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Boukhrared River Remediation By Coagulation-Flocculationtreatment

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Abstract: *The study was done on Boukhrareb river in Fez – Morocco. It is characterised by severe pollution from the domestic and industrial wastewater discharge produced by the city itself into the Boukhrareb river without any treatment. Coagulation-flocculation treatment has been used to reduce the turbidity and remove heavy metals from Boukhrarebriver especially Mercury which is the one of the most toxic heavy metals. Aluminium Sulphate was the coagulant used. After treatment, the turbidity of the sample decreased directly from 1093 to 4,1. Also, The pH reduced from moderate alkanity type to neutral. Moreover, the heavy metals decreased too ; Mercury has been decreased from 68 to -0.003 mg/L, Al from 2.83 to 0.2728mg/L, Phosphorus from 3.2 to 0.5379mg/L and Potassium from 13.5 to 5.62. This treatment is effective and inexpensive. Also, it is easy to be used principally in the epuration station of Fez city to be delivered to the population.*

Keywords: *Coagulation-flocculation, Drinking water, River treatment, Turbidity.*
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I. Introduction

Water scarcity is an essential substance that represents a severe problem for so many countries. This is due to the growth of ressources, shortage and deterioration of sources qulity as well as water surface. Moroever, this quality degradation is because of many reasons ; the most important one is the discharge of industries, agriculture, urban discharges and so on directly to rivers without any treatment. [1]In the same context, this leads to a global environmental pollution while it affects all people. Consequently at a recent time, the environmental protection rised to a continuous of environmental laws and regulations. This consequence turned into a hard assimilation for all small and medium companies [2].In Morocco, a North African countryfaced a quick increase of the environmental awareness problems [3] increasing due to the big amount of studies that criticized the situation of many Moroccan watercourses [4]. In Morocco, water resources access is affected by the geoclimatic conditions The reason why here, the wastewater effluents treated in sewage treatment plants before being discharged into the environment is not more than 18%, urbanization and industrial activities. Besides, a big quantity of a very polluted water is used directly for irrigation. Hence in other words, water scarcity is affected by water pollution problems caused by domestic sewage and industrial effluents [5].

Rivers are a vital and dynamic systems that are under the control of a complex natural processes such as the fact of weathering and erosion of rocks [6]. [6]. Either the river is able to carry the heavy metals or the dissolved in water or the suspended particles. Also, they can be observed as sediments in the bottom of the river. These sediments have an essential role in river environmental studies while they don't just resist a long time for their interaction with the biotic components of the river's ecosystem, but they also play a buffer role when it comes to the control of dissolved metals[7]

The fast industrialization is loaded with heavy metal contamination that becomes everyone's concern while it has clear negatif effects on human and aquatic life [8]. These heavy metals carried by the river. Some of them are too toxic and they represent an environmental concern because of their level of toxicity. The most toxic heavy metals are Mercury (Hg), Cadium (Cd) and Plomb (Pb)[7, 9].

Here, we focused on Boukhrareb river (also called Oued Boukhrareb, Fez river or Binlamdoun river) in Fez city in Morocco. It contains 33 km main course long and 615 km^2 catchment area. 10% of this catchment area is located in Fez [10].It is know as Fez city's upstream and it is the principal water body crossing the

city[5, 11].The river flows in an easterly direction from the springs of ‘‘Ras el Ma’’ with an elevation of 420 m a.s.l. through Fez city and into Sebou river with 4 km downstream from Fez city with an elevation of 210 m a.s.l[12]. It represents one of the best examples of Mediterranean semi-arid and intermittent rivers. Boukhrareb river suffers from 1 million population and its industries (like tanneries, oil mills, metal works, potteries[13]) and its domestic sewage wastewater that are directly discharged into it without any treatment as well. [5, 14, 15].This constitutes a source of pollution of surface waters. Indeed, the landfill of the city is located in a section of the Boukhrareb river itself [1].

