STUDY OF PHYSICOCHEMICAL AND BACTERIOLOGICAL QUALITY OF WASTEWATER DISCHARGED INTO COASTAL WATERS FROM THE CITY OF EL JADIDA (MOROCCO) AND PROPOSED A SYSTEM OF TREATMENT BASED ON BIODENITRIFICATION

SALAMA Youssef[1,2*], CHENNAOUI Mohammed[1,2,3], MOUNTADAR Mohammed[2], RIHANI Mohammed[1], ASSOBHEI Omar [1]

[(1)]BIOMARE Laboratory, Biology Department, Faculty of Science
University Chouaib Doukkali, Morocco.
[(2)]Laboratory of Water and Environment, Faculty of Science
University Chouaib Doukkali, El Jadida, Morocco
[(3)]Regional Centres for the Professions of Education and Training (CRMEF)
Laboratory of Life Science and Earth (SVT), El Jadida, Morocco
Email: salama.youssef@gmail.com

Abstract.- *In the city of El Jadida, disposal of untreated wastewater in the ocean has a negative impact on the environment and the health of the populations who live along the urban effluents. The main objective of this study is to monitor the physicochemical and bacteriological quality of raw sewage from the city of El Jadida. Several takings were made at the level of three collectors of the city of El Jadida between year 2011 and 2012. The parameters studied are temperature, pH, electrical conductivity (EC), nitrates (NO_3^-), nitrites (NO_2^-), total phosphorus (TP), orthophosphate (PO_4^{3-}), chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), total kjeldahl nitrogen (TKN), total suspended solids (TSS), volatile suspended solids (VSS), fecal coliform (FC), fecal streptococci (FS), spore sulfite-reducing anaerobes (SSR). Analysis of wastewater in three collectors (C_1, C_2 and C_3) showed that the concentrations of physicochemical and bacteriological parameters are very high and largely exceeding the Moroccan standards and that can cause very serious problems environmental. In this study, the biological treatment of raw sewage from the sewer in El Jadida (Morocco) had been tested in laboratory by using a bioreactor (immerged bacterial bed) colonized by a heterotrophic denitrifying flora. The obtained results show that parameters of removal efficiency were 97.69, 96, 90, 82.11 and 89.30 % of nitrate (NO_3^--N), dissolved chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), total phosphorus (TP-P) and total Kjeldahl nitrogen (TKN-N) respectively when the system was operated at optimal conditions; pH 8.4, temperature of 28.9°C and COD/NO_3^--N ratio equal to 5. Consequently, the treated effluent has respected the norms defined in Moroccan's project for all analyzed parameters.*

Key words*: Wastewaters, Bacteriological, Physicochemical, Biodenitrification, El Jadida, Morocco.*

ETUDE DE LA QUALITE PHYSICOCHIMIQUE ET BACTERIOLOGIQUE DES EAUX USEES REJETEES DANS LES EAUX COTIERES DE LA VILLE D'EL JADIDA ET PROPOSITION D'UN SYSTEME DE TRAITEMENT BASE SUR LA BIODENITRIFICATION

Résumé.- *Dans la ville d'El Jadida, l'élimination des eaux usées non traitées dans l'océan a un impact négatif sur l'environnement et la santé des populations qui vivent le long des effluents urbains. L'objectif principal de ce travail est d'étudier la qualité physico-chimique et bactériologique des eaux usées de la ville d'El Jadida et de proposer par la suite un système de traitement adéquat à ces eaux usées. Plusieurs prélèvements ont été effectués au niveau de trois collecteurs des eaux usées de la ville d'El Jadida entre l'année 2010 et 2012. Les paramètres étudiés sont la température, le pH, la conductivité électrique (CE), les nitrates (NO_3^-), les nitrites (NO_2^-), le phosphore total (TP-P), l'orthophosphate (PO_4^{3-}), la Demande Chimique en Oxygène (DCO), la Demande Biochimique en Oxygène (DBO_5), l'Azote Total Kjeldahl (NTK), les Matières en Suspension (MES), les Matières*

