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Evaluation of Rural Household Drinking Water Treatment: A Case Study of Rajaf Payam Central Equatoria State, Juba-South Sudan

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ABSTRACT

The supply of clean drinking water is one of the most critical facets of primary health care, the main challenges of sustainable development in rural regions. However, Rajaf Payam experiences significant challenges in accessing clean and safe water. The study is designed to explore drinking water treatment methods in Rajaf Payam. Questionnaire was designed to conduct survey on sources of drinking water and drinking water treatment methods in the area, published articles included reports from the national government and some NGOs working in the rural drinking water sector were collected. So far 200 people participated in this study, from whom 60% were male, 40% female. However, 50 critical informant interviews and surveys were conducted, with 150 participants filling out questionnaires. The results show that 66% of the community use chlorine for drinking water treatment. Nonetheless, 19% are using boiling method, 10% using normal filtration (Water settling). At the same time, 5% know nothing about drinking water treatment. Therefore, this study recommending the Point-of-use (POU) of drinking water treatment technologies such as boiling, slow sand filtration, chemical disinfection, flocculation and coagulation, UV-C disinfection, and solar disinfection to the community of Raja Payam to enable them to access high quality drinking water and to avoid chronic drinking water related disease.

Keywords: rural household; drinking water sources; drinking water treatment; Rajaf Payam Juba-South Sudan

INTRODUCTION

Water treatment (WT) is describing as steps taken to make drinking water cleaner, including boiling, filtering, or chlorine treatment. The typical protective factor was water treatment since these procedures were meaning to kill or inactivate bacteria introduced by fecal-oral contamination. Lack of treatment makes it possible for water to remain polluted, leading to the spread of disease and has been a projected risk factor[1]. Drinking water (DW) had a satisfactory physical-chemical and bacteriological consistency and could be safely consumed, cooked with, and used for other purposes. The most common and widespread health hazards associated with drinking water in developing countries are biological hazards. According to the WHO, almost 1100 million people worldwide consume contaminated water, and 88 percent of diarrheal disease causes a lack of clean water, sanitation, and hygiene [2]. In contrast, 1.8 billion people across the world lack access to healthy drinking water. Boiling remains the most popular HWT process worldwide, despite decades of mixed performance in marketing HWT utilizing retail items such as chlorine and ceramic filters. Though boiling helps microbiology, HAP from biomass and coal combustion induces cardiovascular and pulmonary disease, and biomass processing is time-consuming; the water boiled in pots is quickly re-contaminated black carbon pollution worsens climate change[3].

Drinking contaminated water is a leading cause of preventable disease, particularly among the young, immunocompromised, and frail. As a consequence, water is essential for preserving human health. According to a joint tracking effort led by the WHO and the UNICEF, For the last 15 years, the Millennium Development Goals (MDGs) have made significant progress in expanding access to clean drinking water and better sanitation[4, 5]. Three elements make up a clean drinking water system (SWS): (1) point-of-use disinfection with a locally manufactured sodium hypochlorite solution, (2) stable water treatment, and (3) behavior improvement communications. SWS decreased the chance of diarrhea by 26–85 percent in field trials[6]. The supply of clean water is one of the most critical facets of primary health care; centralizing water delivery to rural regions is one of the main challenges of sustainable development. Farm operators lack an understanding of primary care concepts: inadequate equipment upkeep, budgetary pressures, and neighborhood participation during the planning period. As a result of the Insufficient water management facilities, remote areas are at risk of disease. The rural areas are affected by this unsatisfactory situation[7].

The United Nations Millennium Development Goals (MDGs) state that by 2015, the number of citizens lacking access to drinking water would have decreased by half. Rural people in many developed countries must receive their drinking water from unregulated surface streams, primarily located far from their homes. Around 1.1 billion citizens in low-income countries do not have connections to better water supplies[8]. According to UNEP/UN-Habitat, the planet faces a water shortage in terms of consistency and quantity due to population development. However, water policy was established in South Sudan in 2009 and acted as a holistic structure. The need to prioritize better access to basic sanitation in small towns and peri-urban areas over rural sanitation spending and the need to include technological options to give citizens a preference based on financial restrictions were fundamental principles. Water is considered a fundamental right in the policy. Via the distribution of water resources through the private sector strongly promotes voluntary engagement and national solidarity (NSP) [9]. Entry to clean and secure water is challenging in Rajaf Payam. The vast majority of the populace drinks water extracted from rivers or wetlands. Both factors contribute to the spread of waterborne infections, as well as poor water treatment. Access to drinking water is especially challenging in places on the outskirts of Juba, such as Rajaf Payam. Gumbo had 14 boreholes under Rajaf Payam in the 1980s, but only three are now operational. Just one of four boreholes in Rajaf Payam is still active. The majority of citizens, however, depend on mobile water trucks. Residents of Rajaf Payam (Tokiman) have connections to the plant's safe water. Others, on the other side, depending on trucks for their water supply. The water sold in its natural state, with a barrel of water (200 liters) costing about SDG 5, or $2[10].

