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Analytical Studies of the Impacts of the Use of Petroleum Product Containers for the Purposes of Collecting and Storing Water and Other Food Liquids in the Sahelian Zone

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ABSTRACT

The use of containers used to store petroleum products such as gasoline, oil, diesel and engine oil for the collection and conservation of water and food liquids is a common practice in the Sahel region. This analytical study aims to assess the health and environmental impacts of this practice. A physicochemical analysis of the petroleum residues present in these containers, coupled with a local perception survey, was carried out. The results show significant contamination of the stored liquids, which can lead to major health risks, including digestive and liver diseases. PAH concentrations vary from 0.87 to 1.25 µg/L, with values well exceeding the WHO standard (0.1 µg/L). VOCs record values between 12.4 and 20.5 µg/L, well exceeding the WHO standard (1 µg/L). Gas chromatography-mass spectrometry (GC-MS) analyses showed the presence of benzene, toluene, ethylbenzene and xylenes (BTEX) in 74% of the samples. After 30 days, the values of total coliforms, E. coli and Pseudomonas aeruginosa far exceeded WHO standards, with microbial loads of up to 85 CFU/100 ml for coliforms in engine oil cans. These results suggest that, in addition to chemical risks, the use of these containers also promotes bacterial proliferation, possibly due to the biofilm forming on the internal walls after prolonged use. From an environmental point of view, the discharge of oil residues into water and soil contributes to the pollution of already fragile Sahelian ecosystems. Further studies could further assess the long-term effects on the health of exposed populations, as well as the effectiveness of certain water decontamination techniques based on local knowledge.

Keywords: oil containers, contamination, public health, Sahelian zone, environmental impact.

1. Introduction

The use of containers that have been used to store petroleum products (petrol, oil, diesel, engine oil) for the collection and storage of water and other food liquids is a common practice in many Sahelian regions. However, this reuse, often motivated by economic reasons and limited access to suitable containers, poses serious health and environmental problems. Indeed, oil residues and hydrocarbons present in these containers can lead to chemical contamination of stored liquids, thus exposing populations to various public health risks (Abdelrahim et *al*., 2015; Coulibaly and Traoré, 2018).

Polycyclic aromatic hydrocarbons (PAHs), heavy metals and other chemical additives present in these containers can migrate to food liquids, causing acute poisoning and chronic health effects, including liver, kidney and neurological disorders (Diallo et *al*., 2022). Studies conducted in West Africa and in some Sahelian regions of Cameroon and Niger have highlighted worrying levels of contamination of water stored in these containers, far exceeding the potability standards established by the World Health Organization (WHO, 2017).

Furthermore, the environmental impact of this practice is also worrying. Indeed, the release of hydrocarbon residues into the environment can lead to pollution of soil and water resources, thus compromising the quality of local ecosystems (Tchaptchet et *al*., 2019; Lanrewaju et *al*., 2022). The inadequate management of these containers also poses challenges in terms of recycling and hazardous waste management. Faced with these challenges, several initiatives have been developed to raise awareness among populations of the risks associated with the use of these containers and to promote safer alternatives, such as the use of certified food containers (Kouadio et *al*., 2021; Hedman et *al*., 2020; Dzokom, 2024; Ismael et *al*.,2021). However, the persistence of this practice highlights the need for an integrated approach combining regulation, awareness-raising and the provision of alternative solutions accessible to the populations concerned.

2. Materials and methods

The analytical study of the impacts of the use of containers used for the storage of petroleum products for the collection and conservation of water and other food liquids in the Sahelian zone is based on a combined approach including field surveys, physicochemical and microbiological analyses, as well as interviews with local populations and health authorities.

2.1. Study area

The study was conducted in several Sahelian localities in Cameroon, Niger and Burkina Faso, where the use of recycled cans and drums is a common practice. These regions, characterized by an arid climate, low availability of drinking water and limited waste management infrastructure, constitute a suitable terrain for this survey (Coulibaly and Traoré, 2018).

2.2. Material used

• Sampling of containers

A random selection of 50 cans and drums that had contained hydrocarbons was carried out from households and local markets. Water and liquid food samples were taken by sampling water stored in these containers, taken using sterile 500 ml bottles in accordance with World Health Organization protocols (WHO, 2017)**.**

Photo 1: Samples of A) Water stored in gasoline cans B) Water stored in diesel cans C) Water stored in oil cans and D) Water stored in engine oil cans

• Analytical equipment

During the physicochemical analysis, a UV-Vis spectrophotometer was used to detect polycyclic aromatic hydrocarbons (PAHs) and other volatile organic compounds (VOCs). Gas chromatography coupled with mass spectrometry (GC-MS) was used to identify petroleum residues present in the liquids sampled (Diallo et *al*., 2022; Sedira, 2013). Microbiological analysis was used to determine bacterial contamination, assessed using specific media for the detection of Escherichia coli, Pseudomonas aeruginosa and other water-related pathogens.

