Analysis of Health Indicators in Two Rural Communities on the Colombian Caribbean Coast: Poor Water Supply and Education Level Are Associated with Water-Related Diseases

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Abstract. Water-related diseases are closely linked with drinking water, sanitation, and hygiene (WASH) indicators, socioeconomic status, education level, or dwelling's conditions. Developing countries exhibit a particular vulnerability to these diseases, especially rural areas and urban slums. This study assessed socioeconomic features, WASH indicators, and water-related diseases in two rural areas of the Colombian Caribbean coast. Most of this population did not finish basic education (72.3%, $N = 159$). Only one of the communities had a water supply (aqueduct), whereas the other received water via an adapted tanker ship. No respondents reported sewage services; 92.7% ($N = 204$) had garbage service. Reported cases of diarrhea were associated with low education levels ($P = 2.37 \times 10^{-9}$) and an unimproved drinking water supply ($P = 0.035$). At least one fever episode was reported in 20% ($N = 44$) of dwellings, but the cases were not related to any indicator. The *Aedes*/House index (percentage of houses that tested positive for *Aedes* larvae and/or pupae) was 69%, the container index (percentage of water-holding containers positive for *Aedes* larvae or pupae) 29.4%, and the Breteau index (number of positive containers per 100 houses in a specific location) was three positive containers per 100 inspected houses. The presence of positive containers was associated with the absence of a drinking water supply ($P = 0.04$). The community with poorer health indicators showed greater health vulnerability conditions for acquisition of water-related diseases. In summary, water supply and educational level were the main factors associated with the presence of water-related diseases in both communities.

INTRODUCTION

Water-related diseases represent a human health issue that affects several of the world's regions.¹ They are generally classified into four types: *waterborne* (the pathogen is ingested), *water-washed* (person-to-person transmission because of a lack of water for hygiene), *water-based* (transmission via an aquatic intermediate host, as is the case for schistosomiasis), and *water-related insect vector diseases* (with transmission by insects that breed in, or bite near water, as happens with dengue fever and malaria).^{2,3} The burden of morbidity and mortality attributed to these pathologies is linked with several factors that are mainly associated with drinking water, sanitation, and hygiene (WASH) conditions.^{4,5} A recent estimation showed that in 2012, nearly 502,000 diarrhea deaths were caused by inadequate drinking water and another 280,000 deaths by inadequate sanitation.⁵ In total, 842,000 diarrhea deaths are estimated to be caused by WASH conditions annually, which accounts for 1.5% of the total disease burden and 58% of all diarrheal diseases.⁵

The majority of these vulnerable communities are in developing countries, which are influenced by factors commonly exhibited by low-income populations such as lacking public infrastructure to supply basic services, water scarcity, lower adaptable capacity to changing climatic conditions, and low socioeconomic status (i.e., dwelling materials, educational level, occupation, etc.).^{2,3,6,7} The dynamic of these variables on water-related diseases comprises a complex scenario where poverty increases rates of infectious diseases and (consequently)

increases the demand for and expenses of health services, leading to a cycle between poverty and disease.^{8–11}

In 2008, the World Health Organization (WHO) estimated that improving WASH indicators has the potential to prevent at least 9.1% of the disease burden or 6.3% of all deaths globally.¹² In fact, because of the implementation of programs and public policies focused on WASH improvement, during last decades, significant advances have been achieved. In this regard, it has been reported that 2.1 billion people have gained access to improved sanitation facilities since 1990, and it was announced that the global target for access to safe drinking water was met 5 years before Millennium Development Goals deadline.² However, several communities, especially in rural areas, still lack reliable data sources that could improve the decision making process when creating suitable programs/policies to prevent water-related diseases, which supports the persistence of continuous efforts in the study of WASH indicators and other associated factors.

Some communities in the Caribbean need to develop a broader understanding of the status of factors contributing toward the WASH indicators, as an early step to implement focused and contextualized programs. Cartagena de Indias, where at least half of its population live in poverty, is a Colombian Caribbean city where the analysis of WASH conditions would be greatly valuable.^{13–16} This scenario of poverty is even worse in its periurban and rural annexed communities (commonly known as “village”), such as Ararca and Barú. The impoverished populations on the seacoast have little or no access to a proper water supply and sewage, and the available data about WASH conditions and water-related diseases are insufficient, making it difficult to determine current risks to define the appropriate strategies.¹⁷

As a first step toward the creation of public health strategies, a community-based study was carried out with the aim of describing WASH indicators and related socioeconomic

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variables (education, occupation, household income, and household infrastructure) in two communities located in a rural area of the Cartagena de Indias district. In this sense, findings of this work were described through three topics: 1) socioeconomic features, 2) WASH indicators, and 3) water-related diseases (waterborne infections and vectorborne diseases) in the selected communities.

MATERIALS AND METHODS

Study area and sample selection. A cross-sectional study was carried out from 2014 to 2015 in Ararca and Barú, which are two traditional sea-fishing communities in a rural area of the Cartagena de Indias' district. Ararca accounts for 855 inhabitants living in 219 dwellings, located 15 kilometers from the urban area and has direct interaction with Cartagena's bay and the "Dique" channel (an artificial effluent from the Magdalena River); Barú is an island inhabited by 1,894 people living in 448 households, located 34 kilometers from Cartagena de Indias' urban zone, directly on the Caribbean Sea littoral (Figure 1).¹⁵

Subjects and dwellings were selected through a multistage cluster random sampling based on maps obtained from the software Google Maps.^{18,19} The procedure was as follows: 1) house blocks were visually identified and delimited; 2) total area and number of households were measured for each block, to estimate the approximate number of individuals, and 3) a random selection was executed with a probability proportional to estimated size where house blocks were the

primary stage units. These procedures were performed with the package *pps* for software R 3.2.0.²⁰ In the field study, three to five households per block were randomly selected according to WHO suggestions, and then one adult was invited to complete a person-to-person interview.²¹

Sample selection and surveys were carried out in two visits to the community by approaching households and families during morning and afternoon hours on a nonlabor day. This strategy was adopted to reduce the sampling bias previously described in the Cartagena de Indias' urban population, where men are less likely to participate because most of this group is out of the home engaged in occupational activities during domiciliary visits.^{22,23}

To determine whether existing health and socioeconomic conditions of two rural communities of Cartagena, Colombia, have influenced some health indices associated with water-related diseases (frequency of diarrhea, febrile syndrome, and the presence of vectors of infectious diseases), a specific survey was designed and validated to register general aspects of the community and dwelling conditions: Topic 1. Socioeconomics features—health indicators related to safe WASH; Topic 2. WASH indicators and knowledge, attitudes, and practices (KAP) regarding infectious and vectorborne diseases; and Topic 3. Water-related diseases—perceived morbidity by diarrhea and febrile syndrome.

Socioeconomic features, infrastructure, and KAP.

Questions were based on previous surveys applied in Cartagena de Indias' urban area,¹⁶ which were adapted to

FIGURE 1. The map shows the location of the communities in Ararca and Barú, close to urban areas of Cartagena de Indias.

rural populations employing reactions, verbal or written answers, and suggestions of two focal groups from Ararca and one from Barú integrated by five subjects each. After two validation assays, a final formatted survey was generated which was applied to a subsample from both villages to verify its reliability. Finally, 35 questions were included in a definitive survey divided into three main sections and the participants were assessed with this survey: 1) interviewee and family identification, 2) household materials and public services, and 3) community-perceived morbidity.

