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EVALUATION OF SANITARY CONDITIONS AROUND GROUNDWATER CAPTURE STRUCTURES IN THE MUNICIPALITIES OF GUIDIMOUNI AND GUIDIGUIR (ZINDER-NIGER REGION)

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ABSTRACT

This study focuses on evaluating the hygiene of groundwater capture structures in the municipalities of Guidimouni and Guidiguir in order to improve the health of the population. The methods used are based on a quantitative survey conducted using a structured questionnaire on the characteristics of the water intake facilities and their immediate surroundings. The study was conducted at 12 water sources spread across two municipalities: Guidimouni and Guidiguir. The results show that 100% of the water sources pose no risk related to factors such as the location of latrines, chemicals used in agricultural fields, water clarity, and the protection zone. However, the results showed that certain facilities triggered a “dirty” alert due to the presence or absence of factors such as manure pits (8%), animal pens and fencing (25%), pump leaks (25%), dirt on the floor (17%), overflowing water troughs (25%), normal dripping (17%), and deterioration of the superstructure (8%). These results confirm that most of the structures studied can be used to supply water to the populations of these localities.

Keywords: Water capture structures, Groundwater, Sanitation, Pollution.

1 INTRODUCTION

In Africa, drinking water is subject to chemical and/or bacteriological contamination ; the former is caused by natural contamination of water by elements found in rocks [1], industrial effluents, alloys, wood preservatives, fossil fuels, and so on, while the latter is caused by direct or indirect fecal contamination of human or animal origin. The use of this water in food preparation or as a beverage can lead to numerous cases of infection caused by pathogens such as bacteria, viruses, and protozoa [2].

In sub-Saharan Africa, access to safe drinking water is generally limited, especially in rural areas, where the majority of the population lives and faces sanitation challenges [3]. In developing countries such as Niger, despite the desire of most households to have access to safe drinking water from the public distribution network, the financial resources needed to access it are not always available to everyone. Less than one in ten people in Niger has access to safely managed drinking water. In fact, more than 35.4% of people living in urban areas have access to this type of water, compared to 1.01% of people in rural areas; in the Zinder region, 2.63% have access [4]. Several studies have been conducted on the physicochemical and microbiological quality of water in African countries, particularly in Niger, highlighting the characteristics of water at the source and in storage reservoirs [5, 6]. Numerous studies have established a link between declining water quality and the incidence of certain diseases. To complement these studies, wouldn’t it make sense to focus research on assessing the sanitary condition of groundwater collection facilities? To shed some light on this issue, we set out to evaluate certain hygiene parameters of drinking water sourced from groundwater abstraction facilities (wells and boreholes) in the municipalities of Guidimouni and Guidiguir. This study will therefore examine the design, construction, and monitoring of a water supply system in order to identify some of the causes of water pollution.

2 MATERIALS AND METHODS

2.1 Description of the Study Area

The Zinder Region is located in the central-eastern part of the Republic of Niger (12°48’ and 17°30’ North, 7°20’ and 12°00’ East). It is bordered to the east by the Diffa Region, to the west by the Maradi Region, to the north by the Agadez Region, and to the south by the Federal Republic of Nigeria along a border approximately 300 km long. Its area is estimated at 155,778 km², representing 12.3% of the national territory. Two areas were selected for the study:

The first study area is the commune of Guidimounie. The rural commune of Guidimouni is located in the southern part of the Damagaram Takaya Department, Zinder Region (Figure 1). It covers an area of 660 km². The commune of Guidimouni is bordered to the north by the rural communes of Damagaram Takaya and Mazamni, to the south by those of Wacha and Hamdara, to the east by the rural commune of Guidiguir (Gouré Department), and to the west by the rural communes of Zermou and Hamdara (Mirriah Department) (Figure 1).