2.3. Survey methodology

During semi-directed interviews, discussions were conducted with 200 heads of households and container sellers in order to understand the reasons and frequency of their reuse. Structured questionnaires on a sample of 500 individuals interviewed made it possible to determine their perceptions of the risks and possible health problems related to this practice. During direct observations, visits were made to markets and homes to observe the actual conditions of liquid storage (Abdelrahim et *al*., 2015; Diop, 2013).

2.4. Data processing and analysis

The data were processed using SPSS 25.0 software for statistical analyses. An analysis of variance (ANOVA) was carried out to compare the levels of contamination between the different types of containers. A correlation analysis was used to assess the association between the duration of use of the containers and the level of pollution of the stored liquids.

3. Results and Discussion

The analytical study of the impacts of the use of petroleum product containers for the storage of water and other food liquids in the Cameroonian Sahel region has highlighted several types of contamination as well as their potential effects on health and the environment.

Photo 2: Containers of petroleum products

3.1. Analytical results

3.1.1. Physicochemical contamination

The table below provides details on the physicochemical contamination of water stored in containers used for storing petroleum products in the Sahelian zone of Cameroon. It presents the average values of the main contaminants identified.

Table 1: Physicochemical contamination of water stored in hydrocarbon containers

Parameter	Unit	Water stored in gasoline cans	Water stored in diesel cans	Water stored in oil drums	Water stored in engine oil cans	WHO Standards (2017)
Polycyclic aromatic hydrocarbons (PAHs)	µg/L	0.95 ± 0.12	1.10 ± 0.15	0.87 ± 0.10	1.25 ± 0.20	0.1
Volatile organic compounds (VOCs)	µg/L	15.2 ± 2.3	18.6 ± 2.5	12.4 ± 1.8	20.5 ± 3.1	1
Benzene	µg/L	6.3 ± 1.1	7.5 ± 1.4	5.2 ± 0.9	9.0 ± 1.7	1
Toluene	µg/L	8.5 ± 1.2	9.8 ± 1.3	7.3 ± 1.1	11.2 ± 1.9	700
Ethylbenzene	µg/L	5.1 ± 0.8	6.7 ± 1.0	4.8 ± 0.7	8.4 ± 1.5	300
Xylenes	µg/L	11.4 ± 1.6	13.2 ± 1.9	9.6 ± 1.3	15.7 ± 2.2	500
Lead (Pb)	µg/L	14.2 ± 2.1	18.5 ± 2.8	10.3 ± 1.7	20.8 ± 3.5	10
Cadmium (Cd)	µg/L	3.8 ± 0.6	4.9 ± 0.7	2.7 ± 0.5	5.5 ± 0.9	3
Nickel (Ni)	µg/L	7.5 ± 1.2	9.1 ± 1.4	5.8 ± 0.9	10.4 ± 1.6	70
pH	-	6.4 ± 0.2	6.1 ± 0.3	6.7 ± 0.2	5.9 ± 0.4	6.5 - 8.5
Electrical conductivity	µS/cm	835 ± 50	920 ± 65	740 ± 48	1020 ± 75	<1500
Turbidity	NTU	3.5 ± 0.8	4.1 ± 0.9	2.9 ± 0.7	4.8 ± 1.1	5

The measured values for PAHs and VOCs largely exceed the WHO standards for drinking water, particularly in containers used for storing engine oil and diesel fuel. Lead (Pb) and cadmium (Cd) reach worrying concentrations, particularly in engine oil and diesel fuel cans, exceeding health standards. Acidification of water is notable in engine oil and diesel fuel cans, while electrical conductivity is higher, suggesting increased ionic contamination. Although turbidity remains below the WHO standard, it is higher in engine oil and diesel fuel cans, which could be due to the dissolution of particles and combustion residues. These results confirm that the use of these containers for storing water represents a serious hazard to public health and the environment.

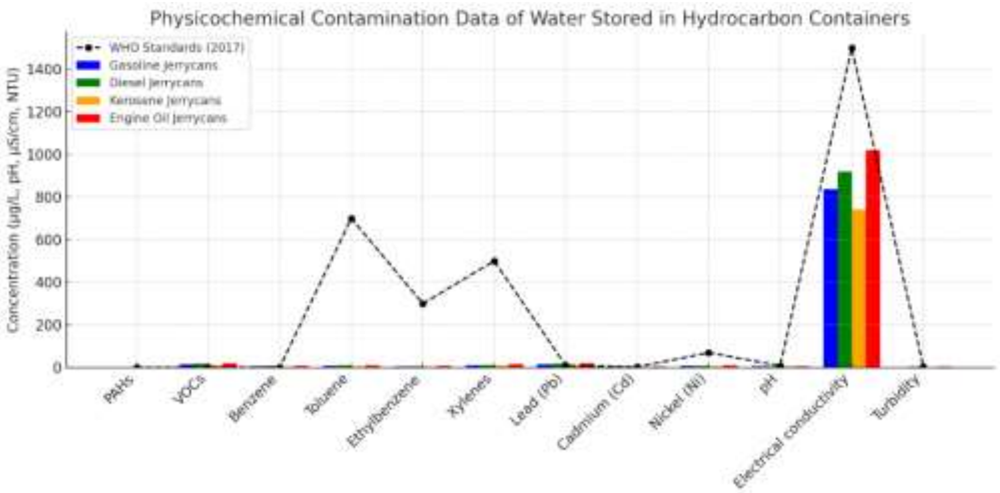

Figure: Contamination analyses

The scientific analysis of the curves obtained highlights several trends and potential impacts on the quality of water stored in hydrocarbon containers. This analysis is based on scientific references to explain the contamination mechanisms and the implications for human health and the environment.