Volatiles en Suspension (MVS), les Coliformes Fécaux (CF), les Streptocoques Fécaux (FS) et les Spores anaérobies sulfito-réducteurs (SSR). L'analyse des eaux usées dans les trois collecteurs (C1, C2 et C3) ont montré que le taux des paramètres physico-chimiques et bactériologiques sont très élevés et dépassant largement les normes marocaines et qui peut causer de très graves problèmes de l'environnement. Dans cette étude, le traitement biologique des eaux usées des égouts de la ville El Jadida (Maroc) a été effectué au laboratoire en utilisant un bioréacteur anaérobie à lit bactérien immergé colonisé par une flore hétérotrophe dénitrifiante. Les résultats obtenus ont montré que le rendement d'élimination des paramètres étaient 97; 69; 96; 90; 82.11 et 89,30% pour le nitrate (NO_3^--N), Demande Chimique en Oxygène dissous (DCO), Demande Biochimique en Oxygène (DBO_5), le Phosphore Total (TP-P) et l'Azote Total Kjeldahl (NTK), respectivement, lorsque le système est exploité dans des conditions optimales ; le pH égal 8.4, la température de 28.9°C et le rapport COD/NO_3^--N égal à 5. Par conséquent, l'effluent traité a respecté les normes définies dans le projet marocain pour tous les paramètres analysés.

Mots-clés : *Eaux Usées, Bactériologique, Physicochimique ; Biodénitrification, El Jadida, Maroc.*

Introduction

Demographic, economic and urban increases are the cause of different environmental pollution sources (air pollution, surface and groundwater pollution, soil pollution ...), and especially in developing countries. Among these pollution sources, the production of untreated wastewater often released into the receiving environment (sea, rivers, soils…) causes physico-chemical and biological degradation, which generate many hydric diseases [1, 2, 3, 4].

However, pollution also affects unenclosed sea. The composition of wastewater from household can be extremely variable and depends on three factors, which are the original composition of drinking water, the various uses by individuals who can provide a nearly infinite number of pollutants, and finally the users themselves who will reject the organic matter in wastewater (urine, feces) [5].

Other studies conducted by LAMGHARI (2007, 2005) [6-7] on the parasitological characterization of the wastewater from the city El Jadida in Morocco, their impact on the coast (waters and sediments) and on the infantile population of the discharge area showed that pollution detected in the effluent of wastewater as well as at the coast of El Jadida, is in fact a problem for the environment of the city.

It is therefore necessary to take preventative measures to minimise this real danger: simple measures such as increasing public awareness about the contamination threats to more serious measures like the comprehensive treatment of wastewater before it is dumped into the ocean.

Our study aims to evaluate the physicochemical and bacteriological quality of wastewater rejected on the coast from the city of El Jadida between year 2011 and 2012 and to predict their impact on the global state of the environment and the state of the marine ecosystems in particular.

Our study also aims to evaluate the biological treatment of domestic wastewater in a submerged bacterial bed with packed plastic. This kind of procedure has a large surface adhesion of purifying microorganisms as well as the easy supply of the reactor [8, 9]. The advantage of this method lies in its low cost compared to other treatment systems, which

require large amount of energy. After determining the physicochemical characteristics of the raw domestic effluent and performing its pre-treatment by the passing through a settling tank, we evaluated the purification performance of the denitrifying biomass by measuring temperature, pH, NO_3^--N, NO_2^--N, COD, TKN-N and TP-P of the wastewater collected at the outlet of the bioreactor.

1.- Material and methods

1.1.- Wastewater Sampling

The wastewater that is dumped into the sea comes of domestic origin or a mixture with industrial wastewaters (95 and 5%). Samples of wastewater were collected (once per month) and stored at 4°C (fig. 1).

