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Drinking-Water Quality and Intestinal Infectious Diseases in a Colombian Department, 2010-2016

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Materials and methods: A time-trend ecological study. The drinking-water quality of the National Institute of Health and the Institute of Hydrology, Meteorology and Environmental Studies was identified. The disease burden was calculated based on the mortality registered in the National Department of Statistics and the records of morbidity attended by the Social Protection Integrated Information System. The etiological agents reported in morbidity records and the observation of environmental conditions in the municipalities of the study were included. The disease burden was determined according to the methodology recommended by the World Health Organization (WHO).

Keywords: *drinking-water quality, sanitation, intestinal diseases.*

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Drinking-Water Quality and Intestinal Infectious Diseases in a Colombian Department, 2010-2016

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Results: High rates of potential drinking-water quality alteration were observed in 55% of the municipalities and high rates of drinking -water quality risk in 81%. During the period 12161.7 Disability Adjusted Life Years (DALY) were lost per million inhabitants, 42.5% corresponded to the years lost due to premature death in all age groups. The burden of disease attributable to the most affected were those over 60 years old. Although no significant correlation was found between the burden of disease and the drinking-water quality indicator, what is documented through drinking-water quality by region, microbiological results from reported cases and interviews with municipal officials corroborate this.

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I. Introduction

Universal and equitable access to safe and affordable drinking water is one of the major Sustainable Development Goals (SDGs) adopted by many countries worldwide (1). This objective has been part of the pronouncements and follow-up of the Pan American Health Organization for several decades (2); the Millennium Development Goals (UN) (3) and the Sustainable Development Goals and Agenda 2030 (ODS) (4). While there are advances in access to water resources and sanitation, inadequate water resource management, water pollution, and poor land use are some of the environmental factors that, along with social components such as housing, work and community are related to the burden of diseases such as diarrhea, lower respiratory infections, malaria and unintentional injuries (5,6). This calls for a process of monitoring the supply of drinking water to maintain human health and improve economic development (7).

In developed countries, 17% of mortality is attributable to environmental causes, while in developing countries this figure is 25% (8). The population without access to drinking water is forced to seek alternative sources of water lacking in the right conditions to make it drinkable, and so intestinal diseases are more frequent (9). A study assessing the Global Burden of Disease (GBD) shows that more than 25% of diarrheal diseases are due to factors such as inadequate drinking water and sanitation (10). Waterborne microbes are the most common etiological agents of intestinal parasitosis (11).

In Colombia, which is considered a developing country, the richness of its water heritage does not guarantee universal access to drinking water. The areas of the central Andean region where the main agricultural, industrial and mining activities take place, a significant proportion of the population in rural areas, although they have access to water resources, are exposed to water that does not meet the standards required for human consumption. One of the pieces of evidence for this is the association of morbimortality with water quality in the rural area of the municipalities that did not have a high enough drinking-water quality as established by the Colombian regulations (12).

Colombia has implemented the Water Quality Monitoring System for Human Consumption, which aims to verify and evaluate the public health risk of water through routine and continuous monitoring of its microbiological and physicochemical characteristics, in order to guarantee the population high quality water in accordance with the provisions of Resolution 2115 of 2007 and Article 12 of Decree 1575 of 2007. The Water Quality Risk Index (IRCA) for human consumption ranges from 0 to 100 points: 0 points when it complies with all acceptable values and 100 when it does not comply with any of them. The classification of the risk level according to the above criteria indicates the actions to be taken, as follows (13):

IRCA 0 – 5 Water is suitable for human consumption.

IRCA 5,1 – 14 The water is not suitable for human consumption, the risk is low and it is susceptible to improvement.

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IRCA 14,1 – 35 Water is not suitable for human consumption. It presents high risk and requires management with service providers.

IRCA 35,1 – 80 Water is not suitable for human consumption. It presents high risk and requires management with service providers and health authorities.

IRCA 80,1 – 100 The water is unhealthy and unsuitable for human consumption. Management with health authorities is required at all levels.

The department of Caldas (Colombia), located in the Andean region, is one of the departments that presents high scores of drinking-water quality risk index for the population in rural areas. This article documents the characterization of the burden of intestinal disease attributable to drinking-water quality in the sub-regions of this department between 2010-2016 and the relationship with the infectious agents that affect a greater proportion of the population. The results can help guide interventions to increase the coverage of drinking water and make the achievement of sustainable development objectives feasible.

