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Bacteriological Profile of Drinking Water Treated and Packaged in Cans Sold in Pharmacies in the City of Goma (DRC)

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Abstract: Urban growth and the economic accessibility of treated drinking water packaged in cans raise fears of risks of microbial contamination. This study aims to evaluate the Bacteriological Profile of treated drinking water, packaged in cans delivered to pharmaceutical pharmacies in the city of Goma. A cross-sectional analytical study based on laboratory analyzes carried out on 30 samples of drinking water packaged in 20L cans taken from pharmaceutical pharmacies in the study area. During the investigation, statistical, analytical methods and documentary techniques were useful to us and the data were analyzed using SPSS 25 software. The results revealed that the majority of these samples were sterile compared to 16.6% of Klebsiella; 16.6% Salmonella SP; 16.6% Pseudomonas aeruginosa; 33.3% Proteus and 16.6% Aeromonas spp. This rate remaining high, the delivery of water to pharmaceutical pharmacies in our study environment must be subject to regulations to guarantee its potability. The need for water hygiene education for suppliers is essential in order to reduce the risk of contamination of this water.

Keywords: *Profile, Bacteriological, Treated, Drinking Water, Packaged.*

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I. INTRODUCTION

According to the WHO, humans consume on average 2200g of water per day, which is 3.1% of their own body weight per day (WHO, 2017). Water is used in its natural state (river, spring) for daily needs (clothing hygiene, body hygiene, livestock, bathing, maritime transport, swimming, rural activities, etc.) or in treated and packaged form (mineral water, purified water, etc.) for consumption. The WHO states that 11% of the world's population, more than 78 million individuals, did not have access to drinking water in 2013 (WHO, 2023).

Kayembe J.M et al. showed that sub-Saharan Africa has also experienced improvement; the percentage of people without access to drinking water was 37% in 2011 compared to 51% in 1990. Despite this progress, this continent is the most affected, notably due to its population explosion: 327 million people did not have access to drinking water in 2011 in this region, compared to 264 million in 2010. Today, 300 million Africans do not have access to drinking water despite the Millennium Development Goals (Kayembe J.M et al., 2020).

Hamon J. L states that the DRC is not spared from public health problems. The DRC has about 70 million inhabitants and also possesses a significant amount of fresh water, but according to the latest estimates, it loses more than 40,000 m3 of fresh water per minute every day, which flows into the Atlantic Ocean due to the lack of rational management of this resource (Hamon J. L, 2020).

CORACON revealed that access to drinking water is a real headache in the North Kivu province. The lack of drinking water in the city of Goma is a paradox, as it is built on the shores of Lake Kivu; to cope with this water shortage,

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the population is forced to consume bottled mineral water perceived as purified. In light of this situation, the Bacteriological Profile of treated drinking water, packaged in containers delivered to the pharmacies in the city of Goma, represents a strategic interest for public health (CORACON, 2024). The present investigation had as its general objective to evaluate the Bacteriological Profile of treated drinking water, packaged in jerrycans delivered to pharmaceutical outlets in the city of Goma, to enable decision-makers to carry out essential and concrete actions to maintain the potability of drinking water at various points of sale in the Democratic Republic of the Congo in general and in the city of Goma in particular.

II. METHODOLOGY

A. Type of Study

This investigation is part of a quantitative and cross-sectional approach aimed at determining the bacteriological quality of treated drinking water packaged in jerrycans delivered by pharmacy outlets in the city of Goma. It is located in the North Kivu Province, in the east of the Democratic Republic of the Congo, at the foot of the active Nyiragongo volcano. Our study area is situated at an altitude of 1,500 meters in the Rift Valley. It borders the Rwandan city of Gisenyi to the east. The climate is tempered by the winds from Lake Kivu. It is a commercial and tourist center, distinguished from other cities by its rapid population growth, housing more than 2.5 million inhabitants. Its population growth makes it relevant for the provision of quality drinking water. The choice of this study setting is not by chance; it is justified by the consumption of drinking water sold, perceived by the population of our study area as pure, which would constitute a public health problem and requires special attention from health authorities.2.2. Population et échantillonnage.