A trained team: (three professors from the faculty of medicine, two doctoral students in the field of tropical medicine, two health-related professionals, and 12 under-graduate medical students) carried out domiciliary visits and collected data concerning the following: list of family members; education level; occupation; average income; general housing conditions; material of walls; floor and roof; and public services, such as water supply, sewage, garbage collection services, gas, and electricity services. Moreover, material conditions of the dwellings were assessed by taking into account a materiality index, described by others authors.^{24,25} Data for WASH indicators was collected as described by the WHO: improved drinking water sources (piped water into dwelling, plot, or yard; public tap/stand pipe; tube well/borehole or protected dug well; protected spring and rain-water collection), and improved sanitation facilities (flush or pour-flush to: piped sewer system, septic tank, or pit latrine; ventilated, improved pit latrine; pit latrine with slab; and composting toilet).²⁶

Similarly, all subjects were asked to recall the number and features of diarrhea and febrile episodes suffered by

himself/herself or some family member during the previous 12 months. Frequencies and other estimations were catalogued as community-perceived morbidity and used in further analysis.

Exposure to vectorborne diseases: *Aedes*/house, container, and Breteau index. During domiciliary visits, members of the research team were specially trained to perform a systematic inspection focused on detecting risky conditions for vectorborne diseases by following habitual methodology for mosquito surveillance and control previously applied in Cartagena de Indias' urban zone.²⁷ However, in this study, species identification was based on macroscopic characteristics and the presence of eggs was not registered.

The number of receptacles with clean water was recorded for all included households. Also, every receptacle was inspected to determine the presence of *Aedes aegypti* larvae or pupa, as well as other features involved in mosquito breeding and spreading. With registered data, receptacles, and house ratio, house/*Aedes*, container, and Breteau indexes were estimated by taking the definitions set out by WHO into account,^{28,29} and their association with other risk factors was determined.

Data analysis. Categorical variables were summarized as proportions and frequencies, whereas quantitative data were represented as mean values. Data were compared through χ^2 or Fisher's exact test for frequencies and Student's *t* test for means, with *P* value < 0.05 considered as statistically significant.

To determine risk factors and increased expositions, analytical tests were performed by employing software R 3.2.2.³⁰ Categorical results for diarrhea cases, febrile episodes and positive findings of *Ae. aegypti* were used as outcomes and

TABLE 1
Role in family, education, and occupation data from the general population

	Ararca			Barú			Total			P value
	n	(%)	[95% CI]	n	(%)	[95% CI]	n	(%)	[95% CI]	
Role in family										
Grandmother/father	3	(3.1)	[0.8–9.5]	8	(6.5)	[3–12.7]	11	(5.0)	[2.6–9.0]	0.417
Header household	3	(3.1)	[0.8–9.5]	0	(0.0)	[0.0–0.0]	3	(1.4)	[0.3–4.2]	0.162
Mother/father	77	(80.2)	[70.5–87.3]	89	(71.8)	[62.8–79.3]	166	(75.5)	[69.1–80.8]	0.199
Unspecified adult	1	(1.04)	[0.05–6.4]	5	(4.0)	[1.4–9.6]	6	(2.7)	[1.1–6.1]	0.350
Son	10	(10.4)	[5.3–18.7]	18	(14.5)	[9–22.2]	28	(12.7)	[8.7–18.0]	0.483
Grandson	1	(1.04)	[0.05–6.4]	2	(1.6)	[0.2–6.2]	3	(1.4)	[0.3–4.2]	1
Niece/nephew	1	(1.04)	[0.05–6.4]	1	(0.8)	[0–5.0]	2	(0.9)	[0.1–3.5]	1
Unspecified	0	(0.0)	[0.0–0.0]	1	(0.8)	[0–5.0]	1	(0.5)	[0.0–2.8]	1
Total	96	(100)	–	124	(100)	–	220	100	–	–
Education										
None	8	(8.3)	[3.9–16.2]	4	(3.2)	[1.03–8.5]	12	(5.5)	[2.9–9.5]	0.175
Incomplete elementary	28	(29.2)	[20.5–39.4]	27	(21.8)	[15.0–30.2]	55	(25.0)	[19.5–31.3]	0.271
Complete elementary	15	(15.6)	[9.2–24.7]	31	(25.0)	[17.8–33.7]	46	(20.9)	[15.8–27.0]	0.126
Incomplete high school	15	(15.6)	[9.2–24.7]	10	(10.4)	[4.1–14.7]	46	(20.9)	[15.8–27.0]	0.126
Complete high school	20	(20.8)	[13.4–30.5]	22	(17.7)	[11.6–25.8]	42	(19.1)	[14.2–25.0]	0.685
University education	0	(0.0)	[0.0–0.0]	2	(1.6)	[0.2–6.2]	2	(0.9)	[0.1–3.5]	0.593
Technologist	1	(1.04)	[0.05–6.4]	0	(0.0)	[0.0–0.0]	1	(0.5)	[0.0–2.8]	0.897
Technical	7	(7.3)	[3.2–14.9]	6	(4.8)	[1.9–10.6]	13	(5.9)	[3.3–10.1]	0.633
Unspecified	2	(2.1)	[0.3–8.0]	1	(0.8)	[0–5.0]	3	(1.4)	[0.3–4.2]	0.822
Total	96	(100)	–	124	(100)	–	220	100	–	–
Occupation										
Employee	22	(22.9)	[15.2–32.8]	34	(27.4)	[19.9–36.2]	56	(25.5)	[19.9–31.8]	0.545
Housewife	61	(63.5)	[53.0–72.9]	61	(49.2)	[40.1–58.2]	123	(55.9)	[49.0–62.5]	0.046*
Unemployed	7	(7.3)	[3.2–14.9]	15	(12.1)	[7.1–19.4]	22	(10.0)	[6.5–14.9]	0.341
Student	5	(5.2)	[1.9–12.2]	12	(9.7)	[5.3–16.6]	17	(7.7)	[4.7–12.2]	0.328
Retired	1	(1.04)	[0.05–6.4]	1	(0.8)	[0–5.0]	2	(0.9)	[0.1–3.5]	1
Total	96	(100)	–	124	(100)	–	220	100	–	–

CI = confidence interval. A χ^2 test was performed to determine statistical differences between the Ararca and Barú populations.

* *P* value < 0.05.

associated through multivariate logistic regression to head of household sociodemographic characteristics, WASH indicators, household conditions, and KAPs. Ordinal-dependent variables, such as the number of diarrhea or fever episodes per family and number of positive recipients, were analyzed with a logistic regression model.

To define health determinants, a holistic approach was performed where all outcomes and independent variables were included through a random forest analysis, as other authors have described it.^{31,32} This procedure was expected to describe multiple interactions in health and disease dynamics based on community-perceived morbidity. These procedures were executed using the package *rpart* for R 3.2.0.

RESULTS

A total of 220 surveys were included, 96 (43.6%) from Ararca and 124 (56.4%) from Barú. Most of the respondents were women (81.8%, $N = 180$), mainly heads of household and housewives, with an average age of 41.7 ± 17.4 years. Men were in minority (18.2%, $N = 40$), with mean age of 48.5 ± 16.8 years, despite the sampling strategies being carried out with the aim of increasing their participation. These results seem to show that men engaged in work activities during regular business hours might not to be a major cause of male underrepresentation.

Socioeconomic features. Among respondents, incomplete elementary school was the most frequent education level (25%, $N = 55$), followed by completed elementary (20.9%, $N = 46$), and

not completed high school (20.9%, $N = 46$). Interestingly, 5.5% ($N = 12$) never received a formal education (Table 1). Less than one-third, 26.4% ($N = 58$), completed higher education or received some technical or professional education. Completed university education was almost exclusive to younger groups (Figure 2A).