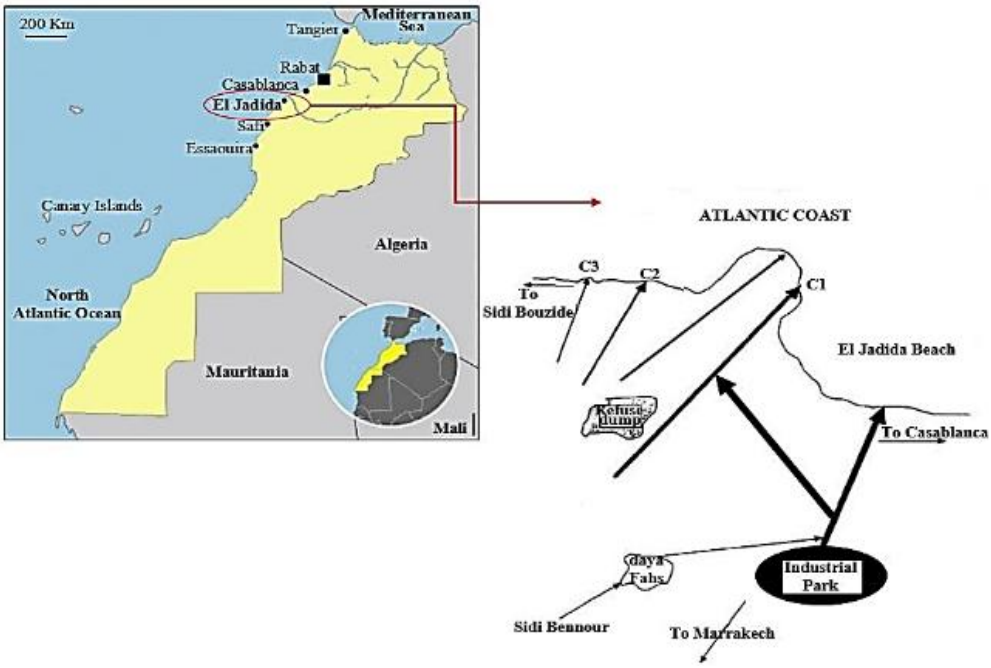

Figure 1.- Geographical situation of the site of study

1.2.- Wastewater Sampling

1.2.1.- Physicochemical parameters

The pH and temperature of the wastewater samples were measured at the collection site. Electrical conductivity, nitrate, nitrite, total phosphorus, orthophosphate, COD, BOD_5, NTK, TSS, VSS, were analyzed in the laboratory according to the methods prescribed in AFNOR [10].

1.2.2.- Bacteriological parameters

The bacteriological analysis of the various samples of wastewater consisted of an enumeration of the fecal coliform (FC), fecal streptococci (FS), spore sulfite-reducing anaerobes (SSR) [11].

1.3.- Experimental apparatus

Experimental device used for the treatment of this urban wastewater was composed of an anaerobic reactor.

The reactor built in steel, of capacity 64.5 L packed with PVC ring (tab. I) was used as the anaerobic filters.

Table I.- Characteristics of packing media

	
- Material	PVC
- Surface texture	smooth
- Outside diameter (mm)	25
- Height (mm)	25
- Thickness (mm)	2
- Porosity (%)	75
- Specific surface (m^2/m^3)	187
- Equivalent pore diameter (mm)	18

The reactor was 0.25 m in diameter and 1.05 m height (fig. 2). The substrate was pumped into the bottom of the reactors through a variable speed pump "PERCOM N-M" Peristaltic and flows upward through the porous medium. Sampling taps provided along the depth of the reactor allow extraction of samples for analysis at various stages of treatment.

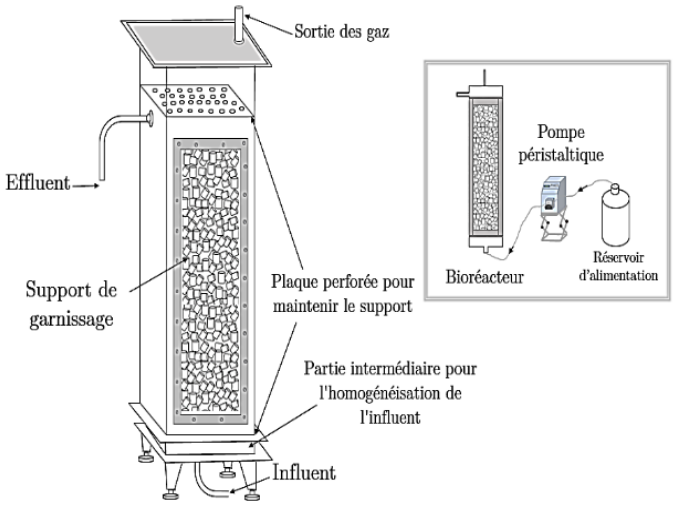

Figure 2.- Experimental anaerobic bioreactor system

2.- Results and discussion

2.1.- Wastewater characterization

The measure of temperature, pH and dissolved oxygen were achieved in situ. The wastewater was brown in colour. It was characterized by considerable pollutant of

suspended matter, volatile matters and high concentrations of BOD_5 and COD.

