American Journal of Rural Development, 2013, Vol. 1, No. 5, 106-115
Available online at http://pubs.sciepub.com/ajrd/1/5/2

DOI:10.12691/ajrd-1-5-2

Perception of Water Quality and Health Risks in the Rural Area of Medellín

Luisa Fernanda Roldán Rojas*, Andreas Megerle

Institute of Regional Science, Karlsruhe Institute of Technology, Karlsruhe, Germany
*Corresponding author: luisa.rojas2@kit.edu

Received September 09, 2013; Revised September 24, 2013; Accepted October 06, 2013

Abstract In Latin America and the Caribbean, approximately 36 million people lack even basic access to drinking water, most of them living in rural areas. This uneven spatial distribution of the drinking water supply poses a continuous public health risk, results in low economic productivity, low prosperity and thus contributes to the enforcement of regional disparities. As to the successful implementation of drinking water systems, the focus is still on technical factors and on measures to improve the knowledge of the target groups. Using the example of three rural quarters of Medellín (Colombia), this study shows how the perception of water quality and health risks by different social target groups may influence the implementation process of drinking water systems. A social area analysis was carried out to determine the socio-economic framework of the study, followed by 125 face-to-face interviews with drinking water consumers, complemented by additional expert interviews. Within the study area, 36% of the households use exclusively drinking water from the provided drinking water infrastructure. 10% of the respondents still consume only raw water and 54% are connected to both the raw water and drinking water supply system. The main factors influencing peoples' water quality perception are its colour and appearance, which form a sort of "quality standard" used to evaluate the water quality, even of raw water. The use of raw water for hygiene practices and irrigation is not perceived as a potential risk. A relatively small group of consumers of drinking water seem to have a suitable risk perception with a link between the river pollution and waterborne health risks and diseases. The implementation process of drinking water systems must consider the target groups' socio-economic and cultural context forming their perceptions. A realistic risk perception should be prevalent among the target group prior to the introduction of drinking water supply systems.

Keywords: *water quality, health risks, rural areas of large cities, Colombia, Medellín, quality perception, risk perception*

Cite This Article: Luisa Fernanda Roldán Rojas, and Andreas Megerle, "Perception of Water Quality and Health Risks in the Rural Area of Medellín." *American Journal of Rural Development* 1, no. 5 (2013): 106-115. doi: 10.12691/ajrd-1-5-2.

1. Introduction

1.1. Water Quality and Health Risks in the Rural Area of Underdeveloped Regions

Although 94% of the households in Latin America and the Caribbean have access to potable water through household connections, approximately 36 million people in these two regions still lack even minimal access to water [1]. In addition, drinking water supply coverage is much higher in urban than in rural areas [1,2]. This uneven spatial distribution of the drinking water supply poses a continuous public health risk, and causes a low economic productivity and low prosperity in rural areas of both Latin America and the Caribbean [3,4,5].

There are different challenges in improving the access to drinking water. On the one hand, as a natural product, water underlies a dynamic availability over space and time which may vary between scarcity and abundance. The same applies to its consumption, which may show peak and slack periods [6] throughout a given period of time according to the households' dynamic pattern of demand. Consequently, drinking water supply systems are needed to manage and accommodate these dynamic variations in claims over drinking water.

On the other hand, there are cultural, social and economic factors which can facilitate or inhibit the evolution and development of drinking water supply systems [6,7]. Most often, due to different reasons, small drinking water supply systems are most often affected [5].

One reason is that drinking water supply is only one of many municipal tasks communities need to deal with apart from e.g. housing, hygiene and socioeconomic problems [5]. Above, the perception of the community that there is no ownership of a water supply system and no awareness of the true cost of water, which may result in poor decision-making [5], such as the use of water of poorer quality that represents a greater risk to health [1,7,8,9].

1.2. Expanding the Water Supply Systems: the Role of the Target Group's Perception

The assessment of drinking-water related risks by the consumers as well as their "acceptance" [10] towards drinking water supply systems in general play a major role to the drinking water supply systems' sluggish expansion. Therefore, it is essential to account for the public perception of drinking water and drinking water supply systems in order to anticipate problems and maximize the impact of the introduction of a drinking water supply system in an urban or rural area.

Published research on perception of water quality and water-related risks has focused so far on developed countries and/or on the perception of drinking water quality as a parameter to evaluate drinking water consumption patterns of tap water and bottled water [11-18]. Doria (2006) [12] argued that most research in this area has been conducted in developed countries with stringent drinking water quality standards and reliable supplies, and consequently, extrapolations to developing countries may be inadequate. Notwithstanding, as there is no reliable data on the water quality and health risk perception in developing countries respecting the differences between raw and drinking water consumption, organoleptic properties, risk perception, previous experience, contextual cues provided by the supply system, perceptions of chemicals, trust in water companies, impersonal and interpersonal information (e.g. from the mass-media and family members) and demographic variables [19] seem to be adequate evaluation parameters.

Using the example of the rural area of Medellín, this paper aims to show that and to which extent the perception of water quality and water quality-related health risks of different social groups should be considered within the implementation process of drinking water systems.

All these studies show that the population has a crucial role. Politicians and drinking water supply entities should therefore strive to involve the people concerned throughout the planning, construction and operation process of drinking water supply systems. If organized as a two-way exchange of knowledge, this participation process can contribute to raising awareness about the importance of clean drinking water and its supply systems.

1.3. Background of the Case Studies

1.3.1. Rural Area of Medellín

Medellín is the second-largest city in Colombia with a population of approximate 2.4 million [20] and is located in the Aburrá Valley, on the Central Andes mountain range at a height of 1,460 - 3,200 m above sea level. Administratively, the city is divided into 16 communes for the urban area (107.34 km2) and five rural quarters for the rural area (273.30 km2) (see Figure 1). The rural area is mainly characterized by agriculture (40.8%) and natural forest (31.6%) [21]. Only 4% of the rural area is covered by villages and areas for recreation [21].

Figure 2 shows that the urban population (population of the communes) has consistently accounted for more than 94 percent of the total population over the past 25 years. Such a spatial distribution of the population does not only entail an agglomeration of the urban area, but also promotes an uneven distribution of economic, technical and administrative resources to the detriment of the rural area.