➢ *Target Population and Inclusion Criteria*

The target population consists of 30 samples of treated drinking water packaged in jerry cans sold in the pharmacies of the city of Goma during our laboratory analyses. Samples collected from various points of sale after free and informed consent were included in the research. Pharmacies that are not points of sale for water and any untreated, unpackaged drinking water jerry cans found at the points of sale in our study area were excluded from our investigation.

➢ *Sample Size*

The size of our sample is exhaustive, which is 30 samples.

➢ *Technique d'échantillonnage*

L'échantillonnage adopté était aléatoire simple.

➢ *Tools and Techniques for Data Collection*

- *Research Technique*

✓ *Data Collection Technique*

We used the bacteriological analysis technique of samples in the laboratory. This technique allowed us to obtain results translated into numerical data. We followed the following steps: Sample collection, Enumeration, Inoculation, Gram staining of purity, Identification.

- *Data Analysis Methods*

✓ Statistical method: It was useful for quantifying and presenting the results in the form of figures.
✓ Analytical method: Allowed us to dilute the sample in peptone water and lauryl medium, and to inoculate on MacConkey medium.

- *Materials and Culture Media Used*

✓ Materials for bacterial culture: Precision balance, Bunsen burner, Erlenmeyer flask, Test tube, Refrigerator, Sterile syringe, Petri dish, Durand tube, Autoclave, Rack, Platinum loop, Marker, Incubator, Precision balance, Spatula, Aluminum foil, Distilled water.b. Culture media: Mac Conkey and Peptone Water

- *Preparation of Enumeration Media (Peptone Water)*

✓ Turn on the precision balance, place the aluminum foil on the precision balance and then tare,
✓ Using the spatula, take 25.5 g of peptone water, place it on the aluminum foil on the precision balance to weigh it,
✓ Measure 1 liter of distilled water in the Erlenmeyer flask, add the 25.5 g weighed,
✓ Place on the magnetic stirrer until the powder is completely dissolved,
✓ Heat while frequently stirring and boil for one minute,
✓ Distribute 9 ml into the tubes and cap them,
✓ Place in the metal rack and then put in the autoclave for sterilization at 121°C for 15 minute.

- *Preparation of Isolation Medium (MacConkey)*

✓ Place the number of Petri dishes to be prepared on the disinfected workspace,
✓ Weigh the powder using a spatula,
✓ Wash the spatula with water and dry it carefully before reusing it,
✓ For agar preparation, use a graduated cylinder to measure the volume of water,
✓ Add a small amount of water to the Erlenmeyer flask,
✓ Also add the sterile magnetic stirring bar,
✓ Add 51.55g of MacConkey medium, stir gently, then add the remaining amount of water up to 1000ml,
✓ After boiling, remove the Erlenmeyer flask from the hot plate immediately using heat protection gloves,
✓ Pour about 10ml of MacConkey into the Petri dish and let it cool,
✓ After the culture medium has solidified, store the Petri dishes in the refrigerator, away from light, until use.

- *Identification of Bacteria*

To identify bacteria, we used 4 culture media:

✓ KLIGLER: culture medium poured as a butt and slant in a tube. On this medium, 4 characteristics are observed:

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- Glucose fermentation: it is indicated by the butt changing from red to yellow.
- Lactose degradation: it is indicated by the slant changing from red to yellow.
- Gas production: detected by the presence of air bubbles or a void above the butt or in the medium.
- Hydrogen sulfide production: indicated by the blackening of the culture medium.



Fig 1 Identification of Bacteria

Lact +	Gaz+	Gluc +	Glu-	H2S+
Glu –	Glu+	Lact -	Lact -	Gluc -
Gaz –	Lact+	Gaz -	Gaz -	Lact -
H2S-	H2S -	H2S -	H2S -	Gaz -

➢ *Procedure*

Using a platinum loop sterilized in the flame of an alcohol lamp, let the platinum loop cool and pick a single isolated colony on MacConkey. With the right hand, uncork the inoculation tube between the little finger and the palm of the hand, then flame the opening of the tube before inoculation. Pierce the pellet and then streak on the slant of the culture medium.

