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ARTICLE

Assessment of the Pollution Load by Raw Waste Waters from Mechraa BelKsiri (Morocco)

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ABSTRACT

Population growth and the industrial production modernization have generated considerable water needs. This consumption has led to a disproportionate discharge of untreated wastewater, directly into receiving environments (Oceans, Rivers, Lakes, Surfaces waters, etc.) and leads to thus promote the spread of waters-borne diseases. The main objective of our present work is the description of the pollutant load of wastewater from the city of Mechraa Belksiri (Kénitra - Morocco), to classify them and identify their composition and their intensity to seek an adequate treatment allowing their subsequent reuse and reducing their dangerousness on their receiving environment Oued Sebou. The analysis of temperature, pH, redox potential, electrical conductivity, dissolved oxygen and salinity are recorded in the field using a portable multiparametric analyzer. The wastewater samples intended for analysis in the laboratory were preserved following the general conservation protocol and handling of samples according to ISO 5667/3. Total Suspended Solids (TSS) are measured by filtration. The analysis of the BOD5 is determined using a BODmeter and the COD, according to DIN 38409-H52. Wastewater from Belksiri town has a pH of 7.2 and an average temperature of 20.5°C and an electrical conductivity of 3145 µs/cm. The average concentration of oxygen is very weak at 0.35 mg/L. Wastewater is loaded with organic matter estimated by Suspended Solid matter (average 446 mg/L), BOD5 (280 mg/L) and COD (557 mg/L). The

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overall pollutant load of wastewater presents satisfactory biodegradability and is well prepared for suitable biological treatment with activated sludge plant.

Keywords: Wastewater; Analysis; Pollution; BOD; COD; Belksiri; Morocco

1. Introduction

Water is the origin of life on earth. It is one of the most esteemed natural foods that must be protected from all kinds of pollution. Water is found in seas, oceans, rivers, lakes, ice, etc.

In Morocco, water resources are facing strong climatic and human pressures. The situation is all the more serious because it is a country with a water deficit (**Figure 1**).

Morocco's water resources are limited. Renewable water resources are estimated at 29 billion m^3/year, or 1044 m^3 per inhabitant per year in 1998 (**Tables 1** and **2**) [1]. In 2020, it was only 786 m^3 per inhabitant per year [2].

Indeed, reading the United Nations World Water Development Report, several states, including ours, are already in a deficit situation. Due to a volume of water that can be mobilized of barely 971 m3/inhabitant/year, Morocco is ranked 155 out of 180 countries [3].

They are also subject to extreme cyclical variations. A succession of acute drought cycles has significant consequences on the natural environment and the national economy, particularly agriculture (fall in cereal production, etc.).

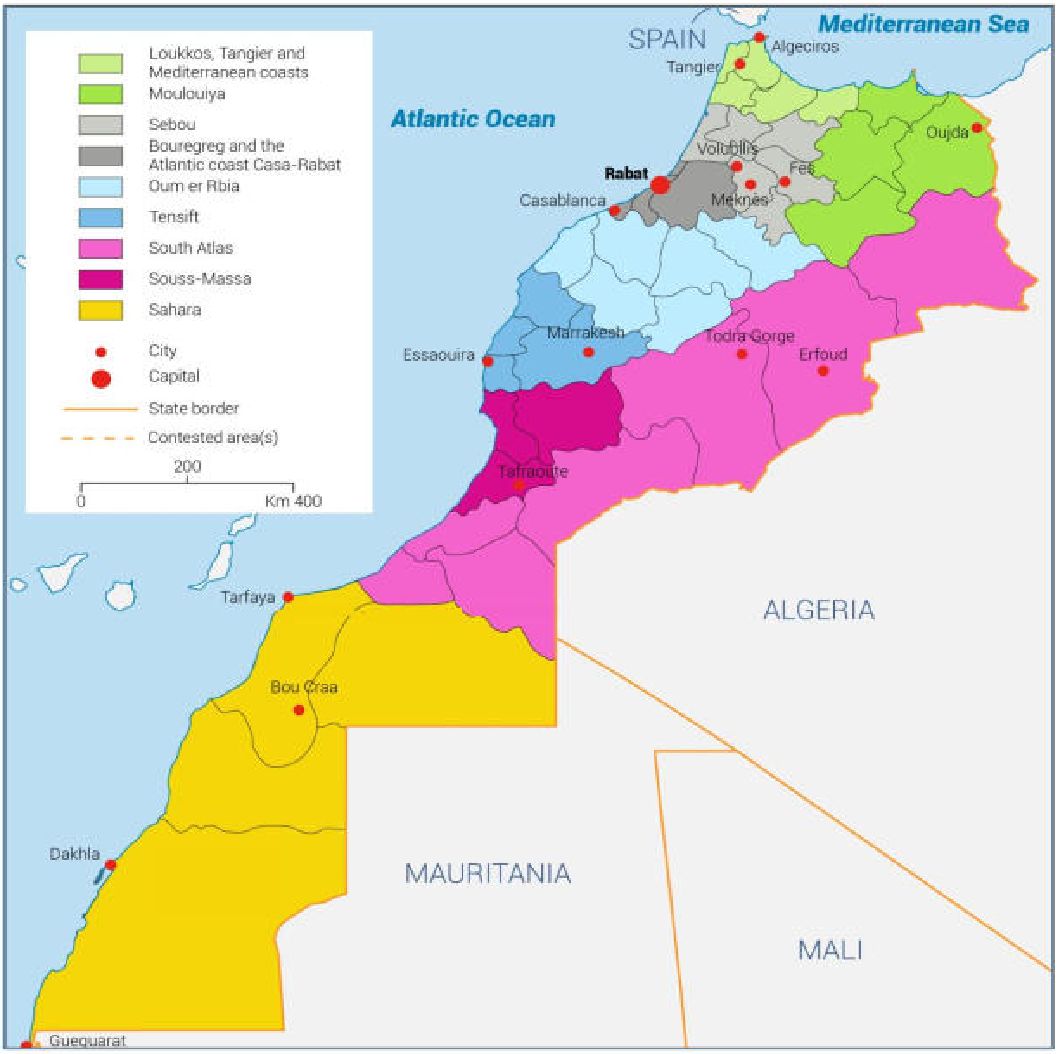

Figure 1. Map of Morocco (1 cm = 100 km).

Table 1. Surface Water Resources by Basin in Morocco [1].