Besides, poor drinking water treatment caused several associated ailments, including diarrhea caused by inadequate drinking water treatment. Imagine attempting to extract water from a river daily, and it will take more than an hour. Diarrhea may not keep the children from receiving the foods they need to eat, eventually contributing to malnutrition. Many people carry water from a long distance, resulting in long queues for water collection. You will also stand in line for hours and then walk away without water. The majority of residents reside in tiny agricultural areas and isolated settlements with little access to safe drinking water. Established drinking water delivery facilities are redundant and in urgent need of maintenance. However, to overcome the water treatment and management challenges. They considered the high demands for rural drinking water treatment and management policies. A healthy lifestyle necessitates contaminant-free water.

Diseases like trachoma, cholera, typhoid, and schistosomiasis have been transmitting by polluted drinking water. Because of environmental, physical, and radiological reasons, drinking water may contaminate toxins harmful to human health. Women and children, particularly those living in rural areas, may need drinking water because they are frequently responsible for transporting water over long distances[11].

Disinfection is typically performed in combination with particle removal processes to include several obstacles to waterborne disease treatment is a crucial feature of water treatment. Chemical disinfectants, especially chlorine, have traditionally been used to achieve this goal, but new alternatives are becoming available[12]. Chemical or physical disinfectants are used, with chlorine being the more popular (added to water as a Gas or Solid) to drink clean water; chlorination is the term for thorough disinfection [13]. While water source measures mitigate diarrhea, research shows that point-of-use interventions, such as household water treatment and storage (HWTS), are much more efficient. In rural areas where household piped water connections are not accessible, household water treatment methods are fundamental. Pollution at the source or improper post-processing treatment endangers open water. HWTS technologies that are available include boiling, slow sand filtration, chemical disinfection, flocculation and coagulation, UV-C disinfection, and solar disinfection [14]. Oxfam's direct financing has supported a solar-powered water treatment plant in Rajaf Payam, one of Juba's poorest and most cholera-affected regions, as part of the 2016 Rajaf Payam Rural Water Treatment Initiative. The Gumbo Water Treatment Plant (WTP) in Rajaf Payam, with an optimal 300 m3 output capacity, offers a lifeline facility to approximately 20,000 residents in an environment where public and private utilities are unavailable. It worked by bringing in freshwater from the Nile River. They are either washed and chlorinated or pumped by a filter pump, Sedimentation, Coagulation, Chlorination, and other methods. While the elevated water tank and electrical operating device provide clean and potable water to approximately 13 water tank drivers, 30 water bicycle sellers, and 600 households, as seen below **FIGURE 1**[15]. As a consequence, the ultimate aim of this paper is to evaluate the rural household drinking water treatment in Rajaf Payam, Central Equatoria State-Juba South Sudan. To provide local areas with higher drinking water treatment levels for achieving the UN's 2030, Agenda's Sustainable Development Goals (SDGs). To ensure the provision and sustainable treatment and management of clean water and sanitation (SDG 6), all residents must have access to safe drinking water and sanitation by 2030.

