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EVALUATION OF PHYSICOCHEMICAL AND BACTERIOLOGICAL PARAMETERS OF EFFLUENTS IN TAZA HOSPITAL-MOROCCO-APPLICATION OF PRINCIPAL COMPONENT ANALYSIS (PCA)

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ABSTRACT

In order to manage and assess the effluents quality in Taza city provincial hospital center, sampling campaigns were carried out during one year (May 2018-April 2019). The wastewater physicochemical characterization revealed a very high organic matter load in terms of chemical oxygen demand (COD) (600.87 mg/L), biochemical oxygen demand (BOD5) (372.94 mg/L) and suspended matter (SM) (165.99 mg /L). However, COD / BOD_5 ratio varies between 2.10 and 1.69, showing a satisfactory biodegradability for this waste water. The bacteriological analyses results showed the presence of indicating fecal contamination germs, at very high concentrations for total coliforms (2.95 10^4/100 mL), fecal coliforms (5.93 10^3/100 mL) and fecal streptococci (4.81$0^3$/100 mL). Statistical data processing gave us an idea about correlation between the different variables, thus principal component analysis (PCA) allowed us to reduce our database dimension by collecting as much information as possible about their trends.

KEY WORDS : Hospital effluents, Physico-chemical, Bacteriological analysis, Principal component analysis (PCA).

INTRODUCTION

Water is an essential natural resource on earth, both for human's survival and health. Moreover, it has a benefit for agricultural, industrial and tourist activities (El Morhit *et al.*, 2014). Water resources are so important both for life and economy, that water shortages are seen as limiting country's socio-economic development (Këpuska, 2016; N'Diaye *et al.*, 2013).

Morocco is characterized by rainfall spatial heterogeneity, temporal irregularities and a strong sensitivity to both climate change and adverse effects of human activities (extraction, introduction of pollutants ...). This situation can seriously harm public health, biodiversity, environment, in particular, country's water resources in quantity and quality.

The problem of hospital effluents discharges is becoming more and more important. These establishments consume daily significant water amounts, ranging from 400 to 1,200 L/day (Deloffre-Bonnamour, 1995; CLIN Paris-Nord, 1999) and produce large volumes of liquid effluents containing specific substances such as drug residues, chemical reagents, disinfectants, detergents, x-ray fixatives and pathogens such as bacteria, viruses and fungi.

These effluents are generally discharged into urban networks without prior treatment, as are domestic wastewaters. These releases, if not properly treated, can have an impact on the environment and human health and can cause epidemics, infectious diseases and water-borne illnesses (Gautam *et al.*, 2007). In addition, some substances in these effluents are genotoxic and are suspected to be a possible cause of cancer disease observed in recent decades (Jolibois and Guerbet, 2006).

The purpose of this study is to assess, for the first time to our knowledge, the physicochemical and bacteriological quality of Taza city hospital center effluents, in order to determine their impact and their degree of pollution on the local environment on one hand and to propose a suitable strategy for improving these discharges quality on the other hand.

MATERIALS AND METHODS

Study site

The provincial hospital center (PHC) of Taza, created in 1956, represents the only large care structure in the Province with a litter capacity of 317 beds. It serves an urban population of approximately 214,347 inhabitants (MSM, 2019). It is a provincial surgical training hospital whose activity covers both medical and technical disciplines and services.

It includes five departments namely the medical, surgical, mother and child, medico-technical and emergency-resuscitation departments. Its water consumption is estimated on average at 420 l / bed / functional day. The hospital's effluents are discharged into the city's sewerage system, where they are mixed with urban wastewater without any prior treatment.

Sampling

Sampling campaigns were carried out in one year, from May 2018 to April 2019, in the hospital's main collector (Figure 1). Samples were taken in one liter polyethylene bottles for physicochemical analyzes and in sterile 250 mL glass bottles for bacteriological analysis according to Moroccan Standard NM 03.7.059. The samples transport and storage was carried out according to requirements and methods recommended by Rodier (2009).

