61 mg/L, respectively, which are higher than

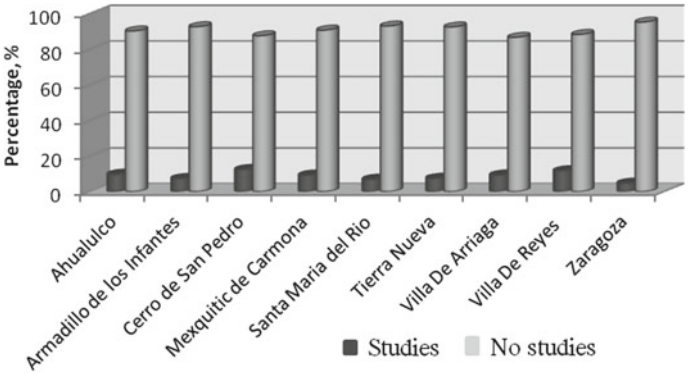

Fig. 22.6 Localities of some municipalities of the Center region of San Luis Potosi that have or do not have water quality studies

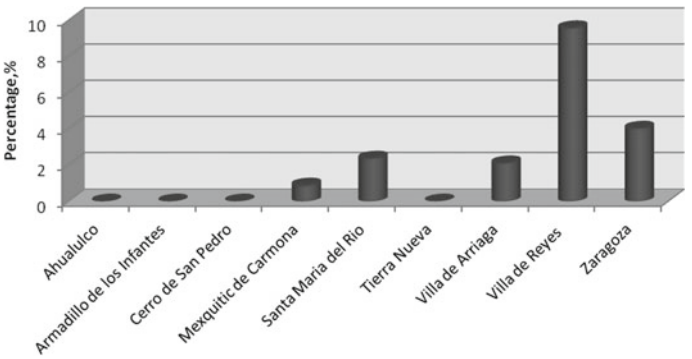

Fig. 22.7 Communities of municipalities that have water quality studies and where the maximum allowable limit of fluoride in water is exceeded

the maximum permissible limits. The water from these wells was selected to perform adsorption tests using bone char because of the high level of fluoride present in them.

The results of this study, shown in Fig. 22.6, revealed that approximately 90% of the localities in the municipalities analyzed in the diagnosis do not have water quality studies for their wells. Also, Fig. 22.7 shows the percentages of the communities that exceed the maximum permissible limits of fluoride which varied in the interval from 1 to 10%.

22.7 Conclusions

In the state of San Luis Potosi, the infrastructure to provide safe quality water for the population is not enough. In some cases, both the infrastructure to provide drinking water and that related to sanitation are obsolete or inexistent in rural and urban

areas resulting in environmental pollution affecting the groundwater, surface water resources, the population, and water quality. The wastewater discharges from industries and municipalities represent the most significant source of pollution in the state.

Water management in the different regions of the state of San Luis Potosi depends substantially on the interests of the municipal authorities and the involvement of the inhabitants. Water quality is affected by both anthropogenic activities and nature, though there is not an adequate treatment process to generate water of quality for human consumption.

In the state of San Luis Potosi, it is necessary to encourage a regionalized management plan for this resource, with the intention of minimizing the main problems related to the water quality supply in order to protect the health of the population.

This work will contribute to developing other studies about water management, infrastructure development, quality and quantity water monitoring, water distribution and the issuing of water rights.

Acknowledgements Dr. Simon Yobanny Reyes López by the technical review which helped to improve the quality of this manuscript.
CONACYT Projects CB-286990-2018 and P.N.-3947-2018.

References

Alexander KT, Tesfaye Y, Dreibelbis R, Abaire B, Freeman MC (2015) Governance and functionality of community water schemes in rural Ethiopia. Int J Public Health 60(8):977–986. https://doi.org/10.1007/s00038-015-0675-x

Antonio MD, Hernández HR (2015) Gestión integral del agua desde un enfoque social hacia una economía ecológica. NÓESIS: revista de ciencias sociales y humanidades 24(47):160–174. https://doi.org/10.20983/noesis.2015.1.6

Barrett D, Chen Y, Gao L, Zhou M, Renzullo L, Liu R, Emelyanova I (2014) Managing mine water under extreme climate variability using a model predictive control approach ACARP report C21037. Retrieved 01 Dec 2018, from https://scholarsarchive.byu.edu/cgi/viewcontent.cgi?article=1168&context=iemssconference

Bocanegra-Salazar M (2006) *Evaluación de riesgo en salud por la exposición a fluoruro y arsénico en agua de pozo para consumo de las zonas altiplano, centro y media del estado de San Luis Potosí.* Tesis Maestría en Ciencias Ambientales, Programa Multidisciplinario de Posgrado en Ciencias Ambientales, Universidad Autónoma de San Luis Potosí. Mexico: UASLP

Cardona A, Banning A, Carrillo-Rivera JJ, Aguillón-Robles A, Rüde TR, Aceves-de-Alba J (2018) Natural controls validation for handling elevated fluoride concentrations in extraction activated Tóthian groundwater flow systems: San Luis Potosí. Mexico Environ Earth Sci 77(121):1–13. https://doi.org/10.1007/s12665-018-7273-1

CONAGUA (2009) Ley Federal de Derechos en Materia de Agua. Diario Oficial de la Federación. Retrieved 11 Nov 2018, from http://dof.gob.mx/nota_detalle.php?codigo=5126145&fecha=23/12/2009

Diario Oficial de la Federación (2000) Modificación a la Norma Oficial Mexicana NOM-127-SSA1-1994, 2000. Salud ambiental, agua para uso y consumo humano. Límites permisibles de calidad y tratamientos a que debe someterse el agua para su potabilización