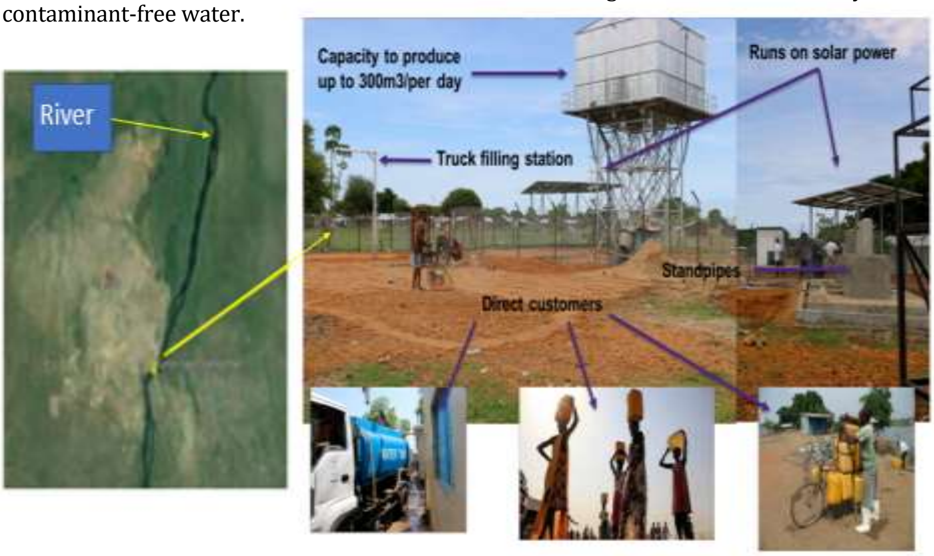

FIGURE 1: Rajaf Payam Solar-Powered Water Treatment Plant

MATERIAL and METHODS

Description of the Study Area-Rajaf Payam

Rajaf Payam is one of the Payam of Juba County, Central Equatoria State in South Sudan, located on the White Nile's west bank. Its Latitude is 4.752233°and Longitude 31.571871° as shown below **FIGURE 2**, while its Elevation is 489m[16]. It populated since colonial times, and the population distribution size of Rajaf Payam in 2009 in 31,000 people[17].

Socio-Economic Activities of Rajaf Payam

The economy of Rajaf Payam is relying on the gathering of firewood. Small bundles, large bundles, Charcoal-burning Stone splitting, or mountain rocks Smearing homes, Creating bricks, Small-scale farming and vegetable production, as well as manufacturing alcohol and riding motorcycles, are both examples of agricultural practices (Boda-boda) [18].

Overview of Rajaf Payam Climatic Conditions

Rajaf Payam is the Payam under Juba County Central Equatorial State in the out shirt of Juba city**.** Its climatic conditions are close to those of Juba, a tropical rainy and dry atmosphere. Temperatures are high all year due to their proximity to the equator. From November to March, the hottest months of the year, there is little rain, with high temperatures exceeding 38°C in February. And more than 100 millimeters of rain falls per month from April to October, and the average temperature, both high & low temperature, is shown in **TABLE 1**[19]

TABLE 1: The average rainfall, average temperature both (high and low temperature)

Months	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Average Rainfall Amount (mm)	5.1	11	36.7	111.5	129.9	117.6	144.7	127.5	103.7	114.5	43.1	8.2
Average Temp (High Temp) ^{0}C	36.8	37.7	35.4	33.5	32.4	31.1	31.6	33.1	34	34.7	34.7	35.9
Average Temp (Low Temp) ^{0}C	20.1	21.7	23.6	25.4	22.6	21.9	21.1	21	21.1	21.5	20.9	20