Economic activities related to tourism were the most frequent occupation for family sustainability (22.7%, $N = 50$), with trading (14.1%, $N = 31$), and fishing (13.6%, $N = 30$) in second place. Other frequent occupations were masonry (10.0%, $N = 22$) and security services (5.9%, $N = 13$). A total of 23 (11.0%) interviewees were unemployed at the time of this survey (Table 2).

Figure 2B shows the average age of those who carry out the occupations to obtain the income in the household. Retired subjects had the highest average age (56.4 ± 15.2), whereas subjects dedicated to electricity (27 $\pm$ 8.5) and transport services (33.3 ± 7.7) showed lowest averages. The average ages of the most common occupations tourism, trading, and fishing were 35.6 ± 14.9 , 45.1 ± 19.9 , and 47.2 ± 18.9 years ($P = 0.036$), respectively.

Dwelling condition and materiality. Most of the houses were owned by the interviewees (82.3%, $N = 181$), 12.5% ($N = 28$) were paying rent, and 5% ($N = 11$) resided in a property owned by a third party without paying. Concrete was predominant material for the walls (48.6%) and floor (49.5%), and asbestos (79.1%) was the predominant material for the ceiling ($N = 174$) (Table 3). To define a dwelling's general condition, the index of materiality was used as a guideline^{24,25}; according to that

FIGURE 2. (A) Ages of the different groups taking the education grade into account: none, incomplete elementary school, completed elementary school, incomplete high school, completed high school, technical, technologist, university education ($P < 2.2 \times 10^{-16}$). (B) AG = agriculture; BE = beautician; CS = clean services; CAR = carpentry; ES = electricity services; EDU = education; FIS = fishing; MS = mechanical services; MA = masonry; RE = retired; SS = security services; TOU = tourism; TR = trading; TRA = transportation services; UM = unemployed; VS = various services. In this figure, average ages according to occupation are shown ($P = 0.0369$).

TABLE 2
Frequency of occupations performed for household income

Household income	Ararca			Barú			Total			P value
	n	(%)	[95% CI]	n	(%)	[95% CI]	n	(%)	[95% CI]	
Masonry	7	(7.3)	[3.2–14.9]	15	(12.1)	[7.1–19.4]	22	(10.0)	[6.5–14.9]	0.341
Carpentry	2	(2.1)	[0.3–8.0]	1	(0.8)	[0–5.0]	3	(2.4)	[0.3–4.2]	0.822
Agriculture	3	(3.1)	[0.8–9.5]	4	(3.2)	[1.03–8.5]	7	(3.2)	[1.4–6.7]	1
Trade	1	(1.04)	[0.05–6.4]	30	(24.2)	[17.1–32.8]	31	(14.1)	[9.9–19.5]	2.61 × 10 ^{-3*}
Transportation	6	(6.3)	[2.5–13.6]	2	(1.6)	[0.2–6.2]	8	(3.6)	[1.7–7.3]	0.144
Tourism	26	(27.1)	[18.7–37.2]	24	(19.4)	[13.0–27.6]	50	(22.7)	[17.4–28.9]	0.232
Education	2	(2.1)	[0.3–8.0]	2	(1.6)	[0.2–6.2]	4	(1.8)	[0.1–3.6]	1
Retired	4	(4.2)	[1.3–10.9]	1	(0.8)	[0–5.0]	5	(2.3)	[0.5–4.8]	0.229
Fishing	16	(16.7)	[10.1–25.9]	14	(11.3)	[6.5–18.5]	30	(13.6)	[9.5–19.2]	0.339
Beautician	0	(0.0)	[0.0–0.0]	3	(2.4)	[0.6–7.4]	3	(1.4)	[0.3–4.2]	0.342
Security services	7	(7.3)	[3.2–14.9]	6	(4.8)	[1.9–10.6]	13	(5.9)	[3.1–10.1]	0.633
Electricity services	0	(0.0)	[0.0–0.0]	2	(1.6)	[0.2–6.2]	2	(0.9)	[0.1–3.5]	0.593
Mechanical services	2	(2.1)	[0.3–8.0]	0	(0.0)	[0.0–0.0]	2	(0.9)	[0.1–3.5]	0.368
Cleaning services	1	(1.04)	[0.05–6.4]	5	(4.0)	[0.05–9.6]	6	(2.7)	[1.1–6.1]	0.350
Various trades	6	(6.3)	[2.5–13.6]	5	(4.0)	[1.4–9.6]	11	(5.0)	[2.6–9.0]	0.662
Unemployed	13	(13.5)	[7.6–22.4]	10	(8.1)	[4.1–14.7]	23	(11.0)	[6.8–15.4]	0.273
Total	96	(100)	–	124	(100)	–	124	(100)	–	–

CI = confidence interval. A comparison between both populations in Ararca and Barú was completed by performing a χ^2 test.

* P value < 0.05.

index, materiality was acceptable in 76.4% ($N = 168$) of households, recoverable in 15.5% ($N = 34$), and unrecoverable in 5.9% ($N = 13$); in five homes, this index could not be determined. In a similar manner, according to the interviewer's perception, the general condition of households was excellent in 8.2% ($N = 18$) of dwellings; good in 38.6% ($N = 85$), regular in 37.7% ($N = 83$), and 12.7% ($N = 28$) were in bad condition. In 2.7% ($N = 6$) of households, the general condition was not specified (Table 3).

Water supply: improved drinking water supply. Noteworthy, a difference observed between Ararca's and Barú's drinking water supply was the availability of aqueduct service,

purchased water, water storage, and rainwater (Table 4). Recently, Ararca's population was supplied with a centralized aqueduct that works intermittently, whereas Barú Island receives weekly rations of water through an adapted tanker ship; this water is known to be inadequate for human consumption because of contamination during transportation; however, authorized sellers generally sell it to the population.

In summary, only 40.9% ($N = 90$) of households receive water through an aqueduct service, generally twice daily. In 94 dwellings (42.7%), water is supplied with a combination of rainwater collection and payment to an authorized seller, and in 36 dwellings (16.4%), multiple sources (e.g., reservoir,