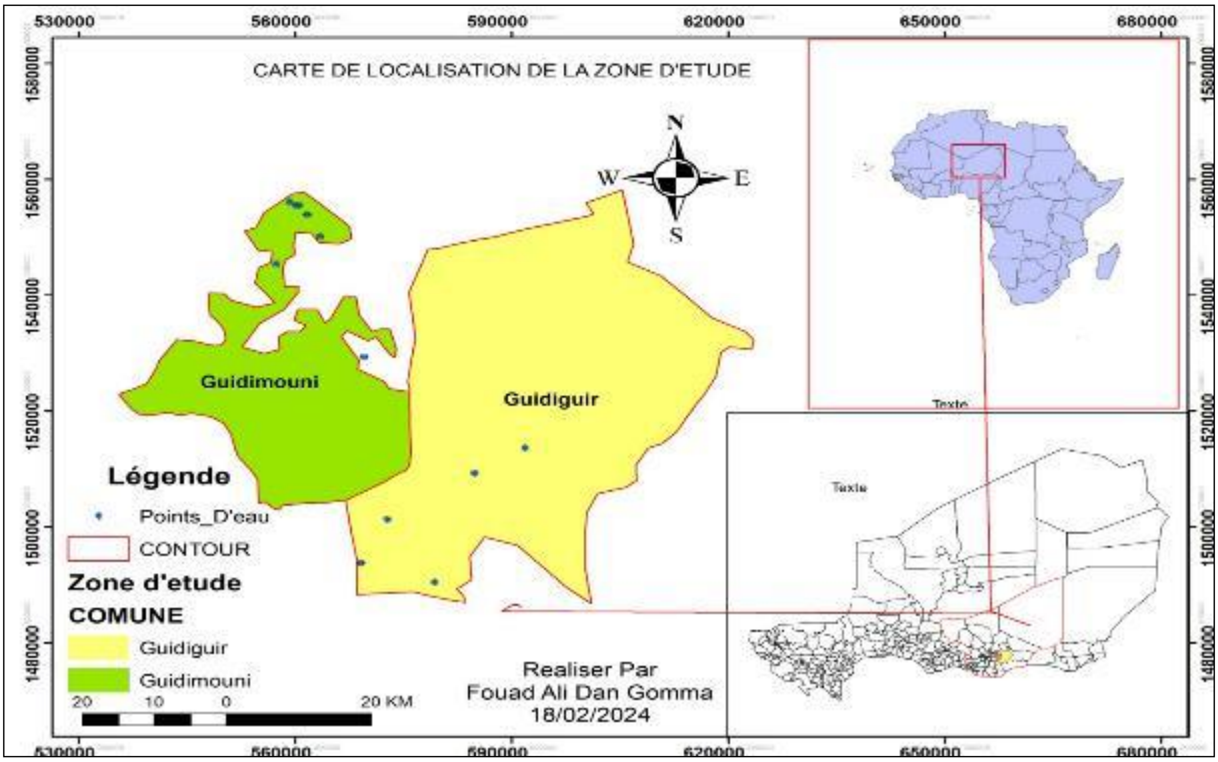

Figure 1: Map of the study areas

Applying the intercensal growth rate of 4.7% for the Damagaram Takaya department yields an estimated population of 102,836 in 2020. The second study area is the Guidiguir commune. The rural commune of Guidiguir is located in the southwestern part of the Gouré department, in the Zinder Region. The commune of Guidiguir is bordered to the north and east by the commune of Gouré, to the south by the commune of Bouné, and to the west by the communes of Gouchi, Guidimouni, and Damagaram Takaya. It covers an area of 1,794 km² (Figure 1). Applying the intercensal growth rate of

4.3% for the Gouré department, the population of the commune of Guidiguir in 2020 is estimated at 93,969 inhabitants [7].

2.2 Geology and Hydrogeology

The geology is characterized in the center by outcrops of the crystalline basement in the Damagaram-Monio massifs, which separate two major sedimentary basins: the Ouillimindens Basin to the north, and the Lake Chad Basin to the east and south.

The rock formations encountered, from the most recent to the oldest, are alluvial, continental, and basement, respectively. In the very south, there is a system of fixed dunes that represents the surface geology (Figure 2).