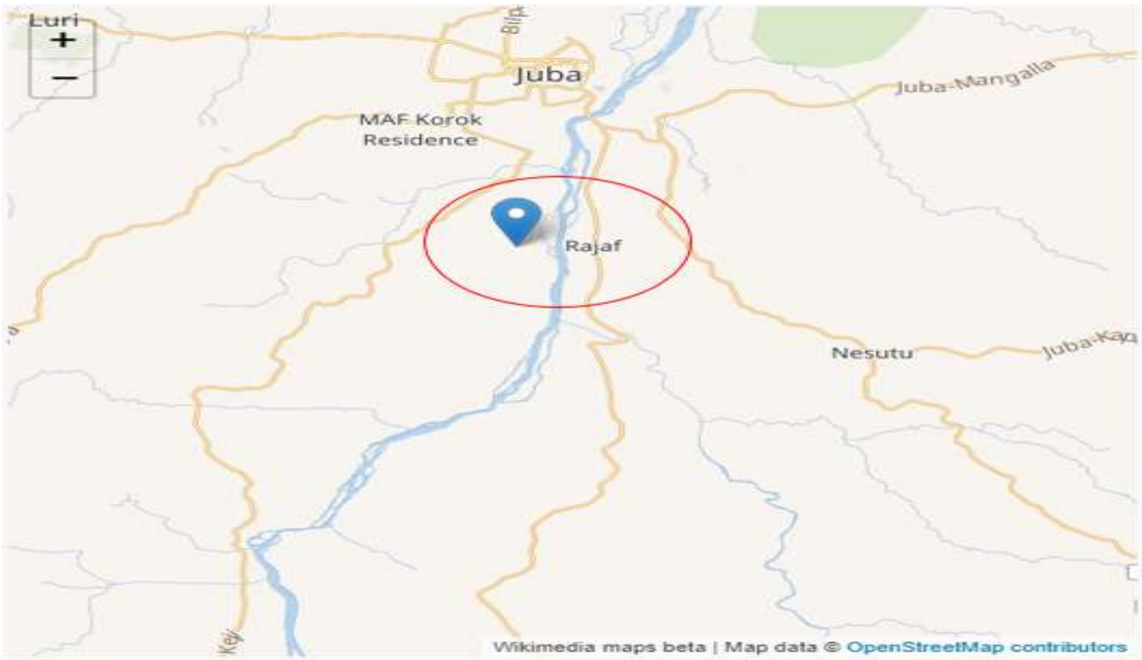

FIGURE 2: Map showing the location of Rajaf Payam

Sampling Strategy

The selection of respondents is applied using systematic simple random sampling. The sampling's general aim was to determine the correct sample that would be right for the population. The sample size was 200 respondents out of 395 total respondents in the Rajaf Payam household of 31.000 by using the Yamane (1967:886) provides a more straightforward procedure to calculate the sample size in the Rajaf Payam household of 31.000; the sample size has been compute using this method. An equation to have a 95 percent trust level and a precision level of P = 0.05. In 2009, Rajaf Payam had a population distribution of 31,000 inhabitants[17]

TABLE 2: Sampling flame (respondent's rate by Bomas)

S/N	Bomas (Villages)	Frequency	Percentages
1	Rajaf Main Office	47	23.5
2	Rajaf Lologo	4	3
3	Rajaf East	56	28
4	Rajaf West	77	38.5
5	Rajaf Gumbo	3	1.5
6	Rajaf Jondoru	2	1
7	Rajaf Checkpoint	11	1.5
	Total	**200**	**100**

The formula is:

$$n = \frac{N}{1+N(e)2}$$

- ✓ **n** = Sample Size
- ✓ **N** = Population Size
- ✓ At **95%** level of confidence and **P=5**
- ✓ **n** = 31,000/1+31,000 $(0.05)^2$ n = 395 Sample size of the respondents
- ✓ **e** = Level of Precision (05)

Research Design and Data Collection

The Rajaf Payam was chosen as the research study area to access the information about the rural household drinking water treatment. The questionnaires on demographics, rural drinking water treatment types, and water sources have been administering. It has applied both qualitative and quantitative research methods to collect the relevant data. In summary, the instruments used for data collection included observations, individual interviews, key informants, and photographs. It's essential to identify and define the specific field for compliance when the observer is looking at the events or place of data collection[20]. Secondary data on drinking water treatment and other relevant information gathered from the state, non-governmental organization studies, and several scientific

Data Analysis Method

The information on a household, including drinking water treatment and storage, socio-demographics, and participants' education level, was collected with a questionnaire administered in the rural area.

Questionnaire answers were entered into an Excel Sheet 2013 and checked for accuracy and fullness in Microsoft Excel 2013. The data analyzed by applying Origin software such as 3-D Color Pie Chart, Stack Bar, Column plus Label, and Bar/Line plus symbol to identify the rural household percentages treating their drinking water treatment in Rajaf Payam.

RESULT and DISCUSIONS

Percentage for Gender Respondent's Rate

A total of 200 households were interviewed, with male respondents higher than female respondents, whereby male respondents representing 60% and females representing 40%. It shows that both sexes, male and female, were met by the researcher. During the questionnaires distributions and the interviews carried out in the residential areas, the male respondents were more than female respondents.