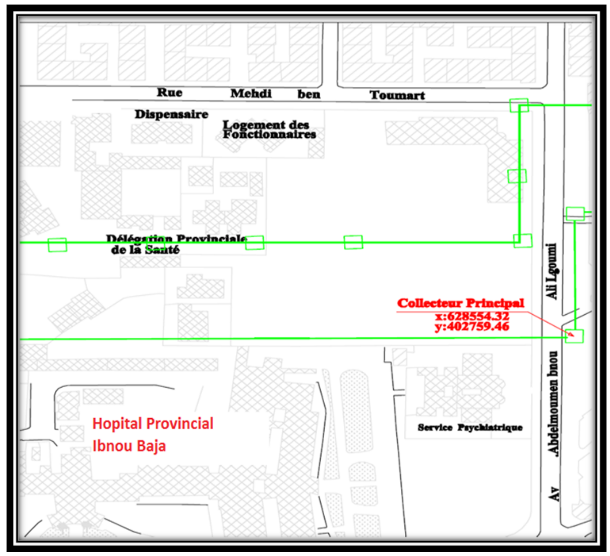

Fig. 1. Typical sanitation plan (AWEDAT, 2014)

Physicochemical analyzes

Physicochemical parameters are controlled using the techniques of Rodier *et al.* (2009). These parameters are listed in Table 1. Temperature and pH are measured locally by the ADWA model AD111 multi-parameter device. The standards and analytical methods used to determine conductivity, nitrates (NO_3^-), nitrites (NO_2^-), ammonium (NH_4^+), suspended matter (SM), chemical oxygen demand (COD), and biochemical oxygen demand at 5 days (BOD5) are listed in Table 1.

Bacteriological analysis

Table 1. Methods of physicochemical parameters analysis

Parameter	Norm	Analysis Method
T°C		
pH		
Conductivity (µs/cm)	NM ISO 7888	Electrometric
NO_3^-	NM ISO 13395	Colorimetric method by continuous flow
NO_2^-	NM ISO 13395	Colorimetric method by continuous flow
NH_4^+	NM ISO 11732	Colorimetric method by continuous flow
SM (mg/L)	NM EN 872	Gravimetry
COD (mg/L)	ISO 15705	Colorimetric Oxidation by potassium dichromate
BOD5 (mg/L)	WTW-OXYTOP	OXITOP

The Bacteriological analyzes are based on quantification of faecal pollution's indicating germs: total coliforms (CT), faecal coliforms (*E. coli*) and faecal streptococci (intestinal enterococci). Identification and enumeration of pathogens is done using the Most Probable Number (MPN) method according to the National Electricity and Drinking Water office (NEWO).

Statistical Analyzes

Data statistical analysis is carried out using SPSS 21 software, using the principal component analysis (PCA) method. It consists of moving from a table of quantitative data, containing a whole set of variables into a few factors or components which are new variables (Morineau, 1998). Statistical analysis is performed on 19 samples and 12 variables (temperature, pH, conductivity, NH_4, NO_3, NO_2, SM, COD, BOD5, TC, FC, FS).

RESULTS AND DISCUSSION

Results of the effluents physicochemical and bacteriological parameters analysis are collected in Table 3.

Temperature plays a very important role in the solubility of salts, gases and on the speed of chemical and biochemical reactions (HCEFLCD, 2007). The increase in temperature promotes microorganism's development and dissolved oxygen consumption in water (Vrignaud, 1998). During our sampling campaigns the average temperature value is about 20.79 °C, which is below 30°C set by the WHO (2012). This value is comparable to those found at Avicenne hospital in Rabat (El Morhit *et al.*, 2015) and at Sidi Kacem provincial hospital center (Sadek *et al.*, 2012).

