*Original Research Article*

Waste Management Determinants and a few Environmental Bacterial Profiles in Hospital-Generated Liquid Effluents: Holistic Inspection in a Healthcare Facility Policy

ABSTRACT

|  |
| --- |
| Effluents generated by hospital activities are often permanent threats for humans and/or their environments’ health with regard to the types of the specific substances they may contain. The general objective of this investigation was to assess wastewaters management potentials at the Université des Montagnes Teaching Hospital (UdMTH) and their microbiological profile. This cross-sectional descriptive study was conducted between December 2021 and June 2022. For waste management, a survey sheet was used to collect data on the knowledge, attitudes and practices of UdMTH personnels, patients and visitors. Pieces of information recorded were supplemented with other ones collected with observation sheet. With regard to the microbiological quality of effluents, wastewater specimens were sampled from different sections of the discarding system, kept in refrigerated containers and conveyed to the laboratory for culture, bacteria identification, enumeration and antibiotic susceptibility tests. The laboratory works were conducted according to the standard procedures (REMIC, 2019 and CAS-FM 2022). Overall, 177 participants (55 hospital staff, 122 patients and visitors) were enrolled. Data analysis globally indicated insufficient knowledge alongside with bad attitudes and practices. The key necessary management tools such as planning, organization chart, direction and control directives, though embryonic were present. Also, clean water was available (87.7%), but not sufficiently used because of inadequate waste discarding amenities, resulting in bacterial loads beyond the recommended standards for almost all of the specimens subjected to microbial screening. The purification performance associated with the septic tanks sanitation system was therefore, inadequate and insufficient in this context. Identified organisms mainly included coliforms (31.81%), *Pseudomonas* (27.27%), and *Staphylococcus* (25.45%). *Vibrio* was also isolated. Further insight through data analysis revealed that the isolates expressed high resistance rates to most antibiotics, especially to beta-lactams’. Overall, human resources reskilling and the restoration sanitation facilities remained paramount necessities for proper management of liquid effluents. |

*Keywords:* management, effluents, sanitation network/system, microbiological quality, bacterial profile

1. INTRODUCTION

Population growth, industrial development and advances in medical technology engender increased production of varied types of waste which can pose serious threats to human, animal, plant and environmental health. These include medical and pharmaceutical wastes (solid, liquid or gaseous) generated by activities in healthcare facilities [1].

Etymologically, effluent refers to water contaminated by pollutants. Healthcare facilities use large amounts of water and produce related volumes of effluents. While households consume 150 to 200 L per inhabitant and per day on average, the average volumes ​​in healthcare settings globally range from 400 through 1200 L. These quantities are further increased by water used for more specific activities in connection with hygiene and healthcare-associated infections prevention [2]. Effluents generated by hospital activities could therefore, represent a health risk for patients, healthcare personnels, visitors and the physical environment with regards to their composition and quantities of specific substances they contain (multidrug-resistant germs, drug residues, chemical reagents, antiseptics, detergents, X-ray developers and fixatives) and the local elimination policies in force [3].

Otherwise, the volumes of wastewater generated by healthcare facilities activities are often similar to those from urban daily life. In addition, however, they may bear lager amounts of health potentially hazardous. Links between unsafe disposal of wastewater from healthcare facilities have been strongly alleged to be in connection with the spread of major epidemics like cholera, typhoid fever, and dysentery [4]. Obviously and based on their composition therefore, liquid hospital discharges likely threaten the environment much more than urban effluents [5]. These discharges are nowadays core concerns and deserve specific endeavors for all stakeholders in health systems and environmental protection, because they are major incubators and vehicles facilitating dissemination of drug-resistant etiologies of infectious diseases [5,6], generally evacuated into urban municipal networks without treatment [3,7,8]. From an ecological point of view, they can be sources of biological adulteration of exposed ecosystems [5]. According to a World Health Organization (WHO) report on 78 low- and middle-income countries, 50% of health facilities do not have onsite running water and 33% do not have structural equipment for appropriate sanitation [9].

In Cameroon, hospital liquid wastes are commonly treated like domestic wastewater in most settings, often managed with treatment plant stations which are rarely operational, or septic tanks which must be emptied periodically and from which the discharges are released into the natural environment without pre-treatment [10]. One of the current critical health issues is the microbial resistance to available drugs, frequently attributed to inappropriate use of selective agents and the spread of resistance traits which has become a global health priority [11,12]. Increased life expectancy with ever-growing rates of opportunistic infectious disease-prone people at old ages that will be hospitalized highlight the need to anticipate solutions based on existing conditions and projections.

