

Original Research Article

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Efficiency of Ultra-Violet (UV) Water Treatment Systems in Packaged Water Production Companies of Ouagadougou (Burkina Faso) and Antibiotic Resistance Profiles of Isolated Bacteria

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ABSTRACT

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Among water treatment techniques, UV rays are mainly used to disinfect packaged drinking water. The objective of this study was to evaluate the effectiveness of water disinfection by UV rays in packaged water production companies in the city of Ouagadougou. Fifty-four (54) packaged water samples were taken from 27 companies in the city of Ouagadougou. Detection of different microorganisms was carried out using the membrane filtration method. The identification of the isolated coliforms was made using the API 20E trips. Antibiotic resistance was assessed using the KIRBY BAUER agar diffusion method. using ampicillin, amoxicillin, ceftriazone, imipenem, meropenem, kanamycin, gentamicin, ciprofloxacin and norfloxacin. The results of microbiological investigations showed the presence of bacteria in some packaged water from certain companies. Of the 27 companies investigated, total coliforms were detected in 20 companies, *E. coli* in one company, *Pseudomonas aeruginosa* in one company, and sulfite-reducing anaerobic bacteria in 4 companies. Of the 27 companies, the effectiveness of UV disinfection was observed in only 25.92% with a total absence of coliforms, *E. coli*, intestinal enterococci, *Pseudomonas aeruginosa* and sulphite-reducing anaerobic bacteria. Twelve (12) species of coliforms including *Enterobacter* ssp, *Enterobacter cloacae*, *Enterobacter amnigenus*, *Serratia liquefaciens*, *Chryseomonas luteola*, *Chryseobacterium indologenes*, *Stenotrophomonas maltophilia*, *Myroides* spp, *Pantoea* spp, *Burkholderia cepacia*, *Serratia ficaria* and *Enterobacter sakazakii* have been detected. The resistance profile showed that some coliforms were resistant to β -lactams and aminoglycosides. This study shows that the technique of disinfection of water by UV rays is not effective in certain companies in Ouagadougou and could be explained by diverse reasons including UV systems defiances.

Introduction

Water disinfection is considered to be an essential step aimed at minimizing any risk of infection by pathogenic microorganisms and thus preventing the spread of waterborne diseases (Gerba *et al.*, 2003; Le Chevallier *et al.*, 2004). There are currently different methods of disinfecting water. Techniques that are based on chemical processes, namely the use of oxidizing substances with high disinfecting power such as chlorine, chlorine dioxide, ozone and bromine (Baker *et al.*, 2002). There are also physical treatment techniques, such as disinfection of water by ultraviolet irradiation at a germicidal wavelength.

Each water disinfection technique has its advantages and disadvantages. Generally, the choice of a water disinfection technique is established by considering numerous technical, economic and environmental constraints.

The best-known disinfection process is chlorination. Indeed, chlorine is a very strong oxidant that reacts mainly with most constituents of microorganisms, eventually disrupting cellular integrity (Adegado, 2005).

Despite its germicidal effectiveness, this chemical disinfectant can have a significant impact on the natural environment as well as on public health. Indeed, the use of chlorine as a disinfectant agent can generate, in reaction with the organic matter of the water, organochlorine by-products, some of which are potentially dangerous (Oliver *et al.*, 2005). Thus, the use of physical treatment by ultraviolet C (UV-C) irradiation, at a germicidal wavelength of 253.7 nm, makes it possible to eliminate the disadvantages associated with chemical disinfectants.

In Burkina Faso, over the past ten years, we have witnessed the emergence of packaged water companies. According to statistics provided by the Ministry of Trade, Industry and Handicrafts, in 2016, 51 packaged water companies out of 99, or approximately 52% of the companies inspected, were in compliance with the regulations (MCIA, 2016).

These packaged water companies use UV lamps for water disinfection in order to provide good quality water to the population. However, the quality of the water from certain companies is sometimes decried by consumers. In January 2017, only 23 packaged water companies in the

city of Ouagadougou were under control protocol with the National Agency for Environmental, Food, Labor and Health Products Safety (ANSSEAT, 2017). The results of the microbiological analysis of the quality control carried out by the ANSSEAT showed that certain packaged waters showed non-compliance for certain microorganisms. These non-conformities are detected both in water at the source (drilling) and in packaged water.

Consequently, the presence of microorganisms observed in packaged water invites us to study the effectiveness of UV water disinfection in these packaged companies.

This study aimed to evaluate the effectiveness of UV water disinfection in packaged water production companies in the city of Ouagadougou.

Materials and Methods

Study Setting and Sampling

The samples were collected in packaged water companies in the city of Ouagadougou. Ouagadougou, the capital of the country is the biggest city with a population estimated at more than 2.8 million inhabitants in 2022, which represents more than 45 % of the urban population. Sampling was carried out at packaged drinking water production units across the city (Figure 1).

Sampling

The samples were taken according to EN 25667-2 and ISO 5667-3 standards. For each production unit, 2 samples were taken. A water sample is taken before and after the UV lamp under aseptic conditions. Water was collected in sterile 500 mL borosilicate glass bottles.

A total of 54 samples were taken from 27 packaged water companies (Table 1). The companies have been coded for confidentiality. After each sampling, the bottles were placed in an isothermal cooler containing ice boxes maintaining the temperature between 4 °C and 8 °C and transported to the laboratory for analyses within 24 hours.

Microbiological Analyzes

The collected packaged water samples were subjected to microbiological analyses. The membrane filtering

method was used for the isolation and the count of total coliforms, *E. coli*, Intestinal enterococci, *Pseudomonas aeruginosa*, sulfite-reducing anaerobic bacteria spores (SRABS). A 100 mL volume of the water has been filtered through a cellulose nitrate filtration membrane (0.45 µm or 0.20 µm porosity depending on the microorganisms sought). The membrane has been transferred to the appropriate culture medium and incubated in an oven at the appropriate temperature.

Total coliforms are isolated according to the ISO 9308 (2014) method. The cellulose nitrate filtration membrane with a porosity of 0.45 µm was used for filtration and then transferred to the selective Chromocult Coliform Agar (CCA) medium and incubated in the oven at 37°C for 48 hours. The characteristic colonies are red.

E. coli has been isolated according to the ISO 9308 (2014). The cellulose nitrate filtration membrane with a porosity of 0.45 µm is transferred to the selective Chromocult Coliform Agar (CCA) medium after filtration and incubated at 37°C for 48 hours. The characteristic colonies are purple or blue in color.

Intestinal *enterococci* have been isolated according to the ISO 7899-2 (2000) method. The cellulose nitrate filtration membrane has a porosity of 0.45 µm and is transferred to Slanetz Bartley (SB) selective medium. The presumptive colonies are red in color and confirmation (transfer of the membrane from SB medium to BEA medium) on Bile Esculin Azide (BEA) agar at 44°C for 2 hours causes the color to change from red to black indicating the presence intestinal enterococci.

Pseudomonas aeruginosa is sought according to the NF T90-421 method (1989). The filtration membrane used has a porosity of 0.20 µm and is transferred to the selective medium (cetrimide agar). Presumptive colonies are green in color and confirmation on King A agar reveals pyoverdine at 22°C for 48 hours.

Sulfite-reducing anaerobic bacteria spores (SRABS) have been isolated according to the NF T90-417 (1993). The sample is first heated to 80°C for 15 min and then cooled.