In the rural areas of Medellín, to this day, the municipal administration's failure to counteract the uneven distribution hindered the development of an area-wide drinking water supply system. As a consequence, inhabitants of the rural quarters built raw water supply systems on their own initiative, which by their nature neither meet the statutory technical aspects for water supply nor the official criteria for drinking water quality. Raw water supply is a risk to human health and the environment [1,7,8,9]; therefore the introduction of drinking water supply systems in these areas is an urgent requirement.

Figure 1. Medellín and its rural area [22]

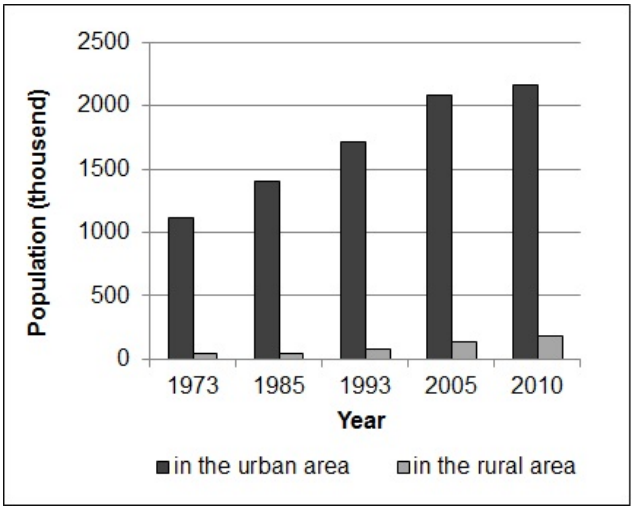

Figure 2. Population development of Medellín 1973-2010 [40]

1.3.2. Drinking Water Supply Projects

According to the Colombian Law 142 of 1994, ratified with Law 117 of 2007, it is a municipal responsibility to ensure that drinking water supply is provided efficiently to their inhabitants by official, private or mixed utilities companies or by the respective municipality itself. Hence, the municipality of Medellín has launched the "Manejo Integral del Agua para el Consumo Humano" (Integrated Management of Drinking Water) project. It supports the construction of drinking water supply systems in the city's rural quarters and in some peripheral urban areas as well as the establishment of the respective drinking water supply entities, where the public utility service company

"Empresas Públicas de Medellín" cannot [22]. The project also includes the payment of subsidies for the Colombian socioeconomic strata 1 (Low-Low), 2 (Low) and 3 (Medium-Low), through the Solidarity Fund for Subsidies and Income Redistribution, in order to fulfill the Law 142 of 1994. Due to the characteristic topographical distribution of the villages in the rural areas of Medellín, it is not possible to realize the drinking water supply with one drinking water supply system only. For this reason, 18 drinking water supply systems, which nowadays supply drinking water in four rural quarters, have been built under this project since 1993. These drinking water supply systems perform the treatment phases required to achieve the drinking water quality, all according to the required water quality standards for human consumption of the "Reglamento Técnico del Sector de Agua Potable y Saneamiento Básico 2000" (Technical Regulations of the Drinking Water and Sanitation Sector) [23-28].

Table 1. Colombian drinking water quality standards and its value for some streams in the studied areas [44-47]

Parameter		E. coli	Coliform bacteria	Colour	Turbidity	pH
Units		No./ 100ml	No./ 100ml	Pt/Co scale	NTU	
Colombian drinking water quality standards (Resolution 2115)		0	0	15.00	2.00	6.5-9.0
Stream / Water without treatment (Point of measure: near the raw water collection point)	La Aguapante	172	221		0.76	7.71
	El Hato	26	>1600	9.18	0.68	6.78
	El Hato (near to the water treatment plant)	14	>1600	10.33	1.17	6.86
	Guayabala	<2	>1600	4.26	9.89	7.38
	La Chata	39	>1600	1.31	2.00	6.91
	La Chata's affluent (1)	48	>1600	1.15	6.00	7.46
	La Chata's affluent (2)	70	>1600	1.64	3.00	6.90
	La Iguaná	33	36	2.46	0.55	6.87

1.3.3. Actual Water Consumption Patterns and Hygienical Situation

In spite of these infrastructure development projects, the water consumption pattern is as follows:

- There are houses with or without connection to the drinking water distribution network, in which only raw water is consumed.
- In some houses with connection to the drinking water distribution network, there is consumption of both drinking and raw water.
- There are houses with connection to the drinking water distribution network, in which only potable water is consumed.

Water supply systems in the rural areas of Medellín get raw water from surface water (streams). Water collection points are located near the springs, where the pollution probability is the lowest. Measurements of some key organoleptic parameters near the water collection points of some of the analyzed drinking water supply systems (see Table 1) showed that they were in the range of tolerance, whereas leading chemical and microbiological parameters in the same collection points indicated that the water requires treatment prior to being supplied to the inhabitants of the selected rural quarters. In fact, due to the considerable presence of E. coli and coliform bacteria, the consumption of this kind of raw water is only adequate for a limited number of domestic purposes. Consequently, as raw water supply systems do not clean the water by means of flocculation, sedimentation, filtration or disinfection prior to feeding it into the supply system, they represent a considerable risk to public health [8,21,29].

1.3.4. Aim of the Paper: Perception and Acceptance of the Projects

Although the rural community has been involved in the planning, construction, and more recently in the operation of the drinking water supply system in their villages, observations during the author's field research suggest that there are different attitudes towards the acceptance of the drinking water supply.

Analyzing the public perception of drinking water quality as well as the risks linked toward water consumption in the rural areas of Medellín, this paper explores the influencing factors of consumption of both raw water and drinking water in the light of socioeconomic indicators. Following a review of the drinking water supply situation and the characteristics of the selected rural quarters' population, the authors introduce the research methods, present quantitative and qualitative research findings and then review these results in relation to the perception of drinking water supply. In the final section some concluding remarks are made on the applied method and a number of suggestions are given that may help municipalities and drinking water supply companies to design strategies for encouraging the rural population's acceptance of both drinking water supply and potable water use.