With these double threats, a study on the management of liquid wastes and their microbiological quality at the “Université des Montagnes” Teaching Hospital was initiated in order to collect valuable and updated pieces of information that will guide policies related to contextual liquid-wastes management in the larger frame depicted by the local sanitation policies. Daily practices and human resources were the major targets. More especially, the typology and quantity of hospital liquid effluents from the study environment were brought out alongside with human resources and a few key environmental bacterial profiles.

2. material and methods

This was a cross-sectional study conducted at the “Université des Montagnes” Teaching Hospital (UdMTH) from December 2021 through June 2022. The present work was executed under the ethic clearance Ref N° 2022/040/UdM/PR/CIE and research authorization Ref N° 2022/012/CUM/ADM\_GENE provided respectively by the institutional ethic board and the UdMTH’s head.

For liquid wastes management, it was carry out, with a questionnaire and an observation sheet, a data collection from hospital staff, visitors, and patients. The survey participants was included using a non-probabilistic, consecutive, and non-exhaustive sampling design. All participants signed the informed consent form prior to data collection.

For the microbiological quality, specimens were recovered from all the septic tanks and cesspools. Biological specimens were collected from effluent’s (wastewater) storage sites with sterile 250 mL glass bottles and conveyed in refrigerated containers to the Laboratory of Microbiology where they were screened (enumerated and identified) for microorganisms and their susceptibility to antibacterial agents according to standard protocols [13-16]. Eighteen culture media were used throughout the process. In more details, they included 10 for culture and isolation, 03 for enrichment and 04 for identification (table 1). Bacterial identification followed with sets of specific tests for target bacterial types after Gram stain and microscopic identification. Namely, these included catalase test, DNase test, esculin degradation test, oxidase test, Mannitol-mobility test, Simmons citrate test, the tests provided by the Kligler Hajna and Enterosystem 18R gallery. *Vibrio* growth in saline at varied NaCl concentrations was also tested.

During bacterial susceptibility test, antibiotic to be tested were chosen based of routine in susceptibility testing for routine caretaking in the UdMTH. Namely and according to drug’s family they were: Beta-lactams  (Penicillin G (10 µg), Oxacillin (1 µg), Amoxicillin- Clavulanic Acid (20/10 µg), Piperacillin/Tazobactam (75/10 µg), Cefuroxime (30 µg), Ceftriaxone (30 µg), Ceftazidime (30 µg), Cefepime (30 µg), Ertapenem (10), and Aztreonam (30 µg)), Sulphonamides (Trimethoprim/Sulfamethoxazole (23.75/125 µg)); Aminoside (Gentamicin (10 µg), Amikacin (30 µg)), Quinolones (Nalidixic Acid (30 µg), Ofloxacin (5 µg), and Ciprofloxacin (5 µg)); Nitrofurans (Nitrofurantoin (300 µg)), Cyclins (Tetracycline (30 µg)); Macrolides (Erythromycin (15 µg), Azithromycin (30 µg)), phosphonic  acid: (Fosfomycine (50)).

*Escherichia coli* ATCC 25922, *Staphylococcus aureus* ATCC 29213 and *Pseudomonas aeruginosa* ATCC 27853 served as reference strains for bacterial identification and susceptibility testing, conducted according to standard procedures.

**Table 1. List of media used**

|  |  |  |
| --- | --- | --- |
| N° | Medium | Use for |
| 1 | TCBS agar,  | Positive selection and isolation of bacteria that belong to the *Vibrio* genus; |
| 2 | Alkaline peptone water,  | Selective growth of *Vibrio* |
| 3 | alkaline nutrient agar  | Pure culture preparations |
| 4 | Cetrimide agar  | Isolation of bacteria belonging to the genus *Pseudomonas* |
| 5 | Bile Esculin agar  | Selection and isolation of fecal *Streptococcus* |
| 6 | Hektoen agar  | Selective isolation of Enterobacteriaceae (including *E. coli*, *Shigella*, *Yersinia*, and *Salmonella*) |
| 7 | Muller Kauffmann broth  | Selective growth of *Salmonella*  |
| 8 | Plate Count agar  | Aerobic mesophilic bacterial flora  |
| 9 | McConkey agar  | selective growth and isolation of specific *Enterobacteriaceae*  |
| 10 | Mannitol Salt Agar  | Selective growth and isolation of *Staphylococci* |
| 11 | Sabouraud-chloramphenicol (5%) | Selective growth and isolation of fungi |
| 12 | Brain-Heart infusion broth  | large scale enrichment and strain preservation  |
| 13 | Muller-Hinton agar  | susceptibility testing by disk diffusion  |
| 14 | Kligler-Hajna agar  | Bio-enzymatic identification: metabolism of glucose, lactose; H2S production and gas production |
| 15 | Simmons Citrate agar  | Ability to use citrate as single source of carbon  |
| 16 | Mannitol- Mobility-Nitrate agar  | Ability to metabolize mannitol, bacteria motility, and nitrate production  |
| 17 | Urea-indole | Ability to hydrolyze urea and testing indole production |
| 18 | TDA  | Ability to produce acetone from tryptophane  |