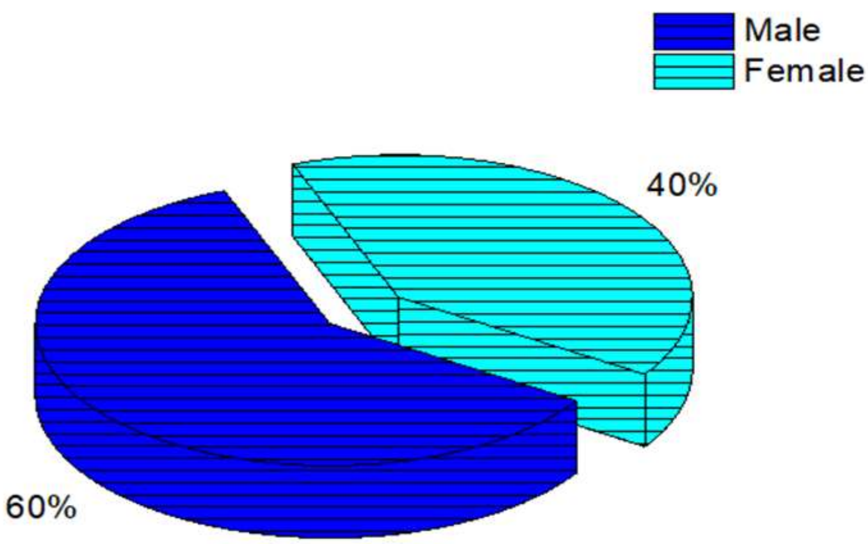

FIGURE 3: Percentage for gender respondent's rate

The Rajaf Payam Main Drinking Water Sources

The word "drinking water supplies" applies to the region from which residential and public-sector water is extracted and includes rivers, streams, ponds, and groundwater[21]. Rajaf Payam populations depend on a variety of drinking water sources, including surface water, boreholes, and streams according to the closest accessibility to drinking water. The research study finding has identified the following main primary sources of drinking water in Rajaf Payam, as shown in **Figure 4-5.** Therefore, rural Rajaf Payam communities used various primary drinking water sources for drinking and other activities. The public tap, boreholes, protected dug well, unprotected drilled wells, rainwater collection, surface water, nd stream.

Most of the Rajaf Payam communities have their primary source of drinking water. From boreholes representing 59%, because there is no pipeline water supply system and some districts communities use surface drinking water, 23.5%, the protected dug well is 3.5%, and water tank trucks represent 3.5%, other used 2.5% of drinking water from the stream. Finally, drinking water from an unprotected dug is 3% for rural communities and 3% for the public tap. Simultaneously, 2% of the communities get their drinking water from rainwater collection simply because other ones in the rainy season prefer to get their drinking water from rainwater collection.

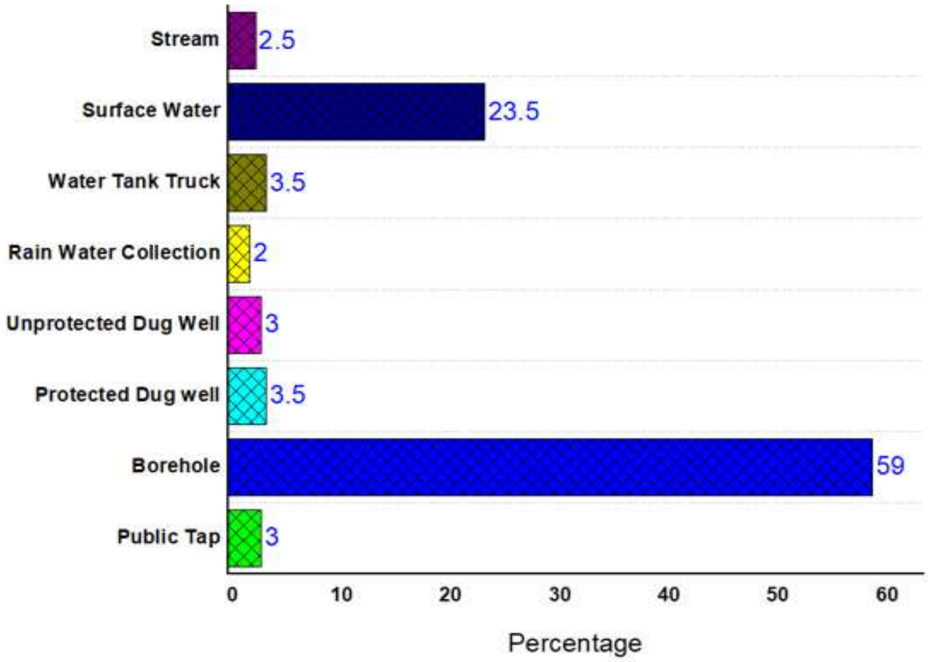

FIGURE 4: Percentage distribution for Rajaf Payam primary drinking water sources

A. Borehole

B. Surface Water

C. Public Tap

D. Water Tank

FIGURE 5: Rajaf Payam Drinking Water Sources

Rajaf Payam Household Drinking Water Treatment Method

A fundamental need for good health is healthy drinking water; access to drinking water may be essential for women and children, especially in rural areas, who often bear primary responsibility for carrying water over long distances[11]. The critical aspect of water treatment is that disinfection is usually achieved in conjunction with particle removal processes to provide multiple waterborne disease treatment barriers. Chemical disinfectants, particularly chlorine, have been the traditional means of achieving this objective, although other options are becoming accessible[12]. Therefore, the treatment method for drinking water in Rajaf Payam is shown in below **FIGURE 6.** It has indicated that most of the community, 66%, use chlorine to treat their drinking water.