2. Methods

2.1. Research Area

Three of the five rural quarters of Medellín were selected as study areas: Altavista, San Antonio de Prado and San Cristobal (Figure 1). The remaining two quarters were not eligible for the study purpose: In San Sebastian de Palmitas, there is no drinking water supply system, which means that the perception of drinking water quality and risk in this quarter cannot be compared to the same parameters in the other rural quarters which have access to drinking water supply. In Santa Elena, finally, there was no support to carry out the surveys by the drinking water supply systems administrators. According to estimations of the Municipality of Medellín [30,31,32], the population was 28,973 inhabitants in Altavista, 77,007 in San Antonio de Prado and 60,025 in San Cristobal; the population development in the three selected rural quarters shows an upward trend (see Figure 3), which means an increasing demand for the consumption of either drinking or raw water. As to the socioeconomic situation in the

three selected rural quarters, most of their households have been classified under the three lowest socioeconomic strata (1: Low-Low (8,6%), 2: Low (68,5%) and 3: Medium-Low (22,7%) [30,31,32].

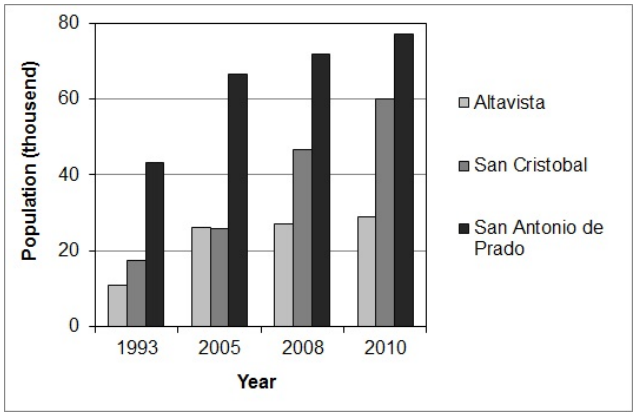

Figure 3. Population development of Altavista, San Antonio de Prado and San Cristobal 1993-2010 [41-43]

2.2. General Design

In order to investigate customer perception of drinking water supply in the selected rural quarters of Medellín, a social area analysis [33,34] was carried out during an inspection of the selected rural quarters. This analysis included cultural, social and economic factors, which were useful to define the adequate social research. Two main factors defined the research method: First, the majority of the households in the rural area of Medellín have been classified under the three lowest socioeconomic strata (1: Low-Low, 2: Low and 3: Medium-Low). Second, although the illiteracy rate did not exceed 4% in 2010 [30,31,32], most of the selected rural quarters' inhabitants have only visited elementary school: 45.9% in Altavista, 36.5% in San Antonio de Prado and 40.2% in San Cristobal. Those data covers population, which did not finish the school. The research is based on a mixed-methods approach with face to face surveys with consumers-allowing taking into account consumers with a low education level or illiterate – and expert interviews which improve the validity of the findings through the triangulation of complementary data sets [13,35,36].

2.3. Sampling

The sampling procedure intended to provide data that are representative of the rural quarters of the western rural areas of Medellín within calculable margins of error. The sample size was determined by the number of households (users) connected to the 11 drinking water supply systems located in Altavista, San Antonio de Prado and San Cristobal. Although there are households in the rural quarters that are not connected to the drinking water supply system, there is no information on the number of these households. This is not relevant for the study's purpose, though, as only the consumers with access to the drinking water supply systems have a starting point to compare drinking water to raw water.

In this work, the perception of the drinking water supply by the inhabitants of three of the five rural quarters of the city of Medellín, is determined and analysed by means of 125 face to face interviews with those inhabitants already connected to a drinking water supply system, sorted according to the six facility systems and the respondents' socioeconomic strata. With a population size of 5,822 connected households, the sample size needed for a confidence level of 95% and a sampling error of 8.85% was estimated to be 125. The sample used for this study was first sampling according to the population of each drinking water supply system (6 systems were chosen, see Table 2) and consequently sorted according to the socioeconomic strata (see Table 3). Therefore, the data of the surveys of the villages in the area of the six selected drinking water supply systems can be analysed cumulatively [37]. The surveys were carried out between March and April 2011.

Table 2. Selected drinking water supply systems and their supply area [22]

Rural quarter	Drinking water supply system	Supply areas (villages)
Altavista	Junta Administradora Acueducto Aguas Frías	Aguas Frias
	Junta Administradora Acueducto Manzanillo	Manzanillo
San Antonio de Prado	Corporación de Acueducto Montañita	Montañita
	Junta Administradora Acueducto El Manantial	Potreritos
		Barrio El Vergel
		La Florida
San Cristobal	Junta Administradora Acueducto La Iguaná	Boquerón
		San José de la Montaña
		Travesías (La Cumbre)
	Junta Administradora Acueducto El Hato	El Yolombo
		El Carmelo
		San José de la Montaña
		Pedregal Alto
		La Ilusión

Table 3. Household connections selected drinking water supply entity [48] and performed surveys

Drinking water supply entity	Household connections per socioeconomic stratum						Performed Surveys	Performed Surveys per socioeconomic stratum					
	1	2	3	4	5	6		1	2	3	4	5	6
Manzanillo	93	151	2	1	0	0	22	8	14	0	0	0	0
Aguas Frias	27	182	11	0	0	0	13	3	8	2	0	0	0
Montañita	3	50	12	9	0	0	20	1	16	2	1	0	0
El Manantial	10	239	46	13	0	0	30	0	24	6	0	0	0
La Iguaná	11	219	22	9	0	0	16	2	12	1	1	0	0
El Hato	12	248	40	22	12	9	24	2	16	2	2	1	1

2.3.1. Face to Face Interviews

To survey water-related knowledge, perceptions and behaviour of the population, it is important that respondents are able to freely answer. A rapid and reliable method is to obtain qualitative data through "face to face interviews" [37], which in this research, consisted of guided interviews with open questions, in order to facilitate the free expression of the respondents.

The open questions dealt with the following subject areas:

- Water-related knowledge: meaning of drinking water, identification of waterborne diseases
- Water-related perceptions: differences between drinking and row water, role of drinking water supply system and role of the drinking water supply entity
- Water-related behaviour: recognition of the type of water used in the household, raw water use or drinking water use.
- Demographic questions: age, sex, socioeconomic stratum, education of the respondents.