II. Materials and Methods

A time-trend ecological study was carried out to determine the disease burden by intestinal infectious diseases attributable to the drinking-water quality, in a department of the central region of Colombia in the period 2010-2016. Data was obtained on mortality, morbidity by sub-regions, and indices of water quality and potential alteration of drinking-water quality in the department according to hydrographic zones.

III. Morbidity and Mortality

Mortality and morbidity records for infectious intestinal diseases in Colombia are kept by the National Department of Statistics (DANE) and the Comprehensive Social Protection Information System (SISPRO), respectively, using the ICD-10 codes of the International Statistical Classification of Diseases of the Pan American Health Organization (PAHO) (14).

For the morbidity addressed, the codes included were A00 to A09 through which intestinal infectious diseases caused by bacteria, viruses, protozoa and others are identified. Prevalent cases of intestinal infectious diseases attended by health services were obtained using an algorithm that identified the patient only once to avoid duplication. For mortality, records of basic cause or direct cause or previous cause of death were obtained to ensure that all deaths occurred in each of the years 2010 to 2016 in each municipality of the department of Caldas.

IV. Water Quality Indices

The quality of water for human consumption is measured in Colombia through the Water Quality Risk Index (IRC) that measures the physical, chemical and microbiological characteristics of water, which is periodically registered in the "Information System for the Monitoring of Water Quality for Human Consumption-SIVICAP". From SIVICAP (16), the IRCA values were obtained for each of the years under study in each municipality of the department of Caldas.

The Index of Potential Alteration of Water Quality (IACAL), is evaluated from the contaminating loads of organic matter, suspended solids and nutrients exerted by the domestic, industrial and agricultural sectors (17), which are registered periodically (18). IACAL values were obtained from the hydrographic areas of the department.

The identification of the problems related to drinking-water quality and the care of the water heritage were obtained through interviews with officials of the local entities responsible for environmental health in each municipality.

V. Analysis

The annual percentages of mortality and morbidity addressed were calculated for each municipality, by year, sex and age groups, through the number of officially registered deaths as the numerator; and the population projection estimated by DANE for the respective year was used as the denominator. The percentages of mortality and morbidity were adjusted by sex and age, taking the population of Colombia in 2016 as a standard reference according to projections of the DANE census, 2005.

Years of life lost due to premature death.– YLL. This indicator was calculated by sex and age group for each year in two stages: first, the difference between each of the ages of death and life expectancy was obtained. This difference was multiplied by the number of deaths registered for each age. After this calculation, the sum of total YLL for all ages, by sex, department and for each year was recorded.

The formula used to calculate the YLL was the following:

The YLLs are obtained by adding the products of the number of deaths at each age and the difference between this age and a cutoff age.

YEARS OF LIFE LOST (YLL) =

dx = number of deaths at each age

ex = standard life expectancy for each age

l = last age group

The YLL calculation used the life expectancy for each sex and age group according to the Princeton model life table, western family, level 26, modified, published by the Ministry of Health (19) in 2016 in the Asis (Health Situation Analysis) Bulletin. This decision was made to improve the comparability and interpretation of the measurements. For the 0-year-old

and 1 to 4-year-old groups, in both men and women, life expectancies were averaged to form a 0 to 4-year-old group.

Years of life lost due to disability – YLD. These were calculated according to the proposal of the World Health Organization (WHO) in 2010 (20), based on the prevalence of the disease and the estimated time of disability generated by the event in the year.

For the calculations, the disease duration values obtained from the Colombia Burden of Disease Study 2005 (21) were used. The average disability per year (average time of disability) or fraction of the disability time of the event was obtained from the WHO (20). In the absence of a reliable differential standard, its value was considered similar for men and women, as well as constant throughout the period.

Burden of disease per year. This indicator, that integrates the time lost due to premature death and disability, was obtained by age group and sex, adding the YLL and the YLD of the analyzed event.

Systematization and review of the testimonies obtained from officials about problems related to water quality and the care of the water heritage.