The mean values of the temperature recorded at each collector range between 23°C and 29°C (tab. II). The values of the wastewater temperature recorded are close to 30 °C limit considered a direct discharge into the receiving environment [12]. These values are below 35°C, considered indicative limit value for water for irrigation [12]. The values of pH vary from 5.9 to 7.2. The electrical conductivity is probably one of the simplest and most important for the quality control of wastewater. It reflects the overall degree of mineralization; it informs us about the salinity [13]. The maximum average value is recorded at the collector C_1 (5.52 mS/cm) and the minimum average value is recorded at least the collector C_2 (2.9 mS/cm). The conductivity values recorded at each collector exceeding 2 mS/cm [14]. Similarly, the mean values are higher than 2.7 mS / cm, considered limit direct discharge into the receiving environment [12].

The Ammonium ions derived from the degradation of animal protein (nitrogen cycle), domestic effluents (urea) and urban runoff [15]. The maximum ammonium observed at the collector C_1 is 282.9 mg/l and the minimum average value of 98.35 mg/l recorded at the collector C_2.

Table II.- The average values of physicochemical parameters of raw wastewater in the three collectors

	Collectors		
Parameters	**C_1**	**C_2**	**C_3**
T°C	29	26.7	24
pH	7.2	5.9	6.2
EC (mS/cm)	5.25	2.9	3.6
TSS (mg/l)	1067.2	524.1	855.9
VSS (mg/l)	611	174	320
NH_4^+ (mg/l)	282.9	98.3	103.1
NO_3^- (mg/l)	11	4.8	9
TKN (mg/l)	118.6	68.4	73
PO_4^{3-} (mg/l)	39	18	19.7
TP (mg/l)	20	14.2	17
COD (mg/l)	1512.1	691.2	811.6
BOD_5 (mg/l)	805.3	587.5	637.1

The major part of the organic phosphorus results from waste of protein metabolism and elimination in the form of phosphates in the urine by man and detergents [16]. The rates of orthophosphates at collectors vary between 18 mg/l and 39 mg/l. The Orthophosphate concentrations recorded at each collector are greater than 10 mg/l considered the limit of discharge into the receiving environment [12].

The COD allows appreciating the concentration of organic matter or mineral dissolved or in suspension in the water, through the quantity of oxygen necessary for their total chemical oxidation. The mean values of COD are vastly superior to 500 mg/l, considered as a limit direct discharge [12].

Table III.- The average values of bacteriological parameters of raw wastewater in the three collectors

	Collectors		
Parameters	**C_1**	**C_2**	**C_3**
CF (UFC/100 ml)	2.24×10^6	4.04×10^6	2.36×10^5
SF (UFC/100 ml)	2.80×10^5	1.94×10^5	1.13×10^5
SSR (UFC/100ml)	4.60×10^5	3.30×10^5	1.77×10^5

COD values recorded at the collector ranged from 691.22 mg/l and 1512.1 mg/l.

The suspended solids are all inorganic and organic particles contained in the wastewater [13]. The effluents analyzed are characterized by a high concentration of suspended matter vary between 524.13 and 1067.2 mg/l, higher than 50 mg/l considered the limit discharge into the receiving environment [12].

For BOD_5/COD higher than 0.4, the wastewater biodegradability is high, and consequently the biological process is the most suitable for the treatment of these effluents [17]. However, at BOD_5/COD ratios lower than 0.30, physical –chemical processes are usually more effective than biological treatments [18]. The values of BOD_5/COD ratio recorded at each collector are presented in the following table IV.