2.3.2. Additional Expert Interviews

The inspection of the selected rural quarters did not only include the inhabitant's water-related attitudes in the supply area, but also the technical infrastructure of drinking water supply system. The technical inspection was conducted during a technical assessment of the drinking water supply systems by the official departments for health and for social development of the municipality of Medellín. On this occasion, it was possible to carry out informal interviews with state officials of both official departments. Parallel to the interviews with the users, the administrators of the six selected drinking water supply systems were also interviewed. The aim of these interviews was to obtain data about the user's water-related behaviour as well as about the acceptance of both drinking water supply and potable water use in their respective rural quarter.

3. Results

3.1. Introduction

In the study areas, the users of the drinking water supply entities can be classified in three different groups according to their type of water consumption:

- users who only consume raw water (group 1),
- users who use both raw water and drinking water (group 2) and
- users who consume only drinking water (group 3).

The results with reference to water-related knowledge, perceptions and behaviour are analysed both for the whole sample size and for each mentioned group.

3.2. General Water-Related Knowledge and Perception

Since the planning and construction of the drinking water supply systems in the rural area of Medellín, drinking water campaigns have been regularly carried out in these quarters by the municipality and the drinking water supply systems. The campaigns aim to establish the term of "drinking water" as a synonym for a high-quality, safe food, thus raising the inhabitants' acceptance of drinking water. However, the efficiency of the campaigns remains unclear as formative evaluations before and after their implementation have not been carried out. Consequently, the popularity of the term of "drinking water" among the population can neither be used as an indicator for the inhabitants' actual acceptance of drinking water, nor for the success of the campaigns. 93% of respondents state to have heard at least once the term "drinking water". Answering the control question, 84% of the interviewees mentioned parts of the Colombian official definition of drinking water (see Figure 4): "Drinking water is water with a suitable and acceptable quality for human consumption because its organoleptic, chemical/physical and microbiological parameters meet the drinking water standards" [38].

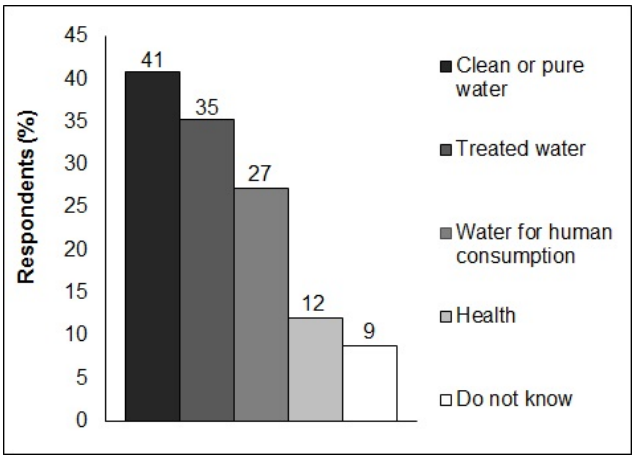

Figure 4. Definition of "drinking water" according to the respondents (multiple answers)

According to the most widely given definition of drinking water as being "pure or clean water", the main factors influencing water quality perceptions are drinking water organoleptics (i.e., sensorial information from taste, odour, colour and turbidity). The way organoleptics were valuated is influenced by a standard perception of transparency, a standard which is mainly influenced by the perception of bottled water. To describe and valuate flavours, odours, and colours, the number of qualitative terms was restricted to the use of general qualitative terms (e.g. "good"). Several participants were concerned about a "white colour", which is usually caused by air bubbles, but was attributed by them to a high quantity of chlorine, which they perceive to be a health risk. 42% of the respondents confirm the importance of water treatments for drinking water quality. For 46% of all respondents indicate the contamination of the water from streams to be the main difference between drinking water and water from streams. Other mentioned distinctions were the higher consumer confidence on drinking water quality (20%). Concerning the water from streams, 5% of the respondents perceived more health risks and more microorganisms and 6% perceived more macroinvertebrates compared to water from drinking water supply systems.

Despite the survey's result suggesting that consumers associate considerable health risks to the consumption of water from streams, the actual organoleptic water quality

of the streams in the study area is acceptable (see Table 1, parameter Colour and Turbidity), turning it difficult to discriminate drinking water and water from streams only by sight. This may represent a risk because raw water supply systems can be mistaken for drinking water supply systems. On the one hand, a reason for confusing raw water supply with drinking water supply is the fact that only 46% of the respondents know the name of the drinking water supply entity in their village. On the other hand, water supply is identified as a public utility by 62% of the participants, but 72% of them does not consider that it is a public utility to validate drinking water quality standards.

As to waterborne diseases, there is a high perception of the health risks associatedwith the consumption of contaminated water (79%). The knowledge about diseases and their symptoms confirm this perception (71%). The most often mentioned waterborne diseases are cholera, gastrointestinal infections, amoebiasis, intestinal parasites and skin infections. The prevalent symptom related with these diseases is the diarrhoea.

3.3. Water-Related Knowledge, Perception and Behaviour of Group 1: Raw Water Consumption

10% of the respondents indicated to consume raw water only, in spite of the fact that their households are connected to a drinking water supply system. The intercorrelation between socio-economic strata and raw water consume (Cramér's V φc = 0,012) shows that there is no association between those variables. However, an analysis of the frequency shows that the consumers of this group mainly belong to the stratum 1 und stratum 2. According to the interviews, a reason to not consume drinking water is the fact that the respondents rate the drinking water supply entities fees – which include the costs of the water meter and the water consume [39] – as more expensive than the fees of the raw water supply systems. Another reason cited by the inhabitants to justify the raw water consumption is their perception of the water quality as being acceptable and the health risk as being low. Both assessments rely on the water's appearance (colour and turbidity), but also on a partial ignorance of the environmental problems in the rural quarters (example: pollution caused by pesticides and waste water).

All respondents of this group affirmed to have heard the term of "drinking water". The control question confirmed this perception as 75% of the group's respondents were able to cite at least a part of the official definition (see Table 4). The most often cited definition parts were "treated water" (67%) and "pure or clean water" (55%). However, it seems that the term of "drinking water" is just related to the type of water provided by the drinking water supply entities and not to the drinking water quality standards: 83% of the group's respondents do not consider the water which they use as drinking water. They cannot see any differences between raw water and potable water regarding water organoleptics. A difference between raw and potable water is only noticed after rains, because raw water acquires colour, but this is considered as a temporal problem. Due to this kind of water quality perception, 83% of the respondents do not regularly boil the water before drinking or using it, as the following exemplary statement reveals: "Cuando hay tiempo y forma, se hierve (el agua)" – "When there is time and it is possible, we boil it (water)".