The membrane used (0.20 µm porosity) and transferred after filtration of 100 mL, onto the selective medium Meat-Liver (ML) agar, placed in an anaerobic jar containing the Anaerocult® system (oxygen-absorbing reagent) and incubated at 37°C for 48 hours. Suspected colonies are black.

Identification of Isolated Coliforms

The coliform isolates obtained during the microbiological analysis were identified using the Api 20E trips.

Antibiotic Susceptibility Testing

The antibiogram was carried out using the disk diffusion method for antimicrobial susceptibility testing on agar medium (CASFM, 2019).

Briefly, pure colonies in the growth phase on Muller Hinton (MH) media, i.e. colonies aged 18 to 24 hours, were used to prepare the inoculum. A colony was taken from the Petri dish and crushed in the medium (NaCl 0.85%). The entire bacterial suspension was well homogenized and standardized to Mac Farland 0.5 before being inoculated on the MH medium and incubated at 37°C for 24 hours. The results were appreciated by measuring the zones of inhibition diameters using a ruler. The sensitivity profile of each bacterium towards the antibiotics tested was determined by reference to a reading table according to CASFM (2019) giving the correlation between inhibition diameter and minimum inhibitory concentration (MIC), which allowed to classification of bacteria as susceptible, intermediate or resistant. Table 2 shows the list of antibiotics used to perform this test in this study.

Results and Discussion

Each year, microbial contaminations of drinking-water are contribute to nearly 1.7 billion episodes of diarrhea worldwide (Fischer Walker *et al.*, 2012). Moreover, inadequate access to safer drinking water is estimated to cause approximately 505 000 diarrheal deaths each year (WHO, 2023). Therefore, is important to have a cost-effective method to efficiently disinfect drinking water without affecting human health. In this study, we evaluated the effectiveness of UV water disinfection in packaged water production companies in the city of Ouagadougou.

Microorganisms recovered in the UV-treated water and their levels

Total Coliform

Figure 2 shows the presence of total coliforms in water samples taken before and after UV treatment. Of the 27

water samples taken after UV, only 7 samples (25.92%) comply with drinking water standards in Burkina Faso (0 total coliform per 100 mL). Seventeen (17) water samples taken before UV disinfection showed total coliform contamination. After passing the water to UV, 02 of these samples (11.76%) are free of total coliforms. The present study says that 11.76% of packaged water companies showed effectiveness in UV disinfection compared to total coliforms.

Of the 17 water samples taken with total coliforms before UV disinfection, 12 (70.58%) recorded a drop in the number of microorganisms after UV disinfection. The intensity of the UV radiation or the contact time was certainly not sufficient for the complete elimination of the germs. This could also be explained by the process of photoreactivation which allows bacteria to repair damage to their DNA (Sanz *et al.*, 2007).

Of the 27 packaged water companies, 7 (25.92%) had an increase in the number of total coliforms after UV disinfection. This unexpected situation can be due to several factors. It could be explained by the presence of biofilms embedded in the pipes which could recontaminate water after it has passed the UV level.

In addition, the presence of microorganisms in the water after UV treatment could also be explained by the non-functioning or poor condition of the UV lamps in the treatment system. The flow of water could also have an impact on the effectiveness of UV rays. Indeed, a very short application time of these rays on the bacteria could be ineffective.

Escherichia coli

In this study, *E. coli* was recovered in a UV-treated water sample while there was no *E. coli* before treatment. Figure 3 shows the presence of *E. coli* in a single sample taken after UV. This presence of *E. coli* is a recontamination of the water after disinfection and this could be explained by several causes. Among these causes, the presence of biofilms embedded in the pipe could be advanced as the most probable cause.

Fass *et al.*, (1996) showed in their study that the experimental introduction of *Escherichia coli* into the water distribution network leads to the formation of biofilms. The concerned water production unit (PU14) should take corrective measures to identify the cause of this problem and solve it.

Intestinal Enterococci

Figure 4 shows that of the 27 water samples taken before UV, 2 samples showed contamination with intestinal enterococci. The UV-treatment allowed the elimination of these bacteria from the water. On the other hand, no sample taken after the UV was contaminated. Maurin *et al.*, (1974) also reported similar results on the use of UV radiation during the treatment of raw water. However, our results contrast with those of Chérif I. Diop (2006) in his study on the microbiological quality of packaged beverage water. He found a contamination rate of 19% which reflects the ineffectiveness of ultraviolet disinfection. Regarding UV-C impact on intestinal enterococci, data are scarce in depth in the scientific literature. However, study conducted by Kamel *et al.*, (2022) showed that intestinal enterococci such as *Enterococcus faecalis* (*E. faecalis*) required a minimum dose and a corresponding time exposure of only 1 min for their inactivation (Kamel *et al.*, 2022). In addition, Lui *et al.*, (2016) found that that 270 nm was effective to disinfect a laboratory strain of *E. faecalis* (Lui *et al.*, 2016).

Pseudomonas aeruginosa

Figure 5 shows that 26 samples (96.29%) of water taken after UV are compliant with drinking water standards in Burkina (no detection of *Pseudomonas aeruginosa* in 100 mL of water).

Disinfection efficiency is observed in five (05) companies with contaminated samples by *Pseudomonas aeruginosa* before UV disinfection and their absence after UV. These results corroborate those of Attal (2013) in his study on the inactivation of *Pseudomonas aeruginosa* in skimmed milk by UV radiation. According to Dykstra *et al.*, (2002), non-spore-forming bacteria are the least resistant microorganisms to UV radiation.

On the other hand, the sample S18 AF was recontaminated after the passage to UV, confirming the hypothesis of the presence of biofilms embedded in the pipes.

Sulfite-reducing anaerobic bacteria spores (SRABS)

The presence of sulfite-reducing anaerobic bacteria spores (SRABS) is shown in figure 6. Twenty-three (23)

samples (85.18%) of water taken after UV rays comply with drinking water standards in Burkina (0 SRABS in 50 ml). However, 8 samples of water sampled before UV were contaminated with SRABS and 6 out of these 8 samples (75%) of water sampled after UV showed effectiveness in UV disinfection. Previous studies have shown the effectiveness of UV treatment on SRABS. Paquette (2004) found 62% and Payment (2005), 43.5% effectiveness of UV treatment on sporulating bacteria.

Three (03) samples (S2 AF, S8 AF and S10 AF) showed recontamination with SRABS after UV disinfection. This recontamination could be due to biofilms embedded in the piping of the corresponding production units.

Coliforms identified in the packaged water samples

The results of identification of total coliforms are shown in figure 7 with 22% *Enterobacter ssp*, 16% *Enterobacter cloacae*, 11% *Enterobacter amnigenus*, 11% *Serratia liquefaciens*, 8% *Chryseomonas luteola*, 6% *Chryseobacterium indologenes*, 5% *Stenotrophomonas maltophilia*, 5% *Myroides spp*, 5% *Pantoea spp*, 5% *Burkholderia cepacia*, 3% *Serratia ficaria* and 3% *Enterobacter sakazakii*.

Surprisingly, these results obtained with packaged disinfected water samples are getting closer to those of Lavoie (1983), who studied well water and found the same types of coliforms but with different proportions compared to ours. Nevry *et al.*, (2012) have also identified the same genera of coliforms but in lettuce irrigation water.