All these, lead us to a serious problem while Boukhrareb river is the tributary of the Sebou River[12](the largest river in Morocco) (fig.1) that is used for the agricultural zones irrigation, industrial activities and drinking water [16].Fez city’s waste is about 25% of all Sebou’s River pollution [17]. And it is responsible for 40% of all water quality impact on Sebou river [10]. A 40,000 km^2 catchment is drained in Sebou river that contributes to 30% of Moroccan surface water and 20% of the ground water resources[18]. Also, it is the principal stream in northern Morocco that drains a part of the Atlas Mountains and the Gharb coastal plain into the Atlantic Ocean [14].

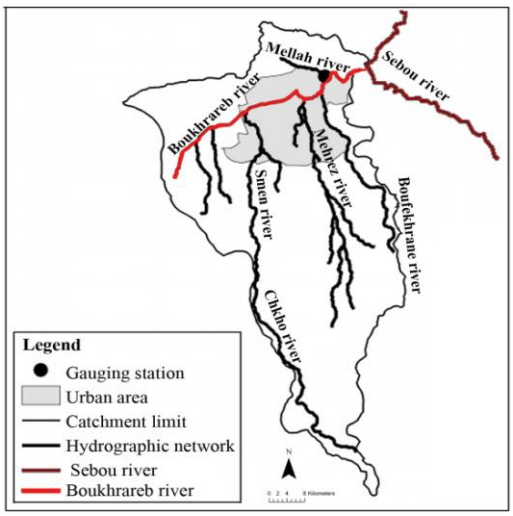

Fig1. Boukhrareb and Sebou river locations in Urban area of Fez.

Conclusively, the aim of this manuscript is to treat turbidity and heavy metals of Boukhrareb river to be a drinking water for Fez’s population.*Fig. 2* contain a summury of the the process flow sheet studied. This process requires a small space, cost and time efficiency. The process has four tanks one for each process : Coagulation, floculation, sedimentation and activated carbon filtration.At common design conditions, for the first part the water is filtred fron the solid wastes and let just the liquid passes.Then, the water goes to the second pre-treatment coagulation; quick mix tank permits for 2 minutes contact time. After that we have the floculation tank where we have a slower mix rotation for 20 minutes. Next, the water goes to sedimentation tank where the water sediments for 30 minutes to be gone next to the retention tank. Finally, the water can be distributed directly.

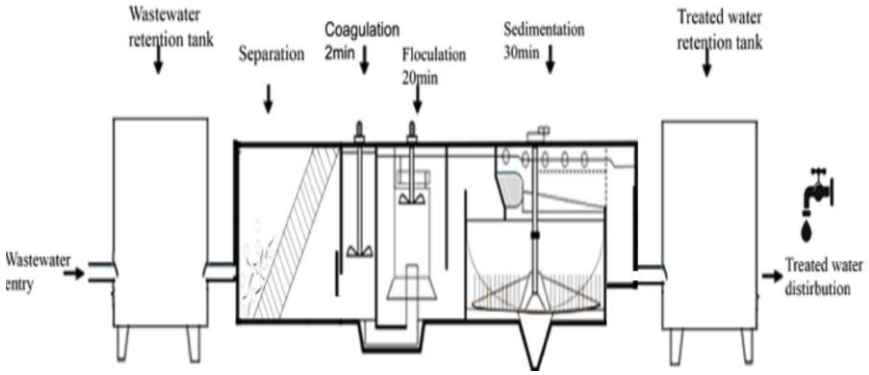

Fig. 2, contains a summury of the the process flow sheet studied. This process requires a small space, cost and time efficiency.

II. Materials And Methods

1-Samples collection :

Water samples were collected using special closed bottles that were dipped at the depth that varies between 0,7 and 0,9m [19]. Then, the bottles were opened inside the river and were closed again in order to take them them out to the surface.

Also, the sample bottles were rinsed in the laboratory with distilled before collecting the water samples in order to get good results.