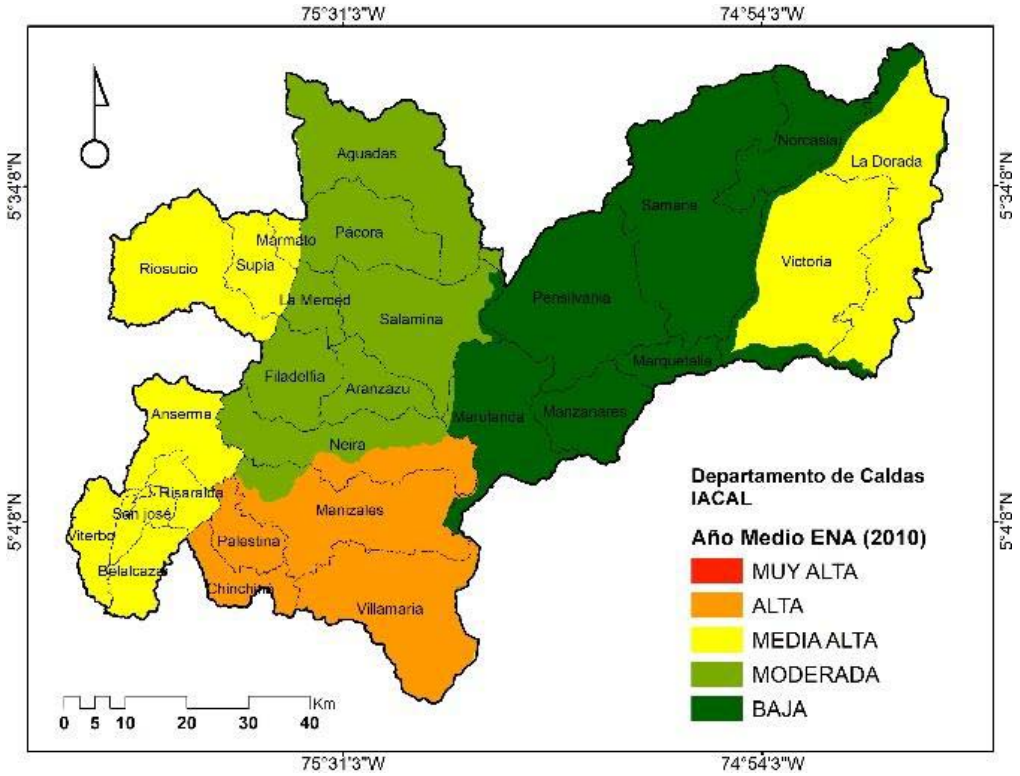
Relationship between water quality and intestinal infectious diseases. The following analyses were performed: a) the correlation between drinking-water quality and disease burden was calculated; b) the correlation between drinking-water quality and toilet and sewerage coverage was calculated; c) the infectious agents reported to SISPRO (Integrated Social Protection Information System) were identified, separated by region; d) The relationship between drinking-water quality and the reports on water coverage and quality declared by the responsible officials of each municipality and subregion was analyzed.

VI. Results

Drinking-water quality results are presented initially, followed by disease burden results.