Antibiotic susceptibility of isolated microorganisms

Antibiotic susceptibility profiles of isolated coliform

The study of antibiotic susceptibility patterns of isolated coliforms gave the results summarized in Table.3.

Enterobacter amnigenus*, *Enterobacter sakazakii*, *Enterobacter spp*, *Enterobacter cloacae

Antibiotic susceptibility testing for *Enterobacter amnigenus* showed high resistance to amoxicillin and kanamycin 100%. Stock and Wiedemann (2002) reported

the same resistance to amoxicillin in 18 strains of *Enterobacter amnigenus*. This same study also reports results similar to ours on sensitivity to fluoroquinolones. Resistance to amoxicillin could be explained by the development of resistance due to the current use of this molecule in various affections.

For *Enterobacter sakazakii*, antibiotic susceptibility testing revealed 100% resistance to ampicillin, amoxicillin, ceftazidime, imipenem, meropenem, kanamycin and gentamicin.

Our results indicate high resistance by *Enterobacter spp* to ampicillin and amoxicillin respectively 100%, 100%.

The test on *Enterobacter cloacae* showed strong resistance to ampicillin and amoxicillin 100%.

Similar results were found by Khennouchi *et al.*, (2015) on clinical strains isolated from urine, blood, cerebrospinal fluid (CSF) for ampicillin and amoxicillin with 100% resistance. The same study showed 62.9% resistance to ceftazidime which is close to our results (66.66%). This study also reveals sensitivity to imipenem, which is also similar to our results.

Myroids spp

In this study, it has been shown high resistance to ampicillin, amoxicillin and ceftriaxone respectively 100%. On the other hand, no resistance is noted with meropenem, gentamicin, ciprofloxacin and norfloxacin. *Myroids spp* was no exception with regard to resistance to antibiotics from the β lactam family. This could be a natural or acquired resistance. Future studies could enlighten us on this subject.

Pantoea spp

It has been noticed high resistance to ampicillin, amoxicillin and ceftazidime 100% respectively. Our results are close to those of Kaboré *et al.*, (2013) for β lactams (87.5%) who worked on clinical strains isolated from oral infections.

Burkholderia cepacia

These bacteria showed high resistance in this study to ampicillin, amoxicillin, ceftazidime, ceftriaxone and ciprofloxacin respectively 100%. Our results are close to

those of Shawn D. Aaron *et al.*, (2012) for ciprofloxacin (94%) who worked on strains isolated from patients with Cystic Fibrosis Infected.

Chryseobacterium indologenes

Ampicillin, amoxicillin Like the other enterobacteria, *Chryseobacterium indologenes* showed high resistance to ceftazidime, ceftriaxone and kanamycin respectively 100%, 100%, 100%, 50% and 50%. On the other hand, no resistance is noted with imipenem, meropenem, gentamicin, ciprofloxacin and norfloxacin. These ampicillin and amoxicillin susceptibility results are similar to those of Delmas (2012), which show a fierce resistance of *Chryseobacterium indologenes* to β -lactams correlated with the production of metallo- β -lactamase. Zeba *et al.*, (2005) also demonstrated the capacity of *Chryseobacterium indologenes* to produce metallo- β -lactamase by working on clinical strains isolated from patient urine.

Serratia liquefaciens

Serratia liquefaciens also showed high resistance to ampicillin, amoxicillin, kanamycin, and gentamicin 75%, 100%, 100%, and 75% respectively. Stocker *et al.*, (2003) confirm our results by also showing resistance of *Serratia liquefaciens* to β lactams. Their study focused on 41 strains.

Serratia ficaria

Antibiotic susceptibility testing showed 100% resistance to ampicillin, amoxicillin. On the other hand, we note good sensitivity (100%) with ceftriaxone, imipenem, kanamycin, gentamicin, ciprofloxacin and norfloxacin. These antibiotic sensitivity tests also showed an intermediate result with certain antibiotics such as ceftazidime (100%) and meropenem (100%).

As with most enterobacteria, *Serratia ficaria* is no exception to the rule with resistance to B lactams. We can think of a production of β lactamases by this bacteria which confers resistance.

Stenotrophomonas maltophilia

Antibiotic susceptibility testing showed high resistance to ampicillin, amoxicillin, ceftazidime, imipenem,

meropenem, and gentamicin 100%, 100%, 100%, 50%, 100%, and 100%, respectively. On the other hand, no resistance is noted with ceftriaxone and ciprofloxacin. Our data are close to those of Amélie Deredjian *et al.*, (2016) who worked on 66 strains of *Stenotrophomonas maltophilia* isolated from agricultural soils. Their study shows 64% resistance to β lactams. This difference could be explained by the number and origin of the strains used on both sides.

Chryseomonas luteola

Chryseomonas luteola showed high resistance to ampicillin, amoxicillin and norfloxacin respectively 100%, 100% and 66.66%. This resistance to β lactams and quinolones can be natural or acquired. But little data exists in the literature on antibiotic resistance in *Chryseomonas luteola*.

Antibiotic susceptibility profiles of isolated *Escherichia coli*

For *Escherichia coli*, antibiotic susceptibility testing showed strong resistance to ampicillin, amoxicillin, ceftazidime, ceftriaxone, imipenem, kanamycin, and norfloxacin. On the other hand, no resistance is noted with gentamicin. These antibiotic susceptibility tests also showed an intermediate result with some antibiotics like meropenem and ciprofloxacin. Fabre *et al.*, (2010) in their study of the susceptibility of 1636 strains of *E. coli* to antibiotics had the following results for resistance: amoxicillin: 73%; ceftriaxone: 98%; gentamicin: 96%; ciprofloxacin: 89%.

These results are very close to ours for amoxicillin and ceftriaxone. On the other hand, for gentamicin and ciprofloxacin, our results are divergent. This could be explained by the fact that we used only one strain for susceptibility testing. Resistance could be due to the prescription of antibiotics, particularly in ambulatory medicine and self-medication even before going to the health center and failure to respect the treatment time by patients.

Antibiotics have lost their effectiveness to varying degrees due to these irrational uses. This phenomenon complicates the treatment of bacterial infections and promotes the emergence of multi-resistant strains (Yala *et al.*, 2001).

Table.1 Codification of the packaged water companies and their samples analyzed.

Packaged water companies' codes	Code of water samples before UV treatment	Code of water samples after UV treatment
PU 1	S1 BE	S1 AF
PU 2	S2 BE	S2 AF
PU 3	S3 BE	S3 AF
PU 4	S4 BE	S4 AF
PU 5	S5 BE	S5 AF
PU 6	S6 BE	S6 AF
PU 7	S7 BE	S7 AF
PU 8	S8 BE	S8 AF
PU 9	S9 BE	S9 AF
PU 10	S10 BE	S10 AF
PU 11	S11 BE	S11 AF
PU 12	S12 BE	S12 AF
PU 13	S13 BE	S13 AF
PU 14	S14 BE	S14 AF
PU 15	S15 BE	S15 AF
PU 16	S16 BE	S16 AF
PU 17	S17 BE	S17 AF
PU 18	S18 BE	S18 AF
PU 19	S19 BE	S19 AF
PU 20	S20 BE	S20 AF
PU 21	S21 BE	S21 AF
PU 22	S22 BE	S22 AF
PU 23	S23 BE	S23 AF
PU 24	S24 BE	S24 AF
PU 25	S25 BE	S25 AF
PU 26	S26 BE	S26 AF
PU 27	S27 BE	S27 AF