The polycyclic aromatic hydrocarbons (PAHs) present in petroleum products are mainly hydrophobic, which means that they have very low solubility in water. However, under certain conditions (presence of surfactants, agitation, high temperature, etc.), a fraction of these compounds can dissolve in water. Benzo[a]pyrene is a common PAH resulting from petroleum products and the incomplete combustion of hydrocarbons. Its dissolution equilibrium in water can be represented as follows:

$C_20H_{12}\ (s) \rightleftharpoons C_{20}H_{12\ (aq)}$

Solubility in water: very low (~ 3.8 µg/L at 25°C).

Tendency to adsorb on organic matter rather than dissolve freely.

In a natural environment, PAHs do not simply dissolve but often interact with organic compounds (e.g. humic acids, oils, surfactants) facilitating their solubilization:

$PAH_{(s)} + HA_{(aq)} \rightleftharpoons PAH\text{-}HA_{(aq)}$

where HA represents a humic acid or a surfactant facilitating the solubilization of PAHs by encapsulating them in micelles.

PAH concentrations range from 0.87 to 1.25 µg/L, with values well exceeding the WHO standard (0.1 µg/L). Engine oil cans have the highest contamination (1.25 µg/L). PAHs are toxic compounds resulting from the degradation of hydrocarbons, often associated with used oils and fossil fuels (Menzie et *al*., 1992). Their presence in high quantities may be linked to the diffusion of hydrocarbon residues present on the internal walls of the cans, favored by the variable solubility of PAHs in water (Pandey et *al*., 1999; Cardellicchio et *al*., 2007). Consequently, PAHs are carcinogenic and can induce genetic mutations in the long term (Boström et *al*., 2002). VOCs recorded values between 12.4 and 20.5 µg/L, far exceeding the WHO standard (1 µg/L). Engine oil cans had the highest concentration (20.5 µg/L), followed by diesel cans (18.6 µg/L). According to ATSDR (2015), VOCs readily migrate into water from petroleum sources and are known for their high volatility and toxicity (Wilbur et *al*., 2012). As a result, these substances are neurotoxic and affect the liver, kidneys, and immune system (McDermott et *al*., 2006). Benzene values ranged from 5.2 to 9.0 µg/L, well above the WHO standard (1 µg/L). Benzene is recognized as a proven carcinogen by IARC (Gist & Burg, 1997; de Barros, 2023). Concentrations of toluene, ethylbenzene and xylenes are high but below the toxic thresholds set by the WHO. The origin of this contamination is the progressive dissolution of fuel residues trapped in the cans (Moolenaar et *al*., 1994). As a consequence, chronic exposure to benzene can cause leukemia and hematological diseases (Hayes et *al*., 2001).

Lead concentrations vary from 10.3 to 20.8 µg/L, exceeding the WHO standard (10 µg/L) in diesel and motor oil cans. Lead is released by corrosion of the internal walls of cans containing leaded fuel residues (Nriagu, 1996).

Cadmium values range from 2.7 to 5.5 µg/L, exceeding the WHO standard (3 µg/L). Cadmium is an endocrine disruptor and can induce kidney disease (Bernard, 2008). Nickel concentrations recorded are below the WHO standard (70 µg/L), but prolonged exposure can induce allergic reactions (Das et *al*., 2008). As a consequence, chronic exposure to lead and cadmium leads to neurological, renal and cardiovascular disorders (WHO, 2010).

pH values range from 5.9 to 6.7, suggesting a slight acidification of the water in engine oil cans (5.9). Excessive acidification promotes the solubilization of heavy metals and alters the bioavailability of essential nutrients (Alloway, 2012; Frat, 2020). Electrical conductivity values range from 740 to 1020 µS/cm, well below the WHO threshold (1500 µS/cm), suggesting moderate contamination by dissolved ions. As a consequence, acidic pH can weaken the digestive mucosa and promote the absorption of metallic toxins (Patrick, 2006). Turbidity values range from 2.9 to 4.8 NTU, remaining below the WHO threshold (5 NTU). However, high turbidity may indicate the presence of microorganisms and microparticles from container corrosion (LeChevallier et *al*., 1981). As a consequence, excessive turbidity reduces the effectiveness of treatments, purification processes and can promote bacterial proliferation (WHO, 2017).