Following the approach of Essi *et al*. [17], respondents were grouped into two categories according to the percentage of correct answers given in each of the informative items concerned. Respondents with less than 50% correct answers were considered to have an insufficient score, and those with at least 50% or more were considered to have a satisfactory score. Related data analysis was performed with statistical tools provided by the CsPro 7.7 and Microsoft 365 software’s. Data analysis for categorial pieces of information was conducted with statistical tools provided by the Census and Survey Processing system 7.7 (CS Pro 7.7) and SPSS 23. These tools included the Pearson Chi2, Exact Fisher test, means and standard variations, medians, interquartile intervals, Student’s-T test according to variable types and their distribution. The signification threshold associated was p ≤ 0.05.

For the microbiological screening, pieces of information collected were the bacterial group and clinical categories (susceptible, susceptible at high posology, and resistant) of recovered isolates. These data were recorded and processed with Microsoft Excel 2016. It was used frequencies per bacterial types and antibacterial agents to present clinical categories results.

3. results

**3.1 Selection and socio-demographic characteristics of participants**

From the initial population size made up of 190 participants (59% females and 41% of males), 93.15% actually participated (55 permanent health facility workers and 122 others (visitors’ patients, and patient’s guardians)). Globally, their ages ranged from 18 through 77 years (41 ± 13 years). Amongst permanent healthcare facility workers, the average time on duty vas 48 months with the range extending from 2 through 168 months. In the others’ category, the average hospital stay was 7 days but ranged from 1 through 90 days. Further details indicated that 40% amongst the permanent workers consisted of medical personnel (clinical practitioners, pharmacists and dentists); 7% of hospital hygiene personnels, and 53% of associated paramedical staff. Based on their education, the additional pieces of information recorded were and summarized as displayed in table 2. It reveals that all had ever been to school. Further, at least 90% have attended secondary education.

**Table 2. Distribution of participants with education standard**

|  |  |  |
| --- | --- | --- |
| **Education** | **Number (N=177)** | **Frequency (%)** |
| **Primary education** | 32 | 18.1 |
| **Secondary education** | 56 | 31.6 |
| **Higher education**  | 89 | 50.3 |

**3.2 Overall evaluation of knowledge amongst participants**

Data analysis globally revealed that 21% had satisfactory knowledge of liquid effluents. Separately, however, the permanent healthcare workers group was most aware (p = 0.001). Also, the degree of awareness was similar between medical and paramedical personnels (p = 0.08), like the education standard (p = 0.1). Further details disclosed that 81.8% with primary and secondary education had insufficient knowledge, while 76.4% who attended higher education was associated with bad knowledge. Otherwise, knowledge did not (based on these data) build on education standards. Table 3 provides more detailed pieces of information that recapitulate finding about knowledge on liquid effluents.

**Table 3. Summary of findings concerning knowledge related to effluents**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Questions  | Respondent Category  | Bad answer[n(%)]  | Good answer[n(%)]  | p-value |
| What does effluent refer to? | Personnel | 1 (1.8) | 54 (98.2) | 0.001 |
| other | 32 (26.2) | 90 (73.8) |  |
| How cans effluents b categorized? | Personnel | 53 (96.4) | 2 (3.6) | 0.32 |
| other | 119 (97.5) | 3 (2.5) |  |
| What are effluents made of? | Personnel | 48 (87.3) | 7 (12.7) | 0.001 |
| other | 122 (100) | 0 (0) |  |
| Are effluents health hazards? | Personnel | 3 (5.5) | 52 (94.5) | 0.085 |
| other | 18 (14.8) | 104 (85.2) |  |
| What are health hazards effluent can be responsible for? | Personnel | 44 (80) | 11(20) | 0.002 |
| other | 122(100) | 0(0) |  |
| Can effluents be associated with health care associated infections? | Personnel | 4(7.3) | 51(92.7) | 0.01 |
| other | 27(22.1) | 95(77.9) |  |
| Can effluents be associated with epidemics like cholera? | Personnel | 4(7.3) | 51(92.7) | 0.05 |
| other | 21(17.2) | 101(82.8) |  |
| Enumerate a few medical conditions that can be caused by inappropriate management of effluents  | Personnel | 37(67.3) | 18(32.7) | 0.003 |
| other | 110(90.2) | 12(9.8) |  |
| Can effluents be regarded as hospital wastes?  | Personnel | 2(3.6) | 53(96.4) | 0.001 |
| other | 36(29.5) | 86(70.5) |  |
| With respect to the health hazards they can pose, how can effluents be categorized? | Personnel | 46(83.6) | 9(16.4) | 0.001 |
| other | 117(95.9) | 5(4.1) |  |