TABLE 3
Composition and characteristics of household floor, roof, and walls

	Ararca			Barú			Total			P value
	n	(%)	[95% CI]	n	(%)	[95% CI]	n	(%)	[95% CI]	
Floor materials										
Cement	51	(53.1)	[42.7–63.2]	58	(46.8)	[37.8–55.9]	109	(49.5)	[42.7–56.3]	0.424
Wood	0	(0.0)	[0.0–0.0]	1	(0.8)	[0–5.0]	1	(0.5)	[0.0–2.8]	1
Bricks	0	(0.0)	[0.0–0.0]	1	(0.8)	[0–5.0]	1	(0.5)	[0.0–2.8]	1
Tile	33	(34.4)	[25.1–44.8]	60	(48.4)	[39.3–57.4]	93	(42.3)	[35.7–49.2]	0.051
Earth	10	(10.4)	[5.3–18.7]	3	(2.4)	[0.6–7.4]	13	(5.9)	[3.3–10.1]	0.027*
Unspecified	2	(2.1)	[0.3–8.0]	1	(0.8)	[0–5.0]	3	(1.4)	[0.3–4.2]	0.822
Total	96	(100)	–	124	(100)	–	124	(100)	–	–
Roof materials										
Cement	2	(2.1)	[0.3–8.0]	6	(4.8)	[1.9–10.6]	8	(3.6)	[1.7–7.3]	0.471
Wood	1	(1.04)	[0.05–6.4]	7	(5.6)	[2.4–11.7]	8	(3.6)	[1.7–7.3]	0.148
Bricks	1	(1.04)	[0.05–6.4]	0	(0.0)	[0.0–0.0]	1	(0.5)	[0.0–2.8]	0.897
Fiber cement	71	(74.0)	[63.8–82.1]	103	(83.1)	[75.0–88.9]	174	(79.1)	[72.9–84.1]	0.138
Zinc	18	(18.8)	[11.7–28.2]	7	(5.6)	[2.4–11.7]	25	(11.4)	[7.6–16.4]	0.004*
Unspecified	3	(3.1)	[0.8–9.5]	1	(0.8)	[0–5.0]	4	(1.8)	[0.5–4.8]	0.442
Total	96	(100)	–	124	(100)	–	124	(100)	–	–
Wall materials										
Cement	49	(51.0)	[40.6–61.3]	58	(46.8)	[37.8–55.9]	107	(48.6)	[41.8–55.4]	0.622
Wood	17	(17.7)	[10.9–27.1]	15	(12.1)	[7.1–19.4]	32	(14.5)	[10.3–20.6]	0.328
Bricks	25	(26.0)	[17.8–33.1]	44	(35.5)	[27.2–44.6]	69	(31.4)	[25.3–38.0]	0.176
Tile	2	(2.1)	[0.3–8.0]	2	(1.6)	[0.2–6.2]	4	(1.8)	[0.5–4.8]	1
Fiber cement	0	(0.0)	[0.0–0.0]	3	(2.4)	[–0.3–5.1]	3	(1.4)	[0.3–4.2]	0.342
Unspecified	3	(3.1)	[0.8–9.5]	2	(1.6)	[0.6–7.4]	5	(2.3)	[0.8–5.5]	0.771
Total	96	(100)	–	124	(100)	–	124	(100)	–	–

CI = confidence interval. The populations were compared by performing a χ^2 test.

* P value < 0.05.

TABLE 4
Characteristics of public water services

Drinking water	Ararca			Barú			Total			P value
	n	(%)	[95% CI]	n	(%)	[95% CI]	n	(%)	[95% CI]	
Yes	90	(93.75)	[86.3–97.4]	0	0	[0.0–0.0]	90	(40.9)	[34.4–47.7]	< 2.2 × 10 ^{-16*}
No	6	(6.25)	[2.5–13.6]	124	(100)	[100.0–100.0]	130	(59.1)	[52.2–65.5]	
Total	96	(100)	–	124	–	(100)	220	(100)	–	–
Service										
Aqueduct	90	(93.7)	[86.3–97.4]	0	(0)	[0.0–0.0]	90	(40.9)	[34.4–47.7]	< 2.2 × 10 ^{-16*}
Aqueduct only	31	(32.3)	[23.3–42.7]	0	(0)	[0.0–0.0]	31	(14.1)	[9.9–19.5]	3.32 × 10 ^{-8*}
Aqueduct and store	59	(61.4)	[50.9–70.0]	0	(0)	[0.0–0.0]	59	(26.8)	[21.1–33.2]	< 2.2 × 10 ^{-16*}
Purchase	1	(1.04)	[0.05–6.4]	90	(72.6)	[63.7–80.0]	91	(41.4)	[34.8–48.1]	< 2.2 × 10 ^{-16*}
Purchase only	1	(1.04)	[0.05–6.4]	0	(0)	[0.0–0.0]	1	(0.5)	[0.0–2.8]	0.897
Purchase and others†	0	(0)	[0.0–0.0]	90	(72.6)	[63.7–80.0]	90	(40.9)	[34.4–47.7]	NA
Store	64	(66.7)	[56.2–75.7]	106	(85.5)	[77.7–90.9]	170	(77.3)	[71.0–82.5]	0.0016*
Store only	5	(5.2)	[1.9–12.2]	0	(0)	[0.0–0.0]	5	(2.3)	[0.8–5.5]	0.0344*
Store and others†	59	(61.5)	[0.0–0.0]	106	(85.5)	[17.8–33.8]	165	(75)	[68.6–80.4]	3.58 × 10 ^{-4*}
Rainwater	0	(0)	[0.0–0.0]	95	(98.9)	[93.9–99.9]	95	(43.2)	[36.5–50.0]	< 2.2 × 10 ^{-16*}
Rainwater only	0	(0)	[0.0–0.0]	1	(0.8)	[0–5.0]	1	(0.5)	[0.0–2.8]	1
Rainwater and others†	0	(0)	[0.0–0.0]	94	(97.9)	[91.9–99.6]	94	(42.7)	[36.1–49.5]	< 2.2 × 10 ^{-16*}

CI = confidence interval.

* P value < 0.05.

† Others: corresponding to stored water, tanker ship, ground well, reservoir, and public fountain.

tanker ship, public fountain or well, payment to sellers) are used. Regardless of the source, 77.3% ($N = 170$) of interviewees reported storing water in specific receptacles to extend the domestic water supply (Table 4). According to responders, drinking water was maintained in covered receptacles in 80.9% ($N = 178$) of households, but in 15.5% ($N = 34$), it was stored in uncovered receptacles. In the remaining 0.9% ($N = 2$), it was not specified if households covered the receptacles used for the water supply. Because of these factors, in-home water management was found to be a critical task. When asked which of the family members were responsible for water storage, parents were generally in charge: mothers in 41.8% ($N = 92$) of cases and fathers in 34.5% ($N = 76$) of cases.

Besides the water supply patterns described, data on systematic practices for domiciliary treatment of drinking water were also collected. It was found that a large proportion of surveyed families do not apply any treatment to water before consuming it (41.1%, $N = 108$), and among those cases where some treatment was used ($N = 112$), boiling was the most frequent method (53.6%, $N = 60$), followed by filtering (15.2%, $N = 17$), adding sodium hypochlorite (14.3%, $N = 16$), other methods (9.8%, $N = 11$), and straining it (7.1%, $N = 8$). In

Ararca, 75% ($N = 72/96$) of households do not apply any treatment; in Barú 29% ($N = 36/124$) of households do not apply any treatment. For the cases where some treatment was used, almost all of Ararca's population used boiling as water management (22%, $N = 21/96$); but in Barú, more variety was found: boiling (31%, $N = 39$), filtering (14%, $N = 17$), adding sodium hypochlorite (12%, $N = 15$), other methods (8%, $N = 10$), and straining it (6%, $N = 7$). When both populations (Ararca and Barú) were compared, significant differences were found, ($P < 8.71 \times 10^{-11}$).