Because chlorine is provided free of charge to local communities by some of the non-governmental organizations, and mostly drinking water is handled by NGOs. Nonetheless, 19% are boiling their drinking water, 10% are placing or letting the drinking water stand and settling for a few minutes to allow the water particles to settle down without adding chlorine. They can drink despite this procedure; however, some of the water particles will remain not settling down. At the same time, 5% said they did not know how to treat their drinking water. It indicated that they use their drinking water directly from the drinking water supplies without water treatment.

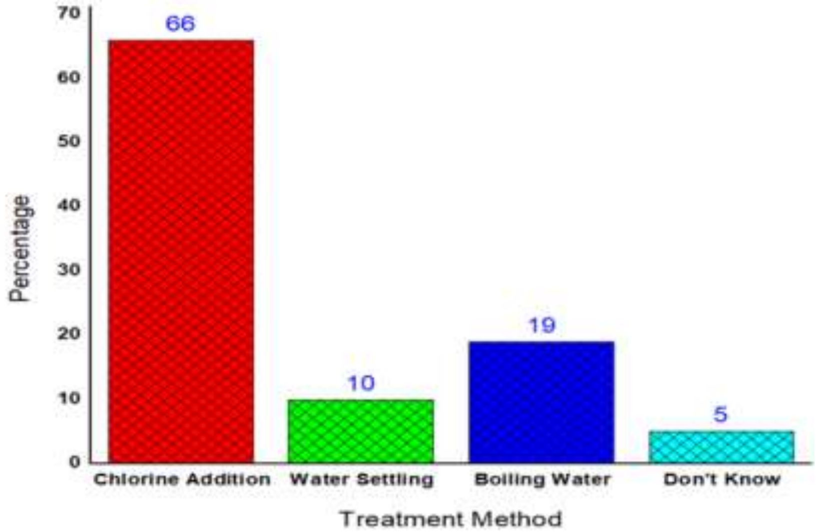

FIGURE 6: Rajaf Payam drinking water treatment method

Rajaf Payam Households Drinking Water Storage Facility

When on-site sources are unavailable or intermittent, storing household water is a popular procedure. Even as changes are made to the continuous on-site implementation of water supplies, dependence on storage water continues due to habit, service interruptions (or fear of interruptions), and ease. Although adequately protected storage water can improve inconsistency over time due to settling and natural pathogen die-off, it can also degrade due to contact with feces- contaminated hands, utensils, and insects.

However, Rajaf Payam household respondents were asks about the water storage facilities they usually used to store their drinking water. Nevertheless, the study found that 74.44% of Rajaf Payam households used plastic barrels to keep their drinking water. In contrast, 20.56% used ordinary water pots to store their drinking water, and 5 percent used other containers.

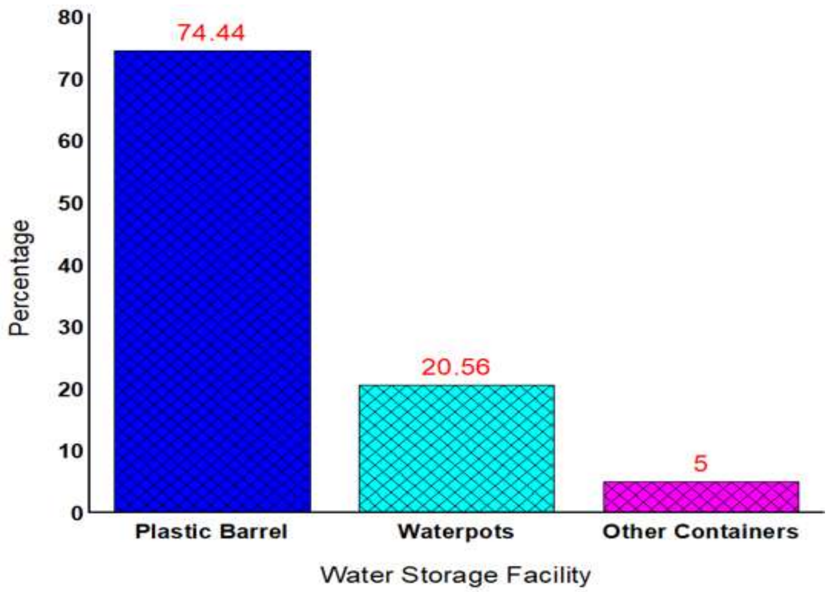

FIGURE 7: Percentage distribution for Rajaf Payam household's drinking water storage facility

