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A survey of wastewaters generated by a hospital in Marrakech city and their characterization

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ABSTRACT

In Morocco, few studies focus on hospital wastewaters. This study is among the first studies on this subject because of its paramount interest to show the necessity of treating these effluents before discharging. This study focuses on the characterization of wastewaters from the University Hospital Centre (Mohammed VI) in Marrakech. This hospital has medical and surgical missions with a capacity of 409 beds. Its water consumption is estimated to 425 m^3/d at the rate of 1.04 m^3/d/bed with a rate of 1.63–12.67 m^3/h. To assess the pollution degree of effluents generated by the hospital, we started with a survey of the different products used in every department of the hospital followed by sampling of different types of wastewaters and their fate in this hospital. Then we conducted a physicochemical and biological characterization of the samples. The investigation revealed that the various hospital departments used several chemicals including detergents, disinfectants used frequently in hospitals. These products are mainly recommended in the cleaning and maintenance of premises and represent 70% of the whole used chemicals. Around 30% of the products are pre-disinfectants and sanitizers such as glutaraldehyde (at concentration 2%). The annual consumption of medicines and drugs within the studied hospital are anesthetics and β-blockers that represent 37% of the total consumed drugs in the studied hospital. Antibiotics, gastro-entero-hepatology, and anti-inflammatory drugs represent 14, 9, and 7%, respectively. Other drugs used for different therapeutic classes represent 33%. From the total reported cases of hospital infections, 29% are died. This shows the risk of potential pathogens load in the hospital effluents. The physicochemical characterization of the effluents of each service revealed that they are heavily loaded with organic matter: 2,641 mg/L of COD, 910 mg/L BOD_5, and 1,490 mg/L TSS. These levels exceed far the levels recommended by the Moroccan discharge standards. Total phosphorus; orthophosphates and Kjeldahl Total Nitrogen are, respectively, in the range of 8.02 mgP/L, 3.55 mgP/L, and 197.14 mgN/L. The heavy metals content are low except for copper (2.84 mg/L) and iron (3.38 mg/L), which are very high. Bacteriological characterization shows that fecal coliforms reached 10^8 CFU/100 mL. These effluents also contain

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pathogens responsible for nosocomial infections. Among these pathogens, *Pseudomonas aeruginosa* and *Staphylococcus aureus* are detected with suspected *Salmonella* and *Vibrio*. The COD/BOD_5 ratio is around 2.9, value indicating that the hospital effluents are biodegradables by selected strains. Furthermore, it is essential to apply an adequate treatment to this hospital wastewaters because of their bacterial load pathogenicity that may have an adverse impact on the health of the population and the risk of epidemic diseases spread.

Keywords: Hospital wastewaters; Chemical and drugs survey; Physicochemical characterization; Biological characterization; Heavy metals

1. Introduction

In Morocco, the problem of hospital wastewaters is becoming increasingly important. Indeed, health care facilities generate large volumes of liquid effluents that contain hospital-acquired chemical substances (drug residues, chemical reagents, disinfectants, detergents, radiographic fixers and developers, etc.) and are likely to spread pathogenic germs.

These micro-organisms could come from the stools or urine (such as *Salmonella*, *Shigella*, coliforms, *Vibrio*, *Streptococci*, and *Enterobacteriaceae*) or from bacteria responsible of nosocomial infections—also known as hospital infections—that are infections acquired during a hospital stay (*Staphylococcus*, *Streptococcus*, *Pseudomonas*, etc.) [1]. All these bacteria are dangerous because they become resistant to antibiotics [2]. Some of them have been identified as being concentrated more than 10 times in hospital wastewaters than in municipal wastewater like *Pseudomonas aeruginosa* and pathogenic staphylococci [3]. A study on hospital wastewater of Rio de Janeiro, Brazil reported that *Klebsiella pneumonia* strains extended-spectrum beta-lactamases (ESBLs) producing were detected in both hospital effluents, in activated sludge and effluent from a sewage treatment plant supporting a 2,000-bed hospital [4]. This study showed that biological treatment was inadequate and led to the spread of multi-resistant strains in the environment via the treated effluents or activated sludge [4]. It was also shown that resistant strains of hospital effluent resisted to the treatment with activated sludge much than strains from municipal wastewater with high concentrations of antibiotics [5]. In a recent study, Verlicchi et al. [6] reported that a biological treatment step is always necessary to remove the carbonaceous fraction from the wastewater influent; suspended biomass treatments are the most common. A recent study of hospital wastewater treatment systems applied in the world during the last 20 years evaluate the effectiveness of different levels of treatment of hospital waste to remove a broad spectrum of pharmaceutical compounds and classic contaminants [7].

According to these authors, the most suited treatment technologies are bioreactors equipped with ultra-filtration membranes in the secondary step and ozonation followed by activated carbon filtration (in powder and in granules) in the polishing step. Interesting research projects dealing with photo-Fenton process acting as primary treatments to improve biodegradation prior to biological treatment, and as a polishing step, thus further reducing micro-contaminant occurrence.

Indeed, on the one hand, the hospital pollutants show that certain substances, especially halogen compounds and drug residues, often still almost unchanged after municipal treatment plants [8–13]; On the other hand, hospital effluents can be 150 times more concentrated in micro-pollutants than urban effluents [14].

In Morocco, hospital wastewaters are generally evacuated in urban networks without any treatment. There are no or few works studying hospital effluents treatment or even their characterization (Table 1).

Our study aims to conduct a survey at a hospital in Marrakech city in order to assess the quantities and the qualities of chemicals and medicines used in each service and to have an overview about the rate of nosocomial infections and; secondly to investigate a physicochemical and bacteriological characteristics of the hospital effluent to show the urgent need for treatment prior to its discharge into the sewer system.