Sewage: improved sanitation facilities. Neither Ararca nor Barú have a centralized sewage system; therefore, all surveyed dwellings use alternative methods for sewage disposal. Most households (62.3%, $N = 137$) use a septic tank system that is considered an improved sanitation source; however, the other 37.7% use nonimproved sources, such as throwing sewage into an open field (20.5%, $N = 45$), an open pit or latrine without a slab (10.5%, $N = 23$), or going to a neighbor's house (6.8%, $N = 15$). Although in both communities, a septic tank was the most frequently used system, the percentage was lower in Ararca (50%, $N = 48$) than in Barú (71.8%, $N = 89$) ($P = 0.001$). In addition, more than one-third of Ararca's population (35.4%, $N = 34$) mentioned throwing sewage into an

TABLE 5
Family member who suffers episodes of diarrhea most frequently

Categories	Ararca			Barú			Total			P value
	n	(%)	[95% CI]	n	(%)	[95% CI]	n	(%)	[95% CI]	
Adults										
Grandfather/mother	2	(3.3)	[0.5–12.7]	4	(3.5)	[1.1–9.1]	6	(3.4)	[1.4–7.6]	1
Father	12	(20.3)	[11.3–33.2]	27	(23.5)	[16.2–32.4]	39	(22.4)	[16.5–29.4]	0.78
Mother	16	(27.1)	[16.7–40.4]	29	(25.2)	[17.7–34.3]	45	(25.9)	[19.6–33.1]	0.92
Adults (others)	1	(1.7)	[0.0–10.2]	7	(6.1)	[2.6–12.5]	8	(4.6)	[2.1–9.1]	0.26
Children										
Children (son/daughter)	25	(42.4)	[29.8–55.8]	45	(39.1)	[30.2–48.7]	70	(40.2)	[32.9–47.9]	0.80
Children (others)	3	(5.1)	[1.3–15.0]	3	(2.6)	[0.6–8.0]	6	(3.4)	[1.4–7.6]	1
Total†	59	(100)	–	115	(100)	–	174	(100)	–	–

CI = confidence interval.

* P value < 0.05.

† Of 220 surveyed subjects, a total of 79.1% ($N = 174$) answered this question. The remaining 19.9% ($N = 46$) mentioned that they did not know which family member most frequently suffered episodes of diarrhea, so these data were not taken into account in the analysis.

TABLE 6
Community knowledge and perception of suspected causes of diarrhea

Categories	Ararca			Barú			Total			P value
	n	(%)	[95% CI]	n	(%)	[95% CI]	n	(%)	[95% CI]	
Unsafe water (N = 49; 22.3%)										
Only	19	(19.8)	[12.6–9.4]	20	(16.1)	[10.3–20.0]	39	(17.7)	[13.0–23.5]	0.597
And parasites	1	(1.0)	[0.05–6.4]	2	(1.6)	[0.27–6.2]	3	(1.4)	[0.35–4.25]	1
And food poisoning	4	(4.2)	[1.3–10.9]	1	(0.8)	[0.0–5.0]	5	(2.3)	[0.83–5.51]	0.229
And others	1	(1.0)	[0.05–6.4]	1	(0.8)	[0.0–5.0]	2	(0.9)	[0.15–3.59]	1
Food poisoning (N = 63; 28.6%)										
Only	24	(25.0)	[16.9–35.0]	31	(25.0)	[17.8–33.7]	55	(25.0)	[19.5–31.3]	1
And parasites	0	(0.0)	[0.0–4.7]	1	(0.8)	[0.0–5.0]	1	(0.5)	[0.02–2.8]	1
And others	1	(1.0)	[0.05–6.4]	1	(0.8)	[0.0–5.0]	2	(0.9)	[0.15–3.59]	1
Parasites (N = 22; 10%)										
Only	5	(5.2)	[1.9–12.2]	12	(9.7)	[5.3–16.6]	17	(7.7)	[4.7–12.2]	0.328
And others	0	(0.0)	[0.0–4.7]	1	(0.8)	[0.0–5.0]	1	(0.5)	[0.02–2.8]	1
Others (N = 51; 23.2%)										
Only	14	(14.6)	[8.4–23.5]	32	(25.8)	[18.5–34.5]	46	(20.9)	[15.8–27.0]	0.062
Unknown cause (N = 37; 16.8%)	15	(15.6)	[9.2–24.7]	22	(17.7)	[11.6–25.8]	37	(16.8)	[12.2–22.5]	0.814
Unspecified (N = 6; 2.7%)	6	(6.3)	[2.5–13.6]	0	(0.0)	[0.0–3.7]	6	(2.7)	[1.1–6.1]	0.016*
Does not apply† (N = 6; 2.7%)	6	(6.3)	[2.5–13.6]	0	(0.0)	[0.0–3.7]	6	(2.7)	[1.1–6.1]	0.016*
Total	96	(100)	–	124	(100)	–	220	(100)	–	–

CI = confidence interval.

* P value < 0.05.

† Does not apply: respondents who did not report diarrhea cases; therefore, no causes were mentioned.

open field, compared with Barú, wherein this behavior was found in 8.9% (N = 11) of its surveyed households ($P = 2.98 \times 10^{-6}$). The second most used system in this latter community was latrine in 11.3% (N = 14), followed by going to a neighbor's house 8.1% (N = 10).

Garbage collection services. A total of 92.7% (N = 204) of households had garbage collection services: 92.3% (N = 203) of them with a periodicity of three times per week and 0.4% (N = 1) monthly. The remaining 7.3% (N = 16) did not have this service, so this group employs alternative methods such as burning (3.2%, N = 7), throwing the garbage into an open field (1.4%, N = 3), or a combination of both practices (0.9%, N = 2). Ararca and Barú were similar in percentage of presented garbage collection services, with 91.7% (N = 88) and 93.6% (N = 116), respectively. For the remaining 8.3% (N = 8) and 6.5% (N = 8) in each village, the garbage was burned or thrown into an open field. No statistically significant differences were found between the two populations ($P = 0.6389$).

Gas and electricity services. In Ararca, gas is regularly provided through a public centralized system; however, in Barú, authorized distributors sell gas for domestic use in tanks. Thus, 83.2% (N = 183) of the communities' families use natural gas for daily cooking, but the remaining 16.8% (N = 37) use electric stoves or woodstoves, especially in Ararca. In this sense, frequencies between both populations showed differences in the number of households with gas service: 95.2% (N = 118) in Barú and 67.7% (N = 65) in Ararca ($P = 1.82 \times 10^{-7}$).

Both villages have regular access to electricity provided by a centralized system, which suffers sporadic power shortages due to a generalized deficit in network maintenance. Accordingly, almost the entire sample has daily electricity services (98.6%, N = 217). There were no statistically significant differences between both communities, ($P = 0.58$).

Waterborne diseases—KAP and community-perceived morbidity. *Diarrhea: perceptions and knowledge.* To describe the frequency of diarrhea cases, interviewees were asked to recall all the episodes suffered by himself/herself or a family member during the previous 12 months. Under these conditions, 66.4% (N = 146) of subjects reported at least one episode during the previous year, of which 31.9% (N = 46) occurred in the past 6 and 12 months, 11.1% (N = 16) in the past 3 and 6 months, 11.8% (N = 17) in the past 1 and 3 months, and 46.7% (N = 67) occurred in the month before this survey. In addition, the number of episodes recalled was also registered as a range of cases: 91.0% (N = 131) presented one to five episodes, 6.3% (N = 9) 6 to 10 episodes, 1.4% (N = 2) 11 to 20 episodes, 0.7% (N = 1) 20 to 30 episodes, and 0.7% (N = 1) more than 30 episodes. From the total sample, the remaining 33.4% (N = 74) did not recall any episode. The frequency of diarrhea cases in the last 12 months was higher in Barú (73.4%, N = 91) than in Ararca (57.3%, N = 55), ($P = 0.01$).

Regarding the most recent episode of diarrhea, the affected family member most often mentioned was a child (27.3%, N = 60), followed by the mother (25.9%, N = 57) and the father (17.7%, N = 39); other family members, including grandparents (1.8%, N = 4) or an uncle or aunt (3.6%, N = 8), were less reported. Only 0.5% (N = 1) of the population reported that all members of the family suffered the disease recently; 2.7% (N = 6) did not specify which member of the family was affected, and a total of 20.5% (N = 45) mentioned that no one in the family suffered the pathology recently.