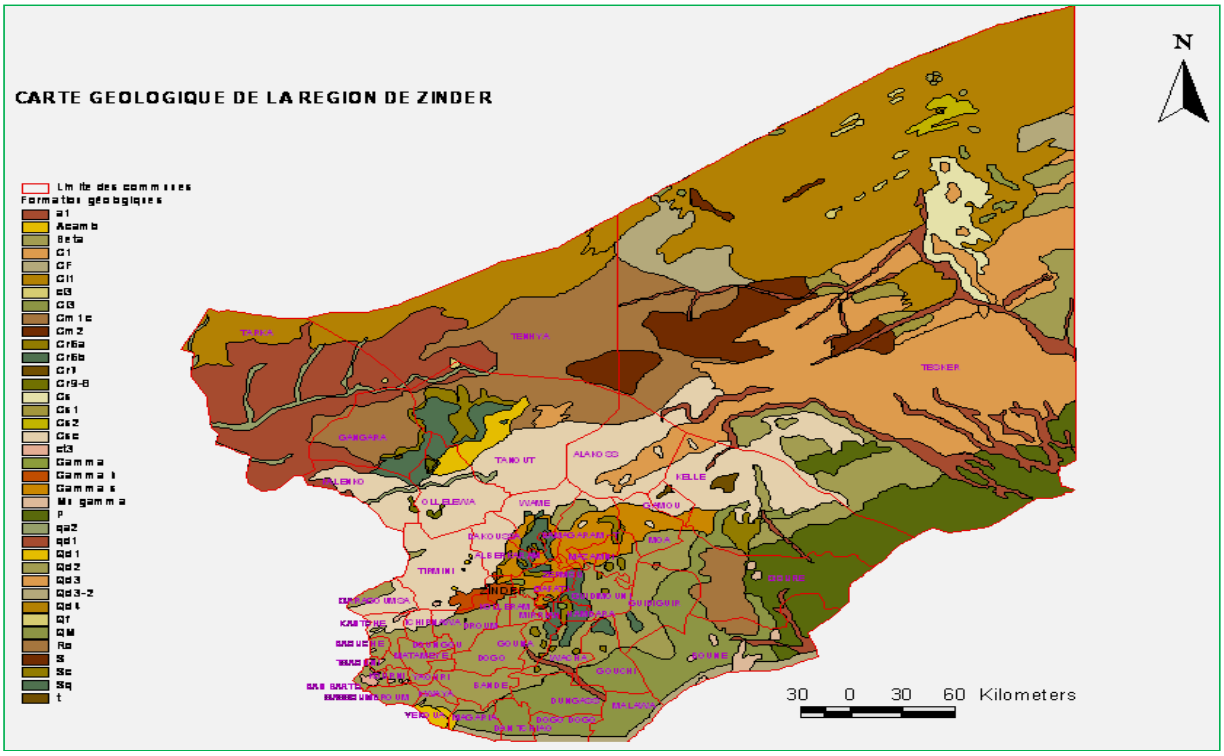

Figure 2: Geological map of the Zinder region.

The Zinder Region encompasses three (3) hydrogeological zones: the Continental Intercalary Zone in the northwest, the crystalline basement in the center, and the Lake Chad Basin in the southeast (Figure 3).