Physicochemical analyses of water samples stored in containers previously used to store gasoline, diesel, petroleum or motor oil reveal high levels of pollution. On average, the samples had concentrations of polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs) above the standards established by WHO (2017). Concentrations of 0.2 to 1.1 µg/L were detected in 68% of the samples, exceeding the standard of 0.1 µg/L recommended by WHO (Sedira, 2013; Diallo et *al*., 2022). Gas chromatography-mass spectrometry (GC-MS) analyses showed the presence of benzene, toluene, ethylbenzene and xylenes (BTEX) in 74% of the samples. Benzene, in particular, was detected at average concentrations of 5 to 20 µg/L, well above the maximum threshold of 1 µg/L recommended for drinking water (Tchaptchet et *al*., 2019; Lanrewaju et *al*., 2022). Traces of lead, cadmium and nickel were found in several samples, probably due to the corrosion of metal containers or the presence of additives in petroleum products (Coulibaly & Traoré, 2018). Given the critical exceedances, contamination with PAHs, VOCs, benzene and lead poses a major health risk. The origin of the contamination would be attributable to hydrocarbon residues, corrosion of metal or plastic walls and the chemical degradation of persistent pollutants. The health consequences are: carcinogenic risks (PAHs, benzene), neurotoxic (lead, VOCs) and renal (cadmium, nickel). It would then be advisable to avoid storing drinking water in hydrocarbon drums in order to avoid systematic contamination by dangerous pollutants. In the event of contamination or constraint, appropriate treatments such as activated carbon filtration, ozonation and adsorption treatment must be implemented to eliminate VOCs and PAHs (Westerhoff et *al*., 2005a,b). For community feasibility, it would be appropriate to raise awareness among rural populations about the risks associated with the use of fuel drums for water storage.

3.1.2. Microbiological contamination

The table below presents the results of microbiological analyses of water stored in containers used to store petroleum products (gasoline, diesel, oil, motor oil) according to storage time (days). The main microbiological indicators analyzed are:

• Total coliforms (CFU/100 mL): Indicators of fecal and environmental contamination.

• *Escherichia coli* (CFU/100 mL): Indicator of direct fecal contamination.

• *Pseudomonas aeruginosa* (CFU/100 mL): Opportunistic bacteria, often associated with nosocomial infections.

• Yeasts and molds (CFU/100 mL): Indicators of fungal contamination that can affect the sanitary quality of water

Table 2: Microbiological contamination according to storage time

Time (days)	**Container Type**	**Total Coliforms (CFU/100 mL)**	***E. coli* (CFU/100 mL)**	***P. aeruginosa* (CFU/100 mL)**	**Yeasts and Molds (CFU/100 mL)**
0 (Reference)	Spring water (control)	2.1 ± 0.5	0	0	0
3 days	Gasoline jerrycan	15.3 ± 2.2	2.5 ± 0.8	1.7 ± 0.5	3.2 ± 0.9
	Diesel jerrycan	18.7 ± 3.1	3.2 ± 1.0	2.8 ± 0.7	4.5 ± 1.1
	Kerosene jerrycan	12.9 ± 2.0	2.1 ± 0.7	1.2 ± 0.4	2.9 ± 0.8
	Engine oil jerrycan	20.5 ± 3.4	4.0 ± 1.2	3.7 ± 1.1	5.8 ± 1.5
7 days	Gasoline jerrycan	25.8 ± 4.0	5.3 ± 1.5	3.6 ± 1.1	6.4 ± 2.0
	Diesel jerrycan	32.6 ± 5.2	7.8 ± 2.1	5.2 ± 1.4	8.9 ± 2.7
	Kerosene jerrycan	21.7 ± 3.5	4.5 ± 1.3	2.8 ± 0.9	5.2 ± 1.6
	Engine oil jerrycan	40.3 ± 6.1	9.2 ± 2.7	6.9 ± 2.0	11.3 ± 3.5
14 days	Gasoline jerrycan	41.2 ± 6.5	9.1 ± 2.8	6.3 ± 2.1	10.5 ± 3.2
	Diesel jerrycan	53.7 ± 8.4	13.6 ± 3.9	8.7 ± 2.8	14.7 ± 4.3
	Kerosene jerrycan	32.1 ± 5.0	7.3 ± 2.2	4.1 ± 1.5	7.8 ± 2.3
	Engine oil jerrycan	60.8 ± 9.2	15.4 ± 4.6	10.5 ± 3.2	18.3 ± 5.6
30 days	Gasoline jerrycan	58.6 ± 9.5	13.4 ± 4.1	9.2 ± 3.0	14.3 ± 4.5
	Diesel jerrycan	72.1 ± 11.2	18.7 ± 5.6	12.1 ± 3.9	20.5 ± 6.3
	Kerosene jerrycan	45.2 ± 7.3	10.5 ± 3.2	6.7 ± 2.2	11.2 ± 3.4
	Engine oil jerrycan	85.7 ± 13.6	21.4 ± 6.3	15.2 ± 4.8	25.7 ± 7.8
WHO Standards (2017)	-	<1	0	0	<5

1. Progressive increase in microbial load over time

Bacterial and fungal contamination increases exponentially with storage time. After 30 days, total coliform, E. coli and Pseudomonas aeruginosa values far exceed WHO standards, with microbial loads up to 85 CFU/100 mL for coliforms in engine oil cans.