2. Materials and methods

2.1. Study site and sampling points

The study was conducted in the University Hospital Centre of Marrakech. This hospital meets the health care needs of the population in the region of Marrakech-Tensift-Alhaouz with a capacity of 409 beds. Its water consumption is estimated to 425 m^3/d at the rate of 1.04 m^3/d/bed with a rate of 1.63–12.67 m^3/h. In addition, the hospital gathers a large number of health services with different activities that generate several types of wastewaters. In the first

Table 1
The works done on hospital wastewaters in Morocco

Nature of the work	Refs.	Year	Studied area
Assessment of physicochemical and biological parameters of Al Ghassani hospital wastewaters, Fez	[15]	2012	Fez
Effect of electro-coagulation treatment of pollution effluents from the Mohamed V hospital in Meknes	[16]	2013	Meknes
Physicochemical and bacteriological effluent characterization of hemodialysis Service	[17]	2014	Fez
Physicochemical and bacteriological characterization of liquid effluents of two hospitals	[18]	2014	Rabat-Salé

time, a survey has been done in order to assess the quantities and the qualities of chemicals and medicines used in each service and the rate of nosocomial infections. In a second stage, three punctual sampling campaigns (May, June, and July 2013) were done at each service effluent for an accurate characterization. Parameter results presented are the average of the three campaigns values. Thus, 12 collection points have been appointed to conduct the physicochemical and bacteriological study of the hospital wastewaters (Table 2).

It was found that the color of the samples differs from sampling points to another with a light color for samples taken at P1 and P5 (Fig. 1). This color difference could be attributed to the input of organic matter which varies depending on the type of liquid effluents evacuated by each service. It could also indicate a great difference on the chemical composition of the wastewater sampled at different points.

2.2. Parameters and analytical methods

After collection, samples were stored following the General guide for the storage and handling of samples according to ISO 5667/3 [19] and the good practice guide of the National Office of Drinking Water [20]. Water samples were collected in plastic bottles and stored at 4°C, then transported to the laboratory within a period not exceeding two hours. Temperature, pH, and conductivity were measured *in situ* using a multi-parameter sensor WTW LF 92. Nitrite, sulfate, chloride and orthophosphate, total phosphorus, ammonia nitrogen, COD, and BOD_5 were analyzed in the laboratory using standard methods of the French Association of Normalization (AFNOR) [21] and according to Rodier [22].

For heavy metals, we used a mineralization methods and analysis by Atomic Absorption spectrophotometer SHIMADZU AA 6300 (air/acetylene flame).

Germs were searched taking into account the current WHO concerns for health risks. Quantitative methods were used for bacteria indicating fecal contamination and qualitative methods for pathogens using Moroccan standard and membrane filtration technique. The studied germs are total coliform (TC), fecal coliforms (*Escherichia coli*) (EC) [23], *Streptococci* (SD), Intestinal Enterococci (IE) [24], the spores of

Table 2
Sampling points at the various departments in the studied hospital

Sampling points	Departments
P1	Hemodialysis
P2	Resuscitation of surgical emergencies
P3	A Trauma; Urology; Surgical visceral; Neurology
P4	C.C.V; B Trauma; Neurosurgery; Plastic surgery; Rheumatology and Neurology
P5	Sterilization of equipment
P6	Bloc surgical emergencies; Central operating room;
P7	Radiology
P8	Anatomy Laboratory
P9	Ophthalmology; Endocrinology and Internal Medicine
P10	Resuscitation; Cardiology; ENT; Gastrology
P11	Pharmacy; Maxillofacial; Office staff
P12	Medical laboratory

Fig. 1. Different samples from 12 sampling points of the studied hospital liquid waste.

anaerobes sulfite-reducing [25], *Staphylococcus aureus* [26], Pseudomonas *aeruginosa* [27], *Salmonella* spp., and *Vibrio cholerae*. Serological identification was carried out for the strains of *P. aeruginosa* and *Salmonella* spp., and the coagulase test to identify *S. aureus*.

2.3. Statistical analysis

The descriptive statistical analysis used to characterize the data-set were made using SPSS (Version 10). The analysis of variance (ANOVA II) was carried out and all the differences were considered significant at 5%.

3. Results and discussion

3.1. Survey analysis

3.1.1. Types of the hospital effluents and chemicals used by service

Various hospital departments produce several types of wastewaters (Table 3):

(1) Biological fluids (urine, feces, vomit, blood, sputum, water basins, etc.).
(2) Chemical effluents (obsolete chemicals and liquids such as acids, bases, various reagents, solvents, etc.).

Table 3
Types of wastewaters generated by the studied hospital and their behavior during the year 2013

Hospital Department	Types of effluent	Capacities (m^3/d)	Behavior
Hospitalization Services	Biological fluids (urine, stool, vomit) the water from sinks, baths, showers	nd[a]	Evacuated in the sanitation network
Operating room	Body fluids: blood, urine, feces, gastric fluids, peritoneal effusion trachea-bronchial aspiration or pleural drainage or irrigation,	11	Recovered for treatment by a private company
Laboratories	Biological fluids. These are organic products remaining after analysis (blood, sputum, urine) chemical effluents: these are the stocks of obsolete liquid chemicals (acids, bases, various reagents, solvents, etc.)	6	Recovered for treatment by a private company
Radiology	Effluent radiology service, responsible for product developers, fixers, and contrast have toxic health risks to humans and the environment	nd	Evacuated in the sanitation network
Sterilizing unit	Liquid effluents containing detergents and disinfectants, including glutaraldehyde (2%)	nd	Evacuated in the sanitation network
Cleaning and maintenance local	Liquid effluents containing detergents and disinfectants	nd	Evacuated in the sanitation network

[a]No Data.