In contrast, 73% of the respondents mentioned to have experienced waterborne diseases or symptoms of them but do not link these diseases to their raw water consumption. Most of the interviewed experts attribute this positive perception of raw water to the customs, because raw water use is justified with statements like "We have consumed water without treatment during our whole life and no one of this family has ever fallen sick from it".

Table 4. Definitions for "drinking water" according to the respondents, who said to have heard it. (Group 1: 12 participants; Group 2: 62 participants; Group 3: 42 participants)

Definition	Group 1 (%)	Group 2 (%)	Group 3 (%)
Treated water	33	26	10
Clean or pure water	17	21	26
Water for human consumption	0	10	19
Health	0	10	7
Treated water and clean or pure water	8	5	14
Treated water and other definition	0	6	2
Clean or pure water and other definition	8	6	14
Three definitions	8	6	2
Do not know	25	10	5

3.4. Water-Related Knowledge, Perception and Behaviour of Group 2: Both Raw Water and Drinking Water Consumption

Among the polled households, 54% have connections to both the raw water and drinking water supply system. However, due to their drinking water consumption, group 2 has a different perception of water quality and water-related health risks than group 1. Drinking water consume is restricted to the preparation of food and beverages, whereas raw water is used for household cleaning, laundry, bathing / sanitation and gardening.

Most respondents within this group (91%) have heard of the term of "drinking water", and 90% of them can define this concept at least partially (see Table 4): Similarly to group 1, the most common definitions were "treated water" (46%) and "pure or clean water" (41%). However, compared to group 1, there is a difference within group 2 as to the defining criteria of drinking water: the quality of "drinking" water is either related to the water's appearance or to the drinking water supply entities. Consequently, drinking water definitions also included elements such as: "water for human consumption" (29%) and "health" (18%). In addition, 78% of the respondents in group 2 declared that the consumption of polluted water was a health risk (78%), and 72% of the group mentioned at least one waterborne disease or related symptoms. This risk perception is associated to the perceived pollution of the streams in the area as the main source of raw water: The most cited differences between raw water and drinking water were "pollution of the streams through waste water and agriculture" (53%), and "treatment of drinking water" (43%).

87% of the group's respondents consider the water of the drinking water supply entities of the area as potable water, while the remaining 13% are not sure whether this water meets the drinking water standards or not. For drinking or preparing food, 71% of this group's respondents use drinking water without previous treatment (i.e., without boiling it before consumption). The other 29% boil the drinking water before using it, though most of these people explained that it was a habit due to the previous consumption of raw water for drinking or preparing food and it should not be interpreted as a sign of distrust to the drinking water quality.

For the members of group 2, drinking water supply is a factor that improves health and quality of life in their villages. Moreover, there is trust in the drinking water supply entities. Typical indicators for this perception are the following opinions: "Uno se siente más seguro tomando el agüita (agua potable)" ("I feel safer when I drink drinking water"), "…Uno sabe que no se va a enfermar por el agua, porque (el agua) está tratada" ("I know that I am not going to get sick from drinking water, because this water is treated") or "El agua de la quebrada está contaminada por el ganado y así llegan los microorganismos al hogar" ("water from streams is contaminated by cattle, thus, the microorganisms can reach the households").

Although the perception of water quality includes microbiological parameters and although raw water consumption is known to bear health risk, raw water is partially used for some domestic purposes (e.g. bathing and showering, washing clothes, and gardening). However, even for these uses, raw water is not adequate due to its content of E.coli and coliform bacteria. To justify their raw water consumption, the respondents of this group cite the higher costs of drinking water and their perception of a high drinking water quality leading them to limit use for drinking and preparing food. According to the interviews, raw water supply is perceived as a way to save costs because the mentioned domestic purposes need large quantities of water compared to a smaller volume of water for drinking and preparing food. Due to the association of drinking water with water for human consumption, there is a trend to think that drinking water is only necessary for drinking and preparing food. Thus, the consumption of raw water for other purposes is accepted without questioning whether its quality is sufficient for it or not.

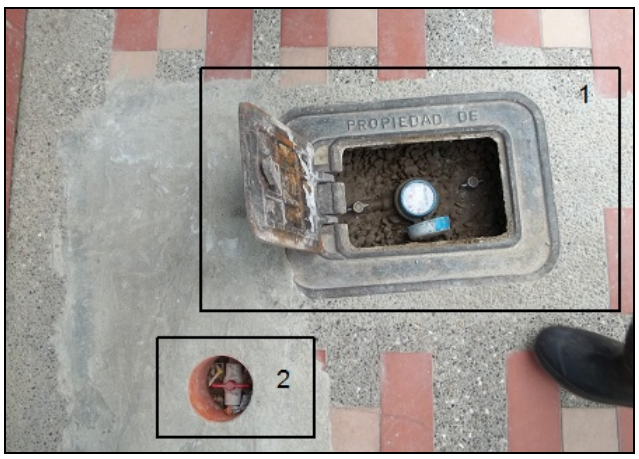

Figure 5. Connection to the drinking water supply system and its respective water meter (1), and connection to the raw water system (2)

47% of the respondents of group 2 use single pipe circuits for the selective transport of either drinking or raw water in their households. In other words, these users have two connections - one for drinking water and other for raw water - (see Figure 5), which can be operated selectively to supply their single pipeline. The remaining 53% of the interviewees have different pipelines for drinking water and raw water inside their households, for example, there is a pipe restricted to drinking water distribution to the kitchen.

During the social area analysis of the drinking water supply area "El Manantial" carried out with inspectors of the municipality of Medellín, turbidity and chlorine concentration of water in two kindergartens did not meet the drinking water quality standards. When the pipelines were analysed to find out the reasons, it was observed that there was a single pipe circuit for both drinking water and raw water in the kindergartens causing these health risk problems. To simulate the effects of a double pipe circuit the inspectors made drinking water flow inside the pipe. After one minute only, the two measured parameters met the drinking water quality standards.