Basins	Surface		Average Surface Flow	
	Km²	**% of the Country's Total Area**	**Mm³**	**% of Total**
Loukkos, Tangier and Mediterranean Coastal	20,600	2.9	4,119	21.7
Moulouya	57,700	8.1	1,656	8.7
Sebou	40,000	5.6	5,600	29.4
Bou Regreg	20,000	2.8	830	4.4
Oum Er Rbia	35,000	4.9	3,680	19.4
Tensift	37,700	5.3	1,110	5.8
Souss-Massa	35,400	5	701	3.7
South Atlas	164,190	23.1	1,300	6.8
Sahara	300,660	42.3	30	0.15
TOTAL	**710,850**	**100**	**19,026**	**100**

Table 2. Groundwater Resource Potential of Morocco [1].

Basins	Exploitable Water Potential (Mm³/ an)	Current Levies (Mm³)	Remaining Exploitation Possibilities
Loukkos, Tangier and Mediterranean coastal	226	140	86
Moulouya	779	270	509
Sebou	453	380	73
Oum Er Rbia	326	500*	-
Bou Regreg	126	510*	-
Tensift	458	640*	532
Souss-Massa	240	230	-
South Atlas	762	-	
Sahara	16		
Diffuse Flow	614		
TOTAL	**4,000**	**2,670**	**1,200**

(*) overexploitation.

In Morocco, water control is vital due to the difficult climatic and hydrological context. Precipitation regimes vary from city to city while remaining dominated by significant spatial and temporal irregularity, both seasonally and interannually. The alternation of sequences of years of high hydraulicity and sequences of severe aridity, which can last several years, is a striking characteristic of Morocco's climatic and hydrological regimes.

Annual precipitation averages reach more than one meter (1 million m^3 per km^2) in the high mountains in the northwest of the country, and less than three centimeters (300,000 m^3 per km^2) in the southern plains and deserts which cover approximately 85% of the Kingdom's territory.

These precipitations generally occur in two rainy periods, the first in autumn and the second in winter. The number of days of precipitation varies from about 30 days in the south of the country to almost 70 days in northern Morocco.

Dry years record very low annual precipitation that can decrease to less than 60 to 75% of normal, generally not producing significant water inputs. Thus, the rainfall heights ensured in dry years of ten-year and centennial frequency are estimated respectively to nearly 115 mm (82 billion cubic meters) and 75 mm (53 billion cubic meters) against 211 mm (150 billion cubic meters) in an average year [1].

Water, already scarce, is also subject to exponential changes in needs, due to the rapid increase in population, the rise in living standards, the expansion of industrial production and the development of irrigated agriculture. These pressures on water resources are accompanied by a growing and increasingly alarming degradation of the quality of these waters.

Pollution, soil erosion and solid transport are the main constraints that oppose the rational management and sustainable development of water resources in Morocco [4]. In addition, these resources are undergoing degradation mainly due to the discharge of domestic, agricultural and industrial wastewater.

The harmful effects of water pollution are multiple, but no appropriate measures are taken. In particular, its role in the destruction of animal and plant populations, and its role in the spread of communicable diseases such as typhoid or paratyphoid fevers, amoebiasis, giardiasis or ascariasis which are due either to direct contamination in bathing areas or by the consumption of contaminated agricultural products (fish, shellfish, vegetables, etc.).

Integrated water resource management is therefore essential to support sustainable development that can reconcile socio-economic development and environmental preservation.

Like most countries on the southern shore of the Mediterranean Sea, our country, with a predominantly semi-arid to desert climate over most of its territory, must face the problems of development and sustainable management of its water resources.

Indeed, although it has large mountain ranges, a wide maritime opening and a great geographical disparity, these water resources are limited in the face of a strong demand resulting from population growth, the improvement of standard of living, the development of various industries and irrigation extension.

Water consumption continues to grow under the pressure of modern civilization's considerable needs for raw materials. This leads to a massive discharge of untreated wastewater directly into receiving environments, thus promoting the spread of several waterborne infections and the contamination of surface and groundwaters [5].

Our study consists of evaluating the annual pollutant load of domestic wastewater generated by the urban population of the city of Belksiri and aims to contribute to the establishment of a very useful technical reference in the management of the sanitation sector at city scale.

Faced with these constraints, Morocco has put in place a technological arsenal and doubled its efforts since the 1960s to increase its water potential in order to cope with demographic growth and ensure its socio-demographic and economic development. In addition, the limited water potential requires, in parallel with the continuation of the mobilization effort, control of extreme hydrological phenomena (floods and droughts) by establishing master plans for water resource management at the watershed level, adopting a water needs management plan in order to meet water needs and ensure the rules for the beneficial use of these water resources, and improving the infrastructure performance (dams, water transfer structures, drilling).

In this work, we were interested in the physicochemical analysis for the evaluation of wastewater that alters the quality of the Sebou wadi at the level of the city of Mechraa Belksiri (**Figure 2**).

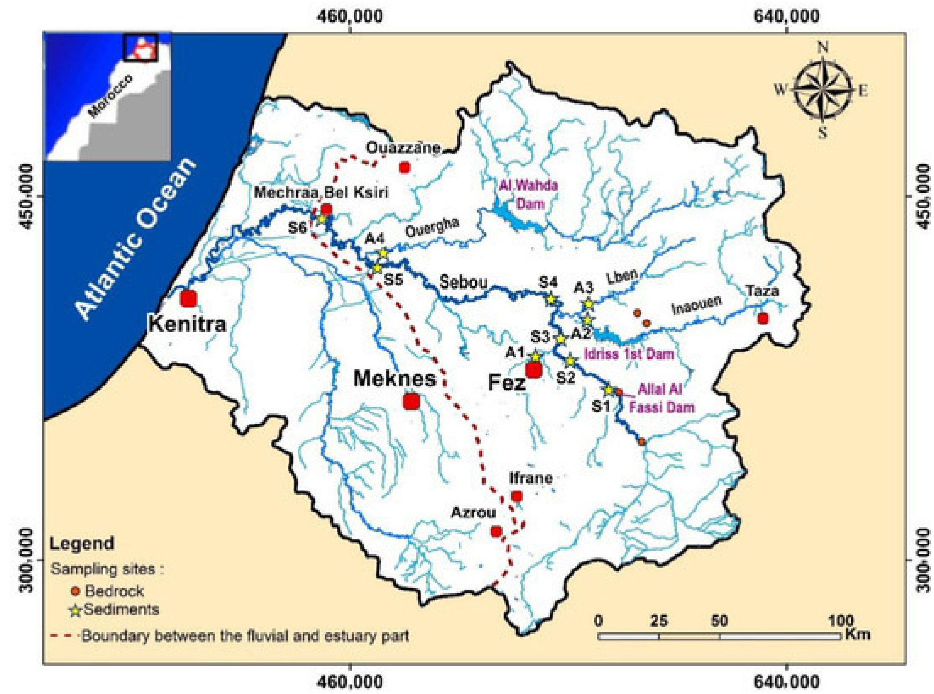

Figure 2. Illustration of Sebou Basin (Gharb Morocco) (1 cm = 20 km).