a) Drinking-water quality

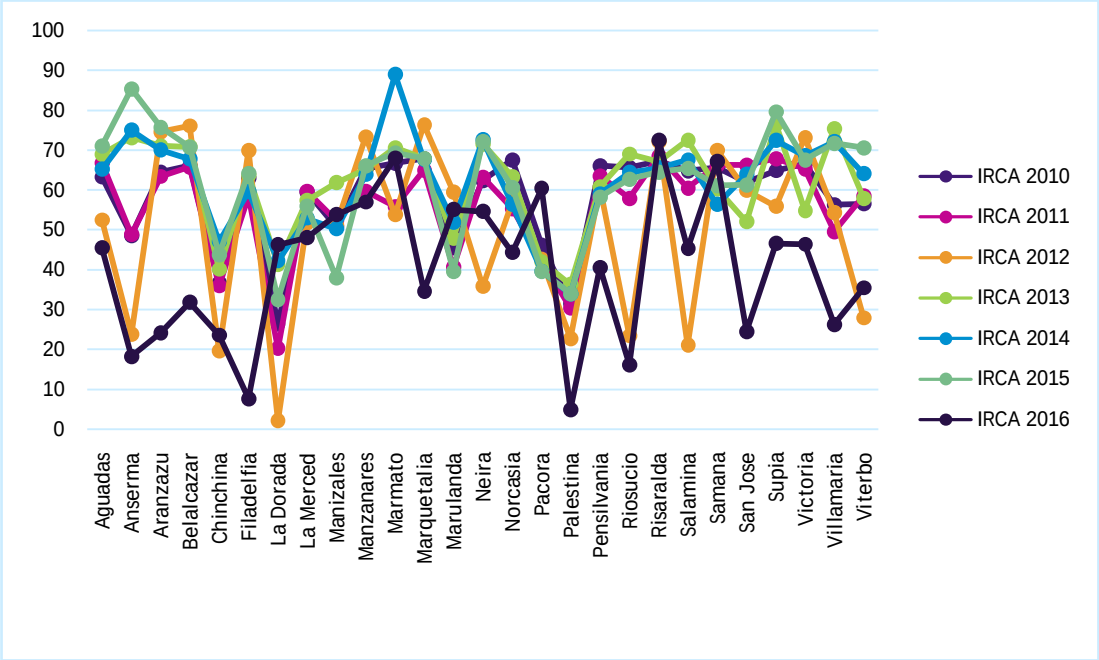
Potential Alteration of Water Quality Index (IACAL) "is the reference of the pressure on the conditions of water quality in the superficial hydric systems of the country". It is calculated based on polluting loads in terms of organic matter (BOD and COD), suspended solids (TSS) and nutrients (Nitrogen and phosphorus). The Colombian Environmental Information System (SIAC) has available the IACAL information from the National Water Study, ENA (shown in Figure 1) for an average year in the hydrographic subzones of interest in the department of Caldas. The potential for water contamination is between low and high. It is observed how the south-central region, the most urbanized area of the department, presents a high index of potential alteration of the drinking-water quality; it is followed by the lower west, upper west region and Magdalena Caldense. The lowest index corresponds to the municipalities of the Upper East region. https://terridata.dnp.gov.co/index-app.html#/mapas



Source: Own Elaboration Based on Information from the Colombian Environmental Information System (SIAC). http://sig.anla.gov.co:8083/

Figure 1: Potential Alteration of Water Quality Index in the department of Caldas

The behavior of the IRCA by municipality (locality) observed during the study period is evidenced in figure 2; only two municipalities present values close to 5. The other municipalities present values between 20 and 80 and more that compromise the viability of the drinking water; and they even become unviable sanitary as in the years 2013 and 2014.



Own elaboration from SIVICAP data

Figure 2: Water Quality Risk Index 2010-2016 Municipalities of the Department of Caldas

b) Burden of Disease from Intestinal Infectious Diseases

Figure 3 shows the adjusted mortality ratio (per million inhabitants) due to intestinal infectious diseases in the population by age group. Mortality occurs from 0 to 4 years of age with a stable behavior until 60 to 69 years of age where it increases; the highest proportions correspond to people over 70 years of age. A trend towards an increase in said mortality is observed in all years, except in 2015.

