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Assessing Water Quality in the Developing World: An Index for Mexico City

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1. Introduction

Safe water supply is one of the most significant worldwide concerns. Since water has become a scarce resource in some regions, over the last several decades efforts have generally focused on supplying more water to people, without considering its quality. Although the quantity of water that people receive influences hygiene and promotes public health, poor quality of water also affects humans and the environment, increasing famine, child mortality, waterborne diseases, environmental deterioration, and social inequalities. The likelihood of being infected by waterborne diseases is not homogeneous among all age groups, indeed the groups most likely to be affected by these diseases are children under five years, the elderly, and people living in poor hygiene conditions (no-running water or proper waste disposal) (World Health Organization [WHO] & United Nations Children's Fund [UNICEF], 2011; WHO, 2008).

Today, freshwater resources (surface and groundwater) are threatened by over-exploitation and pollution. Consequently, they do not necessarily meet the quality standards for ensuring safe human consumption, and must undergo a purification process capable of 1) reducing turbidity, odors and unpleasant taste; 2) removing suspended solids, natural organic compounds (i.e., ammonia nitrogen), synthetic organic compounds (i.e., oil, detergents, pesticides and industrial solvents), and inorganic compounds (i.e., lead, cadmium, mercury, copper and zinc); and 3) eliminating pathogenic microorganisms (bacteria, viruses, protozoa and parasitic worms) that can cause outbreaks of waterborne diseases. Some of these compounds and microorganisms may be present in drinking water, but they must not exceed specific ranges if water safety is to be assured (WHO, 2011; Semarnat, 2011; U.S. Environmental Protection Agency [U.S. EPA], 2001). Nevertheless, some water management practices have increased people's exposure to health risks and insufficient water supply. For example, untreated wastewater discharge to freshwater sources, run-off from agricultural fields with high concentrations of pesticides, or wastewater reuse for crop irrigation.

Use of water polluted with microorganisms and organic and inorganic compounds affects people's health, increasing their exposure to waterborne and other water-related diseases. Waterborne diseases are infectious diseases caused by bacterial, viral or protozoa infections spread primarily through contaminated water (Ashbolt et al., 2001; Grabow et al., 2001;

Payment et al., 2003). The majority of these diseases is transmitted through fecal waste; therefore, lack of or low water quality contributes to their dissemination. The most common waterborne diseases include cholera, typhoid, dysentery, amoebic dysentery, and diarrhea (WHO, 2011). Although water is an important source for the generation and transmission of infectious organisms, waterborne diseases can also be disseminated through different routes, including the ingestion of contaminated food (either due to lack of hygienic conditions for its preparation or because crops were irrigated with untreated wastewater), person to person contact, unsanitary living conditions and/or poor hygiene.

Water-related diseases can as well be caused by high concentrations of organic and inorganic compounds. Many of these compounds exist naturally, but their concentration has increased as a result of human activities. For instance, high concentrations of pesticides, lead, fluoride, nitrates, arsenic, and other heavy metals can affect the nervous system and kidneys; and also cause reproductive disorders, cancer, skin lesions, endocrinal damage, and vascular diseases (WHO, 2011, 2004; Thompson et al., 2007; U.S. EPA, 1998).

People's access to safe water must be assured to guarantee healthy life. To this end, monitoring and assessing the quality of the water that people receive must be an essential component of water management. New methods that support effective water quality management need to be design and implemented. This chapter proposes a method to evaluate the effectiveness of water management in providing safe water, using as an example a study case of Mexico City. A water quality management index (*WQI*) was estimated by principal component analysis. The results were normalized and transformed into decimal units to simplify the data into a language that decision makers can easily understand. Since the quality of the water supply in this city varies among its neighborhoods, it was necessary to identify the distribution and location of the most vulnerable groups using an *ad hoc* Geographical Information System (GIS).

2. Water management in Mexico City

Mexico City is one of the biggest cities worldwide, characterized by important economic, social, environmental and cultural disparities. Its population is around 9 million people distributed in 16 boroughs, but in its metropolitan area are concentrated more than 18 million people. Although many people have access to basic services, including water supply that meet quantity and quality standards, others (mainly those located in irregular settlements) lack access to these services. The city concentrates the highest infrastructure and employment facilities in Mexico.