(3) Effluent from the radiology department loaded of developers, fixers, and contrast products.
(4) Disinfectants generated by the service of medical devices sterilization.
(5) Detergents and disinfectants from cleaning and building maintenance.

The results of preliminary information on the current situation show that detergents and disinfectants are the most used products in the hospital with 17 098 kg/year. Sodium hypochlorite and mild soap alone account for 49% of the total quantity of these products and the use of glutaraldehyde-based pre-disinfectant and disinfectant are in second position with a percentage of 30%. Disinfectants of premises represent 21% of the products of medical devices, maintenance, and cleaning (Table 4).

According to the National Health Accounts (NHA, 2010), total expenditure on health amounted to 47.7 billion Dirham against 30.5 in 2006 (NHA 2006). This expenditure represented 6.2% of gross domestic product (GDP) in 2010 against 5.3% in 2006. Compared to countries whose economic development is similar, overall health expenditure in Morocco is relatively no longer low. For example, the level of overall health expenditure was 6.7% of GDP in Turkey, 6.2% in Tunisia, 4.2% in Algeria, 7% in Jordan and 8% in Lebanon [28].

Pharmaceutical products occupy an important place in the Moroccan health system. Indeed, medicines and medical goods alone absorb 31.7% of total health expenditure in 2010. To improve the availability of medicines at public hospitals, the Moroccan state has made increased budget allocated to health; it also adopted a drug concerted policy with the encouragement of the national pharmaceutical production and promotion of generic drugs [28].

According to the data of drug consumption during 2013 by the hospital services, it is clear from the quantitative distribution according to their therapeutic classes with 106 437 kg/year (Table 5), that drugs for reanimation and anesthesia represented 37% of the total consumed drugs. They mainly concern serum glucose, anesthetic "Propofol" anesthesia inductors and β-blockers "Propranolol". Drugs used in infectious diseases-parasitology, which are usually antibiotics (penicillins, cephalosporins, quinolones, etc.) constituted 14% of pharmaceuticals. As for the remaining percentage, the drugs used by Gastro-Entero-Hepatology service represented 9%, followed by the classes of anti-inflammatory with 7%, cardiology and angiologists drugs with 7 and 26% of the remaining drugs with different therapeutic classes.

3.1.2. Nosocomial infections

The nosocomial infections—also known as hospital infections—are infections acquired during a hospital stay. Nosocomial infections are a serious public health problem with significant consequences both individually and economically [29,30].

In Morocco, although there is still no national regulation requiring the reporting of all cases of nosocomial infections [31], the fight against these infections began to generate interest in recent years and some hospitals have developed their own program. Thus, a first national survey of nosocomial infections was conducted in 1994 revealed a prevalence rate of 14% [32]. Since then, no other studies have been conducted in this country while the problem of nosocomial infection remains a major public health problem. Our investigation revealed that many cases of nosocomial infections were recorded during each month of the year 2013 (except for the month of June when it had no statement of nosocomial infections) (Fig. 2) with an average of three cases per month. The maximum number of cases (5 cases) was recorded during January, February, and May. From the total reported cases of nosocomial infections, 29% have died. This gives us an idea about the risk of pathogens load in the hospital effluents. These effluents represent in one hand a great threat to intra-hospital workplace health and constitute also an

Table 4
Chemicals used by different hospital departments: detergents and disinfectants during the year 2013

Detergent-disinfectant	Quantity in kg/year	Percent (%)
Mild soap	4,560	24
Surface disinfectant	2,846	15
Surface disinfectant aerial	1,138	6
Sodium hypochlorite	4,741	25
Pre-disinfectant	380	12
Disinfectant glutaraldehyde (2%)	3,433	18
Total	17,098	100

Table 5
Monthly medicines consumption of the University Hospital (Marrakech) during 2013 regarding different therapeutic classes

Therapeutic Classes	January	February	March	April	May	June	July	August	September	October	November	December	Total kg/year
Anesthesia, resuscitation	3,183	4,058	3,058	2,959	3,097	3,105	3,235	3,200	2,126	3,254	3,912	2,983	38,170
Analgesics	389	393	394	385	494	454	265	491	325	384	346	386	4,706
Anti-inflammatory	574	584	657	620	756	684	551	425	828	657	488	624	7,448
Cardiology and Angiology	652	486	487	884	658	456	765	567	847	486	798	686	7,772
Dermatology	325	356	365	254	352	225	383	367	395	374	265	254	3,915
Endocrinology	49	95	75	120	88	72	74	120	86	88	98	85	1,050
Gastro-Entero-Hepatology	684	991	495	796	849	784	1,251	665	803	985	665	665	9,633
Hemophilias	78	84	96	84	45	94	124	97	89	126	58	84	1,059
Hemostasis and blood	368	359	486	574	359	484	498	677	464	443	487	486	5,685
Hormones glycogenolytic	95	67	59	95	84	75	105	89	98	146	84	92	1,089
Immunology	96	91	75	69	93	97	70	94	162	84	95	87	1,113
Infectious Diseases—Parasitology	1,105	846	1,706	954	1,058	1,297	1,425	985	1,248	1,564	1,254	1,405	14,847
Metabolism and nutrition	201	153	163	142	191	192	184	225	86	262	182	186	2,167
Neurology, Psychiatry	142	121	94	124	94	206	160	110	130	125	126	124	1,556
Ophthalmology	134	93	110	96	168	110	128	164	136	153	132	181	1,605
Pneumonology	97	104	120	138	164	137	103	184	153	152	131	122	1,605
Diagnostics	94	86	105	64	120	57	45	120	85	64	100	83	1,023
Rheumatology	84	68	57	95	68	64	95	86	93	68	134	86	998
Toxicology	74	97	85	67	153	89	94	46	97	42	94	58	996
TOTAL	8,424	9,132	8,687	8,520	8,891	8,682	9,555	8,712	8,251	9,457	9,449	8,677	106,437