Table.2 Antibiotics tested in this study and interpretive criteria according to the diameter of the zones of inhibition

Families of used Antibiotics	Names of used Antibiotics	Disc load (µg)	Zone of inhibition (mm)		
			Sensitive	Intermediate	Resistant
β lactamines	Ampicillin	10	≥14		<14
	Amoxicillin	20	≥19		<19
Cephalosporins	Ceftazidim	10	≥22	19-21	<19
	Ceftriaxone	30	≥25	22-24	<22
Carbapenems	Imipenem	10	≥22	16-21	<16
	meropenem	10	≥22	16-21	<16
Aminosides	Kanamycin	30	≥18	15-17	< 15
	Gentamicin	10	≥17	14-16	< 14
Fluoroquinolones	Ciprofloxacin	5	≥26	24-25	< 24
	Norfloxacin	10	≥22	29-21	< 19

Source: CASFM, 2019

Figure.1 Map of Ouagadougou, showing location of visited packaged water companies

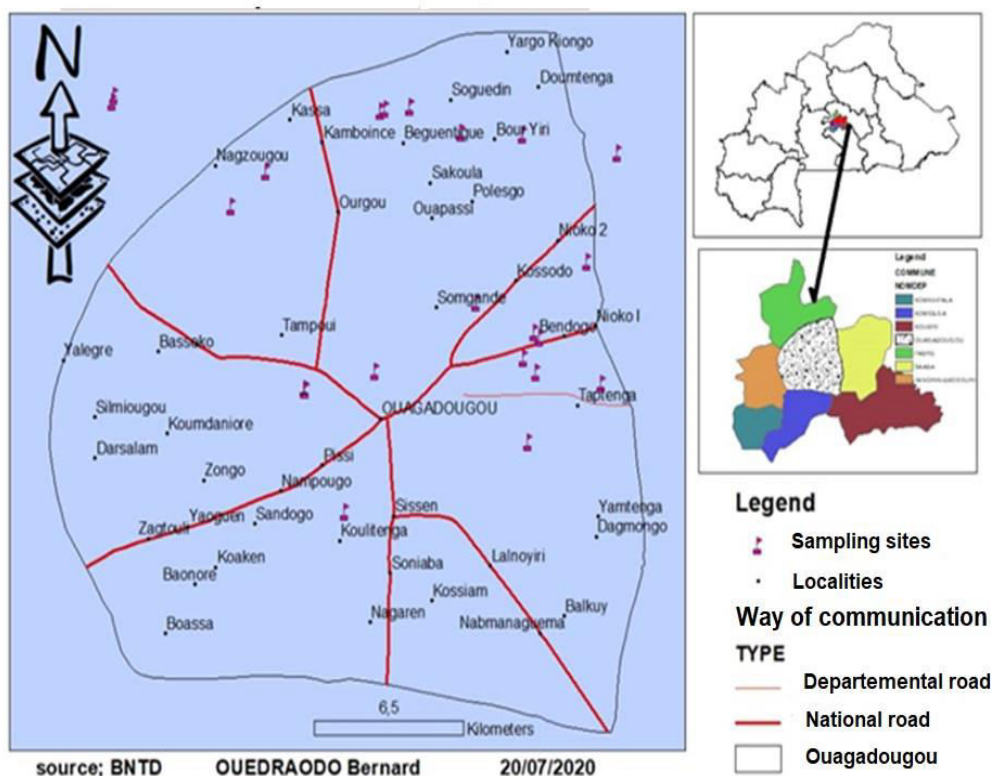


Table.3 Susceptibility of identified coliforms to tested antibiotics.

Antibiotics	<i>Enterobacter amnigenus</i> (4)			<i>Enterobacter sakazakii</i> (1)			<i>Myroides spp</i> (2)			<i>Pantoea spp</i> (2)			<i>Burkholderia cepacia</i> (2)			<i>Enterobacter spp</i> (8)		
	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R
Ampicillin	50%	0%	50%	0%	0%	100%	0%	0%	100%	0%	0%	100%	0%	0%	100%	0%	0%	100%
Amoxicillin	0%	0%	100%	0%	0%	100%	0%	0%	100%	0%	0%	100%	0%	0%	100%	0%	0%	100%
ceftazidim	25%	25%	50%	0%	0%	100%	0%	100%	0%	0%	0%	100%	0%	0%	100%	0%	37.5%	62.5%
Ceftriaxone	0%	50%	50%	100%	0%	0%	0%	0%	100%	50%	50%	0%	0%	0%	100%	25%	0%	75%
Imipenem	50%	25%	25%	0%	0%	100%	0%	50%	50%	100%	0%	0%	0%	50%	50%	37.5%	12.5%	50%
meropenem	50%	50%	0%	0%	0%	100%	100%	0%	0%	0%	50%	50%	0%	100%	0%	0%	37.5%	62.5%
Kanamycin	0%	0%	100%	0%	0%	100%	0%	50%	50%	100%	0%	0%	0%	50%	50%	0%	50%	50%
Gentamicin	50%	0%	50%	0%	0%	100%	100%	0%	0%	100%	0%	0%	50%	50%	0%	37.5%	12.5%	50%
Ciprofloxacin	50%	25%	25%	100%	0%	0%	100%	0%	0%	100%	0%	0%	0%	0%	100%	37.5%	12.5%	50%
Norfloxacin	100%	0%	0%	100%	0%	0%	100%	0%	0%	100%	0%	0%	0%	50%	50%	25%	25%	50%

Table.3 Continuation

Antibiotics	<i>Entrobacter cloacae</i> (6)			<i>Chryseobacterium indologenes</i> (2)			<i>Serratia liquefaciens</i> (4)			<i>Serratia ficaria</i> (1)			<i>Stenotrophomonas maltophilia</i> (2)			<i>Chryseomonas luteola</i> (3)		
	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R
Ampicillin	0%	0%	100%	0%	0%	100%	0%	25%	75%	0%	0%	100%	0%	0%	100%	0%	0%	100%
Amoxicillin	0%	0%	100%	0%	0%	100%	0%	0%	100%	0%	0%	100%	0%	0%	100%	0%	0%	100%
ceftazidim	16.6%	16.6%	66.6%	0%	0%	100%	75%	25%	0%	0%	100%	0%	0%	0%	100%	0%	100%	0%
Ceftriaxone	0%	33.33%	66.6%	0%	50%	50%	75%	25%	0%	100%	0%	0%	100%	0%	0%	0%	100%	0%
Imipenem	100%	0%	0%	100%	0%	0%	50%	25%	25%	100%	0%	0%	0%	50%	50%	66.66%	33.33%	0%
meropenem	100%	0%	0%	100%	0%	0%	75%	0%	25%	0%	100%	0%	0%	0%	100%	100%	0%	0%
Kanamycin	16.6%	33.33%	50%	0%	50%	50%	0%	0%	100%	100%	0%	0%	0%	100%	0%	100%	0%	0%
Gentamicin	66.6%	0%	33.33%	100%	0%	0%	0%	25%	75%	100%	0%	0%	0%	0%	100%	100%	0%	0%
Ciprofloxacin	100%	0%	0%	100%	0%	0%	100%	0%	0%	100%	0%	0%	100%	0%	0%	66.66%	33.33%	0%
Norfloxacin	100%	0%	0%	100%	0%	0%	100%	0%	0%	100%	0%	0%	0	100%	0%	33.33%	0%	66.66%

S: susceptible I: intermediate R: resistant (n): number of strains tested %: percentage

Table.4 Results of tests for the susceptibility of *Pseudomonas aeruginosa* to antibiotics.