Mexico City receives 35.1 m^3/s of water from various internal and external sources. Groundwater from the aquifers of the Basin of Mexico is the main internal source, providing 42% of the total supply. Since the amount of water extracted from the aquifers (20.7 m^3/s) is almost three times the natural recharge capacity of this basin (7.9 m^3/s), cracks in the subsoil of these aquifers have occurred (Sosa-Rodriguez, 2010a). These cracks have exposed groundwater to direct pollution caused by wastewater and garbage leaching, with high concentrations of fecal coliform bacteria, chromium, lead, nickel, cadmium, mercury, and arsenic (Mazari, 1996). Another consequence of the city's groundwater over-exploitation is soil subsidence, which has caused the breakage of water and sewage pipelines and wastewater flooding in some areas of the city.

The most important external sources are the Cutzamala and Lerma Systems. These sources provide 43% of the total supply. Water from these external sources must be transported almost 127 km and pumped up nearly 1,100 m to reach the city (Conagua, 2002). This process requires a large amount of electricity, and has increased the dependency of Mexico City on external sources of both power and water. These water management practices are not sustainable; consequently, city authorities face increasing challenges to supply its inhabitants with a volume of water that meet minimum requirement and quality standards.

Most of the city's inhabitants (86% of the total) have access to water directly from pipelines. The other 14 per cent acquire this resource mainly by car tanks (88 per cent of that total), but also via wells, rivers, streams and springs (INEGI, 2005). These alternative sources do not ensure safe water consumption, and sometimes are more expensive. It is estimated that 1.25 million people are exposed to several risks generated by the lack of safe water supply (Sosa-Rodriguez, 2010a).

Mexico City also generates 25 m^3/s of wastewater, but treats only 9% of this volume (SACM, 2008). The remaining 91 per cent of wastewater is discharged without any treatment; thereby further polluting rivers which are used to transfer effluent from the city to the sea. Unfortunately, agricultural areas located in the Valley of the Mezquital and the Valley of Tula use this wastewater for farming activities (Conagua & Semarnat, 2006). This practice has had severe impacts on the health of producers and consumers of these crops, which include sorghum, barley, oat, wheat, corn, tomatoes, carrots, onions and coriander. Furthermore, it also pollutes the soil, groundwater and air of the areas where these crops are grown (Esteller, 2000). Evidence of this pollution has been a documented increase of waterborne diseases. For example, the morbidity rate caused by *Ascaris lumbricoides* in children between zero and four years increases from 2.7 to 15.3 per thousand children in areas where wastewater is used to irrigate crops. Similarly, the morbidity rate caused by *Entamoeba histolytica* increases for individuals between five and 14 years, from 12.0 to 16.4 per thousand (Sosa-Rodriguez, 2010b; Romero, 1994).

2.1 Water quality analysis

To disinfect drinking water, authorities at the beginning of the water distribution network apply an excessive amount of chlorine (approximately 2mg/liter), which oxidizes organic and inorganic materials, in addition to removing pathogens (bacteria, viruses and protozoa). During the process of water distribution, the residual chlorine reacts at full strength at first, but then decreasing in concentration until it disappears in the most distant points of the network. The gradual diminution of chlorine concentration explains why in some parts of the distribution network chlorine is absent, and so is the desired water disinfection.

Residual chlorine concentrations should be within a specific range considered safe since in excess chlorine is toxic, in addition to generating high concentrations of chlorine byproducts, including trihalomethanes (i.e., chloroform [CHCl 3], bromoform [CHBr3], dibromochloromethane [CHBr2Cl]) and haloacetic acids (i.e., monochloroacetic acid, dichloroacetic, trichloroacetic) (Thompson et al., 2007; U.S. EPA, 2001, 1998).