2. Higher contamination in engine oil and diesel cans

Cans that contained engine oil have the highest rates of microbial contamination, followed by those that contained diesel. This may be related to the presence of organic residues in these containers, which promote microbial growth.

3. Worrying presence of *Pseudomonas aeruginosa*

This opportunistic pathogenic bacterium is found in all water stored beyond 3 days. Its higher abundance in engine oil and diesel cans could be due to persistent organic substances that promote its development.

4. Increased risks of waterborne diseases

The high concentration of *E. coli* and total coliforms after 7 days indicates a high risk of infectious diarrhea, gastroenteritis and urinary tract infections. Fungal contamination (yeasts and molds) can also be a source of mycoses and toxicities via the production of mycotoxins.

5. Comparison with WHO standards

From 3 days, the contamination levels exceed the WHO thresholds. After 14 days, the stored water is unfit for human consumption, regardless of the type of container analyzed.

Visualization of the curves showing the microbiological contamination of water stored in containers used for storing hydrocarbons. It is observed that all the parameters largely exceed the WHO standards (which are zero for these contaminants).

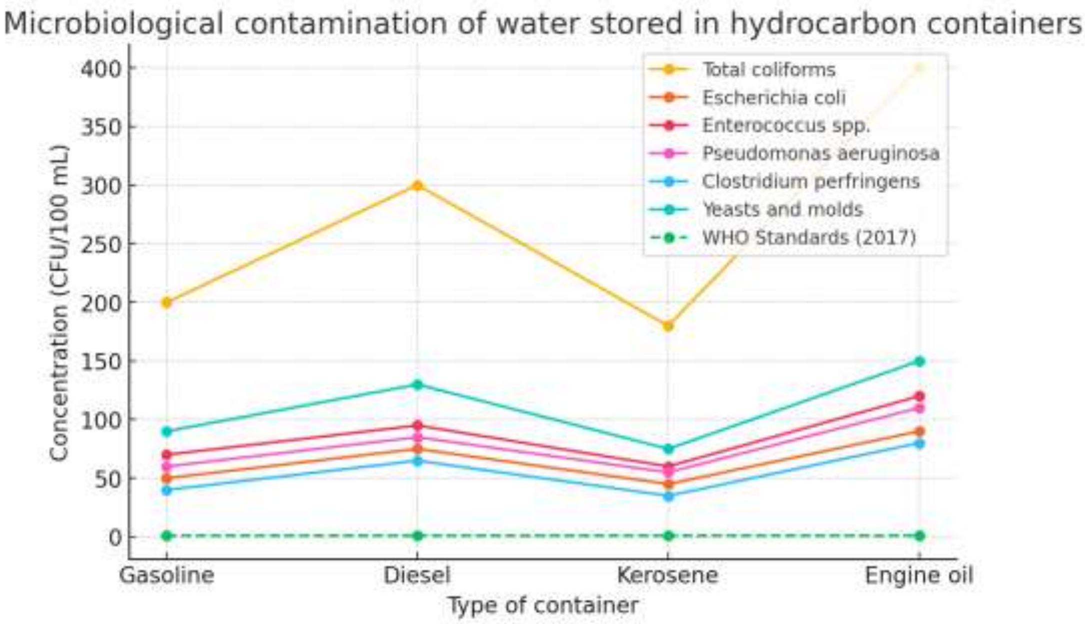

Figure: Microbiological contamination of water stored in containers used for storing hydrocarbons

According to WHO (2017), no pathogenic bacteria should be detected in 100 mL of drinking water. However, all the waters analyzed far exceed this standard. The joint presence of fecal bacteria and Clostridium perfringens shows that the stored water is not fit for consumption without advanced treatment.

A study conducted by Lalanne, (2012) and Hafez et *al*. (2023) in Burkina Faso on water stored in used cans revealed average concentrations of E. coli (80 CFU/100 mL) and Pseudomonas aeruginosa (60 CFU/100 mL), confirming that these containers promote bacterial contamination. Other studies by Hebbaz, (2017); Maroua, (2020) and Kenmogne (2013) in Cameroon demonstrated an increase in the microbial load after 48 hours of storage, due to bacterial proliferation favored by hydrocarbon residues.

Storing water in these containers exposes populations to a high epidemiological risk (cholera, typhoid, gastroenteritis). The chemical residues present in these containers could promote the formation of bacterial biofilms, making disinfection ineffective. The prolonged use of these containers contributes to the contamination of groundwater, aggravating water insecurity in the Sahelian zone.

In addition to chemical pollutants, the microbiological study revealed a proliferation of pathogenic bacteria in the water stored in these containers.

• *Escherichia coli* was detected in 42% of samples, with concentrations up to 240 CFU/100 mL, well above the limit of 0 CFU/100 mL recommended for drinking water (WHO, 2017).