- *Simmons' Citrate*

The medium is poured as a slant on which inoculation is performed, then incubated at 37°C for 24 hours. Check if the organism has used citrate as its sole carbon source for energy, and a positive result is indicated by a color change of the medium from green to blue.

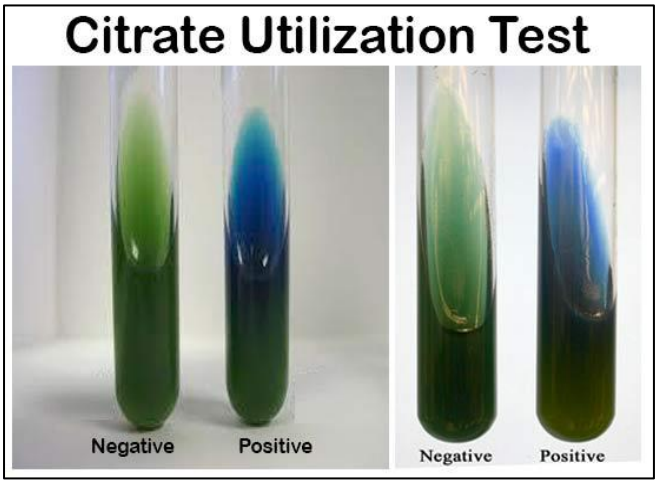


Fig 2 Citrate Utilization Test

✓ Procedure
✓ Take the isolated colony using a platinum loop and inoculate only on the slope.

- *SIM (Sulfide Indole Motility)*

✓ On this medium, three characteristics are read below: we look for the motility of the microorganism, the production of hydrogen sulfide (H2S), and the formation of indole.
✓ Hydrogen sulfide production: this manifests as the appearance of black traces in the medium along the stab or the darkening of the culture medium.
✓ Indole: this is the degradation of tryptophan by tryptophanase, which is revealed by adding 2 or 3 drops of Kovac's reagent to the tube containing the medium. Positivity is indicated by the appearance of a red ring on the surface of the medium..

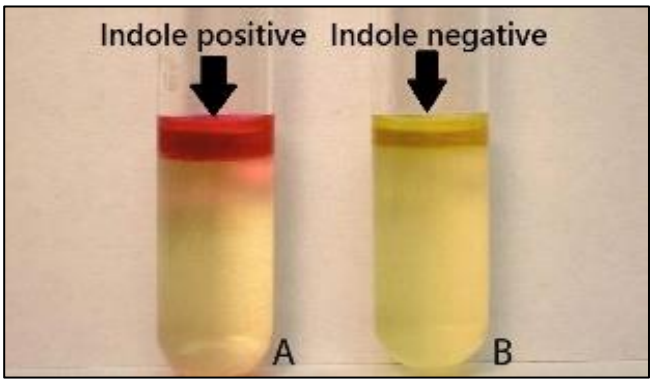


Fig 3 SIM (Sulfide Indole Motility)

✓ Mobility: is positive if the medium becomes turbid after 24 hours of incubation.

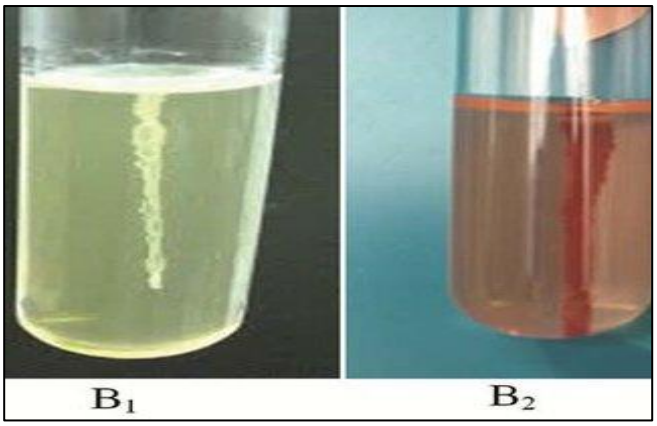


Fig 4 Mobility + Mobility -

➢ *Procedure*

Inoculate the colony by making a central stab in the medium.