According to the Mexican National Water Law, water provided to residents must be free from microorganisms and any substance that could produce adverse physiological effects and cause harm to human health. Parameters such as residual chlorine or fecal coliform bacteria are the most commonly used indicators for evaluating water quality. Based on the norm NOM-127-SSA1-1994, the amount of residual chlorine accepted as safe fluctuates from 0.2 to 1.50 mg/liter (Semarnat, 2011). This range is wider than the standards established by the U.S. Environmental Protection Agency, in which residual chlorine concentration in drinking water must be between 0.1 and 0.3 mg/liter (U.S. EPA, 2001, 1998). Therefore, the city's inhabitants are not only exposed to health risks caused by low residual chlorine concentration, but also to diseases associated to a greater exposure to chlorine byproducts. These byproducts are classified as carcinogens, and can also affect the functions of vital organs such as the liver or kidneys (Craun et al., 2001; Lindquist, 1999; U.S. EPA, 2001).

Pathogenic microorganisms must not be present in drinking water; nevertheless, the existence of heavy metals (i.e., mercury, cadmium, chromium, lead and zinc), nitrates, nitrites, fluorides, chlorides, sulfates, DDT, pesticides and dissolved solids is allowed if the concentration of these organic and inorganic compounds is below the ranges in which they are considered a threat to people's health (Table 1).

Chemical Substance	Concentration Limit	Chemical Substance	Concentration Limit	Chemical Substance	Concentration Limit
Aluminum=	0.20 mg/l	Zinc=	5.00 mg/l	Cyanide=	0.07 mg/l
Cadmium=	0.005 mg/l	Nitrites=	0.05 mg/l	DDT=	1.00 mg/l
Chromium=	0.05 mg/l	Nitrates=	10 mg/l	Hexachlorobenzene=	0.01 m g/l
Copper=	2.0 mg/l	Chlorides=	250 mg/l	Trihalomethanes=	0.20 m g/l
Iron=	0.30 mg/l	Fluorides=	1.50 mg/l	Pesticides=	0.03 mg/l
Lead=	0.025 mg/l	Sulfates=	400 mg/l	Solids Dissolved=	1000 m g/l
Mercury=	0.001 mg/l	Arsenic=	0.05 mg/l	Residual Chlorine=	0.2-1.50 mg/l

Source: Mexican National Water Law, Norm NOM-127-SSA1-1994

Table 1. Concentration limits for chemical substances in drinking water

The Mexico City Water System (SACM) reported in 2007 that 2 per cent of samples analyzed did not satisfy residual chlorine standards. For fecal coliform analysis, pathogenic microorganisms were identified in 12 per cent of the samples (SACM, 2008). In both cases, the most affected areas were south and southeast of Mexico City. It is important to note that water quality monitoring in this city must be improved since the sampling used is not representative: over 80%of the samples tested are gathered from less-affected areas; thus, 20% or fewer samples are collected from the areas reported to be affected by poor water quality (Sosa-Rodriguez, 2010a).

Due to financial constraints, since 1997 the analysis of samples has been reduced from 160,000 per year to less than 30,000 per year. This has increased the exposure to risks that could adversely affect the heath of the city's residents because local authorities are less capable of identifying water quality problems. Additionally, because of the decline of water source quality, the use of chlorine as the only disinfection mechanism is no longer sufficient for providing safe water (Sosa-Rodriguez, 2010a). For example, bacteria such as *Helicobacter pylori*, total coliforms, fecal coliforms, Streptococci and *Vibrio* spp. have been found in some water samples (Mazari-Hiriart et al., 2005).

2.2 Waterborne diseases mortality

Mexico City is the entity in the country with the highest total mortality rate, with 566 deaths per 100,000 inhabitants. The leading causes of death in the capital are chronic degenerative diseases (i.e., heart attacks, diabetes and tumors), with 489 deaths per 100,000 inhabitants. In the case of intestinal infectious diseases (including typhoid, salmonella, bacterial food poisoning, amebiasis, and dysentery), they are the 19th cause of death, accounting for 0.6% of the total deaths in the city. Although in general the intestinal infectious diseases give the impression that they do not constitute a health problem in the city, this is the main cause of death for infants under four years, explaining 9.7% of the total number of deaths in children under four years. The second cause of death in this group was acute lower respiratory infections (8.9% of total deaths in this age group) (Table 2).