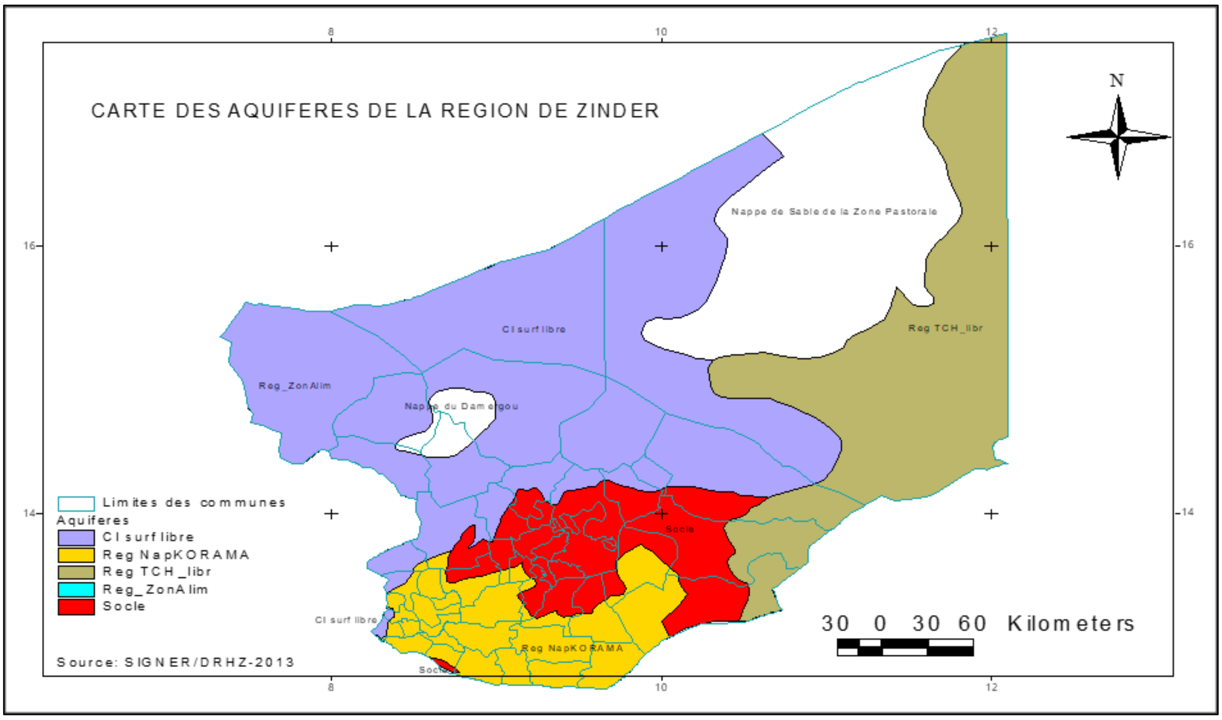

Figure 3: Map of Aquifer Systems (Groundwater Resources).

2.3 Methodology

The methodology used is based on a quantitative survey conducted using a structured questionnaire. To identify the factors contributing to well contamination and the associated health risks, a survey was conducted among the communities that use these wells. This involved observing the immediate surroundings of the wells and holding informal discussions followed by a question-and-answer session. The study was conducted during the month of December 2023. This study focused on a total of 12 water sources. The survey questionnaire consisted of two sections, as follows:

- **Characteristics of the water capture point**: This section provides information on the depth, the state of deterioration of the structure and water distribution facilities, the availability of a protection zone, and whether or not the water sources are covered.
- **Immediate Environment of the Water Capture**: This section provides information on the nature of pollution and the distance between these sources of pollution and the water sources.
- **Characteristics of the Captured Water**: This section provides information on the organoleptic quality of the water.

3 RESULTS AND DISCUSSION

The results obtained from surveys of water capture users, on the characteristics of water capture sites, on the physical quality of the water, and on the environment surrounding the water capture sites. These results are presented in the following table.

Table 1: Survey Results by Presence of Pollution Sources

Sources of Pollution	Number of YES responses	Number of NO responses
Presence of a latrine	0	12
Existence of a manure pit	1	11
Existence of an animal pen	3	9
Existence of Chemicals	0	12
Existence of a closing	5	7
Existence of a pump leak	3	9

Existence of dirt on the floor	10	2
Existence of an overflow in the water trough	3	9
Existence of water clarity	0	12
Existence of Normal Taste	2	10
Existence of damage to the superstructure	1	11
Existence of the protection perimeter	12	0

Figure 4 shows the distribution of water sources based on the presence or absence of pollution sources, the characteristics of the sources and the environment surrounding the capture points, as well as the physical quality of the water.