The pH indicates the water aggressiveness, conditions a large number of physico-chemical balances and depends on multiple factors, including water temperature and origin (Rodier *et al.*, 2009). A pH less than 7 can lead to corrosion of cement or metals in pipes. Highly alkaline waters may have rich and diverse stands. However, for most aquatic

Table 2. Methods of bacteriological parameters analysis

Media used	Temperature and time incubation	Reference	
TC (Coliforms)	Presumptive test: Lauryl tryptose sulfate broth Confirmatory test: Brilliant, bilinated lactose broth	37°C + 0.5 °C during 48H	ISO 9308-2 :1990
CF (*Escherichia coli*)	Presumptive test: Lauryl tryptose sulfate broth Confirmatory test: Indole reaction	37°C + 0.5 °C during 48H 44 °C + 0.5 °C during 24H	ISO 9308-2 :1990
FS (Intestinal Enterococci)	Presumptive test: Azide glucose broth Confirmatory test: BEA agar	37 °C + 1 °C during 48H 44 °C ± 0.5 °C during 48 H	ISO 7899-1: 1990

Table 3. Results of the raw wastewater characterization from the studied sites

	Min	Max	Average
T°C	11.4	25.5	20.79
pH	7	7.87	7.42
Conductivity	735	940	844.21
NO_3^- (mg/L)	5.56	11.46	8.88
NO_2^-(mg/L)	0.15	0.4	0.23
NH^{4+}(mg/L)	4.22	11.29	6.89
SM (mg/L)	88.75	341.37	165.99
COD (mg/L)	414	810	600.87
BOD5 (mg/L)	211.3	546	372.94
FT (germs/100 mL)	$2.1\ 10^3$	$1.12\ 10^5$	$2.95\ 10^4$
FC (germs/100 mL)	$2.7\ 10^2$	$4.7\ 10^4$	$5.93\ 10^3$
F (germs/100 mL)	$2.6\ 10^2$	$3.2\ 10^4$	$4.8\ 10^3$

species, the favorable pH zone is between 6 and 7.2 (Rodier *et al.*, 2009). For this study, the average pH value is 7.42 which is slightly alkaline but respects Moroccan national standards setting discharges pH into the receiving environment at values between 6.5 and 8.5. This result is similar to those recorded at Sidi Kacem hospital (Sadek *et al.*, 2012) and at Avicenne hospital in Rabat (El Morhit *et al.*, 2015).

The electrical conductivity provides information on the overall degree of water mineralization, which depends on the endogenous and exogenous organic matter charge, generating salts after decomposition and mineralization (Rodier *et al.*, 2009; CEAEQ, 2015). The average value, recorded during the study period, of 844.21 µs/cm is below 2700µs/cm considered as the limit value for direct release to receiving environment (MEMEE, 2002). This value presents more or less significant mineralization, which presents an environmental threat to the receiving environment. However, this value is close to that found at Mohammed V hospital in Meknes (Ameziane, 2013) but lower than that found at Al Ghassani hospital in Fez (Tahiri *et al.*, 2009).

The presence of large quantities of ammonium in water indicates process of incomplete degradation of organic matter, which is an excellent indicator of water contamination by human releases probably due to the transformation rate of urea into ammonia (Derwich *et al.*, 2010). Nitrites can be toxic to the human body, their presence in significant quantities leads to a decrease in water quality. Nitrites are the most dominant nitrogen form in stream, are highly soluble and reaching groundwater. The average contents recorded in ammonium is 6.89 mg/L, nitrites 0.23 mg/L and nitrates 8.88 mg/L. These values are higher than those found at Avicenne hospital in Rabat (El Morhit *et al.*, 2015) and Al Ghassani hospital in Fez (El Mountassir *et al.*, 2017). However, these values enable to classify these discharges in the good to medium quality class according to the evaluation grid for overall quality of water intended for irrigation (MEMEE, 2002).