Many households with such a mixed pipe system are not aware of these health risk problems. However, according to the interviewed state officials, the municipality cannot interfere or exact the consumption of just drinking water because the inhabitants of the area have not filed any complaint and no waterborne epidemic has been reported so far. For the administrators of the drinking water supply entities, the widespread use of mixed pipe circuits causes the low consumption of drinking water, due to the technical possibility to limit the use of drinking water in favour of raw water. The interviewed administrators also criticize unfair competition as the municipality commits the drinking water supply entities to supply drinking water in line with the Colombian drinking water standards and thus more expensive than the water delivered by the municipalities which tolerate relatively cheap raw water supply systems without any water quality controls.

3.5. Water-Related Knowledge, Perception and Behaviour of Group 3: Drinking Water Consumption

Among all interviewees in this study, 36% indicate to consume only drinking water, and that their households have a connection to the drinking water supply system only. Most of the respondents of this group 3 (93%) affirmed to have heard the term of "drinking water" and related it to the same definition elements as group 2: "pure or clean water" (55%) and "water for human consumption" (38%), followed by "treated water" (29%) and "health" (12%). As the respondents in group 2, the members of group 3 judged organoleptic parameters important criteria to assess the drinking water quality: The presence of certain organoleptic characteristics is seen as an indicator for treated water ready for human consumption. This water is believed to be beneficial for the consumers' health and quality of life. The survey revealed a high level of trust in the drinking water supply entities (98%) among the respondents. 47% of the interviewed persons regard water treatment to be the main difference between drinking water and raw water from the

streams in the area. Above, 44% of the interviewees think the streams in the area to be contaminated by agriculture or garbage, and 9% believe that the streams may cause diseases: Of all respondents in group 3, 71% mentioned at least one waterborne disease or its symptoms, and 20% of the respondents in group 3 still boil the drinking water before using it. According to the interviewees, this was rather a habit due to the previous use of raw water for drinking or preparing food than a sign of distrust in the quality of drinking water.

4. Discussion

4.1. Perception of Drinking Water Quality

The results of the study show that organoleptics have a strong influence on the perceived water quality, with water colour and turbidity (appearance) being the main factors influencing perceptions [8]. Therefore, both the consumers' attitude towards their raw or drinking water and towards their drinking water supply entities is strongly affected by the appearance of the delivered water. This has a negative effect on the drinking water consumption in the study areas, as in case of drinking water, neither of these two parameters applies as quality indicator. In contrast, odour, as a third parameter, can help to identify drinking water due to its distinctive odour of chlorine. Chlorine is commonly known as disinfectant, its odour is related with cleanliness and purity, quality characteristics which consumers tend to transfer to chlorine-treated drinking water.

The subjective perception of water quality also seems to be influenced by the knowledge of the drinking water definition disseminated by the campaigns, as well as by the perception of health risks. Drinking water is always associated with drinking water supplies ("treated water") or with the mentioned drinking water physical characteristics ("pure" or "clean" water). Thus, drinking water and bottled water appearance is assumed as a drinking water standard, compared to raw water.

Due to this perception and to the fact that the appearance aspects colour and turbidity of the raw water from the streams in the study area meet drinking water standards, raw water is mistaken in some cases for drinking water. Consequently, this perception leads to the acceptation of raw water consumption, despite of the existence of knowledge about waterborne diseases.

4.2. Health Risk Perception

The different perceptions of the health risks linked to the use of raw water can be partially explained by the different knowledge of the drinking water definition, the appearance dominated assessment of water quality and the perception of the pollution of the streams in the study area. The knowledge of waterborne diseases alone does not bring the inhabitants to infer that raw water consumption is linked to health risks. This is an important fact which should be considered in the design of future awareness campaigns.

As the parameter of drinking water appearance is a widely accepted standard to evaluate raw water quality in the study area, raw water consumption is common practice among the respondents. This reflects a lack of knowledge of the drinking water treatment and of health risks posed by invisible microbes in raw water. Nevertheless, the survey revealed two levels of raw water acceptance among the respondents: only raw water consumption and partial raw water consumption. Among the participants who only consume raw water, the introduction of drinking water supply systems is seen as the attempt of selling them a good they already have as their raw water meets the drinking water standards in terms of colour and turbidity. Above, this group of participants has never boiled raw water before drinking it, suggesting that they do not associate health risks to the consumption of raw water and even did not do so before the introduction of drinking water systems.

The other participants (from households with partial raw water consumption and households with only drinking water consumption) recognize the importance of water treatments for drinking water quality or perceive the contamination of the water from streams as a health risk caused by both microbes and pesticides, which are related to agriculture and to the discharge of wastewater from households. In addition, some of them associate the drinking water concept with "water for the human consumption" or "health". Moreover, the microbial health risk has been already perceived before the introduction of the drinking water supply systems, due to the fact that they used to boil the raw water before drinking or preparing their food. In this case, the introduction of drinking water supply systems means tranquility because their water is regarded as safe. There is always a direct association of chlorine taste and/or odour with water safety.

What the risk perception of the raw water user group is concerned, the partial consumption of raw water represents a sort of "low risk perception": The use of raw water for hygiene practices and irrigation is not perceived as a potential risk although about 50% of these households use the same single pipe circuit for both the selective transport of drinking water and of raw water. This behaviour increases risks of disease transmissions, but these risks are not perceived.

4.3. Drinking Water Consumption

To explain the drinking water consumption habits of the respondents, their respective perception of waterborne health risks is more significant the than by their respective perception of the water quality. The reason for this lies in the organoleptic influenced perception of the water quality both for raw water and for drinking water.

The main reasons to consume raw water are:

- a limited awareness of the increased water contamination risk caused by the utilization of both the streams disposal site for household wastewater) and the soil (application of agricultural pesticides);
- a limited awareness of the different routes of exposure to the waterborne pathogens,
- the relatively higher costs of drinking water supply compared to the costs of raw water supply and
- a lack of control of the raw water supply systems by the municipality.

Raising the awareness of the interconnection between the areas' environmental problems and public health risks seems to be essential to illustrate the raw water risk and to

increase drinking water consumption among the inhabitants. Although the transmission of waterborne diseases and contamination by pesticides or human and animal excreta are identified as health risks in case of raw water use already today, approx. 60% of the participants who consume drinking water continue to use raw water for bathing, sanitation and gardening. The above-mentioned reasons for raw water consumption show that limited financial funds of the respondents partially explain their water consumption habits. Actually, all the inhabitants of the study area used to have a connection to the raw water supply system before the introduction of drinking water systems. As raw water is not treated before use, its supply is less expensive than the supply of drinking water.