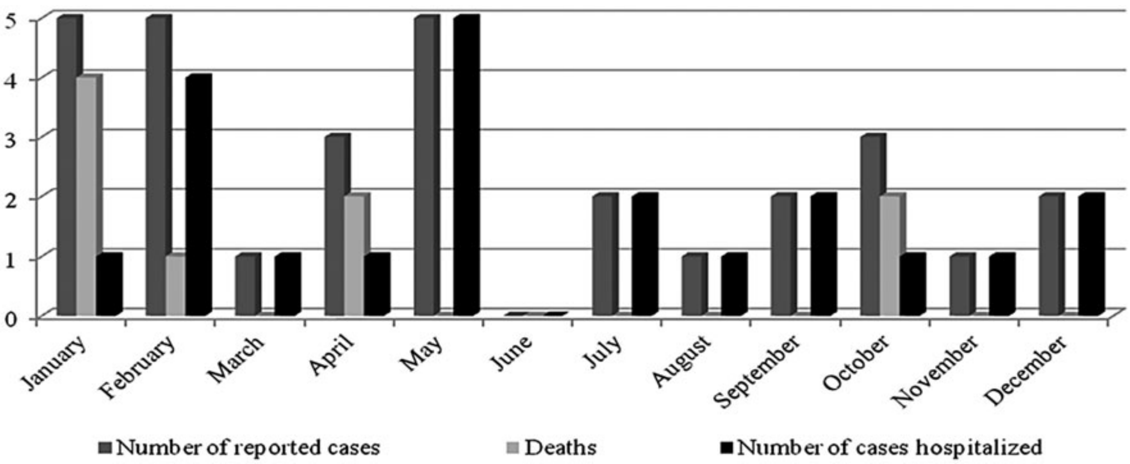

Fig. 2. Number of cases of nosocomial infections recorded during the year 2013.

environmental pollution source of water resources, especially by nosocomial infections agents.

3.2. Physicochemical characterization of the hospital wastewaters

The analysis of results shows that the *in situ* temperature of taken samples varies between 26 and 35˚C with an average value of 29˚C. The maximum value was recorded for samples collected at the point P6. These values are below the permissible limit values for the direct and indirect discharges into the receiving water standards (below 30˚C). Results show that the pH of the studied samples in the three campaigns is between 6.65 and 8.10 (Fig. 3) with a mean value of 7.16.

Concerning the electrical conductivity (EC), the average value is 1,195.60 μS/cm (Fig. 3). The values are between 1,300 and 2,700 μS/cm, which classifies these waters in Class 3 (quality of surface waters Grid) [33], thus these values situate these effluents at the limit of allowed EC for direct discharges (lower than 2,700 μS/cm). This high EC is attributed to the significant inorganic and organic matter load produced by the hospital discharge.

COD values (Fig. 4) measured in the effluents of different sampling points range from 38.52 to 7,763.55 mg/L and are significantly higher ($p < 0.01$) than the value indicated for a hospital wastewaters (43–270 mg/L) cited by [34] and also higher than the average value (500 mg/L) reported by Verlicchi et al.

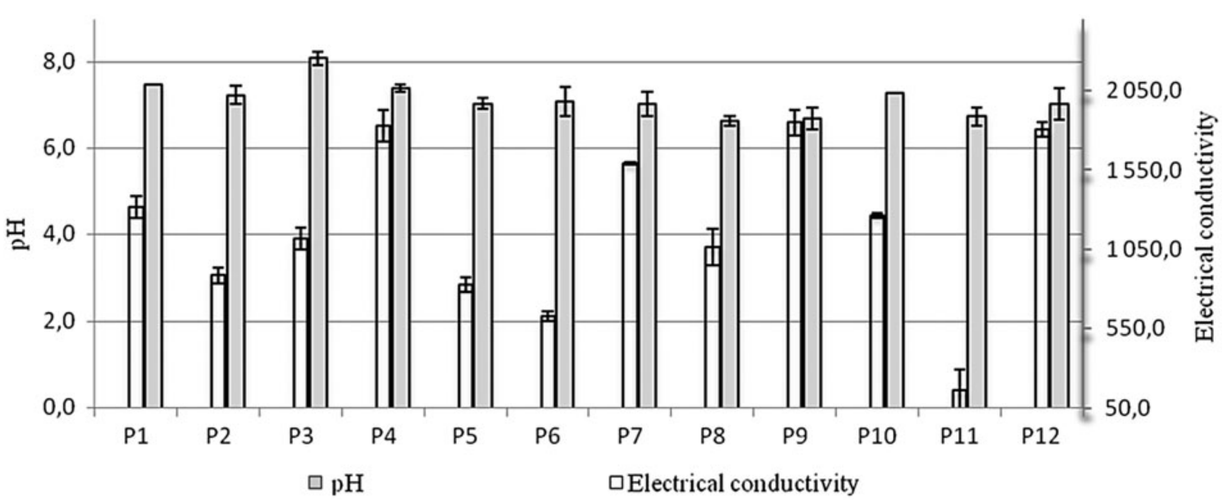

Fig. 3. The average values and standards deviation ($n = 3$) of pH and electric conductivity (μS/cm) of hospital effluents at different collected points (P1 … P12).