The samples were taken from different places in the same river and mixed. They were collected for the phisico-chemical, heavy metals and treatment essays. After that, the samples collection was transported to the laboratory promptly and put in a freezer at 4ºC.

2- Materials :

In this project, we chose Aluminium Sulphate as a coagulant. It was disturbuted by Moroccan Chemical company. Its formula is Al2(SO4)3. The phycical and chemical characteristics of the chemical Al2(SO4)3 are shown in Table1.

Characteristics	Specifications
Physical:	
Aspect	Powder
Molecular weight	342,15
Odor	slight
Chimicals:	
Total $Al_2(SO_4)_3$ (%)	17 ± 0.5
Basicity (OH%)	0.5 max
Arsenic (mg/kg d'Al)	14
Cadmium (mg/kg d'Al)	3
Chromium (mg/kg d'Al)	30
Nickel (mg/kg d'Al)	20
Iron (mg/kg d'Al)	1.6

Table1. Phycical and chemical characteristics of $Al_2(SO_4)_3$.

The Aluminum Sulphate was used as a coagulant and a flocculant respectively.

Choice of coagulant :

Aluminium Sulphate is one of the most used chemicals in Morocco drinking water [19]. It is used as a coagulant and a flocculant at the same time while it is easy to handle, apply and it produces less sludge than lime[20].$Al_2(SO_4)$is used to increase the removal of particulate, colloidal, dissolved substances, suspended, and nonsettleable matter from water by chemical coagulation–flocculation, followed by gravity settling [21].This treatment is being used so many years in the whole world[22].

Aluminum Sulphate reactions that commonly occur in the coagulation process:

Coagulation = Al^{3+} + Colloids

Coagulant Preparation :

The Aluminium sulphate $Al_2(SO_4)_3$ was used as a coagulant and a flocculant too. To be prepared and ready to be used, we took 1g Al2(SO4)3 then we dissolved it in the distilled water. After that, the volume was completed until 100ml in order to obtain 1% w·v−1 solution [23].

Jar test :

It's been more than 60 years that the jar test always has been the standard technique used to optimize the coagulants and flocculants addition used in both wastewater and drinking water treatment industry[21].Even if new technologies has been appeared, it is still used in many countries as the main treatment such as Morocco.

In the epuration station scale, the coagulant interactions are so complicated because we need to consume lot of water quantity. For this reason, in the laboratory scale, we define the optimal dosage, duration, and intensity of mixing and flocculation for the epuration station [20, 24].

Coagulation-floculation procedure :

A standard jar test apparatus, called the Phipps & Bird Six-Paddle Stirrer was put for the tests with six Bakers Plexiglas jars. 1L of sample was put in each baker with different concentrations (20,25,30,35,40,45mg/L).

The procedure coagulation–flocculation process has three differents steps. The first thing is the addition of the coagullant to the water sample with a fast mixing because the aim in this step is to get a complete mixing of the coagulant with the river sample for 2minutes so that we can get the best destabilization effectiveness of colloidal particles and initiate coagulation. The second thing is that we decrease the rotation rapidity to a slower one for 20minutes to increase the contact between the coagulating particles and to develop large flocs easily. The third thing is that we stop the mixing to let the floc settle for 30minutes.

Finally, as the fig3 showed turbidity and pH of the six doses were analyzed to know the optimal dose. After that, a sample of the optimal dose was taken for heavy metals analysis.

III. Results And Discussion

1- Physicochemical characteristics of raw sample:

The raw water sample was too polluted, Its characteristic properties was shown in Table3. Boukhrareb river has a pH with a moderate alkanity and dark gray color. All the physicochemical characteristics are too high; the turbidity (1093mg /L), COD (2950mg/L), NH3-N (235mg/L), TP (222mg/L) and TN (650mg/L) values that need to be treated before drinking the water.

Parameter	Unit	Value
COD	mg/L	2950
TSS	mg/L	96,00
pH	—	8,130
BOD5	mg/L	110,0
Turbidity	µS/m	1093
NH_3-N	mg/L	235,0
TP	mg/L	222,0
TN	mg/L	650,0

Table3.
Physicochemical characteristics of raw river's water.