Table 4. Correlation matrix

	TC	pH	Cond	NO_3	NO_2	NH_4	SS	DCO	DBO_5	TC	FC	FS
Correlation	TC	1.000										
pH	.715	1.000										
Cond	.689	.920	1.000									
NO_3	.614	.650	.626	1.000								
NO_2	.373	.415	.432	.249	1.000							
NH_4	.611	.483	.699	.512	.276	1.000						
SS	.131	.350	.545	.377	.304	.676	1.000					
DCO	.609	.593	.778	.388	.476	.877	.660	1.000				
DBO_5	.531	.377	.585	.142	.421	.798	.571	.938	1.000			
TC	.140	.071	.234	.188	.501	.415	.452	.333	.284	1.000		
FC	.135	-.007	.088	.203	.234	.385	.430	.261	.277	.461	1.000	
FS	.093	-.014	.104	.200	.463	.280	.359	.135	.093	.896	.463	1.000

a. Determinant = 1,914E-007

Table 5. KMO index and Bartlett test

Precision measurement of Kaiser-Meyer-Olkin sampling.		.682
Bartlett Sphericity Test	Approximate Chi-square	281.017
	ddl	66
	Meaning of Bartlett	.000

Table 6. Total variance explained

Component	Initial own values			Extraction Sum of squares of the factors selected		
	Total	% of variance	% accumulated	Total	% of variance	% accumulated
1	5.827	48.561	48.561	5.827	48.561	48.561
2	2.249	18.742	67.303	2.249	18.742	67.303

The average suspended matter (SM) value recorded at the hospital effluent level was about 165.99 mg/L. This value greatly exceeds the standard recommended by WHO (30 mg/L). In contrast, it is below the values found at Mohammed V hospital in Meknes (Ameziane, 2013) and at Jacques Monod hospital center in Havre (Mansotte, 2000). Representing all mineral, organic and colloidal particles suspended in water, very high concentrations of SM can form a screen preventing penetration of solar rays essential for photosynthesis of aquatic plants at the bottom of watercourse and can lead to soil clogging (Rodier *et al.*, 2009). Hence, this pollution could lead to soil clogging and have a harmful effect on receiving waters.

The chemical oxygen Demand COD measures the oxygen amount required to oxidize oxidizable organic and inorganic matter contained in an effluent (Rodier *et al.*, 2009). The average recorded COD value of 600.87 mg/L, largely exceeds Moroccan standards, which set specific limit values for domestic discharge at 250 mg/L (MEMEE, 2002). This recorded value is similar to some hospital effluents such as Sir Seewoosagur Ramgoolam national hospital in Mauritius (Mohee, 2005), Hassan II hospital center in Fes (El Mountassir *et al.*, 2017) and Avicenne hospital in Rabat (El Morhit *et al.*, 2015).

The BOD5 measures the biodegradable organic matter amount in water. This biodegradable organic matter is evaluated through the oxygen consumed by microorganisms involved in the natural purification mechanisms. The average value of BOD5 recorded is 372.94 mg/L. Even though it greatly exceeds the specific discharge limit values for sewage discharges from urban agglomerations set at 120 mg/L, this value respects hospital wastewater limits which are set at 50 to 400 mg/L (EPA, 1989). Moreover, this result is comparable to those found at Dupuytren hospital of the Limoge university hospital center (Leprat, 1999; Dremont and Hadjali, 1997). Thus, it remains lower than those found at Mohammed V hospital in Meknes (Amziane, 2013) and at Villiers hospital (Deloffe-Bonnamour, 1995).

The COD/BOD5 ratio is used to estimate the organic matter biodegradability, to determine pollution degree and to optimize physicochemical parameters of a given effluent, in order to propose an appropriate treatment (Carraro *et al.*, 2016). In our case the COD/BOD5 ratio varies between 2.10 and 1.69, which is in agreement with that obtained in the Villiers hospital in France (Deloffre-Bonnamour, 1995). These values are significantly lower than those found at Al Ghassani Hospital in Fez (Tahiri *et al.*, 2009) and Avicenne Hospital in Rabat (El Morhit *et al.*, 2015). Therefore, this result indicates that these effluents are readily biodegradable and a biological treatment could be quite suitable.