Analysis of samples in the laboratory: In the laboratory, the different procedures followed for culturing the samples are as follows:

- Day 1: Dilution of the samples in peptone water and in lauryl medium by performing successive dilutions and incubate for 18-24 hours at 37°C.

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- Day 2: Reading and isolation on MacConkey medium: using a platinum loop, take the inoculum, deposit it in the medium, then inoculate and incubate for 18-24 hours at 37°C.
- Day 3: Colony reading and isolation on identification medium: Perform identification using the LEMINOR gallery (Kligler, SIM, and Simmons Citrate).
- Day 4: Reading of biochemical characteristics on the identification medium.

➢ *Data Processing and Analysis*

After the data collection phase, the results were exported from Kobo Collect to Microsoft Excel for cleaning and coding. The data were processed using SPSS software version 26.

The results were presented in the form of figures to facilitate the use and understanding of the data, in accordance with the presentation standards of scientific articles. 2.2.5. Ethical Considerations

This investigation was conducted with rigor and respect for the ethical principles of research. To facilitate our sampling, we came with an empty container with a capacity of 5 liters of water, previously sterilized in our research laboratory, then we purchased water from different points of sale. The objectives of the research were explained, the confidentiality and the right of participation of the pharmaceutical shopkeepers were respected, and free, voluntary, and informed consent was verbally obtained before carrying out our sampling activity. The anonymity of participants was guaranteed by alphanumeric coding of the samples, without mentioning any personal identity. The data were stored on a secure server accessible only to the researcher. Finally, we obtained approval from the Ethics Committee and administrative authorization from the local authorities of the city of Goma.

III. RESULTS

➢ *Enumeration of Total General*

It appears from this figure that out of 30 samples of treated drinking water diluted in peptone water, 6 samples, or 20%, showed turbidity and 80% of the samples were not cloudy.