The perceived "high cost" of drinking water is a reason to use raw water as alternative source of water. Moreover, raw water is used for household cleaning, laundry, bathing and sanitation, and gardening. This water utilization for household uses accounts for the largest part of the consumed water volume. Thus, by reducing the households' drinking water consumption, raw water utilization can contribute to reduce the households' overall expenditure.

5. Conclusions

Based on a quantitative and qualitative survey with interviews, this study has shown that the drinking water consumption patterns in three rural quarters of Medellín with recent introduction of drinking water systems depends to a larger extent on raw water risk perception than on the perception of water quality. Consumers of drinking water realize that streams in the area are contaminated through discharge of household wastewater and the pollution caused by pesticides used agriculture. They also see a link between this pollution and waterborne health risks and diseases. The answers of the survey show that this risk perception should already have been developed before the introduction of drinking water supply systems.

In general, the respondents of this survey evaluated "water quality" on the basis of a number of organoleptic properties which served as "drinking water quality standards". As raw water often meets these standards, too, respondents keep on using it, a tendency which is further strengthened by the lower costs of raw water compared to drinking water. Consequently, raw water is mistaken for drinking water or at least used for some household purposes.

Future studies in this area should focus on evaluating how raw water and drinking water are consumed during the day with the aim to detect different behaviours related to the drinking water consumption habits between the three groups. Further research may also measure organoleptic and microbiological characteristics as complementation for perception of water quality and risk, and to evaluate the pollution of the drinking water system through the use of a single circuit into their houses for selective transport of drinking water and raw water.

Finally, the study shows that drinking water campaigns should consider the socio-cultural context and perceptions of the target groups. Beyond this background, formative evaluations featuring "before"- and "after" campaign surveys could be appropriate instruments.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

LFRR conceived the project, designed the study, collected and analysed the data, interpreted the results and drafted the manuscript. AM provided critical feedback on the study design, the analyses and interpretation of results, critically reviewed the manuscript. All authors read and approved the final manuscript.

Acknowledgements

The authors are grateful to the public officials of the official departments for health and for social development of the municipality of Medellín in Colombia, who supported and participated in this research; and also to the managers and employees of the drinking water supply entities in the study area, who provided information and assistance during this research work. Acknowledgement is also made to Prof. Dr. J. Vogt of Institute of Regional Science, Karlsruhe Institute of Technology for his constructive comments.

References

[1] UNICEF & World Health Organization, *Progress on Drinking Water and Sanitation: 2012 update*, United States of America, 2012.

[2] World Health Organization & United Nations Children Fund, *Joint Monitoring Programme on Water Supply and Sanitation (JMP)* 2010. [Online]. Available: http://www.wssinfo.org/data-estimates/table/ [Accessed 2 November 2012].

[3] Fewtrell L. et al., *Water, sanitation and hygiene: quantifying the health impact at national and local levels in countries with incomplete water supply and sanitation coverage*, Geneva, World Health Organization, 2007.

[4] World Health Organization, *Water, sanitation and hygiene links to health*; 2004. [Online]. Available: www.who.int.water_sanitation_health/publications/facts2004/en/print.html [Accessed 20 June 2012].

[5] World Health Organization, *Valuing Water, Valuing Livelihoods*, Edited by John Cameron, Paul Hunter, Paul Jagals and Katherine Pond, IWA Publishing, London, UK, 2011.

[6] Anand PB, *Scarcity, entitlements and the economics of water in developing countries*, Cheltenham: Elgar, 2007.

[7] Banwell C., Stanley U., Dixon J., *When Culture Impacts Health: Global Lessons for Effective Health Research*, Academic Press, 2013.

[8] World Health Organization, *Guidelines for Drinking-water Quality*, Fourth Edition, World Health Organization, 2011.

[9] United Nations Environment Programme, *GEO5 Global Environment Outlook: Environment for the future we want*, Progress Press, Malta, 2012.

[10] Hitzeroth, M. Megerle, A, "Renewable Energy Projects: Acceptance Risk and their Management", *Renewable and Sustainable Energy Reviews 2013;* 27: 576-584.

[11] Doria MF, Pidgeon N, Hunter PR: Perception of tap water risks and quality: a structural equation model approach. *Water Science & Technology* 2005;52(8):143-9.

[12] Doria MF., "Bottled water versus tap water: understanding consumers' preferences", *Journal of Water and Health*, 2006; 4, 271-276.

[13] Doria MF., Pidgeon N, Hunter PR, "Perception of drinking water quality and risk and its effect on behavior: A cross-national study", *Science of the Total Environment* 2009; 407:5455-5464.

[14] Jardine C, Gibson N, Hrudey SE, "Detection of odour and health risk perception of drinking water"**.** *Water Science and Technology* 1999;40(6):91-8.

[15] Jones AQ, Dewey CE, Doré K, Majowicz SE, McEwen SA, Waltner-Toews D, Henson SJ, Mathews E, "A qualitative exploration of the public perception of municipal drinking water", *Water Policy* 2007;9:425-38.

[16] Levallois P, Grondin J, Gingras S, "Evaluation of consumer attitudes on taste and tap water alternatives in Quebec", *Water Science and Technology* 1999;40(6):135-9.

[17] Jakus PM, Shaw WD, Nguyen TN, Walker M, "Risk perceptions of arsenic in tap water and consumption of bottled water", *Water Resources Research.* 2009;45 W05405.

[18] Matos de Queiroz JT, Doria MF, Rosenberg MW, Heller L, Zhouri A, "Perceptions of bottle water consumers in three Brazilian municipalities", *Journal of Water and Health 2013*; 11(3): 520-531.

[19] Doria MF, "Factors influencing public perception of drinking water quality", *Water Policy* 2010; 12: 1-19.

[20] Alcaldía de Medellín, *Encuesta de Calidad de Vida Medellín 2011. Población*, Departamento Administrativo de Planeación, Medellín, Colombia, 2012.