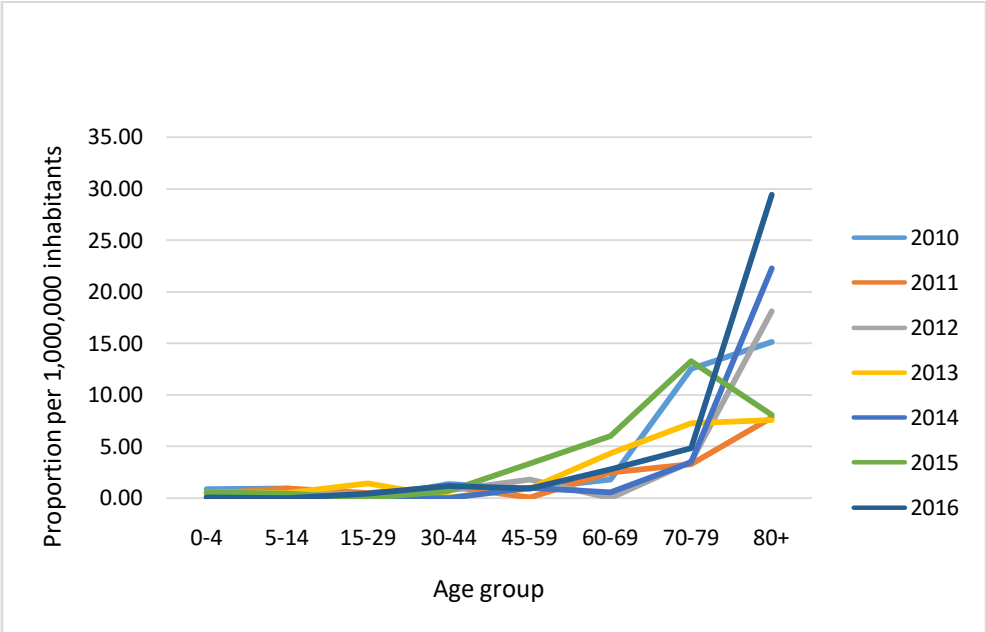


Figure 3: Proportion of Mortality Adjusted by Sex and Age due to Intestinal Infectious Diseases. Caldas 2010-2016

The proportions of morbidity treated per million inhabitants are shown in Figure 4. Morbidity is higher in age groups up to 30 years where it begins to decrease. The highest proportions of morbidity treated in people between 70 and 79 years stand out.

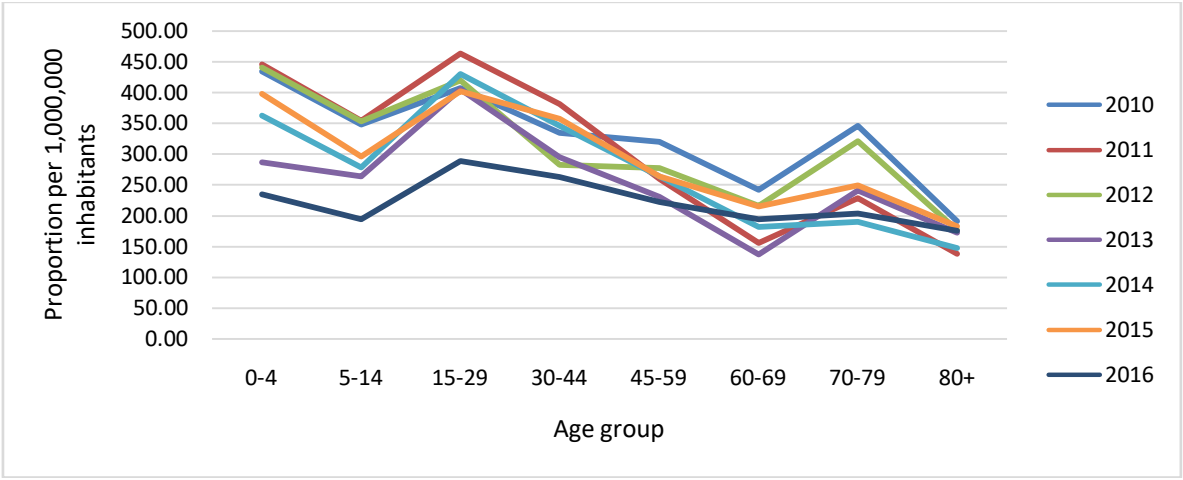


Figure 4: Proportion of Morbidity Treated Adjusted by Sex and Age for Intestinal Infectious Diseases. Caldas 2010-2016

Mortality and morbidity previously exposed resulted in 12,161.7 disability-adjusted life years lost (DALY) in the years 2010 to 2016. Of these, 42.5% correspond to years lost due to mortality, the rest correspond to the disability generated during the event. The behavior of the burden expressed in DALY per million inhabitants according to regions of the department is observed in figure 5. The regions most compromised with the burden of disease due to intestinal infectious diseases are the south-central region, which corresponds to the most urbanized area, and the Magdalena Cal dense area that is a region characterized by a high tourist influx.

An estimate of the burden attributable to water quality as reported by Prüss *et al.* (22) reveals that the consumption of non-potable water alone would be responsible for 34% of the loss of years of life due to intestinal infectious diseases. Taking into account the availability of poor quality water, as well as the deficiencies in sanitation and sewerage, the weight of the burden attributable to the conditions studied would reach 58%, that is, 7053.8 years of life lost due to this cause. This relationship is strengthened even more if the microorganisms reported in the cases of intestinal infectious diseases observed below are analyzed further on.