Antibiotics	<i>Pseudomonas aeruginosa</i> (6)		
	S	I	R
Ampicillin	0%	0%	100%
Amoxicillin	0%	0%	100%
ceftazidim	33,33%	16,66%	50%
Ceftriaxone	16,66%	16,66%	66,66%
Imipenem	66,66%	0%	33,33%
meropenem	50%	33,33%	16,66%
Kanamycin	100%	0%	0%
Gentamicin	83,33%	0%	16,66%
Ciprofloxacin	100%	0%	0%
Norloxacin	50%	16,66%	33,33%

S: susceptible I: intermediate R: resistant (n): number of strains tested %: percentage

Table.5 Antibiotic susceptibility profiles of isolated Sulphite-Reducing Anaerobic Bacteria (SRAB)

Antibiotics	Sulfite-Reducing Anaerobic Bacteria spores (SRABS) (12)		
	S	I	R
Ampicillin	16.66%	8.33%	75%
Amoxicillin	0%	0%	100%
ceftazidim	25%	16.66%	58.33%
Ceftriaxone	16.66%	16.66%	66.66%
Imipenem	83.33%	8.33%	8.33%
meropenem	100%	0%	0%
Kanamycin	16.66%	0%	83.33%
Gentamicin	100%	0%	0%
Ciprofloxacin	75%	8.33%	16.66%
Norloxacin	41.66%	8.33%	50%

S: susceptible I: intermediate R: resistant (n): number of strains tested %: percentage