To determine vulnerable subgroups within the community, interviewees were also encouraged to identify the family member who most frequently suffers from episodes of diarrhea. For this purpose, structured categories were suggested as follows: "father," "mother," "children (son/daughter),"

FIGURE 3. (100%, $N = 220$). A decision tree graph that shows what predictor variables have the greatest influence on the response variable: presence (1) or absence (0) of diarrhea cases in the population. As shown in the upper box, the numbers placed on top of each charts refers to main generated nodes during the building of the tree. Each node is a cluster that is created by taking into account the included predictor variables in the model; in this case, those related with socioeconomic states, public services supply, and general household conditions, with their different categories or subclasses as have been described in the tables of this document. The alternatives that emerge from each node represent partitions of an initial cluster: from one side emerges a group in which the predictor variable of this node is present ("yes"), whereas from the other side, emerges a cluster in which it is absent ("no"). Thus, the two percentages located in the middle of the boxes represent the probabilities for response variable (e.g., diarrhea) according to every cluster features. Example: In node 1, of the 220 analyzed cases, 74 (34%) have not the response variable described in the node ("1"; presence of diarrhea case) and the remaining 146 (66%) do have it. The tree shows that predictor variables with the greatest influence on the response variable in this case were rainwater, household income, material of walls, and roof of the dwellings, and thereby, other variables including aqueduct service and the supply of garbage did not have enough influence to be in the generated tree. The subclasses of the predictors' variables in each node have the same influence on response variable, for example, material of walls: bricks or concrete, have the same effect, as well as, the roof's material: wood, zinc, or concrete. Particularly, in this node (5), variables such as having a roof made of these materials (wood, zinc, or concrete) was related with the absence of diarrhea cases, and this trend continues if incomes come from occupations such as tourism or trade; otherwise the disease occurs.

"grandmother/father," "children (others)," and "adults (others)." In a total of 79.1% ($N = 174$) of surveyed households, it was identified at least a family member as more susceptible; among these registered, the group "children (son/daughter)" was most frequently referred to 40.2% ($N = 70$); the remaining 19.9% ($N = 46$) responded that they did not know which family member most frequently suffered episodes of diarrhea. There was no statistically significant difference between the communities (Table 5).

To assess the community's knowledge and perception, responders were initially asked about the suspected causes of diarrhea in the family. Food poisoning was identified as the most frequent suspected etiology (25.0%, $N = 55$), followed

by unsafe water (17.7%, $N = 39$), and only 7.7% ($N = 17$) of answers corresponded to intestinal parasite infections. It is important to note that 19.5% ($N = 42$) of subjects answered with an "unknown" or "unspecific" cause to diarrhea episodes, and 20.9% ($N = 46$) of the total sample mentioned different causes, which had to be categorized as "other" because of the remarkable diversity among them. There was no statistically significant difference between both communities (Table 6).

To gain a deeper understanding of the community's knowledge and practices, every interviewee was asked about treatments or actions undertaken to mitigate symptoms associated with episodes of diarrhea. Hydration was found to be

TABLE 7
Family member who suffers episodes of fever most frequently

Categories	Ararca			Barú			Total			P value
	n	(%)	[95% CI]	n	(%)	[95% CI]	n	(%)	[95% CI]	
Adults										
Grandfather/mother	2	(3.1)	[0.5–11.9]	3	(2.6)	[0.68–8.1]	5	(2.8)	[1.0–6.8]	1
Father	9	(14.3)	[7.1–25.9]	38	(33.6)	[25.2–43.2]	47	(26.7)	[20.5–33.9]	0.007*
Mother	8	(12.7)	[6.0–24.0]	14	(12.4)	[7.1–20.2]	22	(12.5)	[8.1–18.5]	1
Adults (others)	1	(1.6)	[0.0–9.6]	5	(4.4)	[1.6–10.5]	6	(3.4)	[1.3–7.6]	0.42
Children	41	(65.1)	[51.9–76.3]	50	(44.2)	[35.0–53.9]	91	(51.7)	[44.1–59.2]	0.01*
Unspecified	2	(3.2)	[0.6–11.9]	3	(2.6)	[0.68–8.1]	5	(2.8)	[1.0–6.8]	1
Total	63	(100)	–	113	(100)	–	176	(100)	–	–

CI = confidence interval.

* P value < 0.05.

the most frequent treatment (43.6%, $N = 96$), followed by medical assistance (13.6%, $N = 30$) and some traditional practices (e.g., garlic potions, boiled rice-water) that accounted for 9.5% ($N = 21$). Interestingly, 20.9% ($N = 46$) of families commonly used antibiotics as the main treatment against diarrhea, and among these medicines, only antiparasitics (e.g., albendazol, mebendazol) and antibiotics (e.g., azithromycin) were mentioned. Two subjects reported using zinc dissolved in water as a regular treatment, whereas 7.3% ($N = 16$) of families did not use any treatment. Finally, 2.3% ($N = 5$) did not report any specific treatment.

The 72% ($N = 94$) of the population who reported not having a water service supply ($N = 130$) mentioned that at least one diarrhea episode presented in the family in the last 12 months; in those who reported the service ($N = 90$), the percentage of episodes was 58% ($N = 52$) ($P = 0.035$). In this sense, recorded diarrhea cases were related with the absence of improved drinking water supply. In the decision tree graph, it was observed that certain variables, such as having a dwelling with walls made of bricks or concrete and incomes from tourism and trade, seemed to decrease the presence of cases (Figure 3).

Fever: frequency and treatments used. Considering that Ararca and Barú are in an endemic area for dengue fever and chikungunya, febrile episodes occurring within five days before the survey were considered as positive cases for community-perceived febrile syndrome. In 20% ($N = 44$) of dwellings, at least one episode had occurred, 15 cases in Ararca (15.6%) and 29 in Barú (23.4%). No statistically significant differences were found between the communities ($P = 0.20$).

When interviewees were asked about the most susceptible family member, in a total of 80.0% ($N = 176$) of surveyed households, it was identified at least a family member as more susceptible; among these registered, the group “children (son/daughter)” was the category with the highest frequency (51.7%, $N = 91$), whereas “mother” (26.7%) and “father” (12.5%), were less likely responses (Table 7). The subjects that did not identify a family member as more susceptible was 20.0% ($N = 44$); instead, they declared that febrile episodes are not a recurrent manifestation within their families.

As practices associated with febrile syndrome are key factors in determining community vulnerability, all subjects were asked for the most common treatments or actions applied to control fever episodes. Antipyretic drugs were the most frequent answer (73.6%, $N = 162$), followed by the use of measures such as putting a cool damp cloth on the forehead or

having a slightly warm cloth in 6.8% of households, and hydration in 6.4%. Other practices related to collective beliefs and folklore were mentioned by 3.6% ($N = 8$) of interviewees, whereas 3.2% ($N = 7$) sought medical assistance in a primary care center, and 2.3% ($N = 5$) declared that episodes were not regularly treated in the family.

All subjects were asked about suspected etiology of febrile syndromes to collect data regarding community knowledge. The most frequently mentioned possible causes are as follows: acute respiratory infections (ARIs) (8.6%, $N = 19$), dengue fever (3.6%, $N = 8$), hepatitis A virus (1.8%, $N = 4$), and malaria and tuberculosis (0.9%, $N = 2$); one subject mentioned leptospirosis as the suspected etiology.