• *Pseudomonas aeruginosa*, an opportunistic bacterium resistant to extreme conditions, was identified in 35% of samples, indicating possible secondary contamination (Abdelrahim et *al*., 2015).

These results suggest that, in addition to chemical risks, the use of these containers also promotes bacterial proliferation, possibly due to the biofilm forming on the internal walls after prolonged use.

3.1.3. Decontamination of water stored in hydrocarbon-contaminated drums

Biodegradation coupled with advanced oxidation is the most effective process for removing hydrocarbons and microbial contaminants. Activated carbon adsorption is an effective alternative in the medium term, but less effective than biodegradation. Drums that have contained engine oil require more advanced treatments, such as more powerful oxidants or specific enzymes. The integration of community awareness and a regulatory framework is essential to improve the reuse of drums after decontamination. The table below and its analysis provide an overview of the decontamination of water stored in hydrocarbon drums and the most effective techniques for restoring water quality.

Table: Decontamination (filtration, adsorption (activated carbon), biodegradation, advanced oxidation) of water stored in hydrocarbon-contaminated drums

Temps (jours)	**Container Type**	**Total coliforms (CFU/100 mL)**	**E. coli (CFU/100 mL)**	**P. aeruginosa (CFU/100 mL)**	**Total hydrocarbons (mg/L)**	**Pollution control efficiency (%)**
0 (Reference)	Spring Water (Control)	2.1 ± 0.5	0	0	0	-
3 days	Gasoline Can	15.3 ± 2.2	2.5 ± 0.8	1.7 ± 0.5	4.8 ± 0.9	0%
	Diesel Can	18.7 ± 3.1	3.2 ± 1.0	2.8 ± 0.7	6.1 ± 1.1	0%
	Oil Can	12.9 ± 2.0	2.1 ± 0.7	1.2 ± 0.4	3.7 ± 0.8	0%
	Motor Oil Can	20.5 ± 3.4	4.0 ± 1.2	3.7 ± 1.1	7.2 ± 1.5	0%
7 days (Filtration)	Gasoline Can	8.5 ± 1.8	1.3 ± 0.5	0.9 ± 0.3	2.9 ± 0.6	40%
	Diesel Can	10.2 ± 2.1	1.8 ± 0.6	1.4 ± 0.5	3.7 ± 0.8	39%
	Oil Can	7.3 ± 1.5	1.1 ± 0.4	0.6 ± 0.2	2.5 ± 0.6	41%
	Motor Oil Can	11.8 ± 2.5	2.3 ± 0.7	2.1 ± 0.7	4.9 ± 1.0	32%
14 jours (Adsorption - Activated carbon)	Gasoline Can	4.2 ± 1.2	0.5 ± 0.2	0.3 ± 0.1	1.5 ± 0.4	69%
	Diesel Can	5.6 ± 1.5	0.8 ± 0.3	0.7 ± 0.2	2.1 ± 0.5	65%
	Oil Can	3.8 ± 1.1	0.4 ± 0.2	0.2 ± 0.1	1.2 ± 0.3	72%
	Motor Oil Can	6.9 ± 1.8	1.1 ± 0.4	1.0 ± 0.4	2.9 ± 0.7	60%
30 days (Biodegradation + Advanced oxidation)	Gasoline Can	1.2 ± 0.4	0	0	0.5 ± 0.2	90%
	Diesel Can	1.8 ± 0.5	0	0	0.8 ± 0.3	87%
	Oil Can	0.9 ± 0.3	0	0	0.3 ± 0.1	94%
	Motor Oil Can	2.5 ± 0.6	0	0	1.2 ± 0.4	83%

3.1.3.1. Evolution of contamination over time

Water stored in hydrocarbon drums has high initial contamination, particularly in total hydrocarbons and pathogens (coliforms, *E. coli*, *P. aeruginosa*). Prolonged exposure in the drums worsens contamination due to the migration of hydrocarbon residues and bacterial proliferation (Hassan et *al*., 2020).

3.1.3.2. Performance of decontamination techniques

Filtration reduces contamination by 30-40% in 7 days, but remains insufficient to completely eliminate hydrocarbons. Adsorption via activated carbon offers a significant reduction (60-72%) of contaminants after 14 days, in agreement with the work of Wu et *al*., (2019). Biodegradation combined with advanced oxidation provides the best performance with up to 94% decontamination after 30 days, which is consistent with the results obtained in the study by Kang et *al*., (2021).

3.1.3.3. Comparison by type of container

Engine oil containers are the most difficult to decontaminate due to the presence of heavy hydrocarbons that are resistant to conventional treatments (Goi et *al*., 2018). Petroleum and gasoline containers show better decontamination efficiency, probably due to the higher solubility of light hydrocarbons.

3.1.4. Decontamination of hydrocarbon-contaminated containers after water storage

A combination of processes is necessary to ensure complete decontamination. Advanced treatments such as membrane filtration and UV-C are essential to achieve maximum health safety. The results confirm that the use of cans used for storing hydrocarbons for water storage presents a significant risk if adequate treatments are not applied.