Figure.2 Total coliforms in the water samples before and after UV treatment

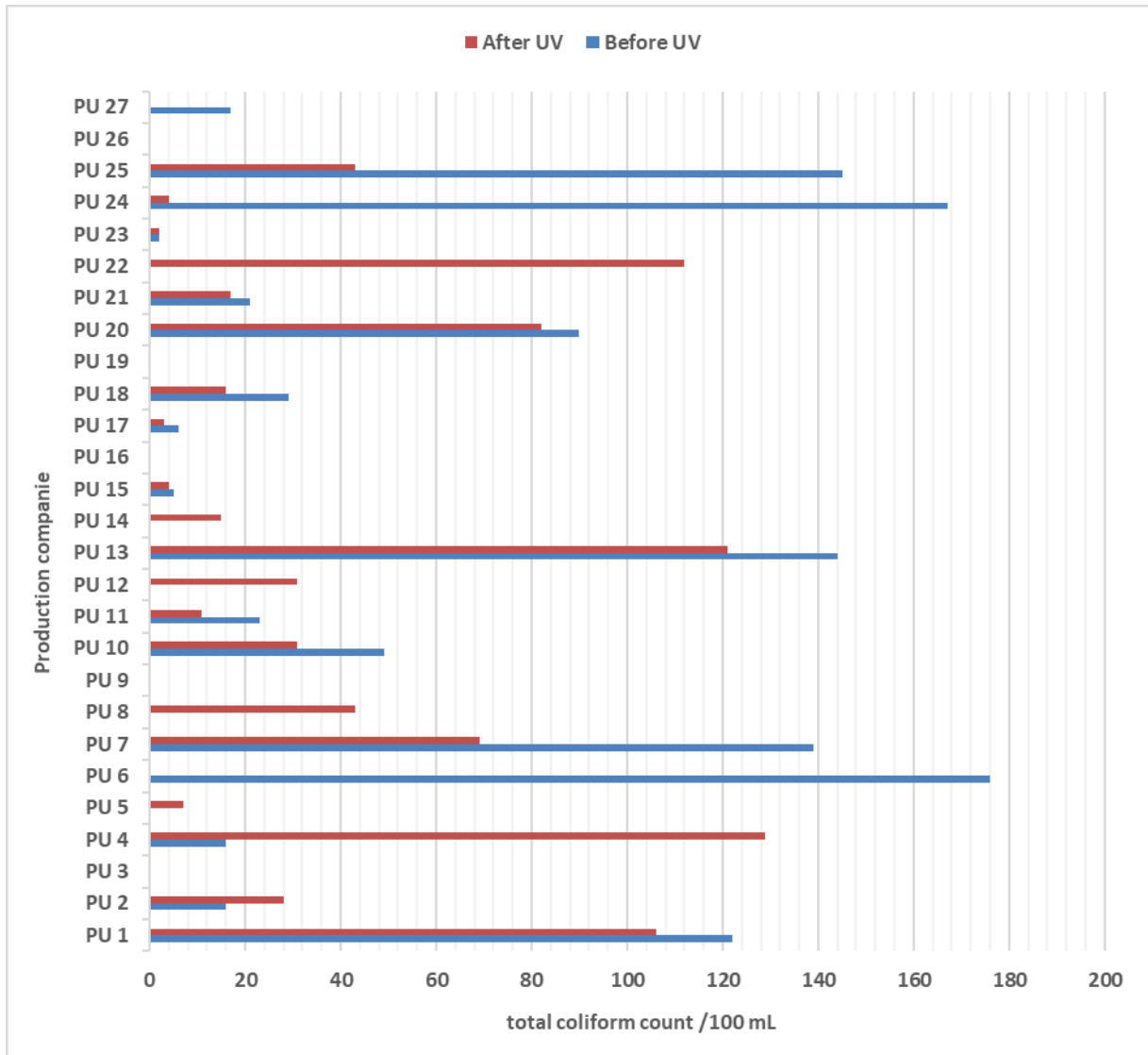


Figure.3 Number of *E. coli* detected before and after UV treatment

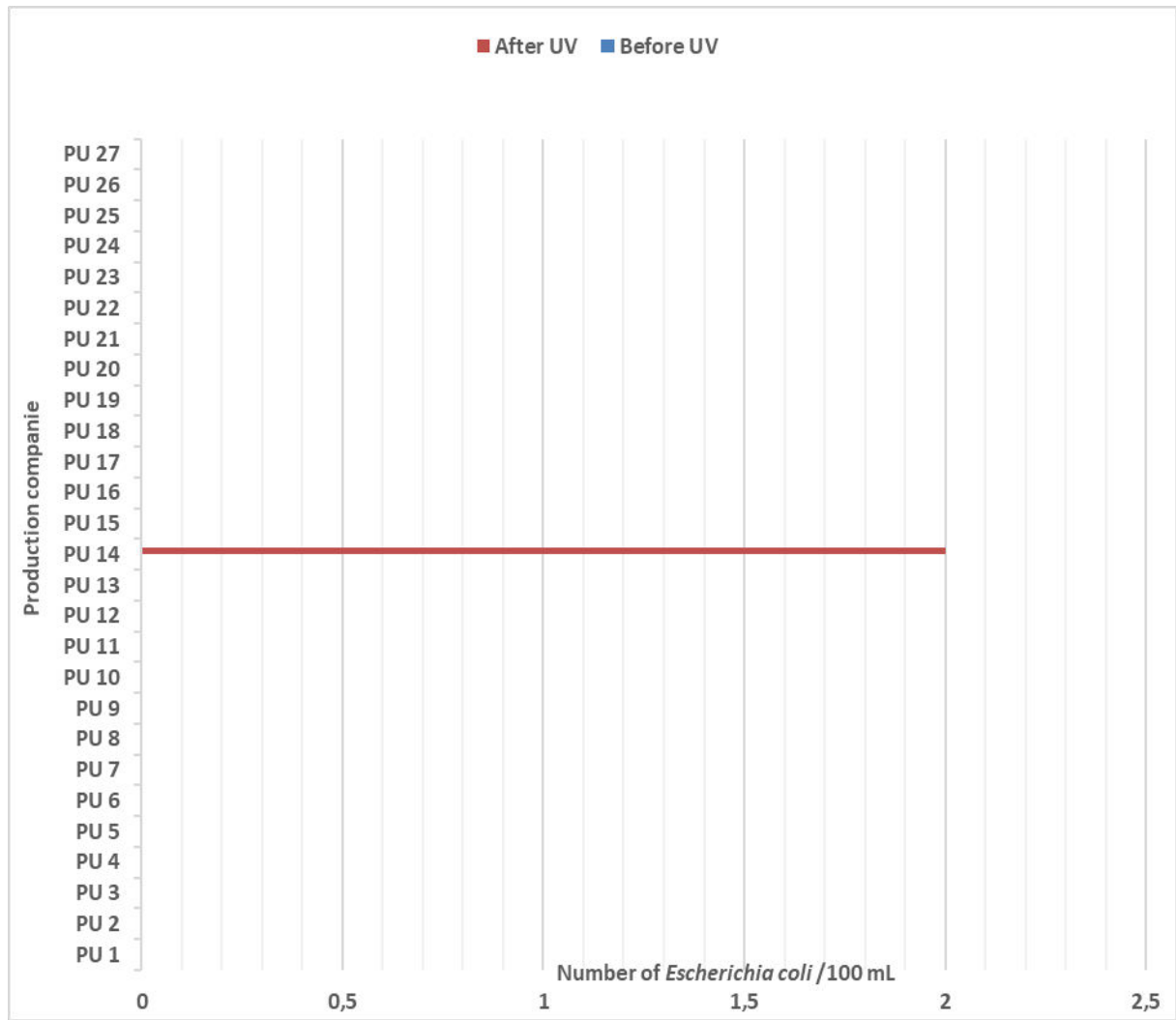


Figure.4 Intestinal enterococci before and after UV treatment