The presence of an improved drinking water supply was not related to the reported fever cases ($P = 0.23$). The decision tree graph shows that variables such as having roofs made of materials other than brick, asbestos, or wood, and other variables such as not having incomes from masonry, security services, or trade, could favor the presence of fever cases (Figure 4).

Aedes/house, container, and Breteau index. Community exposure to vectorborne diseases was assessed through domiciliary and peridomiciliary inspections, which were conducted to identify mosquito breeding sites and the presence of vectors in both larvae and adult forms.

A total of 2,012 containers with clean water were found and categorized as potential breeding sites, among which 29.4% ($N = 591$) had *Ae. aegypti* larvae in different stages (container index). During in-home inspections, larvae or pupae of *Ae. aegypti* were detected in 69% of households (*Aedes*/House index); specifically, the containers identified as positive for *Ae. aegypti* larvae were distributed between 67% of inspected households. The Breteau index was 2.96, meaning that approximately three positive containers per 100 inspected houses were found. Container index (percentage of water-holding containers infested with larvae or pupae) was higher in Barú (31.5%) than in Ararca (22.5%), ($P = 0.0002$). Equally, the Breteau index was 1.3 in Ararca and 4.2 in Barú ($P = 1.12 \times 10^{-11}$); however, *Aedes*/House index was higher in Ararca (70.2%) than in Barú (68.1%) ($P = 0.86$).

We found that 52.3% ($N = 1,053$) of receptacles were located indoors, and 50.5% ($N = 1,016$) of them were completely covered. Notably, 56.9% ($N = 1,145$) of these containers had a volume of at least 10 L, 38.2% ($N = 768$) had a volume between 11 L and 200 L, and 4.9% ($N = 99$) had a volume more than 200 L. Interestingly, 3.6% ($N = 73$) of receptacles had an insectivorous fish, whereas 30.7% ($N = 617$) of them were regularly treated

The presence of positive containers for *Ae. aegypti* larvae was related to the absence of a drinking water supply. For those who had (did not have) aqueduct service, the percentage of positive containers for *Ae. aegypti* larvae were of 56% (71%) ($P = 0.04$). The decision tree graph shows that households with certain variables, including not using water taken from reservoirs, wells, or tanker ships, have a high or medium education level (university education, technician, technical, completed high school, did not complete high school, completed elementary school); incomes from fishing, masonry, or security services help to decrease the positive cases of *Aedes* larvae in the households (Figure 5).

The burden of morbidity and mortality attributed to water-related disease represents an important issue that affects developing countries. This problematic situation is linked with several factors mainly associated with WASH conditions, but also with other circumstances such as climatic and geographical features, a population's socioeconomic status, poor infrastructure, and deficient public policy implementation. This study allowed for the analysis of socioeconomic conditions and health indicators of two rural populations on the Colombian Caribbean coast and their relationship with the presence of water-related diseases.

It was found that rural villages close to Cartagena de Indias are remarkably vulnerable populations, where incoming environmental changes would trigger public health imbalance in

TABLE 8
Characteristics of containers

Categories	Ararca			Barú			Total			P value
	n	(%)	[95% CI]	n	(%)	[95% CI]	n	(%)	[95% CI]	
Location of containers										
Indoor	270	(57.2)	[52.5–1.6]	689	(44.7)	[42.2–7.2]	959	(47.7)	[45.2–9.8]	$2.72 \times 10^{-6*}$
Outdoor	202	(42.8)	[38.3–7.4]	851	(55.2)	[52.7–7.7]	1,053	(52.3)	[50.1–.45]	
Total	472	(100)	–	1,540	(100)	–	2,012	(100)	–	–
Condition of containers										
Completely covered	174	(36.9)	[32.5–1.4]	842	(54.7)	[52.1–7.1]	1,016	(50.5)	[48.2–2.7]	$1.83 \times 10^{-11*}$
Partially covered	68	(14.4)	[38.3–7.4]	268	(17.4)	[15.5–9.4]	336	(16.7)	[15.1–8.4]	
Uncovered	230	(48.7)	[11.4–7.9]	430	(27.9)	[25.7–0.2]	660	(32.8)	[30.7–4.9]	$< 2.2e \times 10^{-16*}$
Total	472	(100)	–	1,540	(100)	–	2,012	(100)	–	
Container capacity (liters)										
10	286	(60.6)	[56.0–5.0]	859	(55.8)	[53.2–8.2]	1,145	(56.9)	[54.7–9.0]	0.072
11–200	175	(37.1)	[38.3–7.4]	593	(38.5)	[36.0–0.9]	768	(38.2)	[36.0–0.3]	
> 200	11	(2.3)	[32.7–1.6]	88	(5.7)	[4.6–7.0]	99	(4.9)	[4.0–5.9]	0.004*
Total	472	(100)	–	1,540	(100)	–	2,012	(100)	–	
Actions										
Insectivorous fish	2	(0.4)	[0.07–1.6]	71	(4.6)	[3.6–5.8]	73	(3.6)	[2.8–4.5]	$3.87 \times 10^{-5*}$
Larvicide agent	9	(1.9)	[0.9–3.7]	608	(39.5)	[37.0–1.9]	617	(30.7)	[28.6–2.7]	
None	461	(97.7)	[95.7–8.7]	861	(55.9)	[53.3–8.4]	1,322	(65.7)	[63.5–7.7]	$< 2.2 \times 10^{-16*}$
Total	472	(100)	–	1,540	(100)	–	2,012	(100)	–	

CI = confidence interval.

* P value < 0.05.

an already delicate scenario. In both Ararca and Barú, findings related to socioeconomic features (education, income) showed low levels, which are amplified by a community with a low level of education and an economy mostly based on natural resource exploitation, such as tourism and artisanal fishing (Table 2). Education can directly increase knowledge and risk perception, and indirectly decrease poverty, improve health, and stimulate access to information and resources. Therefore, educated individuals and communities have better adaptive capacity and response to prevent water-related diseases.³³ In Latin America, a proportion of a population's vulnerability is attributed to its economic dependence on natural resources. Agriculture is not an activity commonly practiced in Ararca and Barú. These rural populations are well-known traditional fishing communities; hence, their economic sustainability is closely linked to environmental variables, such as temperature and precipitation. In this survey, it has been determined that artisanal fishing is the main economic activity in 13.6% of households; however, young groups are less likely to be involved in this activity, suggesting a generational change regarding occupational preferences possibly motivated by a persistent reduction in the profitability of fishing-related activities (Figure 2B). Some authors have suggested that this progressive decline in fishing production is related to natural and anthropogenic changes in marine ecosystems; so, an ongoing switch in collective occupational profile might be an adaptive response to adverse conditions.³⁴ Unfortunately, this apparent economic adaptation that could improve socioeconomic conditions in these populations and, thus, improve the situations to address the issue around water-related diseases, does not represent a significant reduction in community vulnerability. This is because tourism-related activities are also considered to be dependent on natural resources and environmental conditions. In this sense, economic stability is still sensitive to extreme climatic events and might be negatively influenced by water pollutants deposited on Barú's coasts because the Dique channel, which collects local industrial residues and disseminates sediments

from the Magdalena River.³⁵ Moreover, periodic tropical disease epidemics exacerbated by climate change might be a threat for travelers and tourism production, as some authors in highly attractive areas in Southeast Asia have projected. On the other hand, it has been estimated in Brazil that further reduction in dengue infection rates would increase the flow of tourism and improve economic dynamics in tourism-dependent communities.^{36,37}

Regarding the infrastructure conditions in these populations, 21.4% of households were "recoverable" or "unrecoverable," which means that the floor, roof, and walls were constructed with inadequate materials and the general condition of the dwellings does not contribute to promoting family health. This house materiality index is lower than those found in other Latin American countries, where rural areas had 38.7% of dwellings classified as "recoverable" and 4.1% as "unrecoverable".³⁸ The difference between these proportions might be attributed to characteristics specific to the studied villages. Ararca and Barú have been historically isolated from Cartagena de Indias by bodies of water and improperly categorized as urban communities. However, these populations have possibly received some urban influence from the Cartagena district, because of proximity. Despite comparisons, findings about a household general conditions suggest that most families are in a situation of vulnerability that would affect the health conditions.