[21] Universidad Nacional de Colombia (Sede Medellín), *Coberturas vegetales, uso actual del suelo y determinación de conflictos de uso del suelo con base en el POT de la zona rural del municipio de Medellín*, Convenio interadministrativo N° 4600021476 de 2009 UNAL-Municipio de Medellín, 2009.

[22] Alcaldia de Medellín, *Manejo integral del agua para el consumo humano. [Online]* Available: http://www.medellin.gov.co/irj/go/km/docs/wpccontent/Sites/Subportal%20del%20Ciudadano/Desarrollo%20Social/Secciones/Plantillas%20Gen%C3%A9ricas/Documentos/2011/mapa-v-7/inicio.swf [Accessed 13 November 2011].

[23] Estudios Técnicos, *Informe de Diagnóstico Técnico N. 001: Sistema de Acueducto Aguas Frias*, Medellín, Colombia, 2006.

[24] Estudios Técnicos, *Informe de Diagnóstico Técnico N. 001: Sistema de Acueducto El Hato*, Medellín, Colombia, 2006.

[25] Estudios Técnicos, *Informe de Diagnóstico Técnico N. 001: Sistema de Acueducto El Manantial*, Medellín, Colombia, 2006.

[26] Estudios Técnicos, *Informe de Diagnóstico Técnico N. 001: Sistema de Acueducto La Iguaná*, Medellín, Colombia, 2006.

[27] Estudios Técnicos, *Informe de Diagnóstico Técnico N. 001: Sistema de Acueducto Manzanillo*, Medellín, Colombia, 2006.

[28] Estudios Técnicos, *Informe de Diagnóstico Técnico N. 001: Sistema de Acueducto Montanita*, Medellín, Colombia 2006.

[29] Feuerpfeil I, Schindler P, *Bakteriologische Wasseruntersuchung*, In: Feuerpfeil I & Botzenhart, K (Hrsg.): Hygienisch-mikrobiologische 'Wasseruntersuchung in der Praxis: Nachweismethoden, Bewertungskriterien, Qualitätssicherung, Normen, Weinheim : WILEY-VCH, 2008.

[30] Alcaldía de Medellín, *Encuesta de Calidad de Vida Medellín 2010. Perfil Socioeconómico Corregimiento 60 San Cristobal*, Departamento Administrativo de Planeación, Medellín, Colombia, 2011.

[31] Alcaldía de Medellín, *Encuesta de Calidad de Vida Medellín 2010. Perfil Socioeconómico Corregimiento 70 Altavista*, Departamento Administrativo de Planeación, Medellín, Colombia, 2011.

[32] Alcaldía de Medellín, *Encuesta de Calidad de Vida Medellín 2010. Perfil Socioeconómico Corregimiento 80 San Antonio de Prado*, Departamento Administrativo de Planeación, Medellín, Colombia, 2011.

[33] Stockmann R., Meyer W., *Evaluation: Eine Einführung.* Opladen, Farmington Hills, Mich, Budrich, 2010.

[34] Rieger M., Schubert H., *Zur Analyse sozialer Räume. Ein interdisziplinärer Integrationsversuch*, In: Riege, M. & SCHUBERT, H. (Hrsg.): Sozialraumanalyse. Grundlagen Methoden Praxis. VS Verlag für Sozialwissenschaften, 2005, 7-71.

[35] Creswell JW, *Research design: qualitative, quantitative and mixed methods approaches 4th Edition*, SAGE Publications, United States of America, 2014.

[36] Bryman A., "Integrating quantitative and qualitative research: how is it done?", *Qualitative Research*, 2006, 6:97-113.

[37] H.O. Mayer, *Interview und schriftliche Befragung: Entwicklung, Durchführung und Auswertung.* 5., überarbeitete Auflage. Oldenbourg Wissenschaftsverlag GmbH, 2009.

[38] Comisión de Regulación de Agua Potable y Saneamiento Básico, *Reglamento Técnico del Sector de Agua Potable y Saneamiento Básico* 2000, Bogotá, Colombia, 2000.

[39] Comisión de Regulación de Agua Potable y Saneamiento Básico, *Resolución Administrativa 287 de 2004.*

[40] Departamento Administrativo Nacional de Estadística, *Proyecciones de Población Municipio de Medellín por comunas y corregimientos. Años 1993, 2005-2015.* [Online]. Available: http://www.medellin.gov.co/irj/portal/ciudadanos?NavigationTarget=navurl://a2d20c19c9fa69168cea30d571b3110f [Accesed: 23.09.2011].

[41] Departamento Administrativo Nacional de Estadística, *Perfil Sociodemográfico 2005-2015. Corregimiento 60 San Cristobal.* Convenio Interadministrativo DANE-Municipio de Medellín. 2010.

[42] Departamento Administrativo Nacional de Estadística, *Perfil Sociodemográfico 2005-2015. Corregimiento 70 Altavista*, Convenio Interadministrativo DANE-Municipio de Medellín, Colombia, 2010.

[43] Departamento Administrativo Nacional de Estadística, *Perfil Sociodemográfico 2005-2015. Corregimiento 80 San Antonio de Prado,* Convenio Interadministrativo DANE-Municipio de Medellín, Colombia, 2010.

[44] Universidad Nacional de Colombia (Sede Medellín), *Ecosistemas Estratégicos Microcuenca La Chata,* Contrato interadministrativo N° 48000001018 de 2008 UNAL-Municipio de Medellín, Colombia, 2008.

[45] Universidad Nacional de Colombia (Sede Medellín), *Ecosistemas Estratégicos Microcuenca El Hato,* Contrato interadministrativo N° 48000001018 de 2008 UNAL-Municipio de Medellín, Colombia, 2008.

[46] Universidad Nacional de Colombia (Sede Medellín), *Ecosistemas Estratégicos Microcuenca La Aguapante,* Contrato interadministrativo N° 48000001018 de 2008 UNAL-Municipio de Medellín, Colombia, 2008.

[47] Universidad Nacional de Colombia (Sede Medellín), *Ecosistemas Estratégicos Microcuenca La Iguaná*, Contrato interadministrativo N° 48000001018 de 2008 UNAL-Municipio de Medellín, Medellín, 2008.

[48] Alcaldía de Medellín, *Informe del Diagnóstico del estado actual de los Acueductos Veredales del Municipio de Medellín*, Colombia 2011.