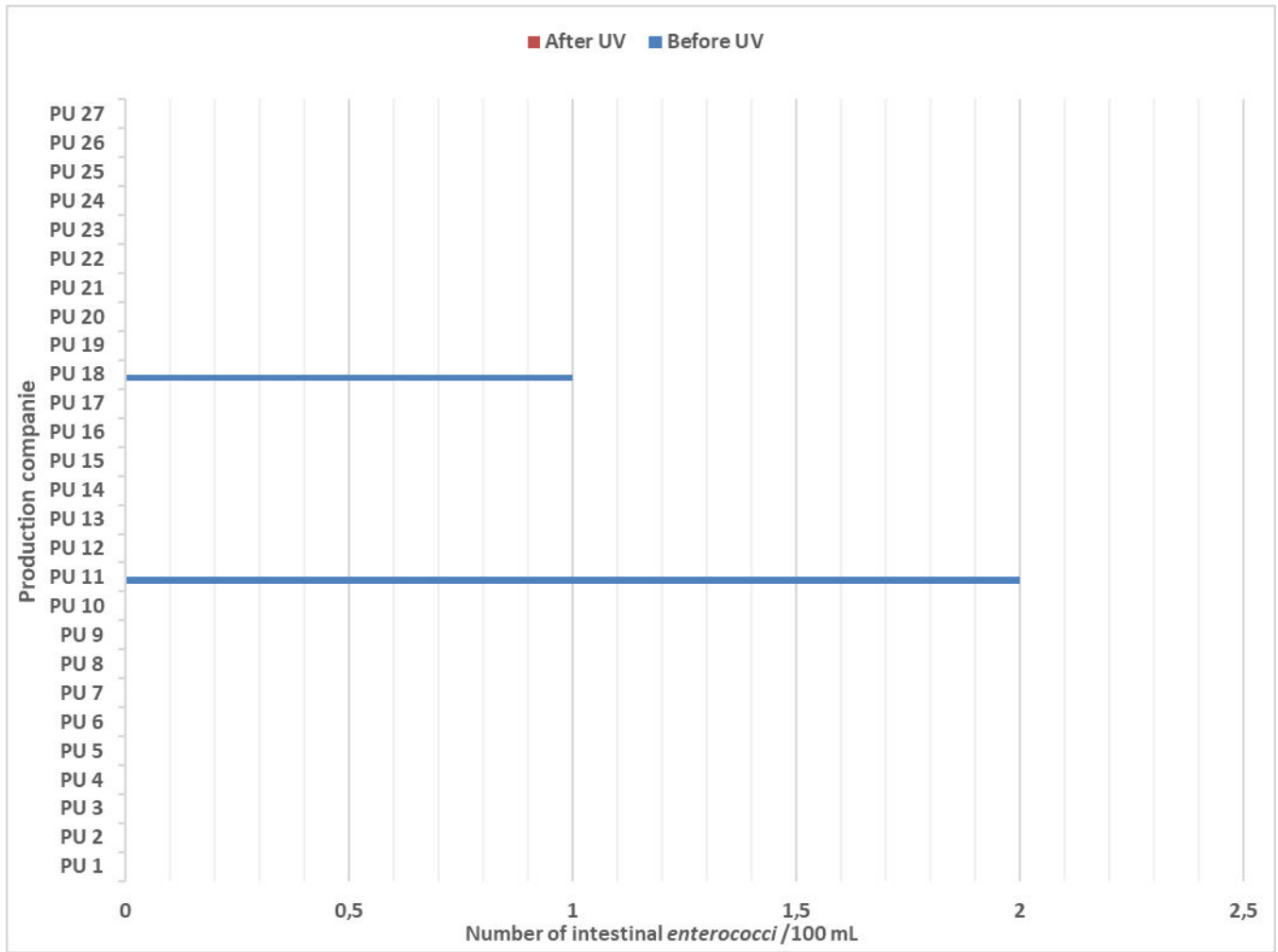


Figure.5 *Pseudomonas aeruginosa* before and after UV treatment

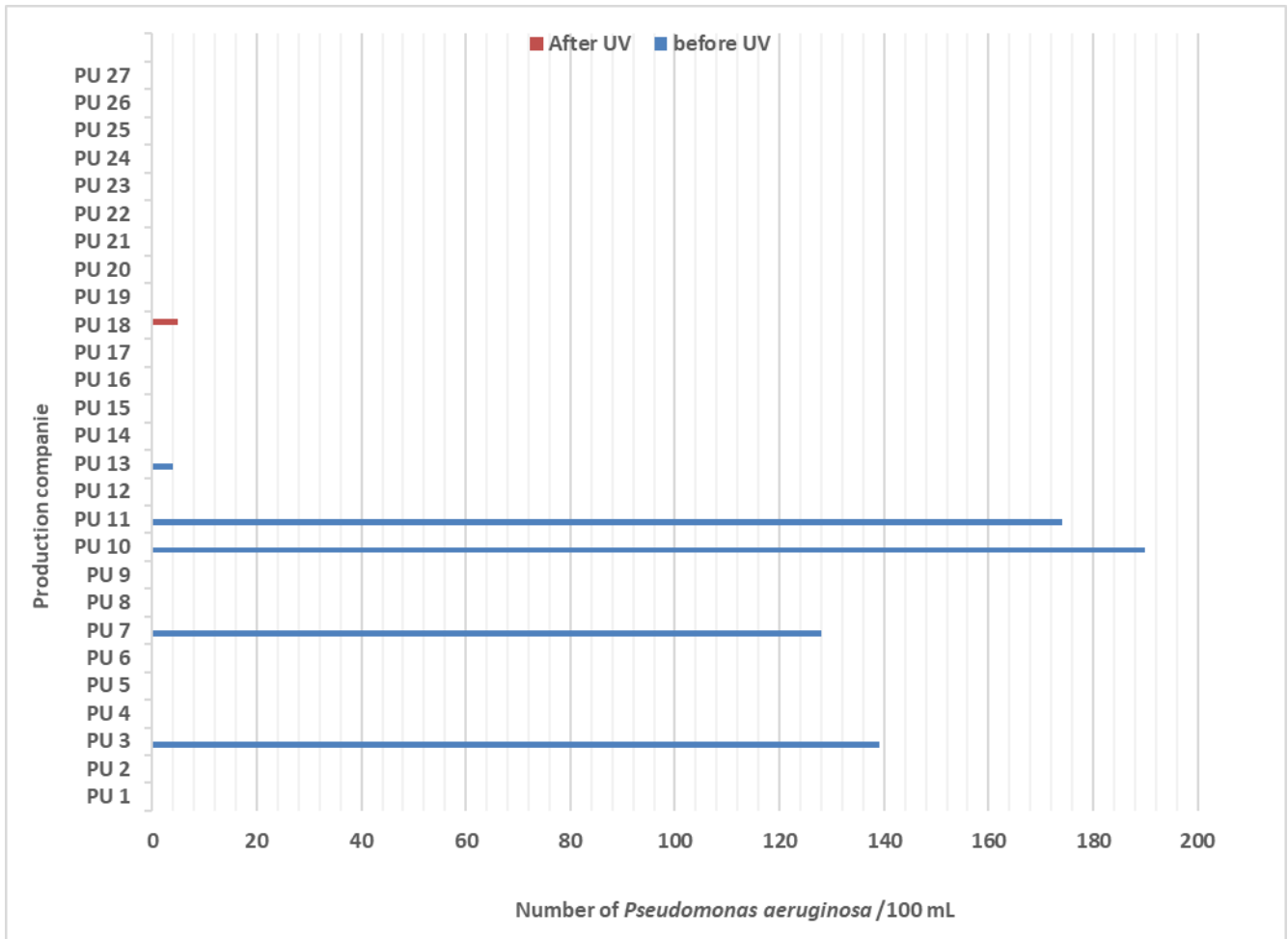


Figure.6 Sulfite-Reducing Anaerobic Bacteria Spores (SRABS) Before and After UV treatment

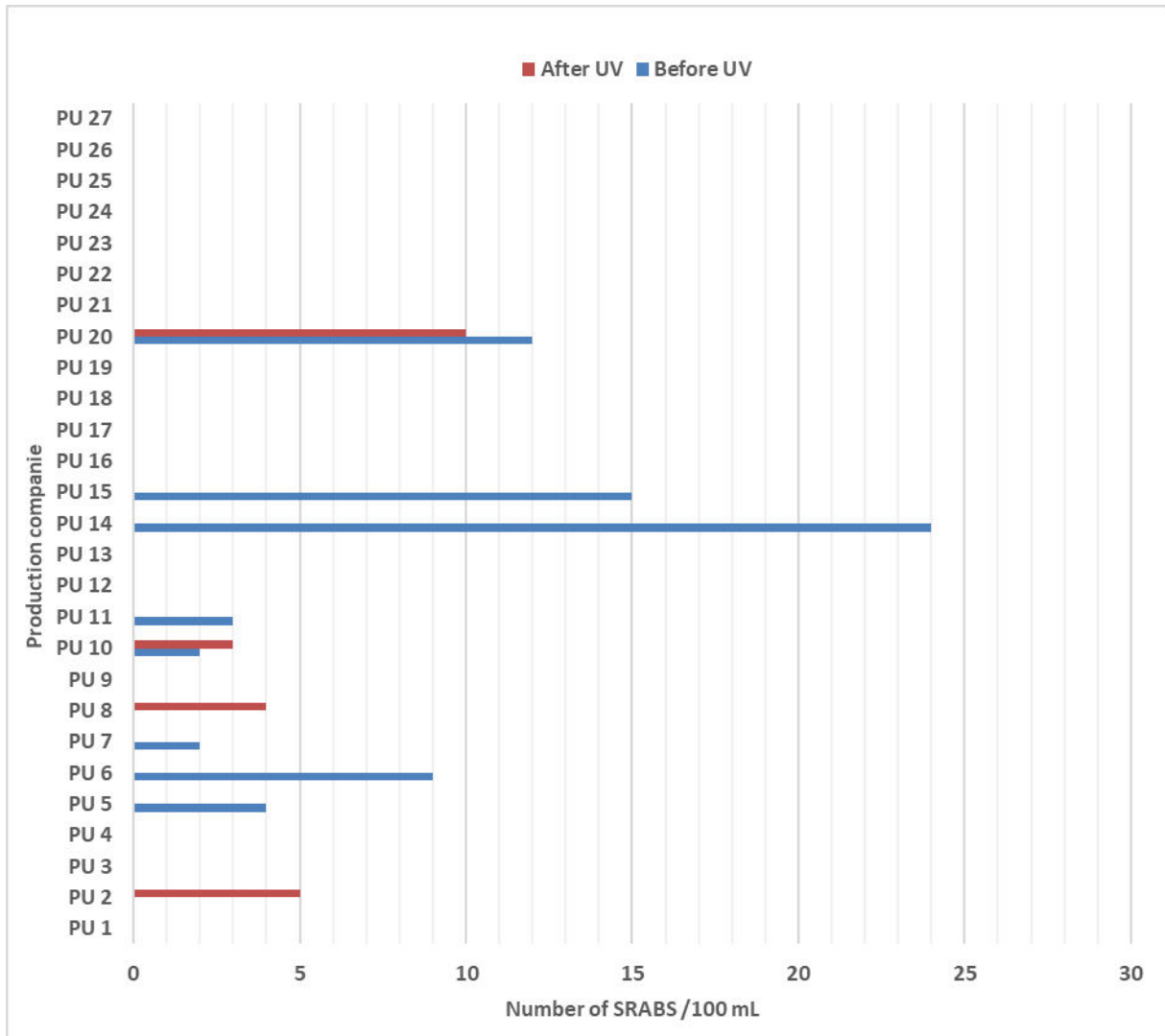
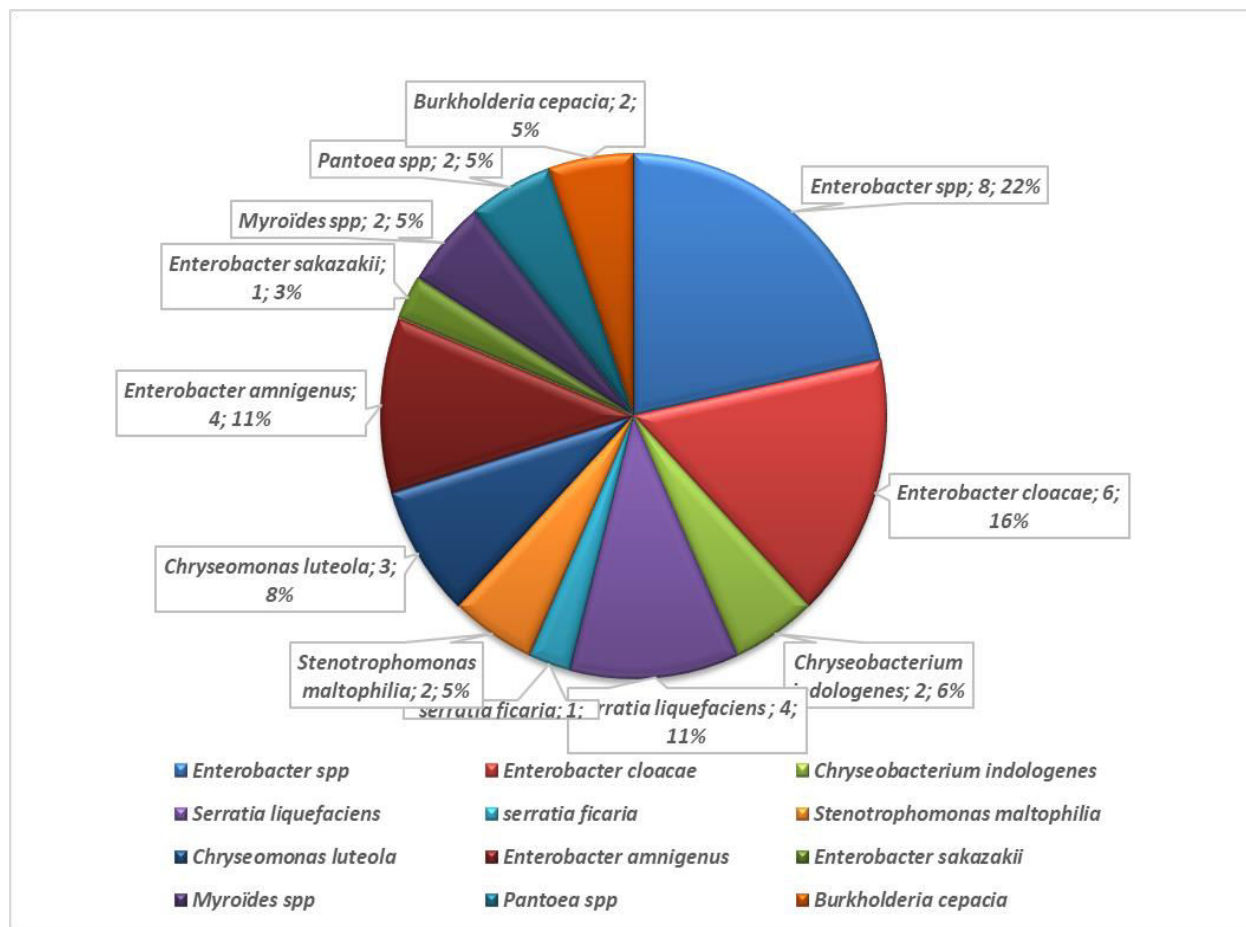