In 2007, the Ministry of Health in Mexico City registered 280 deaths due to intestinal infectious diseases: 93.6% of the total deaths were caused by diarrhea and gastroenteritis, and the remaining 6.4% were attributed to salmonella, *clostridium perfringens* poisoning, typhoid fever, amoebic dysentery and viral intestinal infections (Table 2). The largest number of deaths cause by intestinal infectious diseases occurred southeast of the city, and the borough most affected by these diseases was Iztapalapa, where 22.9% of the total deaths were registered.

Group disease	Rate[1]	Group disease	Rate[1]
Chronic-degenerative	489.2	Total Mortality Rate[1]	565.9
Infectious	62.2	Infant Mortality Rate[2]	20
Injuries	40.57		

Type of disease	Position	Number of deaths	Mortality Rate[1]	Intestinal infectious diseases: Disease	Deaths	Proportion
Cardiovascular	1	10 062	114.1			
Diabetes	2	8 270	93.8	Diarrhea/ gastroenteritis	262	93.6
Cancer	3	6 759	76.7	Enteritis salmonella	6	2.1
Intestinal Infections	19	280	3.2	*Clostridium perfringens*	5	1.8
Respiratory Infections	20	272	3.1	Typhoid Fever	2	0.7
	Total	49 882	565.9	Total	280	100.0

1 Rate/100,000 individuals
2 Rate/10,000 live births
Source: Ministry of Health in Mexico City (SSDF), 2007.

Table 2. Mortality rates in Mexico City

3. Water quality management index (*WQI*)

The water quality management index (*WQI*) was estimated by Principal Component Analysis (PCA) to determine to what extent water management in Mexico City is capable of ensuring safe water supply to the city's inhabitants. This method was chosen due to its capacity to summarize several variables that were measured with different units and to simplify the results interpretation.

Another advantage of PCA is that it avoids problems such as multicolinearity and heteroscedasticity; both problems make the parameters of models biased. In the case of multicolinearity, highly correlated variables can complicate the identification of the individual effect that each variable has on the sample. Regarding heteroscedasticity, which is attributed to non-constant variations in the residuals of a model, the variance of the parameters estimated increases.

The input variables used in PCA were selected based on their capacity to explain the effectiveness of the city's water management in providing a safe water supply—that is, water is free of any pathogenic microorganism, metals and toxic substances so that outbreaks of waterborne and other water-related diseases (i.e., endocrine and reproductive damage, poisoning, skin lesions, and cancer) are prevented. These variables included concentrations of residual chlorine (*RChlor*), the presence of fecal coliform bacteria in water samples (*Fecalbac*), the total number of deaths caused by water pollution (*Totalmort*), and the total number of deaths of children under five years due to waterborne diseases (*Infantmort*). The variables water purification and wastewater treatment plants did not contribute to explain the city authorities' performance in ensuring safe water consumption; therefore, they were not included in the estimated model.

The database and the *ad hoc* GIS built—disaggregated by neighbourhood—were based on information reported by the National Water Commission (Conagua), the National Institute of Statistics and Geographical Information (INEGI), and the Mexico City Water System (SACM)—who together comprise the national and local governmental authorities responsible for managing the water in Mexico and Mexico City.

The index was normalized and transformed into decimal units. By using the 'pass'/'fail' criteria defined by the Mexican Educational System for evaluating the performance of students, and the model outputs were assessed in each neighbourhood. This was done to simplify the results for decision makers, who can easily identify in which neighborhoods water quality problems need to be addressed immediately. Therefore, if $WQI_i = 10$, the water management in the neighbourhood i is effective to provide safe water supply. If $WQI_i \geq 6$, then water quality is not problematic and do not endanger people's health in the neighbourhood i. However, if this index is smaller than this value ($0 \leq WQIi \leq 6$), water quality problems must urgently be addressed, as they may present great risk to the inhabitants of the neighbourhood i.

It is important to consider that *WQI* has been based on 2007 data. Therefore, the accuracy and reliability of the resulting model in other spatial and temporal contexts must still be evaluated.