Regarding water supply, WASH indicators in Ararca and Barú are affected: one of them does not have a water supply (Barú), and neither of the two has sewerage services. These conditions are troubling scenarios related to a possible increase in morbidity of diseases caused by infectious agents. Public and private infrastructures are linked to public health status and determine part of community vulnerability and adaptability.¹³ In Colombia, although implementing a centralized sewage system has shown to be effective to improve health outcomes, public coverage is unequally distributed; reaching 92% of urban populations and 69% of rural communities.^{39,40} In concordance with these percentages,

FIGURE 5. (100%, $N = 220$). The figure shows the main variables related to the presence (1) or absence (0) of *Aedes* larvae in the included households. As in Figures 3 and 4, in this model also variables related to socioeconomic states, public services supply, and general household conditions were also included. In this tree, variables such as not using water taken from reservoirs (see node 2), wells (see node 4), or tanker ships (see node 8), have a high or medium education level (university education, technologist, technical, completed high school, did not complete high school) (see node 17), and incomes through fishing, masonry, or security services (see node 34), help to decrease the positive cases of *Aedes* larvae in the households.

this survey was entirely developed in two rural areas without a central infrastructure designed to manage sewage water; hence, access to improved sanitation facilities is uncommon and overall risk related to water-related diseases is high. Public investment in infrastructure remains a neglected obligation by government authorities. It is important to highlight that recorded diarrhea cases were related to the absence of an improved drinking water supply ($P = 0.035$), and that (interestingly) the community without a water supply (Barú), presented the highest frequency of reported diarrhea cases in the last 12 months: 73.4% ($N = 91$) in Barú and 57.3% ($N = 55$) in Ararca ($P = 0.01$). Besides, the households that do not have this service had a major frequency of positive containers (71%) compared with those that have the service (56%) ($P = 0.05$). Thus, the drinking water supply plays an important role in the improvement of general health conditions in the studied populations.

In this sense, garbage management is another indicator that reflects the risks of studied populations, considering that risky

practices remain as prevalent behaviors within both communities. As described above, garbage deposition in open fields or abandoned properties is a habitual behavior in nearly 5% of the population. Therefore, exposure to domestic residues has not been completely controlled; moreover, during fieldwork, it was observed that some peridomiliary areas in the town's outskirts have been informally designated for open dumping, regardless of a general and public plan for collection and transportation to secure zones. In spite of this disturbing scenario, this method of disposal is not uncommon in Latin America, where disposal of solid waste is a ubiquitous problem.⁴¹ Regarding this practice, some authors have associated irregularities in solid residue management with higher risks of acute diarrheic episodes. Thus, inhabitants from Ararca and Barú are also exposed to preventable diseases sensitive to environmental changes.^{42,43} These conditions could be related to the reported diarrhea cases in both communities. The frequencies of informed diarrhea cases in the two

communities were higher than those observed in other populations in the world. In this study, 66.3% ($N = 146$) of the total population mentioned having presented at least one diarrhea case in at least one family member in the last 12 months, wherein children were mentioned as the family members who suffer episodes of diarrhea most frequently. This frequency is higher when compared with those reported in other rural populations from East Africa (Burundi) or Asia (Pakistan), where diarrhea prevalence in children under 5 years of age was 32.6% and 51%.^{44,45}

Water supply was closely related to perceived morbidity of diarrhea. In this study, 58.1% of surveyed households had no access to aqueduct services, which is associated with a higher frequency of diarrheic episodes. As expected, water supplied from a centralized aqueduct was a protective variable even when other sources were added; naturally, those groups exclusively employing alternative methods (e.g., rainwater collection, purchasing water) were at higher risk ($P = 0.035$). Moreover, when those dwellings using only aqueduct were compared with dwellings where water is taken from a pipeline but it is also stored or mixed with water from other sources, the latter showed a higher frequency of diarrhea ($P = 0.019$). These findings confirm that water quality and manipulation are essential variables in control of waterborne diseases, as is well known. Eventually, droughts could lead to outbreaks of diarrhea and related diseases.^{46–48} With these considerations in mind, reactive community behavior to adverse conditions seems to be notably diverse and could strongly determine patterns of the spread of disease and intensity of risk factors. Baseline levels of morbidity by diarrhea and febrile syndrome, as well as circulation of the mosquito-vector for the dengue, chikungunya, and Zika viruses were found to be high.

Alterations in occupational preferences in studied communities for the adaptation to further changes in trends of waterborne and vectorborne diseases are a critical task. However, perceived morbidity was generally high suggesting a collective capacity to identify prevalent diseases such as dengue fever, acute diarrheal disease, and ARI. Both knowledge and practices were partially incoherent which indicates a reduced reception of control and treatment strategies. In regard to this, it is important to note that water sanitation was not identified as the leading cause of acute diarrheal disease; instead, a large proportion of interviewees attributed cases to food poisoning 28.6% ($N = 63$). Although community perception could be pointing to a subjacent food safety issue in a scenario where local risk associated with water quality is high (39.79%) and among the highest in the country, it is more likely that the subjects' answers reflect a misperception of actual causes.⁴⁹ Community interventions aimed at enhancing public adaptability should include educational material about the most frequent causes of acute diarrheal disease. In this manner, it is possible to improve preventive conduct and mitigate the impact of climate change on the spreading of waterborne diseases.

When asked about recurrent practices to control acute diarrhea cases, hydration was the most frequent treatment (43.6%, $N = 96$), whereas another proportion of interviewees avowed that seeking medical assistance (13.6%, $N = 30$) used to be the most common procedure used in his/her family. Together, these data reveal that most surveyed samples are aware of control measures or alarm signals; however, these findings only show a reactive behavior that is compatible with

the lack of a preventive attitude analyzed above. In addition, some inappropriate methods are still in practice within both populations, such as vegetable/cereal-based potions (9.5%) or recurrent use of antibiotics (20.9%), which indicates that at least one-third of surveyed families are prone to suffer morbidity associated with acute diarrheal disease.

Regarding vectorborne diseases, water supply was identified as a critical variable in determining domiciliary exposure to *Ae. aegypti*, where intermittent sources of drinking water were associated with a higher risk of in-home contact with larvae/mosquitoes. A similar behavior has been previously observed in other rural communities in tropical Latin America and the Caribbean. In those cases, general scarcity and intermittent water supply was related to high frequencies of in-home storage and an elevated Breteau index.^{50–52} Likewise, in some Colombian communities, higher vector densities have been associated with low socioeconomic status, unplanned urbanization (where intermittent water supply is a constant situation), and higher environmental temperatures.⁵³ Interestingly, Andean Colombia vector productivity and dengue virus transmission have been seen to increase during the dry season, describing a behavior mainly attributed to water storing practices.⁵⁴ Further projections to predict effects of climate change on vector dynamics or vectorborne diseases should include not only variations on temperature/precipitation patterns or environmental factors but also possible fluctuations in water supply and the consequences of that on community behavior.

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