Table IV.- The values of BOD_5/COD ratio of raw wastewater in the three collectors

	BOD_5/COD		
	Minimum	**Maximum**	**Average**
Collector C_1	0.52	0.56	0.53
Collector C_2	0.83	0.86	0.85
Collector C_3	0.76	0.81	0.78

The table IV shows that all wastewater has high biodegradability. These values are in the good range of activity of the microorganism.

The results of the bacteriological analyses of wastewater of three collectors reveal the presence of the indicator germs of faecal contamination as well as certain pathogenic germs (tab. III). The fecal coliform load average (CF) varies between $2.80*10^5$ and $2.24*10^6$ (CFU/100 ml). In terms of bacterial load, the collector C_1 is slightly more concentrated than collectors C_3 and C_2. The fecal staphylococci (SF) are $4.04*10^6$ (UFC/100 ml) in the collector C_1 and $3.30*10^5$, $1.94*10^5$ (UFC/100 ml) in the collector C_3 and C_2 respectively.

The value of the enumeration of the spore of sulphite-reducing anaerobes in the wastewater is superior at the collector C_1 ($2.36*10^5$ UFC/100 ml).

The result of the enumeration of the germs of fecal contaminations is in good agreement with the bibliographical data relative to the state of bacterial contamination of urban effluents [19-20-21], but it far exceeds the standard set by the World Health Organization to 1000 CF/100 ml [22].

2.2.- Treatment

2.2.1.- Preliminary analyses

The composition of the raw wastewater, intended to supply the bioreactor is illustrated in Table V.

Table V.- Characteristics of raw wastewater

Parameters	Ave.	Max.	Min.	Moroccan project standards
pH (25.5°C)	6.9	7.2	6	6.5 - 8.5
TSS (mg/l)	441	494.7	383.1	250 - 500
COD (mg/l)	813.3	989	631.5	500 - 800
BOD_5 (mg/l)	451.1	563	322	200 - 400
N-TKN (mg/l)	153.1	166	132.3	30
$N\text{-}NO_3^-$ (mg/l)	12.3	13.87	10.4	-
$N\text{-}NO_2^-$ (mg/l)	7.53	8.12	6.8	-
P-TP (mg/l)	14.5	16.6	12.2	10

2.2.2. - Wastewater treatment efficiency

The measure of temperature, pH and dissolved oxygen were achieved in situ.

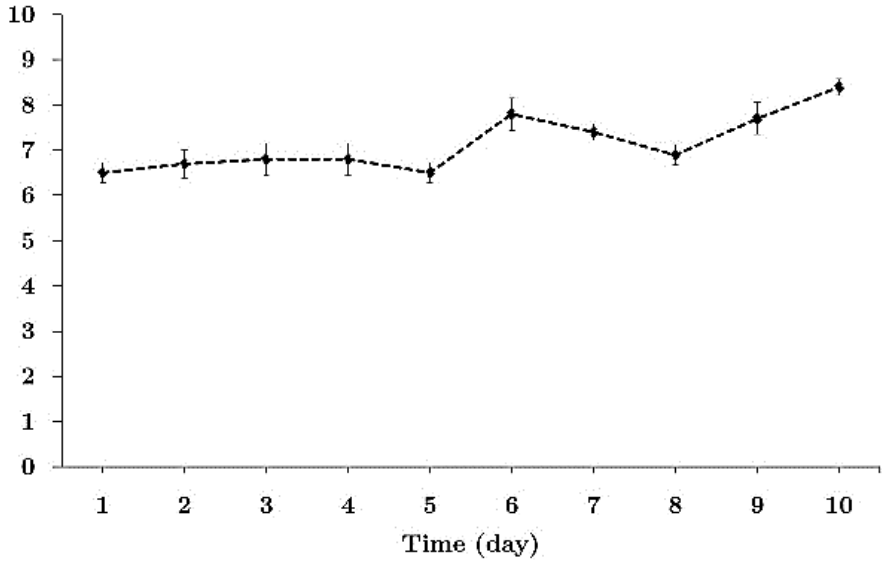

Figure 3.- pH evolution according to the time

The pH varied from 6.5 to 8.4. These values are in the good range of activity of the microorganisms and are favorable for a biological treatment [23]. The temperature was in the average of about 28.9°C and it supported the development of the microorganisms, which take part in the biological treatment of wastewater.