The choice of the study of wastewater flowing into the Sebou River as the object of investigation for the present work was justified, on the one hand, by the socio-economic role played by the Sebou river in the Gharb plain, in particular its use for the irrigation of various agricultural crops, and on the other hand, by the nature of raw wastewater, which can be vectors of many diseases in humans and animals, as well as by the significant pollution pressure it faces (domestic, hospital, industrial and agricultural).

Indeed, Oued Sebou receives polluting discharges from the city's agglomerations and industrial units, processing of agricultural products and dehydration of vegetables, Sunabel and Sunacas sugar factories, all these units are installed on the bank of the Sebou wadi (**Figure 3**).

Furthermore, the excessive use of fertilizers and pesticides in this plain with high agricultural potential only increases the pollution of fruits and vegetables and increases the risk of contamination of surface water and sometimes even groundwater in this region.

This work sets the following objectives:

- Study of the physicochemical quality of wastewater, by spatio-temporal monitoring of several physical and chemical variables.
- Identification of the main compounds responsible for pollution of urban effluents and appropriate methods for depolluting them.

Figure 3. Illustration of a Sewage Collector Discharging Directly into the Sebou Wadi.

2. Environment and Study Methods

The city of Mechraa Belksiri is located in the northwest of the Moroccan territory, at 34°34′ N and 5°57′ W. The city is 47 km north of the city of Sidi Kacem and 80 km east of the city of Kenitra (**Figure 2**).

The BelKsiri region (**Figure 2**) has surface (Sebou River) and underground (Gharb Tablecloth) water resources [6]. The population of the city is around 27,630 inhabitants [7]. The average daily consumption value of drinking water is around 3012 m^3/day [8].

The town of Belksiri has a separative type sanitation system. The network was built in the early 1980s. This network serves 65% of the urbanized perimeter of the center. Wastewater from the remaining population is treated by individual sanitation systems (septic tank) [9].

The wastewater network is structured around two watersheds draining the entire city center and P.A.M districts. and Massira and the discharges are made into Wadi Sebou. Monthly wastewater sampling was carried out from June to May at the urban wastewater outlets of the city of Belksiri [10].

According to DIN (Deutsche Industrie Norms): "wastewater is any water that has been altered by any use whatsoever, as well as any water that reaches the sanitary network [11]. For the World Health Organization, water pollution can be defined as a denaturation that results from human activity and makes water less suitable for the use for which it was suitable in its natural state [12].

The wastewater samples (**Figure 3**) intended for physicochemical analysis were preserved following the general conservation protocol for the conservation and handling of samples according to ISO 5667/3 and Good practice guide [13,14].

Recording of temperature, pH, redox potential, electrical conductivity, dissolved oxygen and salinity was carried out on site in the field using an Inolab WTW portable multiparameter pH meter, a Thermo ORION 3 STAR conductivity meter and a CONSORT 535 model multiparameter analyzer.

Measuring BOD5 standard T90-103, is determined by the manometric method, the measurement is done using a BODmeter Oxitop^R IS6 manometer [15,16]. The principle is as follows:

The sample is introduced into a bottle containing a reservoir (capsule) of soda and connected to a digital manometer. During the incubation (5 days and at 20 °C), the bacteria consume oxygen to degrade the organic substances and produce CO_2. The absorption of CO_2 by the soda produces a depression recorded by the manometer. This variation corrected by a factor linked to the sample volume allows the calculation of the BOD measured in mg/l of dissolved oxygen (**Figure 4**).

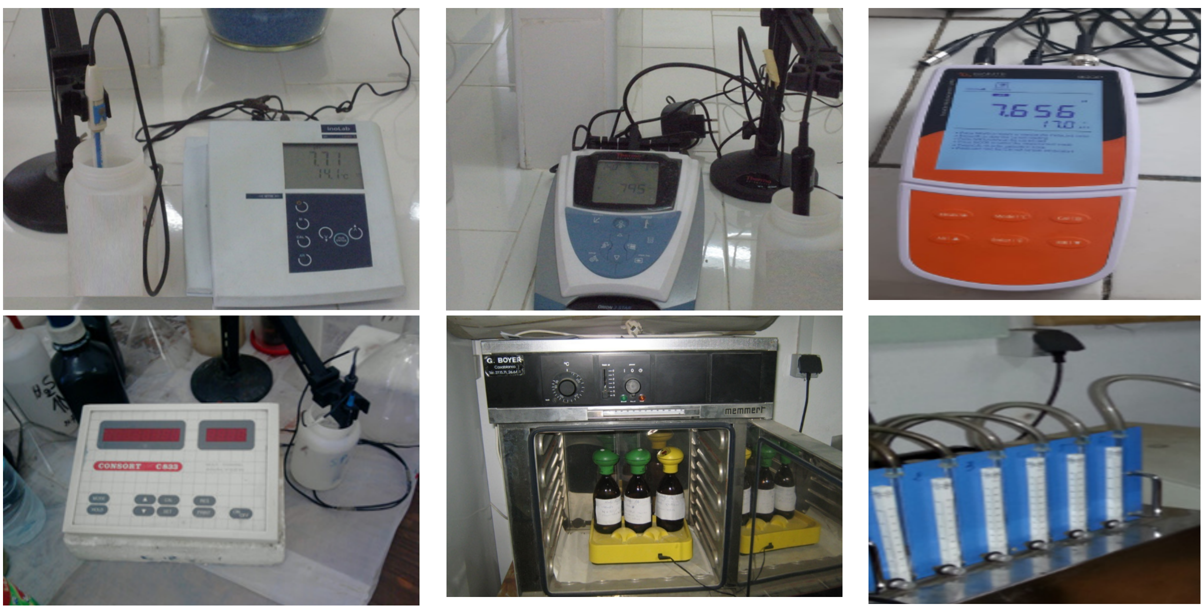

Figure 4. Methods of Physicochemical Analysis of Wastewater.