Figure.7 Identified coliforms with their proportions



Antibiotic susceptibility profiles of isolated Intestinal Enterococci

Antibiotic susceptibility testing showed high resistance to amoxicillin, ceftazidime, ceftriaxone, meropenem, kanamycin, gentamicin, ciprofloxacin and norfloxacin respectively 50%, 100%, 100%, 50%, 50% 100%, 100% and 100%.

On the other hand, no resistance was noted with ampicillin and imipenem. These antibiotic susceptibility tests also showed an intermediate result with certain antibiotics like amoxicillin (50%), meropenem (50%) and kanamycin (50%).

Over the past decades, resistance of intestinal enterococci to several antimicrobials has increased rapidly, particularly in *E. faecium*. Resistance to aminoglycosides (kanamycin, gentamicin), particularly in *E. faecium*, continues to develop (Hamidi and Ammari, 2013).

Antibiotic susceptibility profiles of isolated Pseudomonas aeruginosa

Table.4 presents the results of tests for the susceptibility of *Pseudomonas aeruginosa* to antibiotics.

Antibiotic susceptibility tests showed high resistance to ampicillin, amoxicillin, ceftazidim and ceftriaxone respectively 100%, 100%, 50%, and 66.66%. On the other hand, no resistance is noted with kanamycin and ciprofloxacin. These antibiotic susceptibility tests also showed an intermediate result with some antibiotics like ceftazidime (16.66%), ceftriaxone (16.66%), meropenem (33.33%) and norfloxacin (16.66%).

In Burkina Faso, a study conducted by Savadogo *et al.*, (2015) showed that *Pseudomonas aeruginosa* was resistant to ampicillin, amoxicillin and ceftriaxone. These results, which are similar to our work, show that *Pseudomonas aeruginosa* is a producer of β lactamases.

Antibiotic susceptibility profiles of isolated Sulphite-Reducing Anaerobic Bacteria (SRAB)

Antibiotic susceptibility testing showed high resistance to ampicillin, amoxicillin, ceftazidime, ceftriaxone, kanamycin and norfloxacin 75%, 100%, 58.33%, 66.66%, 83.33% and 50% respectively. On the other hand, no resistance is noted with meropenem and gentamicin. These antibiotic susceptibility tests also showed an intermediate result with some antibiotics like ampicillin (8.33%), ceftazidime (16.66%), ceftriaxone (16.66%), imipenem (8.33%), ciprofloxacin (8.33%), and norfloxacin (8.33%). Poilane *et al.*, (2007) showed in their study on *Clostridium difficile* that resistance with amoxicillin, ceftriaxone and imipenem was respectively 40%; 100% and 81% and our results are lower for ceftriaxone and imipenem and higher for amoxicillin than those obtained in their study.

In the field of drinking water treatment, disinfection is the most important action to have drinking water, without danger for the health of consumers. Several techniques are used to obtain this healthy water, including UV treatment. In this study, it appears that microorganisms manage to escape the UV disinfection phase. Total coliforms, *Escherichia coli*, *Pseudomonas aeruginosa*, intestinal enterococci and sulfite-reducing anaerobic bacteria spores were found in the water after UV exposure. The results of the identification of the isolated bacteria revealed the presence of opportunistic pathogens capable of creating health problems. The study of antibiotic resistance of microorganisms isolated showed resistance to common antibiotics available. This therefore calls to producers of packaged drinking water to take the necessary measures for better water treatment to preserve the health of consumers. Future studies will be needed to understand how certain bacteria escape to the UV treatment.

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Author Contributions

Ouédraogo Bernard: Conceptualization; Ouédraogo Bernard: Methodology; Ouédraogo Bernard, Traoré Roukiatou, Traoré Oumar, Traoré Ousmane, Sawadogo

Adama and Zongo Cheikna: Validation; Ouédraogo Bernard, Traoré Oumar: Investigation; Ouédraogo Bernard: Data Curation; Ouédraogo Bernard, Cheikna Zongo, Traoré Roukiatou, Traoré Oumar: Writing - Original Draft Preparation; Ouédraogo Bernard, Traoré Oumar, Stéphane Dissinviel Kpoda and Zongo Cheikna: Review & Editing; Kabré Elie: Supervision; Zongo Cheikna: Administration

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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