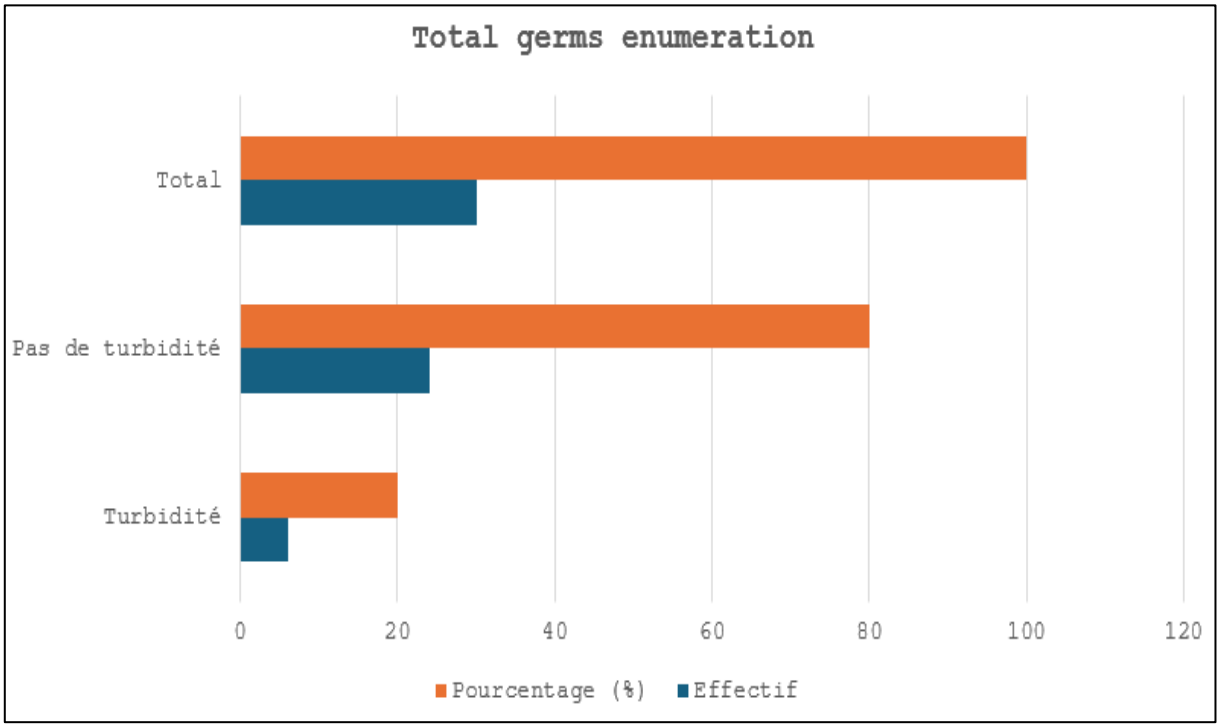


Fig 5 Total Germs Enumeration

This table shows that out of 30 samples of treated drinking water diluted in peptone water, 2 containers of the samples, or 6.7%, contained between 10-100 germs and 4 tubes, or 13.3%, indicated between 100-1000 germs.

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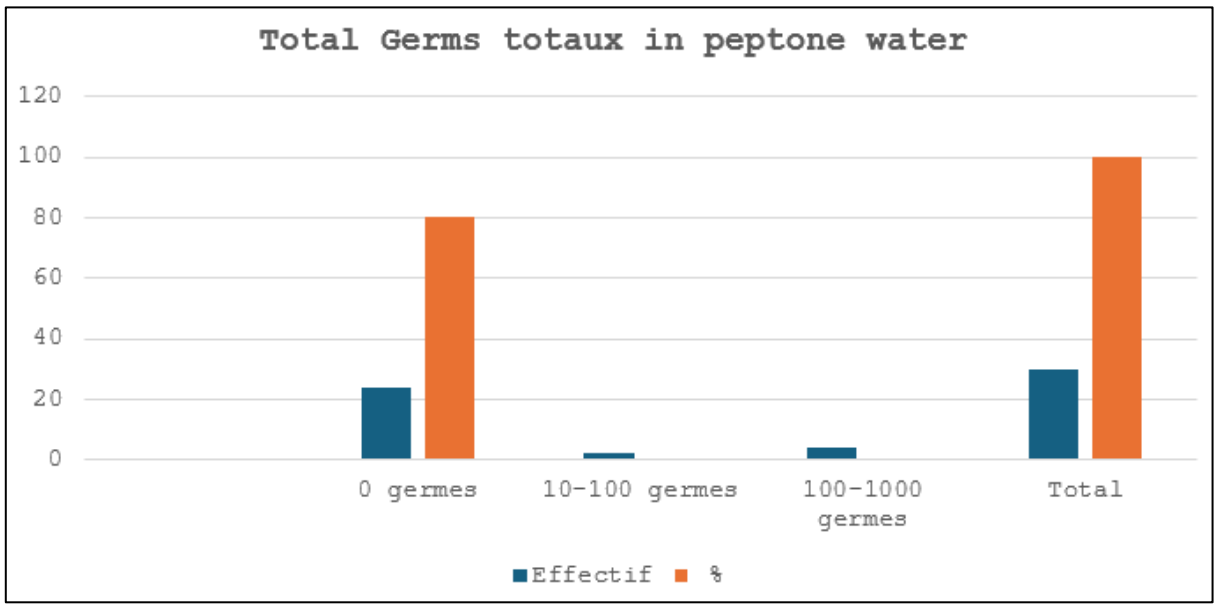


Fig 6 Total Germs in Peptone Water

The bacteriological analysis of the packaged treated water samples showed that 33.3% of the samples contained Enterobacter intermedium and that 16.6% of the analyzed packaged treated water had respectively Enterobacter cloaceae, Citrobacter freundi, Salmonella enteritica, and finally Aeromonas hydrophila. Identification of bacteria on the small gallery of Leon Le Minor.