We tested on the scale laboratory a biological treatment. Before its introduction in the reactor, the effluent was analyzed. The effluent was rich in biodegradable organic matters, and was constituted of nutritive substances.

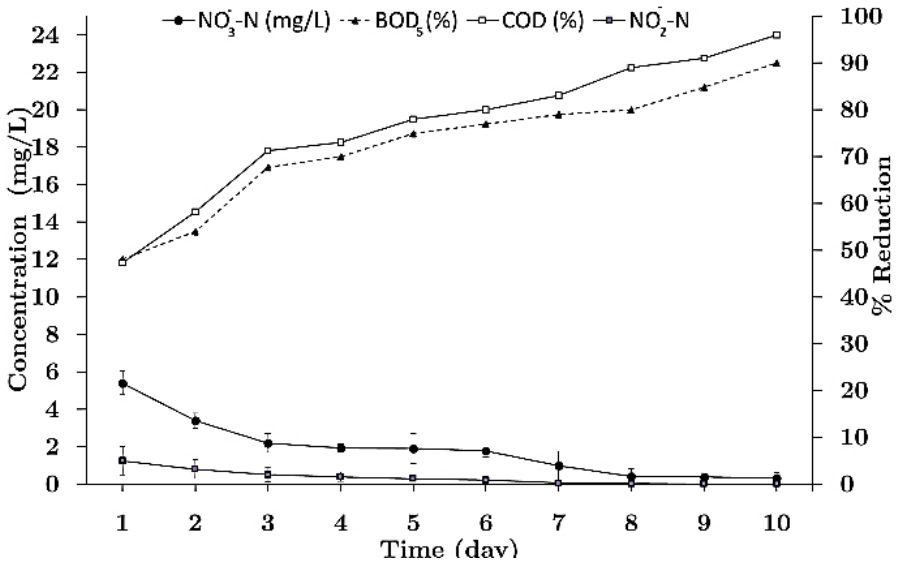

Figure 4.- NO_3^- -N, NO_2^--N, BOD_5 and COD evolution according to the time

Figure 4 shows that the bacterial population has selected very high denitrifying capacity marked by the virtual elimination of nitrates in the effluent after 3 days. These results confirm those reported by [23], working on the combined removal of organic matter and nitrate content in a synthetic wastewater by denitrifying microorganisms optional or strictly anaerobic, said a report COD/ NO_3^--N 4 and 5 and a high concentration of nitrates and are sufficient for a good denitrifying activity.

The bio-denitrification of the effluent is accompanied by the reduction of COD and BOD_5 whose abatement rate is 71.2% and 67.71% after 3 days of treatment in the bioreactor. This reduction of BOD_5 and COD could be explained by the wealth of wastewater readily biodegradable organic matter (BOD_5/COD = 0.57), which is a source of assimilable carbon in biomass heterotrophic denitrification. It is therefore an endogenous biological denitrification using organic carbon present in the domestic effluent as the electron donor without resorting to an exterior intake, leading to savings in the cost of carbon substrate to provide. In this regard, many studies of denitrification of waste water loaded with nitrates were performed using the early organic molecules from an external supply such as sugars, alcohols or organic acids [24, 25, 26, 27]. However, the cost of the carbon source to provide is a drawback. Thus in recent years, exploitation of biodegradable organic matter is present in raw sewage, or sludge in treatment plants is favored [28].

Figure 5 shows that for total phosphorus, a percentage removal of 97.69 % is obtained after 10 days of operation of the bioreactor thereby reducing the initial concentration of 13.87 mg/l to 0.32 mg/l . Phosphorus is removed by bacterial assimilation. This reduction is even more important than high pH and the optimum range would be between 7.7 and 9.7 [29]. We noticed an important reduction in total Kjeldahl nitrogen, a percentage removal of 89.3 % is obtained after 10 days.