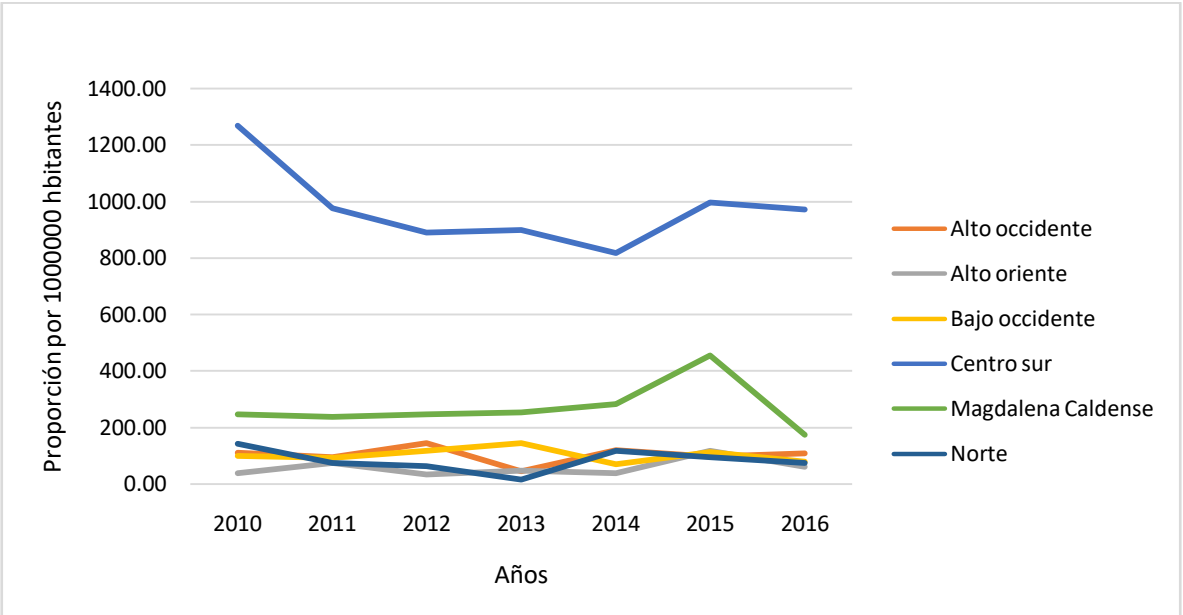


Figure 5: Proportion of Disability-Adjusted Life Years (DALY) associated with Intestinal Infectious Diseases. Caldas 2010-2016

In addition to the behavior of IRCA, the microorganisms reported to SISPRO are the possible relationship between epidemiological behaviors with poor drinking-water quality in the diagnosis of intestinal infectious diseases in the period of interest. (Table1). In all regions, *diarrhea and gastroenteritis of allegedly infectious origin* range from 81.93% in the south-central region to 93.24% in the upper West region between the years 2010 and 2016. In addition, *Shigellosis of unspecified type*; *amebiasis, unspecified*, *viral intestinal infection* and *other viral enteritis* are also reported.

Although this behavior could be associated with other factors such as food consumption and hygiene, it is emphasized that the drinking-water quality from the distribution systems in most municipalities has a high IRCA resulting in unsafe drinking-water for much of the period of interest. Albeit the SSPD defines the public water distribution system as the safe drinking-water, including complementary activities of raw water collection, processing, storage, conveyance and treatment; in the case of rural water systems, activities are mainly for raw water collection, storage and conveyance with poor or no treatment; or failures in drinking-water quality management processes.

Table 1: Infectious Agents Reported in SISPRO by Sub regions of the Department of Caldas 2010-2016.

Infectious Agent	High West	High east	Low West	South center	Magdalena Caldense	North
Cholera due to Vibrio cholerae O1, cholerae biotype/tor/unspecified			x	x	x	x
Typhoid fever A, B, unspecified		x	x	x	x	x
Enteritis, septicemia, unspecified due to Salmonella	x	x	x	x	x	x
Shigellosis due to Shigelladysenteriae, flexneri, boydii, sonnei, and other shiguella infections agents	x	x		x	x	x
Infection due to enteropathogenic / enterotoxigenic, enteroinvasive / enterohaemorrhagic and other Escherichia coli due to E. coli			x	x	x	
Enteritis due to Campylobacter				x		
Enteritis due to Yersinosis enterocolitica					x	
Enterocolitis due to Clostridium difficile			x	x	x	
Other specified bacterial intestinal infections	x	x	x	x	x	x
Forms of amoebiasis: acute, chronic intestinal, colitis, intestinal ameboma, amoebic abscess.	x	x	x	x	x	x
Balantidiasis	x	x		x	x	
Giardiasis giardalambia infection	x	x	x	x	x	x
Isosporiasis		x				
Intestinal disease due to unspecified protozoa			x	x	x	x
Enteritis due to Rotavirus / Adenovirus / Norwalk agent / other viral agents	x	x	x	x	x	x
Diarrhea and gastroenteritis of allegedly infectious origin	x	x	x	x	x	x