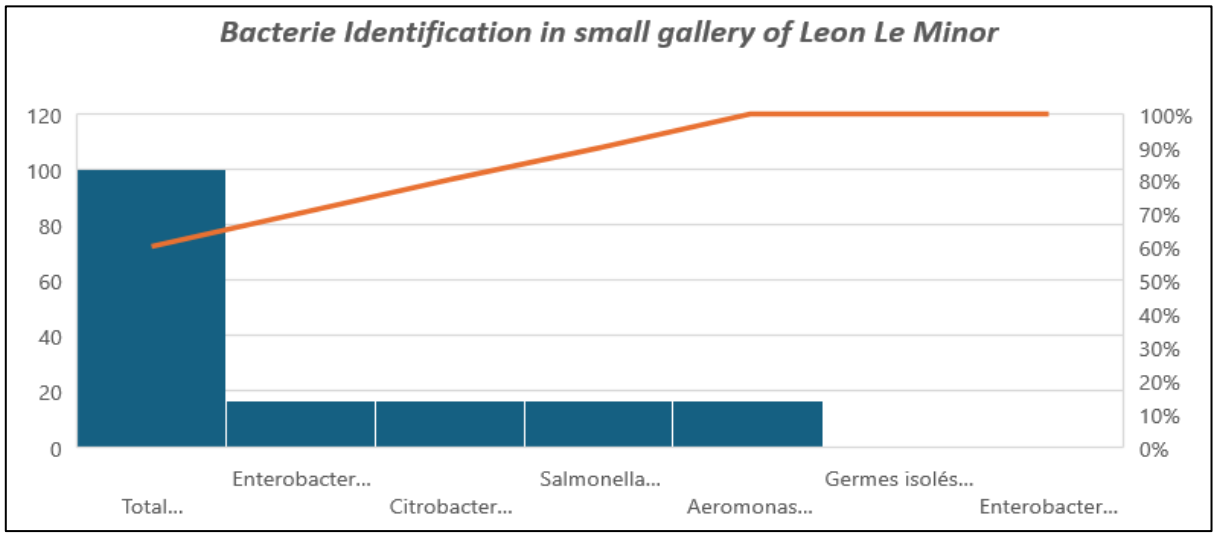


Fig 7 Bacterie Identification in a Small Gallery of Léon Le Minor

IV. DISCUSSION

Water is a crucial element for living beings, including humans; its presence in quantity and quality contributes to the maintenance of human health. Treated drinking water in packaging is the most consumed food, especially in large African cities where it is often used to quench thirst during periods of intense heat.

It can be seen from this figure 1 that out of 30 samples of treated drinking water diluted in peptone water, 6 samples, or 20%, showed turbidity, and 80% of the samples were not cloudy. Our results are almost similar to those of FOURNIER et al. (2012), according to which turbidity is a good marker of free bacterial contamination (FOURNIER et al., 2012).

The results of this research are similar to those of CHOUGAR Lynda (2015), which revealed an increase in the turbidity of treated water by 0.4 NTU compared to that of raw water (CHOUGAR Lynda, 2015). Turbidity is the measure of the more or less cloudy appearance of water. We believe that in water treatment plants it can be due to the regrowth of microorganisms. These results sufficiently demonstrate the need to strengthen the monitoring of water packaging facilities in order to ensure the health safety of consumers of treated water packaged in our study area. It appears from Figure 2 that out of 30 treated drinking water samples diluted in peptone water, 2 containers, representing 6.7%, contained between 10-100 germs, and 4 tubes, representing 13.3%, showed between 100-1000 germs.

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Our results are consistent with those of Chérif Ibrahima Khalil DIOP (2006), who state that 67% of samples did not contain germs, compared to 33.3% that did (Chérif Ibrahima Khalil DIOP, 2006). Our results are similar to those of IBRAHIM MAMADOU (2025), who reveal the bacteriological quality and hygiene conditions in the production chain of sachet water 'pure water' in the city of Zinder in Niger (IBRAHIM MAMADOU, 2025).