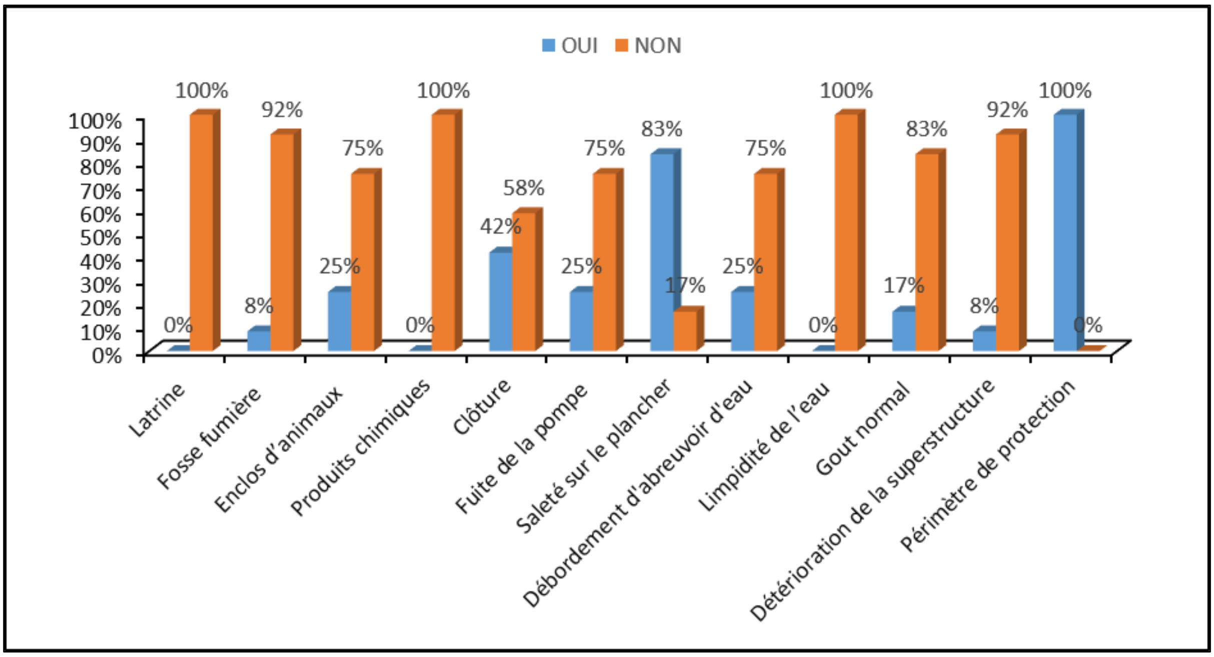

Figure 4: The percentage distribution of water sources based on the presence or absence of pollution sources.

3.1 Position of Water Sources Relative to the Latrine

Figure 4 shows that all water sources are located more than 30 meters from latrines, which is significantly greater than the 15-meter distance recommended by the WHO. This allows us to rule out any risk of microbiological contamination from the latrines. Numerous studies have shown that the extent of pollution from a latrine to groundwater depends on the speed and direction of water flow. This flow velocity depends on the physical structure of the soil, its grain size, and the degree of rock variability [8]. From another perspective, none of these wells were constructed with the slope of the ground in mind. This technical error could lead to fecal contamination [9].

3.2 Distance from Wells to Manure Pits/Garbage Dumps

The results obtained from direct observations of water sources in relation to the distance from wells to manure pits/garbage dumps are presented in Figure 4. The figure shows that 8.33% of water sources are located less than 30 meters from a manure pit or garbage dump, compared to 91.67% that are more than 30 meters away. In fact, water sources located less than 30 m from a manure pit or garbage dump pose a risk of contamination from the chemicals and microorganisms contained in this waste, via runoff and water infiltration. Our results are consistent with those found by El Haissoufi et al. [10] for wells surveyed in the city of Fez. The presence of these substances renders the water unfit for human consumption, as it causes waterborne diseases such as cholera, typhoid fever, and dysentery [11, 12].

3.3 Distance Between Water Wells and Animal Pens

Figure 4 shows the results of the distribution of water sources based on their location relative to animal pens. The figure indicates that 25% of water sources are located less than 30 meters from an animal pen, while 75% are more than 30 meters away. These animal pens can be a source of contamination for these water sources through the mechanisms of stormwater runoff and infiltration [13, 14]. This results in the presence in drinking water of certain microorganisms and chemicals that can cause waterborne diseases such as cholera, typhoid fever, and dysentery [15]. This finding is supported by several other authors, notably [16, 17, 18], who report that a distance of 1 to 25 meters reduces fecal coliforms from runoff by 99 percent.

3.4 Distance from well to fields where chemical fertilizers are applied

Figure 4 shows the distribution of water sources based on their location relative to chemical residues from agricultural activities within 30 meters. This figure reveals that 100% of the water sources are located more than 30 meters from fields where chemical fertilizers and pesticides are applied. These water structures are not exposed to contamination from chemicals resulting from certain agricultural activities. In fact, the inputs used (mineral or organic fertilizers, pesticides) may be partially lost to the environment through surface runoff or infiltration into underground drainage systems. These losses of suspended solids, nutrients, and pesticides affect various water uses [19, 20].