Source: Authors' Own Elaboration from cubos.sispro.gov.co SGD_CUBOS PER-atencionesensalud.odc 2010-2016

Although the results show a low correlation (R: -0.246) and not statistically significant correlation between the burden of disease (DALY) and the average IRCA; a negative correlation was observed (R: -0.625 with $p = 0.0000$) between the average of the IRCA with the average of rural urban cleaning. This evidences the negative effect of the poor basic sanitation conditions on the safe drinking water. In addition, the information provided from the municipal officials' interviews revealed the main limitations in the implementation of public policies and programs aimed at guaranteeing a healthy environment and the quality of life of the population. Some of the testimonies of the said limitations by subregion are described below.

Subregions	Municipalities	Environmental problems
High West	Philadelphia, La Merced, Riosucio, Supía, Marmato	All municipalities lack drinking water in rural areas. Only one of them has a Wastewater Treatment Plant (WWTP)
High east	Marulanda, Manzanares, Marquetalia, Pennsylvania	Lack of drinking water in rural areas. The treatment plants supply the municipal capitals. Growth of the agricultural frontier and pollution of the water heritage.
Low West	Anserma, Risaralda, San José, Viterbo, Belalcázar.	Drinking water only in some rural communities. Lack of WWTP, growth of the agricultural frontier, poor inorganic waste management. Intestinal problems are identified due to consumption of polluted water with waste from coffee treatment.
South center	Manizales, Chinchiná, Palestina, Villamaría, Neira.	Limited access to drinking water in rural areas, some are supplied by Empocaldas and Aguas de Manizales. Lack of WWTP. In some places there is poor disposal of solid waste into water sources.
Magdalena Caldense	Samaná, Norcasia, La Dorada, Victoria.	Lack of drinking water in rural areas. Lack of WWTP. Growth of agricultural frontier Poor waste disposal in green areas and water sources due to tourism

Source: Interviews to Officers Responsible for Environmental Health

VII. Discussion

This time-trend ecological study on the relation between the drinking-water quality and the burden of disease caused by the intestinal infectious diseases was conducted from the analysis of the registries of water quality of the SIVICAP and of the reported morbidity and mortality reported by DANE and SISPRO in a department of the central region of Colombia.

Although the supervision of *Servicios Públicos Domiciliarios* (SSPD) reports an increase in the coverage of drainage (24) and in the monitoring of the drinking-water quality (25), it does not guarantee the access to the drinking water for human consumption because the information is usually about the municipal capitals without including the rural communities and dispersed rural area. This limited information disregards the other water recovery (not only human consumption) as the domestic use, the use by the farming and mining sector, inadequate treatment of residual waters, and the growth of tourism in some areas affecting the preservation of the ecosystem (26). Although the WHO (27) in 2015 highlighted the efforts of the countries to increase the drinking water coverage and basic drainage, in 2019 it indicated that around 2 billion people worldwide consumed polluted water with faeces (28). Similarly, Interamerican Networks of Academies of Sciences (29) (IANAS) in that same year stated that despite of the number of efforts made by the different governments since the 70s, the growth of water and drainage services was still too poor to satisfy the needs of quality and quantity for peri-urban and rural communities

The aforementioned is evidenced through microorganisms found in patients with diarrhea or allegedly clinical diagnoses to SISPRO, that raise a possible relation with the quality of the drinking water, because the values of IRCA in all the municipalities indicate a possible risk of diseases due to the consumption of the water. It is possible to indicate that studies conducted on drinking water in Mexico showed the presence of parasites and the poor effectiveness of its treatment (30).

In the analysis of drinking-water quality in Colombia, Roldán *et al* (31) point out the importance of knowing how it affects the population and its burden of disease thus the greater relevance to this study. It is evident that despite the global commitments and the regulations in force in the country and the region, there is still a gap between the guidelines and the results. The implementation of the policies despite the current regulations does not achieve the expected results.

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