1.1- Coagulant and flocculent dosage :

In order to obtain good and fear results, a pipette was withdrawn in the top 5cm to analyse the turbidity, pH and heavy metals (just for the best concentration dose) after coagulation-flocculation treatment. While putting the samples in the analysing tubes, we paid attention that no air bubbles are available in the sample [25].

The results illustrated in Table 4 represent the quantity of turbidity and pH with each dose. This step of results will give us the possibility to choose the best dose to be given to the epuration station to treat the river's water. From the table we observe that we got good results. Also, Aluminum Sulphate was a good choice to decrease the turbidity from the river's water. The table shows that the turbidity has decreased from 1093 NTU to 10.5 NTU with a concentration of 20 mg/L and it can achieve 4.1 NTU which is its minimal with the concenteration of 40mg/L. The pH decreased as well from an alkaline pH with 8.13 to a neutral pH with 7.4 which is the best result for a healthy nody.

Thus, we can deduce that the Aluminum Sulphate has a superior efficiency in removing turbidity and decreasing pH as well in these conditions. It reacted very well with the colloid particles. Also, the residual turbidities reduced with the addition of the coagulant. The optimum concentration was 40mg/L with a turbidity percentage of 99,62% and the pH decreased to 7.4 which is a good result for a drinkable water.

Table4. Characteristics of Aluminum Sulphate turbidity and pH with different doses.

Concentration	Turbidity	Ph
20	10,5	7,62
25	8,90	7,61
30	7,90	7,61
35	6,00	7,47
40	4,10	7,40
45	6,10	7,50

The fig.3 showed the concentration, turbidity and pH removal efficiency. The first figure in the figure3, it represents the efficiency of the concentration. We can understand that when the dose increase, the removal efficiency of the concentration increase as well until it arrive dits sommun which with the dose of 40mg /L. After that, it started decreasing. For this reason, we have said that the best dose for this samples is using 40mg/L.

The second figure showed the turbidity removal effieciency. From this figure we can emphasize that the dose said before was the best choice because it helped us to decrease the turbidity from 1093 NTU to 4.1 NTU as it was said before.The third and last figure explained the pH removal efficiency percentage. The pH has decreased until 7.4 that is a good while this means that pH is neutral. Thus, the coagulant dosage has a crucial role , the same for the PH , in the efficiency of coagulation mechanism[26].

