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Physico-Chemical and Bacterial Characteristics of Groundwater and Surface Water Quality in the Lagbe Town: Treatment Essays with *Moringa oleifera* Seeds

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ABSTRACT

The river water and groundwater from Lagbe town in Benin Republic were collected and analyzed for physical, chemical and microbiological parameters. The surface water samples were treated with alum, *Moringa oleifera* seeds powder and the combination of alum and *Moringa oleifera* seeds. The jar-test essays were carried out with two water samples at initial turbidities 7.2 NTU and 14.4 NTU. The water samples analyzed are fairly mineralized (conductivity varies between 166 and 687 µS/cm), enough soft and contain the nitrate (104 mg/L for W_4 sample). They are greatly polluted by pathogenic microorganisms such as *Escherichia coli*, *Klebsiella*, *Enterococcus*, *Vibrio*, *Serratia*. The optimal dosages of *Moringa* are 96 mg/L and 80 mg/L respectively. We have observed a reduction of 60% of turbidity and a substantial remove of all pathogenic microorganisms after water treatment with *Moringa oleifera* seeds. For the combination treatment, 93% of initial turbidity and 92% of initial concentration of organic matter in the sample E_2 were eliminated. The pH remained almost constant during the treatment.

Keywords: Groundwater; Surface Water; *Moringa oleifera*; Water Treatment; Physic; Chemical; Bacterial Characteristics

1. Introduction

Water is an indispensable natural resource for life on earth. Potable drinking water is the primary need of every human being. Groundwater and the surface water are the major source of drinking water in both urban and rural areas [1,2]. Man uses water for domestic, agricultural, social and industrial purposes. The increase of the population and its needs have led to the deterioration of surface and sub surface water [3].

In Benin Republic, the rate of effective access to drinking water in rural and semi urban areas is 41% at 2005. In the Lagbe, a rural district, the people do not have access to the drinking water network. They drink the untreated groundwater and the surface water. The World Health Organization estimated that up to 80% of all sicknesses and diseases in the world are caused by inadequate sanitation, polluted water or unavailability of water [4]. The treatment processes cover three major operations: coagulation/flocculation, sedimentation and filtration disinfection. The natural polyelectrolytes of plant origin have been used for many centuries in developing countries for clarifying turbid water. Even under such conditions, a few plant seeds make effective coagulants [5] for water treatment as compared to those of alum. In laboratory and field studies, *Moringa oleifera* seeds extract has shown promise as natural flocculant and coagulant that aid in binding the solids in turbid water [6-10].

In the present study, the determination of physico-chemical and bacterial characteristics of groundwater and surface water quality in the study area and the performance of aqueous extract of *Moringa oleifera* seeds as primary coagulant and as coagulant aid with alum in treatment of surface water samples was examined and compared with the performance of alum used alone.

2. Materials and Methods

2.1. Study Area

Lagbe town is located at 6˚40'34.91" North latitude and 2˚42'2.76" East longitude in Ifangni District. The present study was planned by selecting two different sites around Lagbe area which included two villages Zihan and Lagbe

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Center. The literature survey showed that no groundwater and surface water studies were made in these regions so far. Hence the present study was undertaken.

2.2. Collection of Water Samples

The groundwater and the surface water samples were collected in borosilicate glassware of 500 mL capacity according to the standard procedure NF EN 25667-1 [11]. For the bacteriological analysis, the bottles were sterilized in autoclave at 120˚C for 1 h, after which, the sample was added. For physico-chemical analysis, the sample bottles were rinsed with distilled water and later with water of the sample. Water samples from seven (07) sampling points of groundwater and seven (07) points of surface water situated at different location were collected during six months (August 2011 to February 2012). The water samples were named as well as samples 1 (W_1),···, samples 7 (W_7), and surface samples 1 (S_1),··· samples 7 (S_7). The sampling points data are represented on **Table 1**. The samples were carried to the laboratory at 4˚C in icebox and kept in refrigerator maintained at 4˚C. The parameters such as temperature, initial turbidity, pH, conductivity and dissolved oxygen were measured in the field study.

2.3. Preparation of Coagulants

2.3.1. *Moringa oleifera*

Moringa oleifera seeds used in this study were collected from Zihan. After shelling, the mature dry seeds are crushed in mortar laboratory with pestle and sieved (using 0.8 mm mesh). 2 g of the powder were dispersed in 100 mL of distilled water. The suspension was stirred during 1 hour and settled during 1 hour. The collected supernatant was filtered through Wattman pleated filter paper and the collected filtrate is used as a coagulant. The removed residues were oven-dried at 45˚C until constant weight. The amount of dissolved *Moringa* in filtrate was calculated from the difference between the mass of *Moringa* dispersed in distilled water (2 g) and dried residue.