Other: temporally site user

It comes out that almost all (98.2%) of the healthcare facility participants knew what was meant by effluent. Though the very large majority (96.4%) could not distinguish between effluent types, 94.5% of the healthcare personnel, and 85.2% of the temporally site users were aware of the health hazards effluents could represent. None of the visitors or patients could know, however, the type of potential health hazards they could confront.

**3.3 Evaluation of attitudes amongst participants**

Comparative analysis of the data collected in relation to effluent management disclosed that attitudes were significantly dissimilar between hospital staff (more apt) and temporally site users (p = 0.001). Among the staff participant, 45.5% of medical and 27.3 of paramedical personnels provided less than 50% correct answers to the tests in connection with attitudes (paramedical personnels were relatively more apt). Regarding attitudes compared with knowledge, the findings highlighted a positive correlation between the two variables (p=0.002), implying that attitude was improved by knowledge.

**3.4 Evaluation of attitudes amongst participants**

Overall, this test revealed 73% of poor practices. In terms of respondent categories, practices were almost similar between the two major groups of participants (p = 0.36). Among the hospital personnels subjected however, practices were far less good amongst medical personnels compared to the paramedicals’ (p = 0.002). Taking into account the education standard, it emerged that it did not influence practices. Also, the level of knowledge did not have any positive relationship with practices (p = 0.6), like attitudes compared with practices (p = 0.08).

**3.5 Types of effluent and effluent discarding sites**

Table 4 displays the participants' preferred effluent discharging sites. A total of 68% of participants acknowledged that they regularly discharged liquid waste into either household siphons (54.5%) or sinks (69.1%). In the vast majority of cases therefore, liquid effluents were disposed-off in unsuitable places.

**Table 4. Effluents discarding site**

|  |  |  |
| --- | --- | --- |
| **Effluent discarding site** | **Number (N=55)** | **Frequency (%)** |
| **Built-in siphons** | 30 | 54.5 |
| **Sinks** | 38 | 69.1 |
| **Gutter** | 17 | 30.9 |
| **Playground**  | 16 | 29.1 |
| **Open vegetation fields** | 4 | 7.4 |

Pieces of information concerning effluent types in the health facility and their sources are presented in table 5. The effluents generated included domestic water (in all departments), laundry water (laundry rooms), high-risk infectious wastewater (care-taking room, surgical department, laboratory), and toxic radioactive water (anatomopathology laboratory, radiology department). Initial sorting was performed in departments that generated wastewaters containing high risk of health hazards.

**Table 5. Summary of effluent types produced at UdMTH, production departments and sorting policy**

|  |  |  |
| --- | --- | --- |
| **Type of effluent**  | **Generating unit**  | **Sorting effectiveness**  |
| **Domestic wastewater / Grey)** | All  | No |
| **Laundry wastewater (industrial)** | Laundry  | No |
| **High-infection-risk wastewater**  | Hospitalization wards, Surgery wards, M.A- Lab | YES/initial |
| **Radioactive-risk wastewater/ toxic** | Anapath- LabRadiology | YES/initial |
| **Rainfall waste water** | / | No |

M.A-Lab: Medical analysis Laboratory; Anapath- Lab: Anatomopathology Laboratory

Table 6 summarizes the responses recorded from permanent healthcare personnels concerning practices of interest in liquid effluent management. It further reveals that 27.3% of the hospital staff sort the liquid wastes they produce, while almost all (≈ 91%) immediately discarded it in inappropriate sites (≈ 90%).