The Chemical Oxygen Demand code COD T90-101 is determined using the protocol DIN 38409-H52 by the oxidation of reducing substances contained in water by an excess of bichromate of potash at a temperature of 148°C [17], in a boiling acid solution, in the presence of a catalyst (silver sulfate) and a complexing agent of chloride ions (mercury sulfate) [18,19].

Suspended solids Matters (SSM) are measured by filtration of 100 ml of raw wastewater through a 0.45 µm mesh cellulose filter [20]. The filter with its contents is completely dried in an oven at 105°C for 24 hours. The difference in weight between the dried and wet filter gives the value of suspended solids (mg/l) in the wastewater [21].

3. Results

3.1. Result of Physicochemical Analyzes of Wastewater

The results of the physicochemical analyses of urban effluents from the town of Mechraa BelKsiri are grouped in **Table 3** and show that:

The average (21.5 °C) and extreme values of temperatures (17.3–26 °C) measured on the waters of the selected effluents are less than 30 °C, a value considered as a threshold for direct diversions in nature [22]. Similarly, these measurements are lower than 35 °C, the value authorized for the reuse of wastewater to irrigate crops [22].

The hydrogen potential averages of wastewater are relatively neutral (6.8–7.4) and fall within the range of Moroccan standards for the level of pollution of water intended for irrigation and also within the range of direct discharges which is set from 6.5 to 8.5 [22].

Electrical conductivity varies between (2400–3680) and the recorded averages are 3480 µS/cm and 2816 µS/cm. It should be noted that these averages are higher than the limits set for direct diversions of raw wastewater into nature and for water used for irrigation [22]. The high values are due to the increase in the content of ions and salts in groundwater and drinking water in the region, which is around 2350 µS/cm [23,24].

Salinity analysis revealed that there is a slight fluctuation in its content during the year with an average of around 1.67 g/l and 1.1 g/l. Salinity still remains lower due to dilution by rainwater.

The averages of the Redox Potential −0.10 mV and +0.04 mV are recorded. Wastewater with a negative potential has a reducing power favoring eutrophication of the environment, on the other hand there is an oxidizing power in the wastewater due to a significant contribution of O2 by rainwater drained by the network of the pseudo-separative system [25].

At the collector level, the average value of oxygen content varies from 0.28 to 0.42 mg/l. The average values observed at the two collectors are close to each other and do not exceed 0.5 mg/l. This makes the wastewater of the city of Belksiri undersaturated with oxygen, which accelerates eutrophication and the release of toxic gases.

Table 3. Results of Physical and Chemical Parameters of Wastewaters of Belksiri Effluent (Kenitra-Morocco).

	T°C	pH	EC (µs/cm)	Salt (mg/l)	Redox (mV)	O_2 (mg/l)	BOD_5 (mg/l)	COD (mg/l)	SSM (mg/l)
Sampling campaign 1									
Minimum	18	7.1	3,280	1.6	−0.5	0	220	460	320
Average	21.5	7.2	3,480.83	1.67	−0.1	0.28	282.5	573.33	419.17
Maximum	26	7.3	3,680	1.7	0.1	0.6	330	640	480
SD	3.27	0.08	123.84	0.05	0.16	0.2	35.45	63.15	57.91
Number	12	12	12	12	12	12	12	12	12
Sampling campaign 2									
Minimum	17.3	6.88	2,400	1.1	−0.1	0	250	490	430
Average	19.4	7.19	2,816.67	1.27	0.04	0.42	278.58	541.25	474.17
Maximum	22	7.4	3,400	1.5	0.2	0.9	310	600	520
SD	2.05	0.18	387.49	0.15	0.07	0.33	14.13	27.64	38.95
Number	12	12	12	12	12	12	12	12	12

The BOD5 values recorded are between 220 and 330 mg of O2/l and between 250 and 320 mg of O2/l with an average value of 282.5 mg of O2/l and 278.58 mg of O2/l. The average value of all the collectors in Belksiri city is higher than that found in Marrakech (240 mg of O2/l) [26], (137 mg of O2/l) [27], and Souk Elarba (162.08 mg/l) [28]. On the other hand, it is lower than that recorded in Kenitra (335.5 mg/l) and in Sanaa Yemen (1137 mg/l) [29,30].

The median measurement in all collectors of Belksiri city is higher at 100 mg/l recognized as threshold value for direct effluents [22]. Therefore, these discharges are classified as very bad referring to surface water standards [22].

The recorded measurements of chemical oxygen demand (COD) are between 460 to 640 mg/l and 490 to 600 mg/l with an average of 573.3 and 541.2 mg O2/l. The average of all collectors in Mechraa Bel ksiri city is higher than 500 mg/l recognized as a threshold value for direct effluents [22]. In addition, these discharges are very dirty (> 80 mg/l) with reference to Moroccan standards for surface water [22].

The average COD values recorded in the wastewater of the two collectors studied in the city of Belksiri show that these measurements are lower compared to Sanaa (Yemen) (1888.53 mg/l) and Marrakech (2983 mg/l) [26,30]. On the other hand, they are higher in Ouarzazate (571.3 mg/l) [31], and those recorded in Kenitra (500.7 mg/l) [29], and in Souk Elarba (235.2 mg/l) [28].

The observation of the results shows that the average value of suspended solids matter (SSM) measured in wastewater is approximately 419.17 to 474.17 mg/l. The recorded values are higher than 50 mg/l set as thresholds for any discharge of effluent directly into the natural environment [22].

Our results are lower than those found in Yemen (813.5 mg/l) [30]; more or less similar to those of Kenitra and higher than those found in Marrakech (194.34 mg/l), and in Souk Elarba (224.25 mg/l) [26,28,29].

3.2. Discussion

The variables chosen to assess surface water quality are parameters specific to organic, nitrogenous, phosphorous or bacterial pollution. These parameters indicated in the table grid establish five quality classes according to the uses for which these waters are intended (**Table 4**) [1].

Due to their BOD5, COD and MES loads, the wastewater from Mechraa Bel Ksiri remains comparable to the general characteristics (**Table 5**) of urban wastewater found by other authors [29–34].

The qualitative assessment of Moroccan water resources is carried out regularly at the level of the main rivers and aquifers (**Table 6**) in order to:

Table 4. State of Surface Water Quality in Morocco [1].