4. Results

According to results of the *WQI* for Mexico City, the city authorities' performance in providing inhabitants with a volume of water that meets quality standards is unsatisfactory. A score of 6.1 is associated with a performance that needs to be improved; consequently, governmental strategies to guarantee safe drinking water have not had the desired results, and low water quality in Mexico City threatens people's health. The equation that resulted from PCA (Table 3) for assessing authorities' performance in providing safe water supply is (Equation 1)

$$WQI = 0.61705\, Fecalbac + 0.60687\, RChlor - 0.12889\, Totalmort - 0.08876\, Infantmort \quad (1)$$

Component 1 Water quality analysis		Component 2 Waterborne diseases mortality	
Variable	Charge	Variable	Charge
RChlor	0.60687	*Infantmort*	-0.12889
Fecalbac	0.61705	*Totalmort*	- 0.08876

Extraction method: Principal component Analysis.
Rotation method: Varimax with Kaiser Normalization

Table 3. *WQI* component score coefficient matrix

It is important to note that only 69.03% of the variability of the sample used to evaluate the city authorities' performance in ensuring safe water supply was explained by the variables incorporated in the model: 36.38% is attributed to the residual chlorine concentrations and fecal coliform existence (the first component); the remaining 32.65% corresponds to deaths caused by water pollution and waterborne diseases (the second component) (Table 4). These results can be modified if other variables, such as morbidity rates of intestinal infectious diseases, are incorporated in the analysis. Unfortunately, in the case of Mexico City, the information available for morbidity rates is not systematized by the origin of the people infected; it is only reported by kind of disease and the health facility involved in treatment.

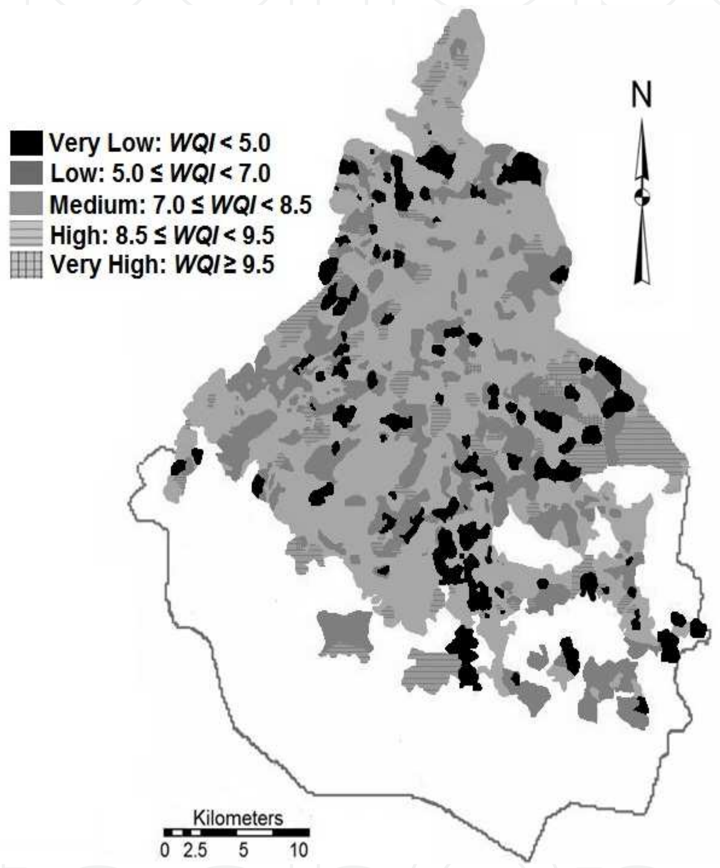
	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	1.345	50.263	50.263	1.068	36.381	36.381
2	1.053	22.455	72.718	1.017	32.653	69.034
3	0.941	15.545	88.263	0.976		
4	0.661	11.737	100.000	0.659		

Extraction Method: Principal Component Analysis
Rotation method: Varimax with Kaiser Normalization

Table 4. *WQI* total variance explained

Although low water quality is a problem widespread in the city, some neighbourhoods are more likely to be affected due to the lack of economic, social and political capacities of their residents to find alternative water sources. These neighborhoods are located south and southeast of Mexico City, and the majority of their residents have low incomes, low education levels, poor housing conditions, and their demands tend not to be a priority of the local government (Figure 1).