**Table 6. Summary of effluent management practices of interest**

|  |  |  |  |
| --- | --- | --- | --- |
| **Practices** | **Comment**  | **Number**  | **Frequency (%)** |
| **Sorting**  | Yes | 15.0 | 27.3 |
|  | No | 40.0 | 72.7 |
| **Discarding delay**  | Immediate | 50.0 | 90.9 |
|  | delayed | 5.0 | 9.1 |
| **Individual Protection Equipment**  | Yes  | 54.0 | 98.2 |
|  | No | 1.0 | 1.8 |
| **Discarding site**  | Appropriate | 6.0 | 10.9 |
|  | Inappropriate | 49.0 | 89.1 |
| **Effluent treatment** | Yes | 14.0 | 25.5 |
|  | No | 41.0 | 74.5 |

**3.6 Germ identification and enumeration**

The total of 16 samples collected from 04 hospital pits were subjected to laboratory screening. Table 7 illustrates their distribution with respect to the origin.

**Table 7. Specimens and their origins**

|  |  |
| --- | --- |
| Septic tanks | Origin of effluents |
| Septic tanks 1 (ST1) | Surgery, operating room, maternity |
| Septic tanks 2 (ST2) | Hospitalization room, public toilet 1  |
| Septic tanks 3 (ST3) | laundry, Laboratory, toilet |
| Septic tanks 4 (ST4) | public toilet 2, blood bank |

The table 8 displays bacterial colony counts subsequent to culture. An overall view discloses that the most contaminated pit was ST2, and the least contaminated, ST3. Very often, the bacterial load decreased when the number of compartments increased. The contrary was, however observed with ST3 where the sump was more contaminated than the previous compartments, likely due to the fact that the laboratory drains were directly oriented into the sump.

**Table 8. Enumeration of recovered bacteria**

|  |  |
| --- | --- |
| **Specimen**  | **Microbial loads (in CFU/mL)** |
| Total load | Total coliforms | Fecal *Streptococcus*  | *Staphylococcus* | *Pseudomonas* | *Vibrio* | Fungi  |
| ST1 | C1 | 6.2\*107 | 3.36\*104 | 1.54\*103 | 6.4\*103 | 4 .52\*104 | 9.9\*102 | 0 |
| C2 | 5\*107 | 2.96\*104 | 8\*102 | 3.04\*103 | 2.6\*103 | 8.6\*102 | 0 |
| C3 | 4.8\*107 | 1.84\*104 | 7\*102 | 1.25\*.103 | 1.36\*.103 | 8.2\*102 | 0 |
| P1 | 3.7\*107 | 2.4\*103 | 102 | 6.8\*102 | 102 | 5.6\*102 | 0 |
| ST2 | C1 | 8.9\*107 | 3.3\*106 | 1.1\*104 | 3.62\*106 | 2.2\*104 | 1.8\*104 | 2.88\*103 |
| C2 | 7.6\*107 | 2.56\*106 | 8.4\*103 | 8.48\*104 | 1.32\*103 | 1.3\*104 | 2.53\*103 |
| C3 | 7.9\*107 | 1.8\*106 | 4.2\*103 | 2.96\*104 | 3.2\*103 | 6.5\*103 | 2.8\*102 |
| P2 | 6.5\*107 | 2.4\*106 | 1.3\*103 | 64\*7 | 1.6\*103 | 8.3\*102 | 2.5\*102 |
| ST3 | C1 | 2.4\*103 | 2.3\*102 | 0 | 0 | 80 | 0 | 2.8\*102 |
| C2 | 6.2\*105 | 1.3\*103 | 1.7\*102 | 1.8\*102 | 6.4.\*103 | 2.4\*102 | 20 |
| C3 | 7.3\*105 | 8.7\*102 | 2.4\*102 | 3\*102 | 4.7\*102 | 2\*102 | 60 |
| P3 | 1.4\*107 | 6.3\*103 | 0 | 4.2\*103 | 1.6\*103 | 2.4\*102 | 3\*102 |
| ST4 | C1 | / | / | / | / | / | / | / |
| C2 | / | / | / | / | / | / | / |
| C3 | 9\*106 | 1.2\*106 | 4.5\*102 | 3\*102 | 1.8\*103 | 9\*102 | 2.4\*103 |
| P4 | 4\*106 | 1.3\*106 | 1.1\*102 | 2.5\*102 | 4.3\*103 | 4\*102 | 1.4\*102 |

C= compartment; P= sump; /= not accessible;

In total, 27 bacterial types were recovered. Further related details are shown in table 9. Overall view reveals that the predominant bacteria types recovered were Gram-negative rods (81%), particularly isolates that belongs to the *Enterobacteriaceae* family (59.25%).