Parameters \ Quality Classes	Excellent	Good	Average	Bad	Very Bad
Dissolved Oxygen (mg/l)	>7	7–5	5–3	3–1	<1
BOD5 (mg/l)	<3	3–5	5–10	10–25	>25
COD (mg/l)	<30	30–35	35–40	40–80	>80
Ammonium (mg/l)	<=0.1	0.1–0.5	0.5–2	2–8	>8
Total Phosphorus (mg/l)	<=0.1	0.1–0.3	0.3–0.5	0.5–3	>3
fecal Coliforms	≤20	20–2000	2000–20000	>20000	-

Table 5. General Characteristics of Urban Wastewater According to Authors [32–34].

Parameters	Average Concentration (mg/l)	Daily Quantity Discharged/Inhabitant (g)
MES	300–600	130
MVS	120–400	100
DBO5	100–500	80
DCO	200–1200	200
COT	50–300	40
N total	50–100	15
P total	10	5

Table 6. Comparison with Some Rivers Located Immediately Downstream of the Discharges of Wastewater [1].

Bassins	Oued	Stations	Date	O_2 mg/l	BOD5 mg/l	COD mg/l
Loukkos	Martil	Aval rejet touabel	28/03/2001	2.4	80	320.6
Moulouya	Isly	Aval rejet Oujda	16/04/2001	0	240	764
Sebou	Sebou	Dar Elarsa	20/04/2001	0.16	60	378.2
Oum-Erbia	Oum-Erbia	Aval rejet Tadla	30/06/2000	0	80	205
Tensift	Tensift	Aval rejet Marrakech	02/11/2000	1.8	18	86
Ziz-Guir et Rhéris	Ziz	Aval confl Ziz/lahmer	18/05/2001	0	200	864

- establish a situation of the quality of water resources;
- specify the trends in its evolution;
- define the main causes that affect it [1].

This information is used to establish the policy for restoring and safeguarding water quality and for decision-making in water resources planning and management.

Water quality assessment is carried out using a measurement network comprising:

- For surface water, 60 main stations, 113 secondary stations, and 36 stations at the level of dam reservoirs.
- For groundwater, 535 sampling stations, spread over 45 aquifers.

With this system, nearly 30,000 physicochemical analyses are carried out annually. The overall quality of surface water observed is good at 46% of the measuring stations, and average at 9%. On the other hand, it is degraded at 45% of the sampled stations.

Watercourses have the ability to naturally purify themselves. But this purification results in the consumption of the river's oxygen and is not without risks for aquatic animals and plants. But when the amount of organic matter discharged exceeds the limits of self-purification of the water, the degradation of the river can become sustainable. Areas deprived of oxygen by pollution cause the death of animals and plants or constitute insurmountable barriers preventing the migration of fish in particular.

The excessive presence of phosphates, in particular, promotes eutrophication processes, i.e., the development of hydrophytes which harm aquatic animals, can make swimming risky and disrupt the drinking water production.

Wastewater can be classified according to its origin, which most often determines its average characteristics. We distinguish:

***Urban wastewater.**

They come from discharges from the multiple household uses of water. They mainly carry organic pollution. They are divided into:

- household water, which comes from baths and kitchens, and is generally loaded with soaps, detergents, bleach, oils, etc.
- "grey water"; is waste from toilets (excrement, urine), loaded with various nitrogenous organic matter and fecal germs.

The daily pollution produced by a person using 150 to 200 liters of water is estimated at:

- 70 to 90 grams of suspended matter
- 60 to 70 grams of organic matter
- 15 to 17 grams of nitrogenous matter
- 4 grams of phosphorus
- several billion germs per 100 ml.

***Industrial wastewater**

They are distinguished from urban wastewater. Their characteristics vary depending on the industry. In addition to carbon, nitrogen or phosphate, they can also contain toxins or micropollutants. Some of them must be pre-treated by manufacturers before being discharged into the sewerage system.

***Rainwater**

They can cause maximum deterioration of watercourses, especially in seasons of heavy storms. Rainwater becomes loaded with impurities when it comes into contact with the ground, as it runs off onto city roads. In addition, when the sanitation system is called "unitary", rainwater mixes with urban and industrial wastewater. In the event of heavy rainfall, the protection constraints of treatment plants may require this highly toxic mixture to be discharged into nature. As for groundwater, the overall quality of the water tables is good at 20% of the sampled stations, average at 29% and degraded at 51%. In general, the poor quality is due to high mineralization of the water and high nitrate levels [1].

For a better appreciation of the origin of wastewater from different collectors studied, the calculation of the BOD5/COD, COD/BOD5, SSM/BOD5 ratios and the estimation of oxidizable matter (OM) is of very important interest. The use of these wastewater characterization parameters therefore constitutes a good way to give an image of wastewater pollution degree. The BOD5/COD ratio is a very valuable indicator of the nature of wastewater and the appropriate methods for its treatment.

In the present study, the calculation of these ratios and the determination of oxidizable materials for each wastewater collector studied reveals the following average values:

The ratio COD/BOD5 makes it possible to deduce whether the wastewater discharged directly into the receiving environment has the characteristics of urban wastewater (ratio less than 3) [35]. The results of this report constitute an indication of the importance of polluting materials with little or no biodegradability [36].

Wastewater has a ratio COD/BOD5 varying from 1.92 to 2.17 and 1.91 to 2.04 with an average of 2.03 and 1.94.

The ratio COD/BOD5 of the effluents is less than the value 3, therefore the wastewaters from the town of Belksiri are classified among wastewaters with a medium organic load and are easily degradable [35]. These results agree with those found by other authors [20].

Wastewater has a BOD5/COD ratio which oscillates between 0.46 and 0.52 and 0.49 to 0.52 with an average of 0.49 and 0.51.

The ratio is around the average of 0.5, so wastewater is loaded with organic matter. This organic load makes this wastewater quite unstable, meaning that it will quickly evolve into "digested" forms with the risk of odors being released.

Wastewater has a SSM/BOD5 ratio varying from 1.10 to 2.18 and 1.39 to 2.08 with an average of 1.52 and 1.71. The oxidizable matter (OM) of wastewater has an average value of 379.44 and 366.14 mg/l.

These results confirm that the wastewater from the town of Belksiri is loaded with organic matter and is easily biodegradable [37]. The values of oxidizable matter in wastewater are higher than those found in Kenitra [38].