3.5 Distribution of Water Sources by Presence of Fencing

The quality of water resources has been deteriorating in recent years due to pollution hotspots caused by human activities. As a result, it has become necessary to implement mechanisms and measures aimed at preserving and protecting these resources [21]. Preventing contamination at the local level involves erecting protective fencing around wells. Protective fencing around groundwater recharge areas is considered an ideal tool for identifying and reducing any sources of pollution that could harm the quality of water intended for drinking water supply. The installation of protective fencing around water catchments intended for human consumption, along with monitoring of the associated regulations, improves public health by reducing the risk of sudden, large-scale microbial or toxic contamination through the control of activities that could lead to accidental pollution affecting water quality [22]. Figure 4 shows the distribution of water sources based on whether they have a barrier to prevent animal access. The figure indicates that 41.67% of water sources have a wall preventing animal access, compared to 58.33% that do not. Therefore, the majority of these water sources are at risk of bacteriological contamination from the feces of animals that drink from them. These feces may contain microorganisms that cause fecal-oral diseases and could increase nitrogen levels, which in turn could raise nitrate and nitrite levels in the water.

3.6 Distribution of Water Points Based on the Presence of Pump Leaks

Figure 4 shows the distribution of water points based on the presence of pump leaks. According to this figure, 25% of water points have leaks at the pump, compared to 75% that do not. Such leaks in water distribution systems can have several negative impacts on water quality. These effects are physical, chemical, and microbiological in nature. Indeed, when there is a leak in a water pipe, the pressure in the system drops. This can allow contaminated water from the soil or the environment to enter the water distribution system. This contaminated water can serve as a vehicle for various forms of contamination, such as microbiological contamination (bacteria, viruses, or parasites), deterioration in chemical quality (nitrates, metals, pesticides, hydrocarbons), and increased turbidity [23]. Furthermore, over time, water leakage at these water points can create swamps around them, which can also be a source of contamination through runoff and infiltration.

3.7 Distribution of Water Sources Based on the Presence of Dirt in the Drainage Pipe

Figure 4 shows the distribution of water supply points based on the presence of debris in the water distribution pipes. According to this figure, 83.33% of the points have clogged pipes (presence of sediment, debris, or scale), compared to 16.67% with pipes clean enough for consumption. Nearly all of these water points show the presence of contaminants in the water distribution pipes. This indicates a problem with regular maintenance that should be addressed by the water point management committee. Contaminants in water distribution pipes cause numerous adverse effects on water quality physically, chemically, microbiologically, and in terms of public health. In fact, in terms of physical impact, contaminants accumulated in the water distribution networks such as sludge, sand, mineral deposits, and corrosion particles can increase water turbidity, alter its organoleptic quality, and lead to the presence of suspended solids. With regard to effects on chemical quality, deposits in pipes often promote metal corrosion, the release of metals such as iron, manganese, or lead depending on the nature of the distribution system and changes in pH. In terms of the impact on microbiological quality, dirt provides a favorable environment for the growth of microorganisms; it can protect bacteria from the action of disinfectants, promote the formation of biofilms inside pipes, and lead to the proliferation of pathogenic germs [24]. Furthermore, the presence of dirt deposits in water distribution pipes can reduce the effectiveness of disinfection (using chlorine or other disinfectants) and cause technical issues in the system (reducing the effective pipe diameter, decreasing flow rate, increasing pressure losses, and contributing to breakdowns and leaks) [25].

3.8 Distribution of Watering Points Based on the Presence of Overflow from Water Troughs

Figure 4 shows that 25% of water sources have overflowing water troughs, while 75% do not. Although this overflow affects only a small proportion of the structures, it can lead to the formation of stagnant water and muddy areas around the water sources. These environments provide habitats conducive to the proliferation of vectors, particularly mosquitoes [26]. The presence of these vectors increases the risk of transmission of vector-borne diseases, such as malaria, dengue, and yellow fever, which poses a public health challenge for local communities.