Fischer TB (2007) Theory and practice of strategic environmental assessment: towards a more systematic approach. Earthscan, London, UK

Giordano M, Shah T (2014) From IWRM back to integrated water resources management. Int J Water Resour Dev 30(3):364–376. https://doi.org/10.1080/07900627.2013.851521

Godinez Madrigal H, van der Zang P, van Cauwenbergh N (2018) A half-baked solution: drivers of water crises in Mexico. Proc IAHS 376:57–62. https://doi.org/10.5194/piahs-376-57-2018

González-Horta C, Ballinas-Casarrubias L, Sánchez-Ramírez B, Ishida MC, Barrera-Hernández A, Gutierrez-Torres D, Zacarías O, Saunders RJ, Drobna Z, Méndez MA, García-Vargas G, Loomis D, Styblo M, del Razo LM (2015) A concurrent exposure to arsenic and fluoride from drinking water in Chihuahua, México. Int J Environ Res Public Health 12:4587–4601. https://doi.org/10.3390/ijerph120504587

INEGI (2015) Anuario Estadístico del clima del Estado de San Luis Potosí. Panorama Sociodemográfico

Kunz NC, Moran CJ (2014) Sharing the benefits from water as a new approach to regional water targets for mining companies. J Clean Prod 84:469–474. https://doi.org/10.1016/j.jclepro.2014.02.053

Ley de Aguas para el Estado de San Luis Potosí (2016) Ultima reforma. Retrieved 14 Dec 2018, from http://aneas.com.mx/wp-content/uploads/2017/02/Ley-de-Aguas-San-luis-Potosi.pdf

Ortiz-Pérez MD (2011) El agua de consumo humano en México. Retrieved 29 Nov 2011, from http://www.agua.org.mx/h2o/index.php?option=com_content&view=article&id=19160:el-agua-de-consumo-humano-en-mexico&catid=1291:saneamiento-basico&Itemid=100148

Ortíz-Pérez MD, Bocanegra Salazar M, Landin Rodriguez LE (2006) *Evaluación de la contaminación de flúor y arsénico en el agua de pozo para consumo humano de las zonas Centro, Altiplano y Media del Estado de San Luis Potosí.* Tesis Licenciatura, Universidad Autónoma de San Luis Potosí. México, UASLP

Peña F (2006) Abasto de agua a la ciudad de San Luis Potosí. In: Barkin D (ed) La Gestión del Agua Urbana en México. Universidad de Guadalajara, Guadalajara, México, pp 249–264

Rocha-Amador DO, Calderón J, Carrizales L, Costilla-Salazar R, Pérez-Maldonado IN (2011) Apoptosis of peripheral blood mononuclear cells in children exposed to arsenic and fluoride. Environ Toxicol Pharmacol 32:399–405. https://doi.org/10.1016/j.etap.2011.08.004

Sánchez TLD, Sánchez TA (2004) Uso eficiente del agua. International Water and Sanitation Centre. Ponencias sobre una perspectiva general temática

Tejeda González JC (2017) *Propuesta metodológica basada en la evaluación ambiental estratégica para la planificación del aprovechamiento sustentable del agua y los recursos naturales en zonas marginadas y con potencial de desarrollo.* Tesis de Doctorado en Ciencias Ambientales, Universidad Autónoma de San Luis Potosi. México, UASLP

Torres Rodriguez A (2016) Problemática de la calidad del agua de consumo humano en zonas rurales. Estrategias de Prevención y Control. Tesis Licenciatura en Química. Facultad de Ciencias Químicas, Universidad Autónoma de San Luis Potosí. México, UASLP

United Nations (2011) The millennium development goals report 2011. Retrieved 03 Nov 2018, from http://www.un.org/millenniumgoals/

United Nations (2013) A new global partnership: Eradicate poverty and transform economies through sustainable development. The report of the High-level Panel of eminent Persons on the Post-2015 development agenda. Retrieved 15 Nov 2018, from https://sustainabledevelopment.un.org/content/documents/8932013-05%20-20HLP%20Report%20-%20A%20New%20Global%20Partnership.pdf

Vargas Valencia JC, Días Nigenda JJ, Ibarrola Reyes HJ (2004) La gestión integrada de los recursos hídricos en México: Nuevo paradigma en el manejo del agua. In: Cotler H (comp) El manejo integral de cuencas en México. Estudios y reflexiones para orientar la política ambiental. Secretaría de Medio Ambiente y Recursos Naturales e Instituto Nacional de Ecología. México

Warner BP, Kuzdas C, Yglesias MG, Childers DL (2015) Limits to adaptation to interacting global change risks among smallholder rice farmers in Northwest Costa Rica. Glob Environ Change 30:101–112. https://doi.org/10.1016/j.gloenvcha

WHO and UNICEF (2014) Progress on drinking water and sanitation 2014. Retrieved 02 Nov 2018, from https://www.unicef.org/publications/files/JMP_report_2014_webEng.pdf

WHO and UNICEF (2015) Progress on drinking water and sanitation 2015. Retrieved 03 Nov 2018, from http://files.unicef.org/publications/files/Progress_on_Sanitation_and_Drinking_Water_2015_Update_.pdf

WHO, JMP and UNICEF (2017) Progress on drinking water, sanitation and hygiene 2017. Retrieved 05 Nov 2018, from https://www.unicef.org/publications/files/Progress_on_Drinking_Water_Sanitation_and_Hygiene_2017.pdf