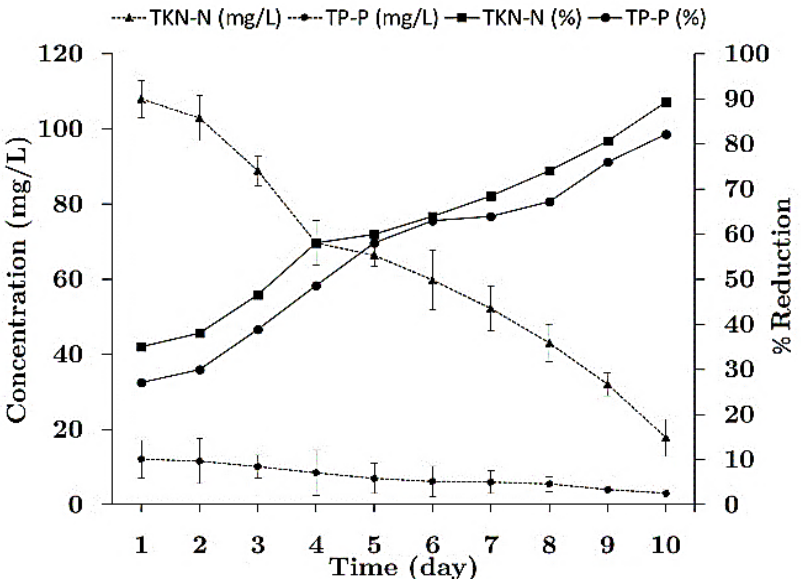

Figure 5. - TKN-N and TP-P evolution according to the time

Conclusion

From the data collected from this research, the physicochemical and biological parameters monitored in point C_1, C_2 and C_3 showed high levels of all the parameters compared to Moroccan standards. This must be as a result of the nature of wastewater. Collector C_3 showed the highest concentration of the physicochemical and bacteriological parameter, while Collector C_2 shows the lowest values.

The bacterial bed colonized by denitrifying flora may be a biological treatment system that is both effective and beneficial. Effective because it helps meet regulatory requirements imposed by the Moroccan standards on wastewater discharges, advantageous as it allows saving energy and space, and a small amount of sludge produced in comparison with other treatment systems such as activated sludge.

Acknowledgements

The authors wish to thank the Hassan II Academy of Science and Technology (Rabat, Morocco) for the financial support of this study.

References

[1].- OMS (Organisation Mondiale de la Santé), 1989.- Technical Report Series No 778. Health guidelines for the Use of Wastewater in Agriculture and Aquaculture, Rapport d'un Groupe Scientifique de l'OMS. Genève: Organisation Mondiale de la Santé 3: 119-124.

[2].- Prost A., 1991.- L'évolution des Normes d'Hygiène pour l'Emploi des Eaux Résiduaires, Session Spéciale N°5, Réutilisation des Eaux Usées, VII^{ème} Congrès Mondial des Ressources en Eau, Rabat, Maroc:.21-26.

[3].- Sadif N., Mountadar M., 2006.- Treatment of Mills Wastwaters by Oxydation and

Coagulation. Phys. Chem. News., 29p.

[4].- Haidar A., Echchelh A., Kassou O., Chaouch A., 2010.- Study of wastewater treatment of oil refinery samir sidi kacem (morocco). Phys. Chem. News, 52p.

[5].- Salama Y., Mountadar M., Rihani M, Assobhei O., 2012.- Evaluation Physicochimique et Bactériologique des Eaux Usées Brutes de la Ville d'El Jadida (Maroc). Science Lib., 4, N°120906, 1-14p.

[6].- Lamghari M. F.Z., Assobhei O., 2007.- Health Risks of Raw Sewage with Particular Reference to Ascaris in the Discharge Zone of El Jadida (Morocco). Desalination., 215: 120-126.

[7].- Lamghari M. F.Z., 2005.- Caractérisation Parasitologique des Eaux Usées d'El Jadida, leur Impact sur le Littoral (Eaux et Sédiments) et sur la Population Infantile de la Zone de Rejet. Thèse d'Etat. Faculté des Sciences, El Jadida, Maroc., 200 p.

[8].- Zaouche M., 1981.- La Pollution de l'Eau par les Etablissements Industriels, R. I. A., 291: 73–81.