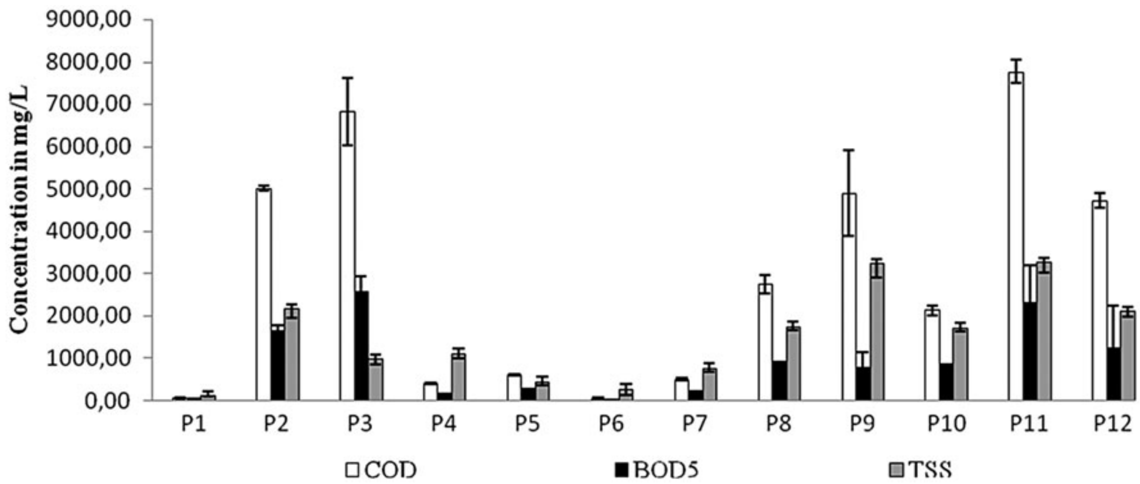

Fig. 4. Average concentration and standards deviation ($n = 3$) of COD, BOD_5, and TSS in the hospital effluents at different collected points (P1 … P12).

[14], or if compared to those of a conventional municipal wastewaters (300 and 1,000 mg/L) [35].

BOD_5 concentrations (Fig. 4) measured in the effluent of Marrakech university hospital fluctuate between 16 and 2,575 mg/L. These values are also significantly higher ($p < 0.01$) compared to those of hospital wastewaters (15 to 120 mg/L) [34]. Similarly, the average value (910 mg/L) of the BOD_5 of the studied hospital effluent is very high compared to the average of a municipal wastewaters generally ranged between 100 and 400 mg/L [10,36]. The indirect discharges limit value according to the Moroccan standard is 500 mg/L. These high COD and BOD_5 levels reflect the significant contribution of organic matters released from the hospital effluents to the municipal sanitation network.

The quotient of COD/BOD_5 gives a first estimate on the biodegradability of organic matters in a given effluent. In our study, this ratio is around 2.90, showing that the effluent is biodegradable but with selected strains [37].

The TSS concentrations (Fig. 4) measured in the effluent of different sampling points range between 116 and 3,260 mg/L well beyond the indirect discharge limits of Moroccan standard (600 mg/L). These values are very high compared to those of municipal wastewaters (150–500 mg/L) [35,36].

These levels allow noting that these effluents are concentrated in mineral and/or organics. A good correlation ($R^2 = 0.85$) is significantly existing between BOD_5, COD, and TSS.

The average concentration of Total Kjeldahl nitrogen measured in different samples is around 197.14 mg/L (Fig. 5). This value is much higher than those found in hospital wastewaters (44 mg/L) [34] and municipal wastewaters (30–100 mg/L) [36].

The ammonium concentration is 32.98 mg/L (Fig. 5) and shows that Total Nitrogen concentration corresponds mainly to organic fraction. Nitrite concentration ranges between 0.06 and 4.46 mg/L with a mean value of 1.46 mg/L (Fig. 5).

Regarding the total phosphorus, the maximum value (23.10 mg/L) was recorded at the point P9 (Fig. 6) exceeding the assigned ones by Moroccan standards that set the amount of total released phosphorus for direct and indirect rejection to 10 mg/L.

Concerning orthophosphate (mainly $H_2PO_4^-$ and HPO_4^{2-} for pH between 5 and 8), these elements are found in unpolluted natural waters at levels below 0.1 mg/L and pollution is suspected from 0.5 mg/L [37]. In liquid effluents of the studied hospital, the average concentration of these phosphate compounds is about 3.55 mg/L (Fig. 6). This value is comparable to that of hospital wastewaters (3.4 mg/L) [34], but relatively low compared with that of municipal wastewater.

The chloride concentrations (Fig. 7) vary considerably from one sampling point to another. Indeed, these values range from 31.40 mg/L (measured at the point P6) to 18,509 mg/L (recorded at the point P9).

As for sulfates (Fig. 7), the contents of measured SO_4^{2-} ranged from 40.5 to 2,370.5 mg/L. These values are very high and well above the limit tolerated by the Moroccan standard indirect discharges to the receiving environment (400 mg/L).