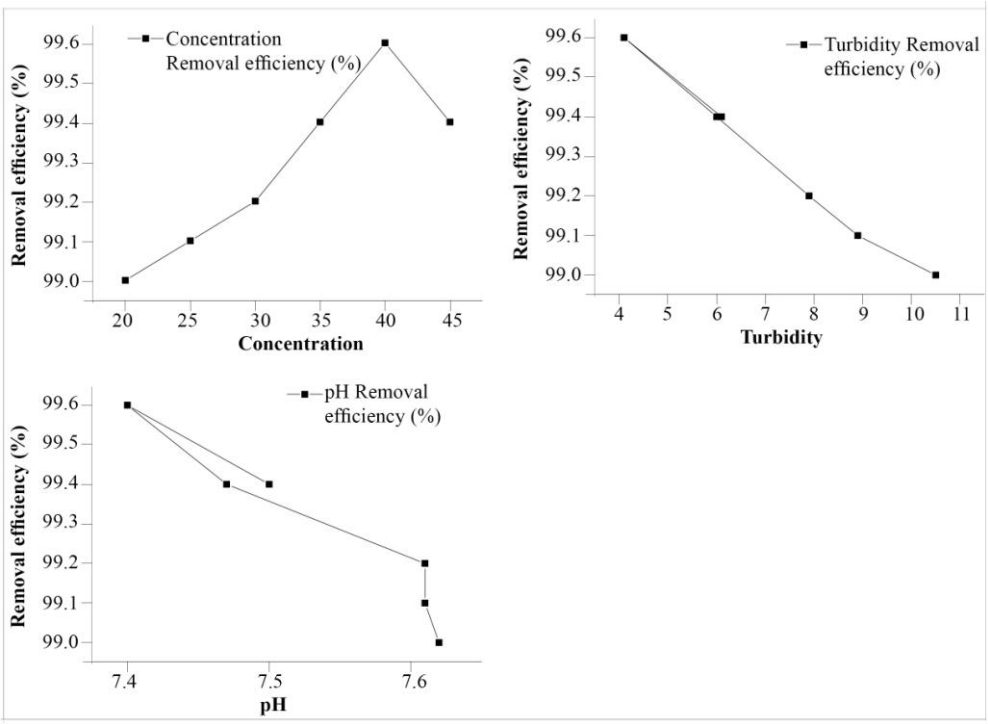

Fig3. Characteristics of Aluminum Sulphate concentration, turbidity and pH removal efficiency.

1.2- Heavy metals before and after the treatment:

As it was said before, we took the best coagulant dose for the heavy metals analysis and we put next to it the moroccan drinking water standards as it is illustrated in Table5.

The results show that before the treatment, five toxic heavy metals were highly present which are : the Mercury, Aluminum, Phosphorus , Potassium and iron. Whereas, the amount of mercury with 68mg/L was ineligible.

After the coagulation-flocculation results, the Mercury removed from 68mgL to -0.003, Aluminuim reduced from 2.833 to 0.2728mg/L, Phosphorus decreased from 3.2 to 0.5372 mg/L, Potassium reduced from 13.5 to 5.62 mg/L and Iron reduced from 3.606 to 0.0275 mg/L. The other heavy metals were reduced but they are not as important as the the ones above while the quantity of the other heavy metals isn't very important.

So, we emphasise that the coagulant Aluminum Sulphate is a good choice while it reduced the Mercury with 99,99%, Aluminum was decreased by 91%, Phosphorus removed by 84%, Potassium was reduced by 82%, and Iron by 70% which are a very good results.So, once the dose increase the turbidity decrease. In addition to that,the removal efficiency of heavy metals increase while increasing the coagulant-flocculant dose concentration until it achieves it sommum[27]. In addition to that, we can obserrbe that our results are less than drinking water standards which helped us to know that our results are a satisfied ones and could be taken as a reference.

Parameter	Standards Value	$Al_2(SO_4)_3$ Value
Hg	0,006	-0,003
Al	0.300	0,2728
P	0.550	0,5372
K	-	5,6200
Cr	0,05 0	0,0002
Fe	0.300	0,0275
Mn	0.400	0,0587
Ni	0.070	0,0031
Cu	1.000	0,0018
Zn	3.000	0,0473
As	0.010	0,0010
Se	0.010	0,0002
Cd	0.003	0,0030
Ba	0.700	0,0625
Pb	0,010	0,0004
B	0.500	0,0620

Table5. Characteristics of heavy metals before and after the treatment:

Aluminum Sulphate reactions that occur in the coagulation process:

$Al_2(SO_4)_3 \rightarrow 2Al^{3+} + 3(SO_4^{2-})$

Coagulation = Al^{3+} + Colloids

$Al_2(SO_4)_3 + 6H_2O \text{---- } 2Al(OH)_3 + 3H_2SO_4$

IV. Conclusion

The fact that Boukhrareb river recieves all the city's wastewater without any treatment leads to potential health risks as they are rich in micro-organisms and toxic chemicals such as heavy metals. Suspended particles, turbidity and heavy metals in water sample was removed by coagulation and flocculation.

This study has demonstrated the presence of many heavy metals especially Mercury that needs to be removed. The coagulation-flocculation treatment is the best solution for the city of Fez by Sulphate Aluminum while it has a positive impact on the river's water quality. Also, it is time and cost efficiency and very easy to operate in Fez epuration station. As a result, treated wastewater could be used to be drunk for population without health risk to humans or animals.

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