[9].- Hamdani A., 2002.- "Caractérisation et Essais de Traitement des Effluents d'une Industrie Laitière: Aspects Microbiologiques et Physicochimiques ". Thèse de Doctorat, Faculté des Sciences d'El Jadida, Maroc, 250 p.

[10].- AFNOR., 1999.- Techniques, la qualité de l'eau, Association Française de Normalisation. Recueil des Normes Françaises, Eaux, Méthodes d'Essais, Paris, France, 135 p.

[11].- AFNOR., 2001.- (Agence Française de Normalisation), Eaux-Méthodes d'Essai. In : Recueil de Normes Françaises (6ème édition), La Défense, Paris, 624 p.

[12].- MEMEE (Ministère de l'Energie, des Mines, de l'Eau et de l'Environnement du Maroc), 2002.- «Normes Marocaines, Bulletin Officiel du Maroc», N°5062 du 30 ramadan 1423, Rabat.

[13].- Guamri Y. El., Belghyti D., 2006.- Etude de la qualité physicochimique des Eaux Usées Brutes Rejetées dans le Lac Fouarat. Journal Africain des Sciences de l'Environnement, 1: 53-60.

[14].- JORA (Journal Officiel de la Republique Algerienne), 2003.- Normes de Rejets dans le Milieu Récepteur., 46: 7-12.

[15].- Erickson E., Auffarth K., Henze M., Ledin A., 2002.- Chacteristics of grey wastewater. Urban Water, 4: 85-104.

[16].- Du Chaufour P., 1997.- Abrégé de Pédologie: Sol, Végétation et Environnement. 5ème édition, Masson, 300p.

[17].- Metcalf E., 2000.- Wastewater Engineering: Treatment, Disposal and Reuse, Inc. 3. Cd., 1334 p.

[18].- Alvarez-Vazquez H., Jefferson B., Judd S.J., 2004.- Membrane Bioreactors vs Conventional Biological Treatment of Landfill Leachate: A Brief Review, J. Chem. Technol, Biotechnol., 79: 1043-1049.

[19].- Baylet R., Mandin G., 1978.- Lagunage et Virologie des Eaux Usées. La Technique de l'Eau et de l'Assainissement., 383: 19-22.

[20].- Boutin P., 1982.- Implication Sanitaire de l'Assainissement des Petites Collectivités et l'Assainissement Autonome. XVIème Journée de l'Hydraulique, (Nantes): 14-15 et 16.

[21].- ONEP (Office National de l'Eau Potable), 1999.- Caractérisation Quantitative et Qualitative des Eaux Usées (Maroc).

[22].- WHO (World Health Organization), 1989.- Use of Wastewater in Agriculture and Aquaculture. Technical Report Series, 778 p.

[23].- Gomella C., Gueree H., 1978.- Le Traitement des Eaux Publiques Industrielles et Privées, Ed Eyrolles, 108-112 p.

[24].- McCarthy P.L., Beck L., Amant P., 1969.- Biological Denitrification of Wastewaters by Addition of Organic Materials Proc. 24th Indust. Waste Conf. Purdue Univ. Eng. Ext.: 1271–1285.

[25].- Akunna J.C., Biseau C., Moletta R., 1993.- Nitrate and Nitrite Reductions with Anaerobic Sludge Using Various Carbon sources : Glucose, Glycerol, Acetic acid, Lactic acid and Methanol. Wat. Res., 27: 1303-1312.

[26].- Ghoualem H., Khouider A., 2007. - Biological Treatment of an Urban Sewage and Analyses of Sediments. Desalination., 206: 507–512.

[27].- Lie E., Welander T., 1994.- Influence of Dissolved Oxygen and Oxidation-Reduction Potential on the Denitrification Rate of Activated Sludge. Water Science and Technology., 30: 91-100.

[28].- Khoudir A., Lamari H., Louehli S., 1997.- Traitement Biologique en Lit Fixe d'une Eau Usée de Laiterie, Eau Ind. Nuisances., 203: 37-39.

[29].- De La Menardiere M.A., 1991.- "Contribution à la Maîtrise de la Déphosphatation des Eaux Résiduaires Urbaines ", Thèse de doctorat, Université de Rennes I, 234 p.