Total coliforms and fecal coliforms can provide information on fecal contamination degree of the effluent being studied. These parameters are considered to be pathogenic due to increased risk of gastrointestinal and respiratory diseases associated with fecal contamination in recreational waters (EPA, 2012). In addition, fecal coliforms concentration indicates the presence or absence of antibiotics or disinfectants in hospital effluents (Emmanuel, 2004). Average concentrations of total coliforms (of 2.95 10^4 germs/100 mL), fecal coliforms (of 5.93 10^3 germs/100 mL) and fecal streptococci (of 4.8 10^3 germs/100 mL) are found. Fecal coliforms and streptococci are found to have lower concentrations than total coliforms. Eventhough, these values exceed the WHO recommended limit values of 1000 FC/100 mL, they remain consistent with those of other studies which has revealed that bacteriological concentration in hospital effluents is generally low in comparison with urban wastewater (Bernet and Fines, 2000). In addition, these values are comparable to those found at Al Ghassani hospital (Tahiri *et al.*, 2009) and are very low compared to those found at Mohammed V hospital (Ameziane *et al.*, 2014). These low values can be explained by the use of cleaning products, particularly chlorinated products (such as bleach which is the most common one) and other products such as disinfectants and antiseptics (Hartemann *et al.*, 2005).

The correlation matrix of the parameters measured during our study is presented in Table 4, significant Pearson correlation coefficients greater than 0.5 are shown in bold. The correlation matrix determinant is relatively very small, without being equal to zero, indicating that one or more variables have a perfect correlation with one or more other variables. The validity of Kaiser-Meyer-Olkin (KMO) test averaging 0.682 and the significance of Bartlett sphericity test which is 0.000 (Table 5) mean that the correlation matrix is different from an identity matrix.

The PCA has achieved a limited number of components (Table 6), the two components 1 and 2 explain 67.30 % of the total information with respectively 48.56 % for axis 1 and 18.74% for axis 2. The first component groups the variables counting towards its positive pole: temperature, pH, conductivity, nitrogen compounds, MES, COD and BOD5. While the second component groups TC, FC and SF towards its positive pole (Figure 2). Consequently, the PCA is a tool which offers the possibility of simplifying the quality of hospital effluents study, by reducing the number of variables to be taken into account and by simplifying the model originally built from 12 variables to restore it to 3 variables, relatively simple and cheaper.

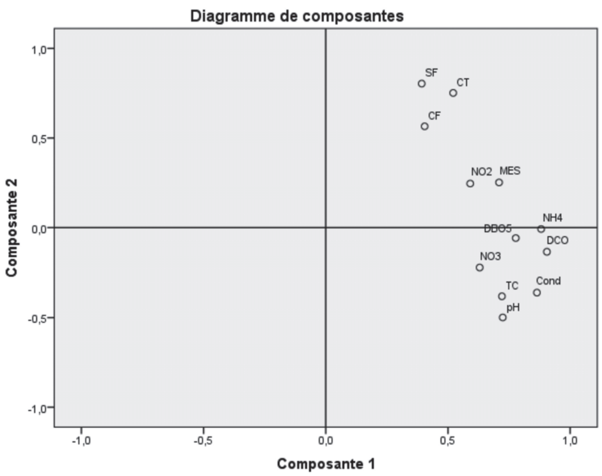

Fig. 2. Variables projection

CONCLUSION

The results of physicochemical parameters of this study showed that effluents of Taza provincial hospital have very high organic pollution degree, since majority of the parameters studied exceed standards recommended by WHO and Moroccan standards (MEMEE, 2002). This could be detrimental to aquatic fauna life in Oued Larbâa, receptacle of these discharges, so that the contamination risk of groundwater is not negligible. Similarly, nitrogen compounds values found remain below standards, but their presence in these effluents could harm to health of livestock as well as humans. However, these effluents are easily biodegradable so a biological treatment could be entirely suitable. Moreover, the microbiological analyzes showed very high concentrations of fecal pollution indicators in these effluents. This bacteriological pollution can have harmful effects on fauna, flora and environment, as well as it can cause transmission of many infectious and parasitic diseases.

In order to improve these discharges quality and to protect health and environment while meeting national standards, these effluents must undergo adequate treatment before being released to a receiving ecosystem.

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