3.9 Distribution of Water Sources Based on Users' Perception of Water Clarity

The results shown in Figure 4 indicate that 100% of these water sources are not muddy. This is because all the water from these sources comes from underground springs. Nevertheless, clear water is not necessarily safe or potable. Clarity primarily indicates the visible absence of suspended solids, but it does not provide information on physicochemical, bacteriological, or sanitary quality [27]. Regarding physicochemical quality, clear water may have good visual characteristics but still contain invisible dissolved substances. Physicochemical quality is assessed based on physical parameters (such as pH, conductivity, turbidity, color, odor, taste, and hardness) and chemical parameters (such as nitrates, nitrites, ammonium, chlorides, sulfates, fluorides, and metals like iron, manganese, and lead) [28, 29]. As a result, clear water may appear visually clean yet be chemically unsuitable for human consumption. From a bacteriological standpoint, clear water may be contaminated with invisible microorganisms. From a public health perspective, clear water is considered safe when it contains no pathogens or toxic substances at dangerous concentrations and poses no short- or long-term health risks to consumers [30, 31].

3.10 Distribution of Water Sources by Taste Quality

Water that tastes bad is not just a matter of comfort: It can have direct and indirect health implications. Taste often serves as a warning sign indicating the presence of undesirable substances or a decline in water quality. Figure 4 shows the distribution of water sources by taste quality [32, 33]. The results presented in this figure show that 16.67% of the water from these boreholes is organoleptically very acceptable, compared to 83.33% that does not have a normal taste. Changes in the taste of water may be due to high levels of certain physicochemical parameters such as turbidity, iron, etc., in the water (Rodier, 2009).

3.11 Distribution of Water Sources by Infrastructure Deterioration Level

The level of deterioration of water infrastructure (treatment plants, reservoirs, pipelines, pumps) plays a decisive role in the final quality of the distributed water. Aging or poorly maintained infrastructure can undermine all initial treatment efforts. In terms of physicochemical quality, infrastructure deterioration leads to material corrosion, the accumulation of deposits, and changes in chemical parameters. In terms of sanitary quality, infrastructure deterioration increases the risk of waterborne diseases (diarrhea, cholera, typhoid fever), exposure to toxic substances, and a decline in user confidence [34, 35]. Figure 4 shows the distribution of water sources according to the state of infrastructure deterioration. According to the results presented in this figure, 8.33% of water sources exhibit deterioration of the superstructure, compared to 91.67% that are in good condition. This deterioration leads to the intrusion of pathogens, pollutants, and organic matter. This leads to the spread of waterborne diseases (cholera, diarrhea, typhoid, dysentery, etc.) and a decline in water quality (taste, odor, color).

3.12 Distribution of Water Sources Within the Protection Perimeter

The protection perimeter is a fundamental element in the management and preservation of the quality of water intended for human consumption. It is a regulated zone established around a water intake (drilling site, well, spring) to prevent any contamination. In terms of water quality, protection zones help prevent microbiological contamination, reduce chemical pollution, shield against physical pollutants, and improve water treatment [36, 37]. Conversely, the absence of a protection zone can result in a high risk of rapid contamination, continuous deterioration of water quality, an increase in waterborne diseases, high treatment costs, and, in some cases, the abandonment of the water source [38]. Figure 4 shows that 100% of water sources have an immediate protection zone (20 m). This protection significantly reduces the risk of water contamination from accidental pollution caused by human activities in the immediate vicinity of the water source.

4 CONCLUSION

This study evaluated certain hygiene parameters of drinking water from groundwater abstraction facilities (wells and boreholes) in the municipalities of Guidimouni and Guidiguir. Our results showed that none of the facilities posed any risks related to factors such as the location of latrines, chemicals used in agricultural fields, water clarity, or the protection zone. However, the results also indicate that several water collection facilities present risk factors that could compromise the sanitary quality of the groundwater. These factors are primarily related to the absence or inadequacy of certain protective and sanitation measures, as well as to structural deficiencies, such as the absence of a waste pit (or manure pit), animal pens, or protective fencing; leaks in the pump; dirt on the concrete slab; overflowing water troughs, poor drainage of runoff water, and deterioration of the superstructure. These deficiencies are likely to facilitate the introduction of contaminants into water collection structures and increase the risk of water quality degradation. For the purposes of this study, physicochemical and microbiological analyses will be conducted to assess the level of water contamination and determine the influence of these risk factors on water quality.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare that they have no competing interests.

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