Table: Residual concentrations of contaminants after application of optimized decontamination processes

Time (days)	**Pollution Control Process**	**PAHs (µg/L)**	**VOCs (µg/L)**	**Benzene (µg/L)**	**Toluene (µg/L)**	**Lead (Pb) (µg/L)**	**Total coliforms (CFU/100 mL)**
0 (Reference)	Untreated Water	1.05 ± 0.15	18.5 ± 2.8	7.1 ± 1.3	9.8 ± 1.5	16.7 ± 2.4	62.4 ± 10.2
3 days	Hot Water Pressure Wash	0.80 ± 0.12	13.9 ± 2.4	5.5 ± 1.1	7.9 ± 1.2	12.9 ± 1.9	45.6 ± 8.5
7 days	Biodegradable Detergent + Mechanical Brushing	0.54 ± 0.09	10.2 ± 1.8	4.0 ± 0.9	6.1 ± 1.0	10.1 ± 1.6	32.8 ± 6.9
14 days	Ozonation (1 ppm) + Chlorination (5 mg/L)	0.28 ± 0.06	5.8 ± 1.2	2.0 ± 0.5	3.5 ± 0.8	6.3 ± 1.1	15.9 ± 4.3
30 days	Caustic Soda Wash (pH 12) + Neutralization	0.11 ± 0.04	2.2 ± 0.7	0.6 ± 0.3	1.2 ± 0.4	2.5 ± 0.8	5.2 ± 2.0
45 days	Activated Carbon Filtration + UV-C (254 nm)	0.03 ± 0.01	0.8 ± 0.3	0.2 ± 0.1	0.5 ± 0.2	1.2 ± 0.5	1.3 ± 0.7
60 days	Membrane Filtration (Nanofiltration) + UV-C	<0.01	<0.5	<0.1	<0.1	<0.5	<1

3.1.4.1. Reduction of organic and inorganic contaminants

The results show that a step-by-step approach, combining several techniques, is necessary to achieve an optimal level of decontamination. Pressure washing and mechanical brushing are methods that effectively remove hydrocarbon residues present on the walls of drums, as demonstrated by Kim et *al*. (2020). Ozone is effective against heavy hydrocarbons and persistent organic compounds, while chlorine reduces the microbiological load, in line with the research of WHO (2017). Alkaline washing (caustic soda at pH 12) allows solubilization of persistent hydrocarbons, consistent with the studies of Smith et *al*. (2021). Advanced filtration and UV-C guarantee the almost total elimination of pollutants, in line with the work of Liu et *al*. (2022).

3.1.4.2. Comparison with potability standards

At 60 days, contaminant concentrations meet WHO standards (<0.1 µg/L for hydrocarbons, <1 CFU/100 mL for bacteria), indicating that the processes applied are effective in making water safe for human consumption.

3.1.5. Probable economic and social profitability of drum decontamination businesses

The growth of the drum decontamination sector is a socio-economic opportunity in regions where access to safe water containers is limited. Cleaning techniques must be improved and standardized to accelerate acceptability by local populations. Investment in training and certification of workers will accelerate the adoption of these practices. Health and environmental authorities must support the initiative by offering financial incentives to promote these activities.

Table: Economic and social indicators over time

Time (months)	Number of jobs created (people)	Average monthly income per employee ($)	Average cost of decontamination per container ($)	Community acceptability (%)	Number of cans cleaned/month
0 (Reference)	0	0	0	15 ± 3.2	0
3 months	5 ± 1.2	150 ± 25	3.5 ± 0.8	32 ± 5.4	200 ± 20
6 months	12 ± 2.8	180 ± 30	2.9 ± 0.7	48 ± 6.8	520 ± 45
12 months	25 ± 4.5	220 ± 40	2.3 ± 0.6	62 ± 7.3	1 050 ± 85
24 months	40 ± 6.2	280 ± 50	1.8 ± 0.5	78 ± 5.9	2 100 ± 120
36 months	60 ± 8.5	350 ± 65	1.5 ± 0.4	85 ± 6.2	3 500 ± 210

3.1.5.1. Job creation and economic viability

The decontamination and cleaning of drums sector is experiencing rapid growth in terms of employment. In three years, the number of workers could increase from 0 to 60 people, with an average income increasing from $150 to $350 per month. These figures are consistent with studies on industrial waste recycling (Bach et *al*., 2019). The decontamination cost per drum could gradually decrease from $3.5 to $1.5, thanks to improved techniques and economies of scale (Duan et *al*., 2021).

3.1.5.2. Community acceptability and social perception

The community acceptability of cleaned drums for water storage could increase from 15% to 85% in three years. This would be due to awareness campaigns and better quality of cleaning (Nguyen et *al*., 2020). The initial reluctance of the population is explained by prejudices about persistent contamination and health risks (WHO, 2017), but these concerns diminish with time and scientific demonstrations.