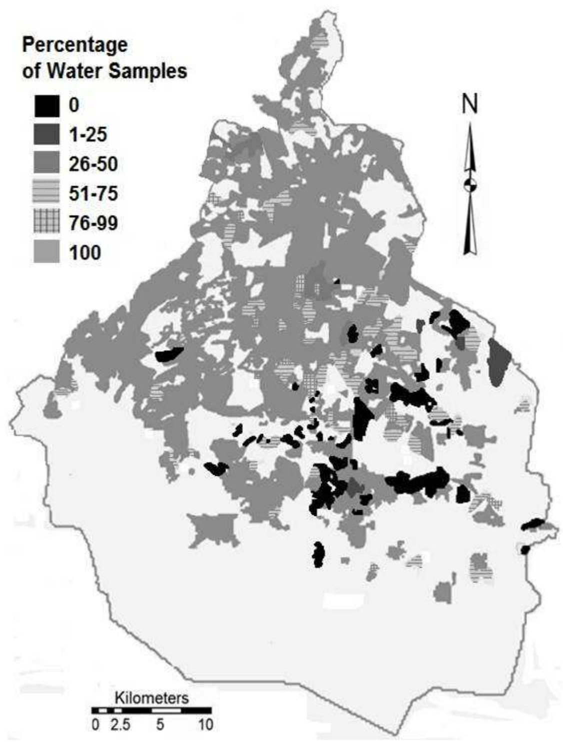
In particular, the areas most affected by the lack of safe water supply as a result of low residual chlorine concentrations are located southeast of Mexico City. The presence of fecal coliform bacteria in some samples that met residual chlorine standards in several neighborhoods confirmed that chlorination does not guarantee the elimination of all pathogenic microorganisms that can affect health.



Source: Based on the results estimated by PCA.

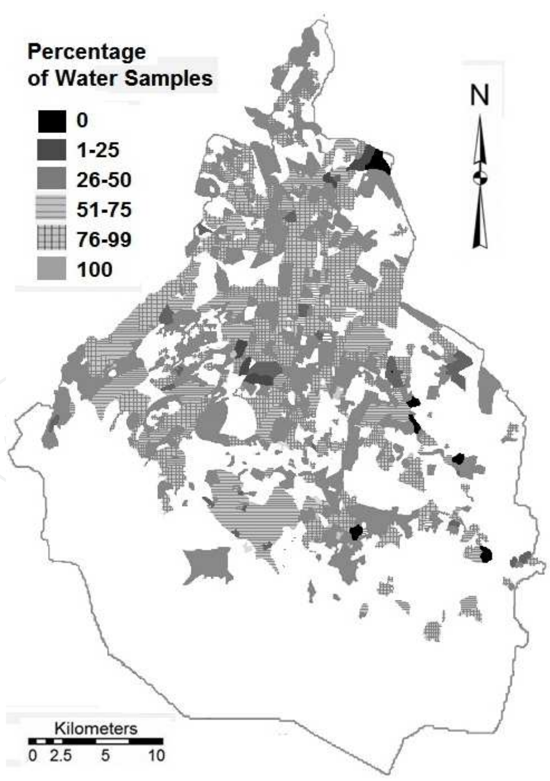
Fig. 1. Water Quality Management Index (WQI)

Furthermore, failure to identify in water samples coliform bacteria, whose presence proves fecal contamination, does not guarantee safe water consumption. Regularly, low concentrations of coliform bacteria (i.e., *E. coli*) are eliminated by disinfection with chlorine (or its derivatives); however, some pathogens can resist chlorine disinfection. For example, enteric viruses and some protozoa that can cause viral and parasitic diseases are more resistant to chlorine disinfection than are fecal coliform bacteria; as a result, these pathogens can survive (Spellman, 2008; WHO, 2008; U.S. EPA, 2001) (Figure 2 and 3). Their removal from drinking water requires alternative water disinfection processes that strengthen chlorine effects. Additionally, water quality varies with changes in temperature, precipitation, pipeline pressure, and intermittent supply, and thus, needs systematic monitoring (Ainsworth, 2004).