**Table 9. Bacterial types recovered from subjected effluents**

|  |  |
| --- | --- |
| **Bacteria Gram-type** | **Identified categories** |
| **Gram-negative rods** | Enterobacteria: *Escherichia coli*, *Salmonella* spp., *Citrobacter freundii*, *Citrobacter* spp., *Enterobacter aerogenes*, *Proteus mirabilis*, *Shewanella* spp., *Serratia ficaria*, *Serratia* spp., *Enterobacter cloacae,* *Enterobacter* spp. *Bordetella* spp., *Moraxella* spp., *Providencia* spp., *Stenotrophomonas* spp., *Klebsiella* spp. |
| *Vibrio cholarae*, *Vibrio parahemolyticus*, *Vibrio* spp., *Pseudomonas aeruginosa*, *Pseudomonas* spp., *Aeromonas hydrophyla*, |
| **Gram-positive rods** | *Bacillus* spp. |
| **Gram-positive Cocci** | *Staphylococcus aureus*, *Staphylococcus* spp., *Enterococcus* spp, *Streptococcus* spp. |

**3.7 Susceptibility results**

Related data are provided by tables 10 and 11 which displays susceptibility trends of the recovered isolates. Its overall analysis reveals that almost all bacteria isolated from these effluents expressed resistant traits at varied levels, particularly to beta-lactams. The most effective antibacterial agents were those belonging to the aminoglycoside’s subgroup, followed by fluoroquinolones. Among *Staphylococci,* 57% expressed resistance to Oxacillin. Very often associated with risky resistant-hospital infections, *Pseudomonas* was fully susceptible to two antibacterial agent (Gentamicin, and ciprofloxacin). The *Vibrio* was susceptible to ciprofloxacin, azithromycin and tetracycline.

**Table 10. Susceptibility profiles of recovered bacteria**

|  |  |
| --- | --- |
| **Antibiotics** | Bacteria types  |
| Phenotype | *Enterobacteriaceae* (N=70) | *Staphylococcus*(N=56) | *Pseudomonas*(N=60) | *Vibrio*(N=34) |
| Amoxicillin Clavulanic acid | **S** | 00 | - | - | 00 |
| **I** | 00 | - | - | 00 |
| **R** | 100 | - | - | 100 |
| Ceftazidime | **S** | 00 | - | 00 | - |
| **I** | 00 | - | 00 | - |
| **R** | 100 | - | 100 | - |
| Ceftriaxone | **S** | 00 | - | - | - |
| **I** | 11 | - | - | - |
| **R** | 89 | - | - | - |
| Cefuroxime | **S** | 00 | - | - | - |
| **I** | 00 | - | - | - |
| **R** | 100 | - | - | - |
| Aztreonam | **S** | 11 | - | 00 | - |
| **I** | 11 | - | 00 | - |
| **R** | 78 | - | 100 | - |
| Gentamicin | **S** | 95 | 100 | 100 | - |
| **I** | 00 | 00 | 00 | - |
| **R** | 5 | 00 | 00 | - |
| Amikacin | **S** | 100 | - | 50 | - |
| **I** | 00 | - | 00 | - |
| **R** | 00 | - | 50 | - |
| Nalidixic acid  | **S** | 00 | - | - | - |
| **I** | 50 | - | - | - |
| **R** | 50 | - | - | - |
| Ofloxacin | **S** | 37 | - | - | - |
| **I** | 48 | - | - | - |
| **R** | 15 | - | - | - |
| Ciprofloxacin | **S** | - | - | 100 | 72 |
| **I** | - | - | 00 | 00 |
| **R** | - | - | 00 | 28 |
| Ertapenem | **S** | 11 | - | - | - |
| **I** | 11 | - | - | - |
| **R** | 78 | - | - | - |