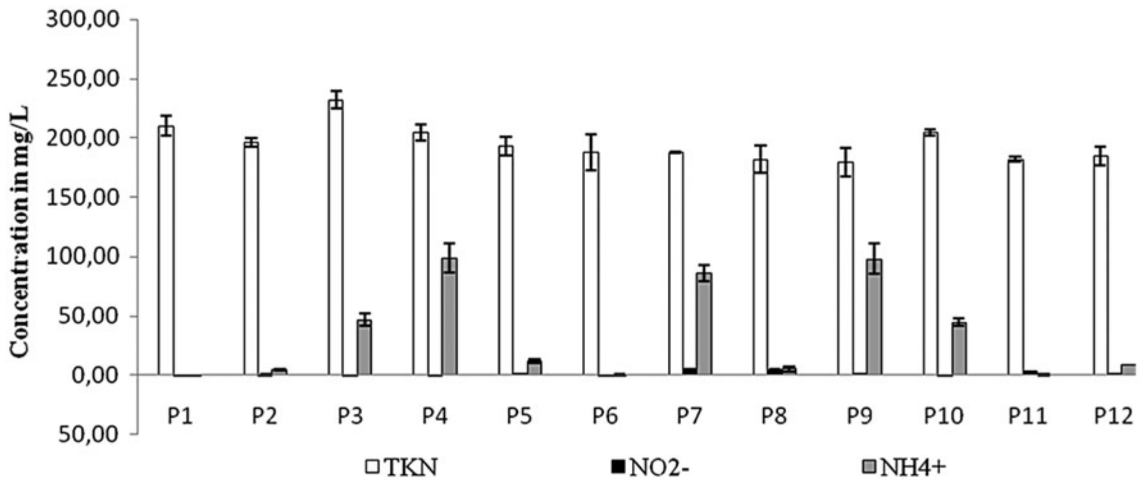

Fig. 5. Average and standards deviation ($n = 3$) of nitrogenous concentration (TKN; NO_2^- and NH_4^+) in the hospital effluents at different collected points (P1 … P12).

3.3. Heavy metals characterization

The evaluation of heavy metals in the hospital wastewaters showed that cadmium, zinc, and lead are present in amounts less than the limits set by Moroccan standards of direct and indirect discharges (Table 6) except for a single value of Pb obtained in the third measurement campaign.

Mean concentrations of copper and iron (Cu: 2.84 mg/L, and Fe: 3.38 mg/L) exceed the limit values cited in Moroccan standards and this can be explained by the use of drugs based on these two ions, as they may come from the erosion of the old drainage pipes of the studied hospital, which was created in 1938. It is also noted that the concentrations of these elements: copper; iron and lead are higher than those found in hospital wastewaters in France as reported by Boillot [34].

3.4. Bacteriological characterization

3.4.1. Indicators of fecal contamination

The assessment of fecal contamination in the hospital wastewaters was determining the total coliform; fecal *Streptococci* (Intestinal Enterococci) and spores of anaerobes sulfite-reducing.

3.4.1.1. Total coliforms. Total coliforms are organisms' indicator of fecal contamination. The analysis of these hospital wastewaters showed a significant variation in the total coliform contamination. The maximum value

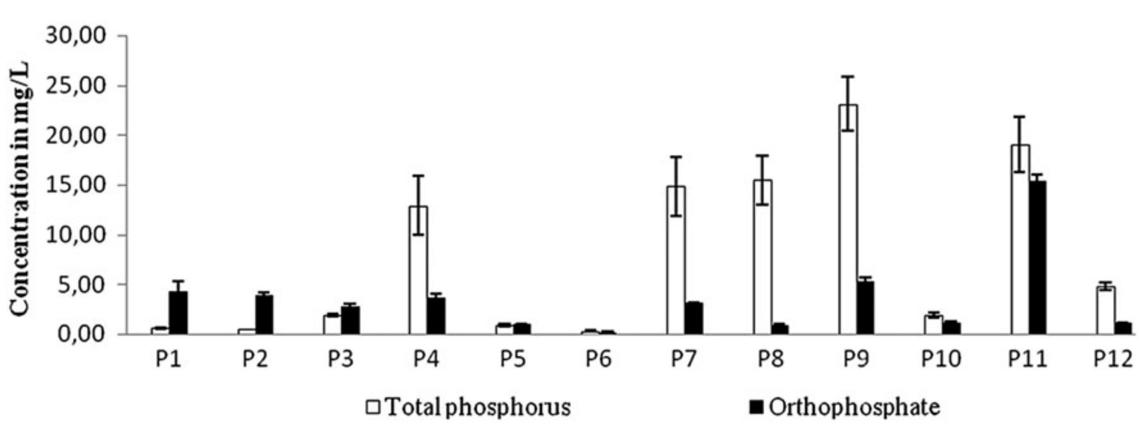

Fig. 6. Average and standard deviations ($n = 3$) of total phosphorus and orthophosphate concentration in the hospital effluents at different collected points (P1 … P12).

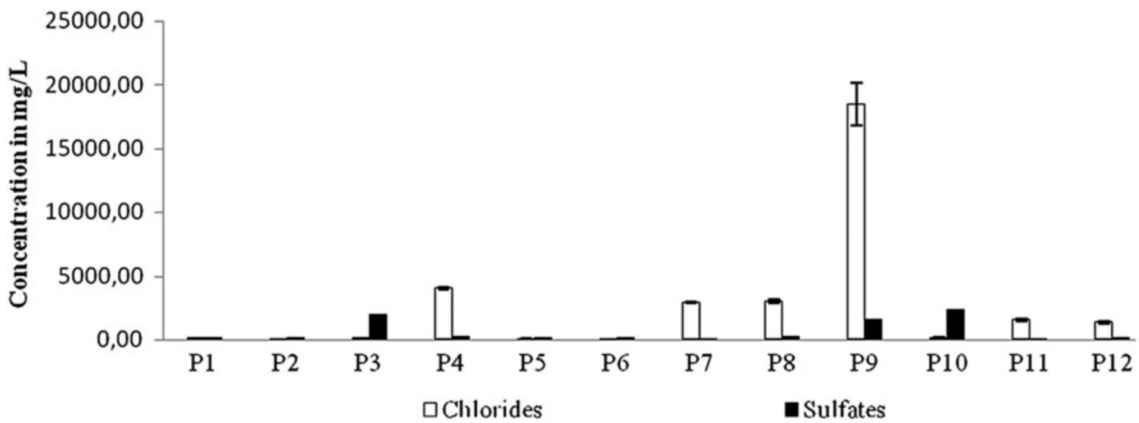

Fig. 7. Average and standard deviations ($n = 3$) of chloride and sulfate concentration in the in the hospital effluents at different collected points (P1 … P12).