The bacteriological analysis of treated water samples packaged shown in Figure 3 revealed that 33.3% of samples contained Enterobacter intermedium and that 16.6% of analyzed packaged treated water had respectively Enterobacter cloaceae, Citrobacter freundi, Salmonella enteritica, and finally Aeromonas hydrophila. Our results are similar to those of AGBOKPONTO Engelbert et al., (2024), who indicated that microbiological tests revealed contamination of packaged waters by coliforms at 7.1% and Escherichia coli at 1.4% (AGBOKPONTO Engelbert et al., 2024).

Our results are consistent with those of Abdullah Ali Halage et al. (2015), according to whom the majority, 21 bottles of water out of 30 water samples analyzed, were contaminated with fecal coliforms in Uganda (Abdullah Ali Halage et al., 2015). The results of this investigation are similar to those of Imokhai Tenebe et al. (2023) in Nigeria, which stated that more than half of the samples did not meet bacterial limits (Imokhai Tenebe et al., 2023). These results align with those of AGBOKPONTO Engelbert et al. (2013), indicating that Salmonella typhi is a reliable indicator of oro-fecal contamination (AGBOKPONTO Engelbert et al., 2013).

Our results are similar to those of Arit Udoh et al. (2021) who observed that Acinetobacter reflected human contamination related to handling during packaging. About 53.27% of the examined samples were contaminated by coliforms (95% CI: 39.05–66.98, I2 = 81%, $p < 0.01$). The statistic for Escherichia coli was 13.30% (95% CI: 8.23–20.80, I2 = 65%, $p < 0.01$). Other pathogenic germs were found such as Pseudomonas aeruginosa, Klebsiella, and Enterococcus faecalis (Arit Udoh et al., 2021).

Our results are consistent with those reported by other authors. For example, Lydia Mosi et al. (2019) and Imokhai Tenebe et al. (2023) reported coliform rates ranging between 20 and 50% in sachet water (Lydia Mosi et al., 2019; Imokhai Tenebe et al., 2023). There is a similarity between our results and those of Oluwaseun J. Ajala et al. (2020) and Awoke Kele et al. (2022), who report that residual contamination in packaged water frequently originates from failures in the filling process, or from not strictly adhering to good hygiene practices (Oluwaseun J. Ajala et al., 2020; Awoke Kele et al., 2022).

The results of this research are consistent with those of Narayan Dutt, P. et al. (2016), which show that 87.5% of bottled treated water samples were found to be contaminated by heterotrophic bacteria (Narayan Dutt, P. et al., 2016). Treated and bottled waters must meet strict microbiological quality requirements to ensure their original purity. They must be free of pathogenic microorganisms from emergence to usage points, and analyses must be carried out to ensure compliance with these requirements. Deficiencies in hygiene practices during the delivery of treated bottled water, particularly during storage and bottling, as well as the environment, play a crucial role in the contamination of these products.

V. CONCLUSION

This study highlights an uncontrolled sale of treated water packaged in jerrycans sold in the pharmacies of the city of Goma. Laboratory analyses showed that some samples are out of the standards required for drinking water. Furthermore, the presence of isolated germs indicates poor disinfection of this water, which calls into question its good bacteriological quality. Our bacteriological analyses confirm our hypotheses, as 20% of these samples grew bacteria, and after isolation and identification, we found pathogenic germs, notably: Salmonella, Shigella, Enterobacter. In Goma, particularly in the city center, the sale of treated drinking water packaged in jerrycans has become an activity with considerable socio-economic weight, especially due to its role in meeting the needs of the urban population.

This thriving activity, however, risks endangering the consumer's health when hygiene measures are not followed. The presence of so-called indicators of fecal contamination is synonymous with health risks, as their survival in drinking water strongly suggests the presence of pathogenic germs. Considering the laboratory results, it is therefore necessary that urgent measures be taken, prioritizing the hygiene of vendors' storage containers, production and sales conditions, rigorous and regular health inspections, and especially emphasizing the awareness and education of vendors and consumers.

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Conflict of interest: We declare that there is no competing interest. Authors' contributions: PALUKU MALISAWA Patrick contributed to the data collection sections, study methodology, and data analysis, as well as to the writing of the manuscript; KAMBALE KISUBA Jacques contributed to the literature review and data analysis, and to the revision of the manuscript. All authors have read and approved the final manuscript.

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