Wastewater generates a polluting load of around 488.16 kg/day and 433.25 kg/day. Thus we estimate the overall pollutant load of the city of Belksiri which oscillates around 921.41 kg/day, i.e. a pollutant load of 336.32 Tons / year.

The comparison of the analyses of raw wastewater from the Mechraa BelKsiri Center is consistent with the classification proposed by GTZ and ONEP in 1998. The city is classified between small center and medium center [35].

It is also noted that in Morocco, urban wastewater is mainly concentrated [39], but above all heterogeneous. It should be noted that the larger the city, the lower the concentration of pollutants expressed in terms of BOD5, COD and MES. Indeed, large cities use a greater quantity of water, resulting in greater dilution of wastewater (**Table 7**) [35].

Table 7. Waste Waters Classification in Morocco [35].

Parameter	Small Centres with Less Than 20,000 Inhabitants)	Middle Center (between 20,000 and 100,000 Inhabitants)	Big Cities (over 100,000 Inhabitants)	National Average
BOD5 (mg/l)	400	350	300	50
COD (mg/l)	1,000	950	850	900
SSM (mg/l)	500	400	300	400
Restitution rate (%)	50	75	80	65
Allocation x Restitution rate (l/inhab)	40	70	80	60

4. Conclusions

Almost all of the deteriorated water stations are located at the level of watercourses polluted by urban and industrial discharges, namely the middle and lower zones of the Sebou River, the middle course of the Oum Er-Rbia, the lower courses of the Tangier and Martil wadis.

The physical and chemical characteristics of the wastewater of the city of Mechraa Belksiri are higher than the threshold values for direct and indirect discharges into

Oued Sebou.

The wastewater from the city of Belksiri creates enormous pollution by flowing into the natural environment such as the Sebou River. In addition, when they stagnate, polluted water can create an ideal biotope for the proliferation of mosquitoes that carry waterborne diseases.

Examination of the COD/BOD5 report clearly highlights the biodegradable nature of wastewater from the town of Belksiri. It can be concluded that the wastewater from this discharge is easily ready for suitable biological treatment.

The overall pollutant load in the city of Belksiri estimated at 921.41 kg/day, i.e., a pollutant load of 336.32 Tons/year, can be useful for agriculture if it is well treated and valorized by a Waste Water Treatment Plant (WWTP). We subsequently deduce that the Ratio of Inhabitant Equivalents in BOD5 of the city of Belksiri has a value of 29.15 g/inhabitant/day.

The need for Morocco to take up the environmental challenge and to place itself in a logic of sustainable development has led to an awareness of this problem through the launch of a National Liquid Sanitation and Wastewater Treatment Program and the issues relating to it on the part of the highest authorities of the Kingdom.

Also, like the PAGER program which enabled the development of drinking water supply at the rural level, it was recommended to adopt a national liquid sanitation and wastewater treatment program to catch up on the delay recorded and to cope with the evolution of the volumes of wastewater discharged: 48 Mm^3 in 1960, a little over 200 Mm^3 in 1990 and 506.2 Mm^3 in 2012. Similarly, the forecasts established show that urban discharges will continue to grow rapidly to reach 741 Mm^3 /year by 2030. The discharge from the industrial sector currently amounts to more than 964 million m^3/year.

This national sanitation program will meet the following objectives:

* Achieve an overall connection rate to the sanitation network of more than 80% in urban areas;

* Reduce domestic pollution by at least 60%.

* Treat and reuse through recovery 100% of the wastewater collected in 2030.

In order to overcome the shortcomings of this sector, the proposed program includes:

* Investments in sanitation with rehabilitation and extension of networks and connections, and reinforcement of the stormwater network;

* Investments in purification with pre-treatment, primary, secondary, tertiary treatment and sea outfall as appropriate;

* Renewal of equipment;

* Acquisition of operating equipment.

This program concerns 330 cities and urban centers, with a total population of more than 10 million inhabitants in 2005. It does not include centers whose sanitation service is managed by private dealers.

The amount of the investment program is of the order of 43 billion dirhams including tax, which breaks down as follows:

* 16.1 billion DH (38% of the total) for the construction of infrastructure related to the extension and rehabilitation of networks, interception, pumping, and wastewater routing works to treatment plants;

* 11.9 billion DH (28% of the total) for the construction of treatment plants;

* 5.6 billion dirhams (13% of the total) for renewal;

* 2.6 billion dirhams (6% of the total) for operating equipment;

* 6.8 billion dirhams (15% of the total) for peripheral districts and rural areas, part of which is targeted by the National Initiative for Human Development.

Water treatment must, as a priority, protect health and contribute to improving the quality of life. At the end of the 20th century, waterborne diseases still killed 25 million people each year, mainly children and mainly in developing countries. Since 80% of these diseases are due to the lack of sanitation, wastewater treatment, even basic, therefore constitutes an important contribution to improving public health. Wastewater treatment also aims to protect the environment from pollution, the consequences of which will be costly in the near future. This awareness of the economic and social value of water means that today sanitation is no longer considered solely as a social well-being but also as an economic investment for the entire Kingdom. In terms of decontamination, we have therefore long reasoned in terms of reducing the organic load to ensure the protection of the receiving environment.

Today, we must add the protection of public health. In addition to the classic purification methods, present in the Kingdom for more than 20 years, costly in terms of energy and financing, natural sanitation solutions, already used nearly two centuries ago, are now rehabilitated and technologically adapted to current needs. Many purification plants have been built, but few are still functional due to problems of monitoring, maintenance or unsuitability of the treatment sector.

To bring the researcher closer to the concerns and priorities of municipal managers, our study must be continued and completed by research on the microbiological, mycological, parasitological and viral loads of raw and treated wastewater.

Similarly, to make the reuse of treated wastewater healthy, we must also be interested in the evaluation of heavy metal and pesticide loads in wastewater.

Author Contributions

Conceptualization, D.B., T.H.; methodology, D.B., S.A., T.H., and I.L.; software, S.S.; validation, D.B. and J.E.; formal analysis, D.B.; investigation, M.M., and K.H.; resources, D.B.; data curation, D.B., and F.A.; writing—original draft preparation, T.H., K.F., and D.B.; writing—review and editing, T.H., H.S., and B.D.; visualization, E.I.; supervision, D.B.; project administration, D.B. and T.H. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article. The research was conducted independently, and no financial or personal relationships exist that could have influenced the work reported in this study.