Table 6
Concentration of heavy metals in the studied hospital effluents during three-monthly sampling (mg/L)

Parameters	Cu	Cd	Pb	Zn	Fe
Average	2.84	0.04	0.10	3.31	3.38
Maxima	4.01	0.07	1.05	4.88	4.83
Minima	1.61	0.01	0.00	1.95	2.06
Hospital effluents[a]	0.16	–	0.01	0.15	–
MSID[b]	1	0.2	0.5	5	3
MSDD[c]	0.5	0.2	0.5	5	3

[a] [34].
[b] Moroccan standards of indirect discharges.
[c] Moroccan standards of direct discharges.

(8.3×10^7 CFU/100 mL) was recorded at the point P3; P9; and P10 while the minimum value (80 CFU/100 mL) was observed at the point P1 corresponding to the Hemodialysis Service (Fig. 8). The average value of total coliforms being recorded is 3.9×10^7 CFU/100 mL (Fig. 9).

*3.4.1.2. Fecal coliforms (*E. coli*).* Fecal coliforms were studied through the determination of *E. coli*, since they represent 80 to 90% of detected thermo-tolerant coliforms [38,39]. *E. coli* are a facultative anaerobic bacteria species predominant in the gut and feces. The presence of these bacteria in wastewater is regarded as an indication of fecal contamination and therefore the presence of pathogenic fecal micro-organisms [39]. The analysis of the obtained results revealed a strong charge during the three campaigns with a maximum value of 7.7×10^7 CFU/100 mL (Fig. 9) obtained at point P10, and a minimum value 60 CFU/100 mL registered—as the case also of total coliforms at the point P1 (Fig. 8).

The calculated average ratio CF/SF is greater than 4, reflecting a dominant pollution of human origin. A significant correlation ($R^2 = 0.64$) was observed

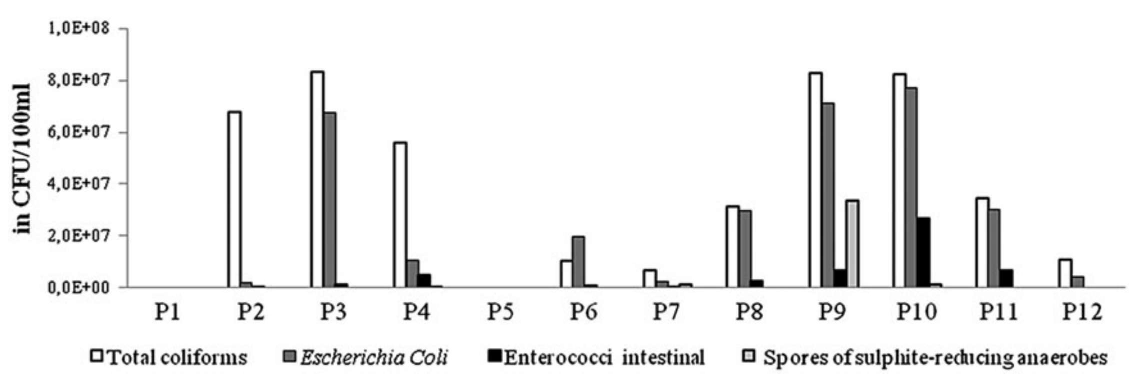

Fig. 8. Average concentration of micro-organisms indicators of fecal contamination in the hospital effluents at different collected points (P1 … P12).

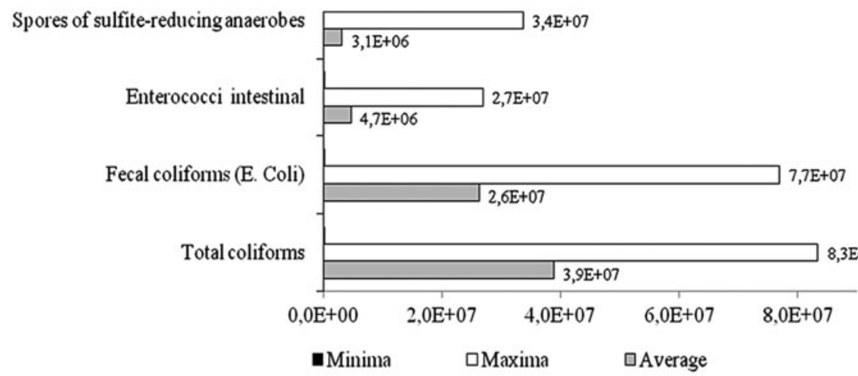

Fig. 9. Average ($n = 3$) concentration of indicator organisms of fecal contamination in the hospital effluents at different collected points (P1 … P12).

between fecal indicators and high levels of organic parameters (COD and BOD_5) at the points that assigns high bacterial loads and *vice versa*.