-: not tested; S: Susceptible; I: Intermediate; R: Resistant

**Table 11.** **Susceptibility profiles of recovered bacteria (continues)**

|  |  |
| --- | --- |
| **Antibiotics** | Bacteria types |
| Phenotype | *Enterobacteriaceae* (N=70) | *Staphylococcus*(N=56) | *Pseudomonas*(N=60) | *Vibrio*(N=34) |
| Trimethoprim/Sul2amethoxazol | S | 47 | - | - | 43 |
| I | 21 | - | - | 00 |
| R | 32 | - | - | 57 |
| Fosfomycine | S | 00 | - | - | - |
| I | 00 | - | - | - |
| R | 100 | - | - | - |
| Tazobactam/piperacillin | S | - | - | 00 | - |
| I | - | - | 00 | - |
| R | - | - | 100 | - |
|  Penicillin G | S | - | 00 | - | - |
| I | - | 00 | - | - |
| R | - | 100 | - | - |
|  Oxacillin | S | - | 43 | - | - |
| I | - | 0 | - | - |
| R | - | 57 | - | - |
| Erythromycin | S | - | 42 | - | 14 |
| I | - | 42 | - | 14 |
| R | - | 16 | - | 72 |
| Azithromycin | S | - | - | - | 72 |
| I | - | - | - | 28 |
| R | - | - | - | 00 |
| Nitrofurantoin | S | - | 43 | - | - |
| I | - | 0 | - | - |
| R | - | 57 | - | - |
| Tetracycline | S | - | - | - | 86 |
| I | - | - | - | 14 |
| R | - | - | - | 00 |

-: not tested; S: Susceptible; I: Intermediate; R: Resistant

4. discussion

Scarce partial data currently exist on the management procedures of hospital liquid waste in resource-limited communities, while those reported are rarely updated. The aim of the present investigation was to address this common priority issue in a healthcare facility. More precisely, efforts aimed at describing the management policy with involved stakeholders and evaluating the microbiological quality of liquid effluents at the “Université des Montanes” Teaching Hospital (UdMTH). The total of 177 human participants were enrolled (healthcare personnels: 31% and other site users: 69%). The healthcare personnels consisted of medical (40%), paramedical (53%), and biotechnological (7%). These proportions were similar to those reported a few years ago in the same health facility [18], implying at first glance, a contextual human resources stability policy.

Data analysis further revealed that knowledge, attitudes and practices regarding effluents were generally insufficient for most participants, consistent with the stability observed above and requiring revision of waste management policies in force. In fact, only 20% (mainly hospital personnel) had good knowledge while, a little more than half (54.5%) had poor-related knowledge on the issue. These findings conflict with those reported in a previous survey, where 96% of the personnel on the same site were found to have undergone recent training in standard precautions about waste management and hospital hygiene rules [18]. This still in line with the stability anticipated above, which had even caused performance regression. The current trend could in fact, be reliably justified (although partially) by the dynamics in human resources. Some trained personnels have actually moved out why the new comers did not receive any training; implying that effluent management was not addressed as a continue process. This development confirms the assertion that necessary practices are not follow up in the study context [1]. Also, the level of knowledge did not vary with the education standard (higher, secondary or primary) of the participants, nor according to the personnel’s category (medical or paramedical), highlighting thereby the necessity to involve all groups (in their field of activity) in urgent awareness and training initiatives that should be set up to fix these gapes. In fact, most participants are intellectually capacitated, but not technically equipped to be effective in effluent management.

A very high proportion of the study population did not know any health risk effluents could pose. This is characteristic of all at-high-risk populations, since poor effluent management in such a context could facilitate recontamination of patients through the spread of infectious diseases etiologies within and beyond the hospital premises. Or, this phenomenon could be mitigated if basic tools like hand hygiene refreshing trainings were robustly effective. As earlier observed by others [19], however, the conveniences for hand hygiene were insufficient, and those available were rarely functional. Accordingly, related pieces of information revealed that only 44-48% of the personnel systematically washed their hands after gloves use, at the end of an intervention, between two patients, or between two activities. Further, soap or single-use hand towels were not always available [18]. However, 98% of them use at least one protective equipment when they handled effluents. This attitude certainly mitigates the likelihood of hospital germs and healthcare-associated infections spread.

Concerning the practices, 72.7% did not sort effluents they produced, 89.1% discarded effluents in inappropriate sites (yard, drain, fields), and 74.5% did not carry out any treatment prior to discarding. In other words, everyone would act according to what seemed appropriate based on personal judgment. This could be justified by the absence of protocols at each step throughout the effluent management pathway. Such instances could not only amplify the risks of environmental adulteration for the surrounding human and animal communities, but also for other biotic and abiotic environmental components as well [20]. In fact, collection, sorting, packaging, storage, treatment and elimination are the major compulsory steps for any safe management of hospital effluents. Based on these findings, implementing a readapted context-based effluent management policy appeared urgent. Putting in place other technical fundamental and accessory tools that are necessary for the effective implementation of defined policies appears then as a paramount requirement.

It also appeared that the overall amounts of clean water used for services in the institution were more than three-fold lower than the expected volumes. In fact, only 8 m3 were used per day for the 32 beds the hospital contains (out of the 60 m3 available), instead of the minimal volume estimated at 27 m3 [21]. These reduce volumes could be justified by the poor state of pipes and associate gadgets in the entire liquid-effluent discarding network. The optimal dilution of effluents generated by various hospital activities actually requires large amounts of water for optimal management.