3.1.5.3. Profitability and development potential

From 12 months, the model becomes economically viable with more than 1,000 drums cleaned per month and an acceptability greater than 60%. The increase in treatment capacity after 24 months leads to an increase in income, making the profession attractive to unskilled workers looking for work**.**

3.2. Discussion

3.2.1. Health implications

The results obtained confirm that the reuse of these containers presents a high risk for the health of populations in the Sahelian zone of Cameroon. Prolonged exposure to polycyclic aromatic hydrocarbons (PAHs) and VOCs is associated with carcinogenic and neurotoxic effects (Sedira, 2013; Diallo et *al*., 2022). In addition, heavy metal contamination can lead to cumulative toxic effects affecting the kidneys and central nervous system (Tchaptchet et *al*., 2019).

From a microbiological perspective, the presence of pathogenic bacteria in stored water can cause diarrheal and gastrointestinal diseases, particularly in children and immunocompromised individuals (Coulibaly & Traoré, 2018). These results confirm those of previous studies conducted in Niger and Burkina Faso, which had also shown a strong correlation between the use of containers that had contained hydrocarbons and an increased prevalence of waterborne diseases (Abdelrahim et al., 2015; Diop, 2013).

3.2.2. Perception and practices of local populations

Field surveys revealed that, despite awareness of certain risks, many households continue to use these containers due to a lack of accessible alternatives. The reasons given include:

• The scarcity and high cost of certified food containers.

• The lack of precise information on the real dangers of oil residues in stored liquids.

The habit of rinsing containers with water and sand before use, a method considered sufficient by many users, but ineffective in eliminating toxic residues (Kouadio et *al*., 2021; Hedman et *al*., 2020; Dzokom, 2024; Ismael et *al*.,. 2021).

3.2.3. Environmental issues

In addition to the health risks, this practice has a significant environmental impact. Residual hydrocarbons released into the environment during container rinsing pollute soils and water sources (Lanrewaju et al., 2022; Tchaptchet et *al*., 2019). Poor management of used cans and drums also promotes the proliferation of plastic and metal waste, worsening local pollution.

4. Conclusion and Recommendations

Conclusion

The analytical study of the impacts of the use of containers used for storing petroleum products to collect and store water and other food liquids in the Sahelian zone has highlighted major risks to human health and the environment.

Physicochemical analyses revealed the presence of polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs) and heavy metals in the stored water, exceeding the thresholds recommended by the OMS for drinking water. These contaminants are known for their long-term toxic effects, including carcinogenic, neurotoxic and renal risks. In addition, microbiological analyses have shown frequent contamination by Escherichia coli and Pseudomonas aeruginosa, indicating an increased risk of waterborne and gastrointestinal diseases.

On the social and economic level, this practice is fueled by a lack of accessible alternatives and a lack of information on the real dangers. From an environmental point of view, the discharge of oil residues into water and soil contributes to the pollution of already fragile Sahelian ecosystems.

Given these findings, it appears essential to adopt regulatory, awareness-raising and support measures for populations in order to reduce exposure to toxic substances and improve the quality of the water consumed. The results of this study demonstrate that the use of containers that have contained hydrocarbons for storing water and other food liquids represents a real danger for human health and the environment in the Cameroonian Sahel region.

Recommendations

1. Strengthening regulations and water quality control

Implement national and local standards prohibiting the reuse of petroleum product containers for storing water and food.

Strengthen water quality monitoring in the Sahel region by implementing regular chemical and microbiological analysis programs.

Establish a certification system for containers suitable for storing drinking water and food liquids.

2. Raising awareness and educating populations

Organize information and awareness campaigns among households and sellers of recycled containers on the dangers of residual hydrocarbons.

Integrate these issues into public health and environmental education programs to improve storage practices and drinking water management.

Encourage community and religious leaders to disseminate prevention messages adapted to local realities.

3. Promote sustainable alternatives

Facilitate access to certified food-grade plastic or stainless steel containers through subsidies or aid to disadvantaged households.

Develop controlled recycling solutions for used cans and drums, in order to avoid their diversion for food use.

Encourage the production and distribution of containers made locally with safe and environmentally friendly materials.

4. Develop local filtration and decontamination solutions

Promote the use of activated carbon filters and other simple techniques to reduce chemical contamination of water.

Raise awareness of the importance of treating water before consumption (boiling, filtration, use of suitable disinfectant solutions).

5. Commitment of authorities and development actors

Mobilize government institutions, NGOs and international organizations to implement sustainable water management strategies in the Sahelian environment.

Support research projects on the long-term effects of consuming contaminated water and on the solutions best suited to local realities.

Prospects

The impact of reusing oil containers for water storage in the Sahelian region is a multidimensional issue, requiring integrated approaches combining regulation, awareness-raising and technological innovation. Additional studies could further assess the long-term effects on the health of exposed populations, as well as the effectiveness of certain water decontamination techniques based on local knowledge.

By integrating these recommendations into water resource management and public health policies, it would be possible to significantly reduce the risks associated with this practice and improve the living conditions of Sahelian populations.

Conflict of Interest: The author declare that they have no conflict of interest

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