Source: SACM Databases (2007): Water Quality Analysis.

Fig. 2. Water Samples that Meet Residual Chlorine Standards



Source: SACM Databases (2007): Water Quality Analysis.

Fig. 3. Water Samples that Meet Fecal Coliform Bacteria Standards

Based on the analysis, improvements in water supply (i.e., infrastructure maintenance and construction, volume supply increase, among others) clearly lead to lower infant mortality rates, but not fewer cases of intestinal infectious diseases. In the case of these diseases, results suggest that advances in sewage disposal and treatment are likely to reduce the number of deaths. This can be explained because greater concentrations of the infrastructure for water supply and sewage disposal are mainly located in the zones that are physically less vulnerable, where live populations with medium and high average income levels (Table 5).

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13
V1	1.000	-0.668	-0.557	-0.054	-0.481	-0.510	0.102	0.422	0.039	-0.042	-0.055	0.161	0.219
V2	-0.668	1.000	-0.596	0.040	-0.172	-0.086	-0.542	0.090	-0.006	-0.347	-0.432	0.039	0.030
V3	-0.557	-0.596	1.000	-0.039	-0.275	-0.266	0.002	-0.228	-0.553	-0.085	-0.095	0.120	0.084
V4	-0.054	0.040	-0.039	1.000	0.023	0.361	-0.595	0.014	-0.022	0.019	0.035	-0.045	0.032
V5	-0.481	-0.172	-0.275	0.023	1.000	0.928	-0.002	-0.680	-0.130	0.671	0.675	-0.684	-0.618
V6	-0.510	-0.086	-0.266	0.361	0.928	1.000	-0.003	-0.643	-0.092	0.579	0.601	-0.657	-0.596
V7	0.102	-0.542	0.002	-0.595	-0.002	-0.003	1.000	0.034	0.293	-0.038	-0.043	0.014	0.077
V8	0.422	0.090	-0.228	0.014	-0.680	-0.643	0.034	1.000	0.159	-0.194	-0.275	0.492	0.652
V9	0.039	-0.006	-0.553	-0.022	-0.130	-0.092	0.293	0.159	1.000	-0.694	-0.755	0.058	-0.025
V10	0.075	-0.006	-0.057	-0.009	0.066	0.090	0.053	-0.063	-0.036	0.034	0.039	-0.052	-0.067
V11	-0.019	0.051	0.007	0.022	-0.050	-0.032	0.016	-0.020	-0.109	-0.020	-0.014	0.027	-0.018
V12	-0.042	-0.347	-0.085	0.019	0.671	0.579	-0.038	-0.194	-0.694	1.000	0.989	-0.302	-0.316
V13	-0.055	-0.432	-0.095	0.035	0.675	0.601	-0.043	-0.275	-0.755	0.989	1.000	-0.313	-0.225
V14	0.161	0.039	0.120	-0.045	-0.684	-0.657	0.014	0.492	0.058	-0.052	0.027	1.000	0.572
V15	0.219	0.030	0.084	0.032	-0.618	-0.596	0.077	0.652	-0.025	-0.067	-0.018	0.572	1.000

V1= Slope
V2= Land Subsidence
V3= Flooding Areas
V4= Water consumption
V5= Households with piped water
V6= Water supply pipeline network
V7= Leaks
V8= Deaths of children under 5 years
V9= Deaths caused by waterborne diseases
V10= Households connected to the sewerage network
V11= Sewerage network
V12= Iliteracy
V13= Low income (less than 6 US dollars per hour)

Note: Each element of the correlation matrix (a_{ij}), known as correlation coefficient (*r*), has a value between -1 and 1. If $|r|$ is close to unity, the relationship among analyzed variables is stronger. When $0 < r \leq 1$, this relationship is positive; when $-1 \leq r < 0$, it is negative; and when $r \approx 0$, there is no relationship among variables.