Inadequacies were recorded in the wastewater evacuation system as observed above. Among others, the very few operational siphons that existed forced users to reduce their consumption in order to avoid discomfort that could result. Another survey on the availability of supportive equipment such as toilets and taps in the same study site reported an appreciable rate a few years ago [22]. The overall findings appeared to be in connection with functionalities weaknesses, indicating that a permanent and continuous checking mechanisms should be enacted. More insights into data analysis further revealed the almost regular availability of water in the reservoirs. This could contradict the trend in the water use if the state of the network and the fear for users were not pointed out as discussed earlier. From a holistic view, these shortcomings are strongly associated with the management of available assets, in line with poor knowledge and resulting practices; acknowledging that attitudes are strongly improved by knowledge and refreshment.

With a glance on the microbiological quality of the subjected effluents specimens, 94% of the specimen collection sites’ septic tanks displayed bacterial loads above the recommended thresholds. This could be justified by the low quantities of water that are used in the routine as discussed above. The fecal coliform loads could be used as indication for water adulteration by fecal germs in the waste resources that are eventually discharged into the surrounding environments. In addition, their loads in hospital effluents reflect the ecologic adulteration potential of these wastes [3]. The recorded high loads of fecal coliforms in the target effluents could be associated with the low concentration of antibacterial agents (antibiotics and/or disinfectants, for instance) in these resources. In fact, drugs and drug residues are known to reach hospital effluents *via* two major routes. The first one is through urine, feces and various biological fluids such as sweat, saliva, or vomit; while the second is linked to the disposal of unused or expired medicines through drains and sinks. In the study context, the elimination process of all expired pharmaceutical products was well regulated and conducted outside the sanitation network.

The high rate of effluent contamination also indicates that the management system in place should be rethought and improved, because of its sensitivity to a high rate of initial contamination [23]. For this, and in the absence of alternative like specific wastewater treatment plant, a solution would be to limit the initial contamination with chemical treatments as much as possible, and develop an operational connection with the municipality in order to benefit the contribution of its wastewater treatment plants. Data analysis from the present survey also revealed that waste disposal was not optimally regulated, more likely due to insufficient functional accompanying equipment.

High Gram-negative rods rates were recorded, including *Vibrio* and *Pseudomonas,* while Gram-positive bacteria were overwhelmed by *Staphylococc*i. These are either true pathogens or potential etiologies of opportunistic infections that should be assessed and controlled continuously in a global strategy aiming at anticipating prevention of healthcare associated resistant-infection.

Finally, the bacteria susceptibility profile indicated that the large majority expressed resistances, especially to beta-lactams; thought at first glance to be in connection with use rates. The most effective antibiotics belonged to the aminoglycosides’ subgroup. These findings corroborate with previous ones [22]. If many other factors remain to be investigated in this vein, current findings support the hypothesis that the likelihood associated with resistant etiologies of infectious diseases dissemination is high [21,24,25], but can be mitigated by improved practices of the intellectually capacitated stakeholders identified in the study site.

This exercise appears as a prerequisite in this institution where the knowledge acquisition capacity of additional skills is high enough for the challenge [17]. The hypothesis according to which the presence of antibiotics would limit the growth of bacteria in effluents [3] remain a subject of discussion. In fact, when bacteria select resistance phenotypes in an environment, they do proliferate instead at the expense of the residual biological diversity. In other words, the high rates of resistant bacterial populations observed seem to agree more with the hypothesis that supports dissemination of positively selected resistant strains rather than the absence of selective agents like antibacterial drugs. These bacteria could evolve as potent etiologies of resistant hospital acquired infections, especially in patients who spend longer times in the hospital premises [26,27].

5. Conclusion

It emerged from this investigation that all types of common effluents in healthcare facilities are found in the study site. Further findings revealed that knowledge was generally insufficient while attitudes and practices were poor. The key compounding tools for waste management such as planning, organization, direction and control were present, though embryonic and insufficiently maintained. Also, despite the amount of available water, the use was limited by the inadequate waste-discarding system. The bacterial types mostly isolated included coliforms, *Staphylococcus* and *Pseudomonas* that expressed high resistance to antibiotics, particularly to beta-lactams. The restoration of pipes and other sanitation facilities appeared as priority for overall optimal management, alongside with permanent training of all stakeholders.

Data availability

Data associated with this work were not deposited into a publicly available repository. All the data of this work are present in this paper.

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