3.4.1.3. Spores of sulfite-reducing anaerobes. The sulfite-reducing bacteria showed an old fecal pollution. The spores of these bacteria are more resistant to environmental conditions and more persistent in the environment. Analyzes showed that the average concentration of spores is 3.1×10^6 order CFU/100 mL with a maximum value recorded at the point P9 (Fig. 8).

3.4.2. Pathogens

The hospital is a place where a lot of people infected with pathogens are present and consequently several infectious agents could be developed. Thus, certain bacteria such as *P. aeruginosa* and *S. aureus* have been identified as being more concentrated in the hospital wastewaters.

3.4.2.1. Staphylococcus aureus. The highest average load of this observed micro-flora is of about 7.5×10^5 CFU/100 mL, registered at the point P12, while this value is zero at the points P1 and P5 (Fig. 10).

3.4.2.2. Pseudomonas aeruginosa. These bacteria are ubiquitous in the environment and can easily colonize a sampling site. In hospital intensive care conditions of patients subjected to multiple invasive procedures and whose immune systems are impaired, promote the onset of patent infections due to these opportunistic bacteria. Mortality due to these bacteria is very high due mainly to sepsis or pneumonia [40]. The maximum average value is 5.3×10^6 CFU/100 mL recorded at the point P12, while the average minimum concentration is zero; value obtained at the sampling points P1, P3, and P5 (Fig. 10).

3.4.2.3. Salmonella *and Vibrion.* After the biochemical identification of *Salmonella*, we suspect the presence of

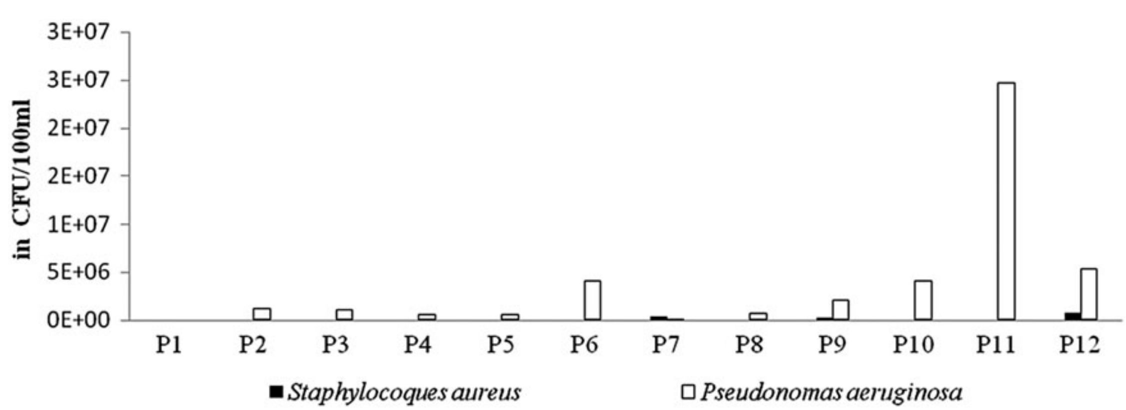

Fig. 10. Variation of pathogens (*P. aeruginosa* and *S. aureus*) in the hospital effluents at different collected points (P1 … P12).

strains of *Salmonella* and *vibrio* in the hospital wastewaters, respectively, at the points (P10, P11, and P12) and points (P6, P7, P11, and P12). The confirmation of this statement has been requested from the Laboratory of Repository Microbiology of the National Institute of Hygiene in Rabat (Morocco). According to national and international standards of direct and indirect discharges, the obtained results show that these hospital effluents are of poor quality and must not be released to environmental receptors without pretreatment.

4. Conclusion

According to the obtained results, all types of pollutants of the studied hospital services are discharged into the sewerage system without any treatment (except liquid waste generated by the laboratories and operating suites which are relatively recovered and sent to the processing plant located in Casablanca city). These liquid effluents contain mainly detergents-disinfectants used in cleaning, disinfectants containing glutaraldehyde (2%) designed for the sterilization of medical equipment and drug residues "emerging pollutants." Once a pharmaceutical administered, it is partially sorbed by the human body (2–98% depending on the substance), while its remaining fraction is excreted as unchanged compound (parent compound) or as its metabolites in the sanitation. All these products are recognized for the hazard that they can cause to public health. On the other hand, the results of analyzes carried out during the three campaigns in 2013 revealed that the hospital effluents have a high rate of both physicochemical and bacteriological pollutions. Indeed, the results of these analyzes showed that the contents of both the physicochemical parameters (TSS, COD and BOD_5) and heavy metals (copper and iron) significantly exceed the levels established by national standards of direct and indirect discharges. Moreover, the bacteriological analysis showed that the obtained pH values are in a pH range favorable to the development of the majority of micro-organisms. This explains the fact that the identified indicators of fecal contamination showed an increasing trend and the average load of pathogenic bacteria (*P. aeruginosa* and *S. aureus* partly responsible for nosocomial infections recorded in the hospital) is high. In addition, it appears from the results, a suspected presence of pathogens such as *Salmonella* and *Vibrio*. These bacteria are known for their virulence and have a high impact on the health of the population, on the spread of epidemic diseases and on the receiving environment. Considering all these data, to remedy the adverse effects that can cause these contaminants and micro-organisms on public health and the environment, a clear and comprehensive legal framework must be developed to process these effluents on an equal footing with hospital solid waste. The knowledge about the characteristics of these hospital effluents will help to provide adequate pre-treatment prior to their disposal into the public sewer system and we can also take advantage of the previous studies conducted worldwide in the field of hospital wastewaters treatment and the selection of appropriate ones.

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