Rajaf Payam Rural Drinking Water Management Problems

Water is a necessary component of humanity's existence. Human progress and population increase, on the other hand, are putting ever-increasing stresses on water safety. Although 76 percent of the people in rural areas had access to clean and drinkable water, this was slightly lower than the 94 percent in urban areas[22]. Therefore, the below graphical representation in **FIGURE 8** indicates that Rajaf Payam's most crucial water management problems show no water protection for drinking water, representing 21.76% in rural areas, followed by a 16.03% lack of water management. Although, according to Resolution 64/292 of the UN: "We have the right to appropriate, healthy, fair, physically accessible, and inexpensive water for personal and domestic usage under the human right to water. However, SDG 6.1 mandates that safe drinking water be completely protected by 2030.

The three following criteria included in the "Safely managed drinking water" indicator: Open on-site, accessible if necessary, and contamination-free[23]. However, the lack of chlorine supply and drinking water awareness of the rural population accounts for 15.27%, 9.54%, and 4.58% of unclean drinking water. Lack of bore-well availability represents by 3.82%. And 3.44% pollution of drinking water, the problem is the absence of government and NGO funding for the rural population, and 2.67% of the management of drinking water issue. Similarly, 1.91% of the rural population no water initiative, 1.53% water gap, and 1.15% bore well congestion. Lastly, lack of worker payment 0.76% for individual who often helps with drinking water management. 17.56% of respondents, on the other hand, did not address the research question about the issues of drinking water management and the extent of preparation.

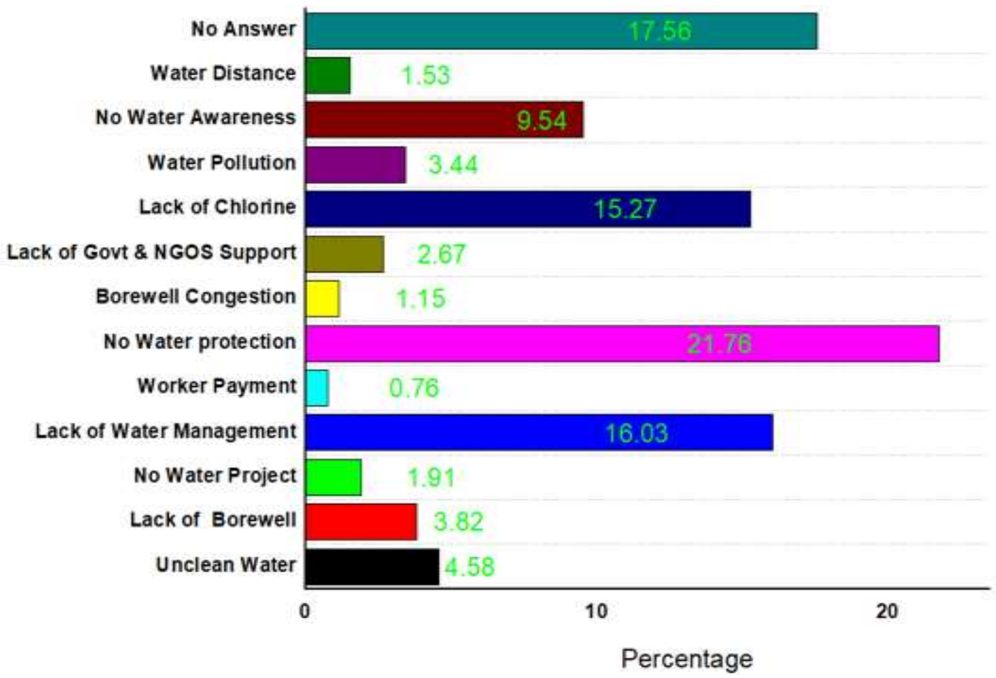

FIGURE 8: Rajaf Payam drinking water management problems

Rajaf Payam Rural Drinking Water Quality

Drinking water content is determining by biological, physical, and chemical factors directly related to the common application of the water. Of all people and wildlife, water quality is the most critical determinant of health and disease. According to a WHO survey, water is responsible for approximately 80% of all human infections[24]. Drinking water can, in theory, be clear of dangerous bacteria and poisonous chemicals. A dual-role strategy used to safeguard public health, separating the functions and duties of service suppliers from those of an official liable for impartial public health regulation "drinking-water source surveillance. "The agency's essential and complementary responsibilities for monitoring and the water provider should be considered in organizational structures to manage and expand drinking water delivery systems[25].