References

[1] Directorate of Water Research and Planning (DRPE), 2004. Water resources in Morocco, national water plan [in Direction de la Recherche et de la Planification de l'Eau (DRPE), 2004. Ressource en eau au Maroc, plan national de l'eau]. Report 2004.

[2] Bzioui, M., 2004. National report on water resources in Morocco [in Rapport national sur les ressources en eau au Maroc]. UN Water-Africa. p.94. OiEAU, 2005. Available from: http://www.pnud.org.ma/pdf/Rappt_national_1%20juin_fr.pdf

[3] FAO, 2002. World agriculture: towards 2015/2030, Summary report [in FAO, 2002. Agriculture mondiale: horizon 2015/2030]. Food and Agriculture Organization of the United Nations (FAO): Rome, Italy, 2002. Available from: https://www.fao.org/4/y3557e/y3557e.pdf

[4] Alibou, J., 2002. Impact of climate change on water resources and wetlands in Morocco [in Impact des changements climatiques sur les ressources en eaux et les zones humides du Maroc]. Regional Round Table in the Mediterranean Athens, Greece, December 10-11, 2002. pp. 1–39. Available from: https://www.uicnmed.org/web2007/CDPRESENTACION/web/documentos/Morocco%20Paper.pdf

[5] MATEE, 2006. National Water Plan [in Plan national de l'eau du Maroc Ministère de l'Aménagement du Territoire, de l'Eau et de l'Environnement.]. Proceedings of the Regional Seminar on National Water Plans; 24–25 January 2006; Ministry of Territorial Planning, Water and the Environment, Rabat, Morocco.

[6] ABHS, 2011. Study to update the master plan for integrated water resources development in the Sebou hydraulic basin [in Etude d'actualisation du plan directeur d'aménagement intégré des ressources en eau du basin hydraulique du Sebou]. Sebou Hydraulic

Basin Agency: Fez, Morocco. Available from: https://www.abhsebou.ma/presentation-du-bassin/eaux-souterraines/

[7] RGPH, 2024. General Population and Housing Census in 2024 Morocco [in Recensement Général de la Population et de l'Habitat en 2024 Maroc]. Available from: https://www.recensement.ma/

[8] ONEP, 2006. National Office of Drinking Water, Mechraa Belksiri station [in Office National de l'Eau Potable, station de Mechraa Belksiri]. Available from: https://www.onep.org.ma/presentaion-onep.htm.

[9] SDNAL, 1998. National Master Plan for Liquid Sanitation: Reuse of Wastewater in Agriculture [in Schéma directeur National D'assainissement liquide: réutilisation des eaux usées en agriculture]. Available from: https://www.water.gov.ma

[10] El Khokh, K., Belghyti, D., El Kharrim, K., et al., 2011. Physicochemical characterization of urban wastewater of Mechraa Belksiri city (Gharb, Morocco). ScienceLib Editions Mersenne. 3, 110205.

[11] Henze, M., Grady, C.P.L., Jr., Gujer, W., et al., 1987. A general model for single-sludge wastewater treatment systems. Water Research 21(5), 505–515. DOI: https://doi.org/10.1016/0043-1354(87)90058-3

[12] WHO, 2017. Drinking Water Quality Guidelines, vol. 1, Recommandations [in Directives sur la qualité de l'eau de boisson, OMS, 2017. vol. 1, Recommandations]. Available from: https://iris.who.int/bitstream/handle/10665/42112/9242545147-fre.pdf. ISBN 978-92-4-254995-9

[13] ISO 5667-3:2024. Water Quality — Sampling. Part 3: Storage and Handling of Water Samples [in Qualité de l'eau — Échantillonnage. Partie 3: Conservation et manipulation des échantillons d'eau]. Available from: https://www.iso.org/standard/82273.html

[14] ONEP, 2017. Quantitative and qualitative characterization of wastewater. Good practice guide [in Caractérisation quantitative et qualitative des eaux usées. Guide de bonne pratique]. Water Quality Laboratory Department, ONEP: Rabat, Morocco. Available from: https://www.onep.org.ma/qualite-2017/controle-qualite.htm

[15] Saidi, Y., 2004. Liquid sanitation; final report on liquid sanitation systems [in Assainissement liquide; rapport définitif sur les systèmes d'assainissement liquide]. Liquid sanitation study management, ONEP: Rabat, Morocco.

[16] ONEP, 2002. Training manual on wastewater characteristics in Morocco [in Manuel de formation caractéristiques des eaux usées]. pp. 30–34.

[17] DIN, 1992. Determination of Chemical Oxygen Demand (COD) according to DIN 38409-H52 [in Détermination de la Demande Chimique en Oxygène (DCO) selon DIN 38409-H52]. National Environmental Laboratory. Ministry of the Environment: Rabat, Morocco. Available from: https://www.environnement.gov.ma/fr/service/laboratoire-national-de-l-environnement.

[18] Bourrier, R., 1991. Sewerage networks : Calculations, Applications, Perspectives. [in Les réseaux d'assainissement]. 5th editions Tec. et Doc. Lavoisier: Paris, France. 1991, pp. 810. Available from: https://side.developpement-durable.gouv.fr/doc/SYRACUSE/86377

[19] Valiron, F., 1991. Sanitation Manual Specific to Low-Income Countries. [in Manuel d'assainissement Spécifique pour les pays à faible revenu]. International Office for Water, OiEau, France. Available from: https://www.oieau.fr/eaudoc/notice/Manuel

[20] ONEP, 1992. Seminar on sanitation, [in Séminaire national sur l'assainissement liquide ONEP, 1992]. 16, 17 and 18 June 1992 ; Rabat, Morocco. Available from: https://fr.ircwash.org/resources/seminaire-assainissement-rabat-16-17-et-18-juin-1992

[21] Rodier, J., 1996. Water analysis: natural water, waste water, sea water [in L'analyse de l'eau: eaux naturelles, eaux résiduaires, eau de mer], 8th ed. Dunod: Paris, France. p. 1383. Available from: https://www.dunod.com/sciences-techniques/analyse-eau-eaux-naturelles-eaux-residuaires-eau-mer-0.