Table 5. Correlation Matrix

Therefore, people with low income levels are more affected by the lack of these services. Although alternative water sources, such as car tanks, have been used to supply with water the most affected areas of the city, other ways to dispose of sewage are basically to discharge it into rivers, springs, or directly into the soil, polluting the water, air and soil of the affected areas, and thus, increasing waterborne disease occurrence. There was no evidence to conclude that interrupted water supply was related to problems in pipeline network pressure; nevertheless, this water supply problem is shown to be associated with the presence of leaks mainly caused by the city's land subsidence, and lack of pipeline maintenance and their over-capacity operation (Table 5). In this context, water management decision-makers must consider that even though people have access to water supply; this does not ensure safe water consumption since this resource is not always provided continuously and does not always met quality standards.

5. Conclusions

Successful measures to mitigate and prevent negative impacts caused by lack of safe water and adequate sewage discharge and treatment must consider social and spatial differences in people's capacity to cope with low water quality. To this end, alternative methods that support the water management decision-making must be developed, and the use of advanced technological tools, such as Geographical Information Systems (GISs), can improve the identification of those areas most exposed to low water quality, as well as the most vulnerable groups. Thus, the Water Quality Management Index proposed in this chapter is useful for assessing the effectiveness of water management in ensuring safe water consumption. Nevertheless, it is still necessary to evaluate the accuracy and reliability of this index in other spatial and temporal contexts to evaluate its capacity to measure changes in water quality analysis or mortality rates.

On the other hand, the results of the Water Quality Management Index (*WQI*) provide evidence that the use of chlorine to disinfect drinking water is not as effective as is generally thought, so water disinfection needs to be complemented with other methods that can remove a broad spectrum of pathogens such as *E. coli*, *Klebsiella* spp., Faecal streptococci, *Vibriosis*, and *Helicobacter pylori*. These microorganisms have been identified in some water samples in Mexico City, and their presence threatens the health of the city's inhabitants making them more likely to be affected by outbreaks of waterborne diseases. Among methods considered more effective for removing bacteria, inactivate viruses, and protozoa are ozonation, ultraviolet radiation, ion exchange, inverse osmosis, and coagulation; the pathogen target to be removed will dictate the disinfection method selected.

Another measure that can contribute to ensure safe water consumption is to improve the bacteriological water quality analysis by incorporating in the indicators used the presence of enteric viruses (such as *rotavirus* or *adenovirus*), protozoa (Giardia and *Cryptosporidium*) and bacteria (including Fecal Streptococci as *Helicobacter Pylori* and Legionella), in addition to the existence of fecal coliform bacteria. Additionally, it is necessary to evaluate the different routes of waterborne disease transmission, considering both the consumption of polluted water and the ingestion of food irrigated with wastewater or that was prepared in unhygienic conditions.

Finally, it is vital to create an autonomous institution responsible for systematically assessing the physical, chemical and biological characteristics of the water supply to Mexico City's inhabitants. This institution must be independent from the SACM, so it can perform a reliable analysis of the quality of the water—it is difficult to be a judge and defendant simultaneously. This institution should have power to sanction SACM when water quality standards are not met and have the expertise necessary to make recommendations aimed to improving water disinfection.

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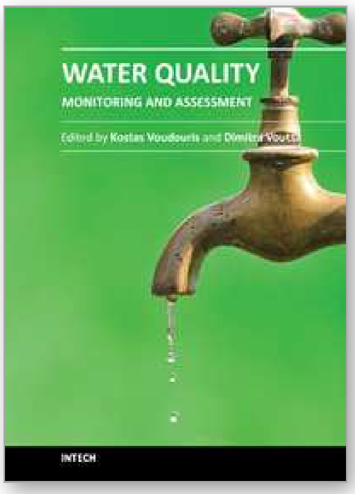

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The book attempts to covers the main fields of water quality issues presenting case studies in various countries concerning the physicochemical characteristics of surface and groundwaters and possible pollution sources as well as methods and tools for the evaluation of water quality status. This book is divided into two sections: Statistical Analysis of Water Quality Data;Water Quality Monitoring Studies.