In Rajaf Payam, drinking water is exceptionally scarce in areas on the outskirts of Juba. Residents sometimes use rainwater, but it is expensive to contain and quickly becomes contaminated. While boreholes exist, several of them are no longer operational due to a lack of maintenance. Gumbo had 14 boreholes under Rajaf Payam in the 1980s, but only three are now operating.

Just one of four boreholes in Lologo, under Rajaf Payam, is still operational. The Southern Sudan Brewery in Tokiman Rajaf Payam, for example, spills liquid waste across a portion of the city regularly, channeling it through a stream that flows down the hill directly through streams and rivers, impacting water quality as seen below **FIGURE 9**. On behalf of the party, the Chief (Sheik-al-Hilla of Tokiman) complained about the plant. The plant, on the other side, is currently constructing a canal. However, this ensures the liquid waste will still guide the Nile, where it becomes a source of pollution unless processed first. Hotels are allegedly polluting the Nile with untreated waste, according to local leaders in Gondokoro Payam; evidently, "people don't realize it is dangerous." People in flood-prone areas like Lologo in Rajaf Payam are susceptible to waterborne diseases like cholera because of contaminated water. Cholera outbreaks occurred in 2006, 2007, and 2008, with 7,496, 3,256, and 1,256 cases each year. The river water flows through open fields used as restrooms, and it has been reporting throughout the rainy season. Contamination risks exist at water storage sites along the riverbank. The diseases are transmitted by water tankers used by vendors[17].

FIGURE 9: The brewery's wastewater flows through the residential area polluting the Nile River [18]

CONCLUSSION AND RECOMMENDATIONS

This is the first research study conducted in Rajaf Payam to evaluate rural household drinking water treatment. As a result, Rajaf Payam populations depend on various drinking water sources, including surface water, boreholes, and streams. The Rajaf Payam communities have their main primary source of drinking water from boreholes representing 59%. There is no pipeline water supply system, and some districts' communities use surface drinking water 23.5%, the protected dug well is 3.5%. Water tank trucks represent 3.5%, while 2.5% of drinking water from the stream. Finally drinking water from an unprotected dug is 3% for rural communities and 3% for the public tap. Simultaneously, 2% of the communities get their drinking water from rainwater collection simply because other ones in the rainy season prefer to get their drinking water from rainwater collection. However, Rajaf Payam the most crucial water management problems show no water protection for drinking water representing 21.76% in rural area, followed by 16.03% lack of water management. However, the lack of chlorine supply and drinking water awareness of the rural population accounts for 15.27%, 9.54%, and 4.58% of unclean drinking water. Lack of bore-well availability represents by 3.82%. And 3.44% pollution of drinking water, the problem is the absence of government and NGO funding for the rural population, and 2.67% of the management of drinking water issue. Similarly, 1.91% of the rural population no water initiative, 1.53% water gap, and 1.15% bore well congestion. Lastly, lack of worker payment 0.76% for individual who often helps with drinking water management. 17.56% of respondents, on the other hand, did not address the research question about the issues of drinking water management and the extent of preparation. The majority of the community, 66%, use chlorine to treat their drinking water. Because chlorine is provided free of charge to local communities by NGOs. Nonetheless, 19% are boiling their drinking water, 10% are placing or letting the drinking water stand and settling for a few minutes to allow the water particles to settle down without adding chlorine. 5% know nothing about drinking water treatment. It indicated that they use their drinking water directly from the drinking water supplies without water treatment. Therefore, this study has recommended the POU water treatment, where piped water connections are not accessible, point-of-use (POU) water treatment is lauded as a low-cost alternative. Boiling, slowing down sluggish sand, and filtration is examples of drinking water treatment technologies. However, chemical and solar disinfection are the same things. It lowers the incidence of diarrhea in millions of people who depend on unimproved drinking water supplies and improves drinking water safety at the point of usage

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest concerning the publication of this paper.

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