[22] Minister of Equipment, Minister responsible for Regional Planning, Urban Planning, Housing and the Environment, of Morocco. Moroccan Standards [in Normes marocaines, Bulletin officiel du Maroc 5062, Ministre de l'Equipement, Le Ministre Chargé de l'Aménagement du Territoire, de l'Urbanisme, de l'Habitat et de l'Environnement, du Maroc, 2002]. Official Bulletin No. 5062 of 30 Ramadan 1423 (December 5, 2002). Available from: https://www.abhsebou.ma/wp-content/uploads/2018/01/Bulletin-officiel-n-5062.pdf

[23] Ait Said, N., 2010. Design and sizing of the Mechraa BelKsiri WWTP [Master's thesis] [Conception et Dimensionnement de la STEP de Mechraa BelKsiri]. University Ibn Tofaïl, Faculty of Sciences: Kenitra, Morocco. p. 112. Available from: https://www.uit.ac.ma/

[24] El Khokh, K., 2006. Physicochemical characterization of urban wastewater from the city of Mechraa Belksiri (Gharb, Morocco) [Master's thesis] [in Caractérisation physico-chimique des eaux usées urbaines de la ville de Mechraa Belksiri (Gharb, Maroc)]. Faculty of Sciences: Kenitra, Morocco. p. 84. Available from: https://www.uit.ac.ma/

[25] El Khokh, K., 2013. Implementation of a wastewater treatment system in Mechraa Belksiri (Gharb, Morocco) [PhD dissertation] [in Mise en œuvre d'un système de traitement des eaux usées de Mechraa Belksiri (Gharb, Maroc)]. University Ibn Tofaïl, Fac-

ulty of Sciences: Kenitra, Morocco. p. 183. Available from: https://eressources.imist.ma/

[26] Gebrati, L., Nejmedine, A., 2002. Photocatalytic treatment and biodegradability of textile effluents from the city of Marrakech [in Traitement photocatalytique et biodégradabilité des effluents textiles de la ville de Marrakech]. Proceedings of the International Conference on Water in the Mediterranean Basin: Resources and Sustainable Development; 20-23 October, 2002; Monastir, Tunisia. pp. 330–334.

[27] Ait Hsine, E., Mandi, L., Benhammou, A., et al., 2002. Analysis and statistics of experimental data from a lagoon wastewater treatment plant [in Analyse et statistiques des données expérimentales d'une station de traitement des eaux usées par lagunage]. Proceedings of the International Conference on Water in the Mediterranean Basin: Resources and Sustainable Development; 20-23 October, Monastir, Tunisia. pp. 410–416.

[28] Kbibch, A., Belghyti, D., Elkharim, K., et al., 2011. Analysis of the pollution of the Mda wadi by domestic wastewater from the town of Souk Elarba of Gharb [in Analyse de la pollution de l'oued Mda par les eaux usées domestiques de la ville de Souk Elarba du Gharb]. ScienceLib Editions Mersenne. 3, 110203. Available from: https://www.academia.edu/118927119/Articles

[29] Eckenfelder, W.W., 1982. Industrial Wastewater Treatment Technology - Recent Developments. Water Science and Technology. 14(1–2), 111–119. DOI: https://doi.org/10.2166/wst.1982.0052

[30] Lakhlifi, M., 2017. Evaluation and design of wastewater treatment systems [PhD dissertation] [in Evaluation et conception des systèmes d'épuration des eaux usées]. University Ibn Tofaïl, Faculty of Sciences: Kenitra, Morocco. pp. 160. Available from: https://eressources.imist.ma/

[31] Sibari, M., 2018. Design and Sizing of a Sanitation Network and a Natural Lagoon Treatment Plant for the treatment of wastewater in the city of Ouazzane - Morocco [PhD dissertation] [in Conception et Dimensionnement d'un Réseau d'Assainissement et d'une STEP Lagunage Naturel pour le traitement des eaux usées de la ville d'Ouazzane - Maroc]. University Ibn Tofaïl, Facultyé of Sciences: Kenitra, Morocco. p. 180. Available from: https://eressources.imist.ma/

[32] Oulkheir, S., 2002. Physicochemical and microbiological characteristics of wastewater from the city of Kenitra [Master's thesis] [in Caractéristiques physico-chimiques et microbiologiques des eaux usées de la ville de Kénitra]. Faculty of Sciences: Kenitra, Morocco. p. 79. Available from: https://www.uit.ac.ma/

[33] Raweh, S., Belghyti, D., Al Zaemey, A., et al., 2011. Physicochemical quality of wastewater from the treatment plant in the city of S'Anaa (Yemen) [in Qualité physico-chimique des eaux usées de la station d'épuration de la ville de S'Anaa (Yemen)]. International Journal of Biological and Chemical Sciences. Int. J. Biol. Chem. Sci. 5(1): 1-10, February 2011. ISSN 1991-8631. DOI: https://doi.org/10.4314/ijbcs.v5i1.68065

[34] El Hamouri, B., Mekrane, M., Khallaayoune, K., et al., 1993. Stabilization performance of the Ouarzazate station [in Performances de stabilisation de la station de Ouarzazate]. Proceedings of the Seminar national research in the field of Water and Environment; 18–19 February 1993; LPEE - Casablanca, Morocco. pp. 261–268. Available from: www.lpee.ma

[35] ONEP, GTZ, 1998. Approach to the typology of urban wastewater in Morocco [in Approche de la typologie des eaux usées urbaines au Maroc]. ONEP et GTZ: Rabat, Morocco.

[36] Rodier, J., Legube, B., Merlet, N., et al., 2016. Water Analysis Control and Interpretation, 10th ed [in L'analyse de l'eau Contrôle et interprétation, 10th ed]. Dunod: Paris, France. p. 1824.

[37] Belghyti, D., El Guamri, Y., Ztit, G., et al., 2009. Physicochemical characterization of slaughterhouse wastewater with a view to implementing adequate treatment: the case of Kenitra in Morocco [in Caractérisation physico-chimique des eaux usées d'abattoir en vue de la mise en œuvre d'un traitement adéquat: cas de Kénitra au Maroc]. Afrique Science. 5(2), 199–216. DOI: https://doi.org/10.4314/afsci.v5i2.61730

[38] Metcalf and Eddy Intc, 1991. Wastewater Engineering Treatment Disposal Reuse, 3rd ed. McGraw-Hill: New York, USA. Fourth Edition. p. 1846. Available from: https://www.researchgate.net/

[39] GTZ, 1990. Wastewater Technology "production, collection, treatment and analysis of wastewater [in Technologie des eaux résiduaires « production, collecte, traitement et analyse des eaux résiduaires]. Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ), Springer-Verlag France: Paris, France. p. 1092.