Table 1. Location of sampling points.

Groundwater samples	Geographical coordinates	Surface water samples	Geographical coordinates
W_1	6˚41'10.0"N 2˚40'32.6"E	S_1	6˚41'05.8"N 2˚40'43.8"E
W_2	6˚41'01.5"N 2˚40'21.5"E	S_2	6˚40'42.3"N 2˚41'56.8"E
W_3	6˚41'15.3"N 2˚40'22.7"E	S_3	6˚41'19.2"N 2˚40'50.4"E
W_4	6˚41'19.6"N 2˚40'14.7"E	S_4	6˚41'19.2"N 2˚40'50.4"E
W_5	6˚40'35.5"N 2˚40'04.3"E	S_5	6˚41'17.6"N 2˚40'53.6"E
W_6	6˚41'24.2"N 2˚40'13.0"E	S_6	6˚41'19.5"N 2˚40'57.8"E
W_7	6˚41'20.5"N 2˚40'04.6"E	S_7	6˚40'56.1"N 2˚41'43.3"E

2.3.2. Aluminum Sulphate

About 5 g of aluminum sulphate which formula is ($Al_2(SO_4)_3 \cdot 18H_2O$) were dissolved in 250 mL of distilled water. The obtain- ed solution is used as coagulant.

2.4. Jar-Test Essays Procedure

Jar-test essays were carried out in a 1000 mL glass beaker with the water surface samples having the initial turbidities of 14.4 and 7.2 Nephelometric Turbidity Unit (NTU). The increased volume of aqueous extract of *Moringa* or of alum solution was then added in 500 mL of raw water with a micropipette (500 µL). The mixture was stirred with the rectangular pale of numeric flocculator Fisher Broslock Scientific. The stirring rate was maintained at 200 trs/min for 3min and slowed down at 50 trs/min for 25 min. At the end of stirring, the aggregated suspension was settled during 2 hours. A volume of 100 mL of supernatant was siphoned. In this sample, the residual turbidity, pH, oxydisability with potassium permanganate and microbiological parameters were measured. The coagulation activity was calculated based on Lee's equation [12].

Coagulation activity = 100 (To − Tr)/To with To = initial turbidity and Tr = residual turbidity.

2.5. Physico-Chemical and Microbiological Analysis

The pH, dissolved oxygen, conductivity and residual turbidity were measured with (WTW) multimeter and HANNA turbidimeter. The total alkalinities of the water samples were determined by titrating with N/50 H_2SO_4 using phenolphthalein and methyl orange as indicators. The total hardness of the water samples was measured by complexometric titration with EDTA using Erichrome black T as an indicator. The organic matters contained in the water sample were measured by oxydisability with potassium permanganate. The anions (fluoride F^-, chloride Cl^-, nitrate NO_3^-, nitrite NO_2^-, phosphate PO_4^{3-} and sulphate SO_4^{2-}) were measured by Dionex ICS - 10001 ionic chromatograph.

The microorganisms (*Escherichia coli*, *Klebsiella* spp, *Vibrio cholerae*, *Enterococcus* spp, *Serratia* spp, *Aeromonas* spp, *Asppergillus* spp) were identified according to [13]. The results obtained were processed and analyzed using SPSS 10.1. The different proportions were compared by X^2 test or Fischer at significance level of 0.05.

3. Results and Discussion

3.1. Physico-Chemical and Bacteriological Characteristics of Groundwater and Surface Water

The collected samples were analyzed. The analysis (**Tables 2** and **3**) of groundwater and surface water samples includes the determination of physico-chemical parameters. The bacteriological characteristics of samples are shown in **Tables 4** and **5**.

The desirable pH suitable for drinking water is between 6.5 and 8.5 [4]. The pH values of water samples in the study area ranged from 4.6 to 5.8, this is under the prescribed standard value for drinking water. This shows

Table 2. Physico-chemical characteristics of well water.

Parameters	Samples						
	W_1	W_2	W_3	W_4	W_5	W_6	W_7
pH	5.6 ± 0.2	5.5 ± 0.2	5.0 ± 0.2	4.7 ± 0.2	5.0 ± 0.2	4.6 ± 0.2	5.8 ± 0.2
Dissolved oxygen (mg/L)	3.4 ± 0.10	2.5 ± 0.10	3.8 ± 0.10	3.9 ± 0.10	3.3 ± 0.10	3.8 ± 0.10	3.3 ± 0.10
Conductivity (μS/cm)	282.5 ± 8	237 ± 8	267.5 ± 8	687 ± 10	556 ± 10	530 ± 10	194 ± 8
Turbidity (NTU)	1.7 ± 0.2	2.0 ± 0.2	2.2 ± 0.2	0.7 ± 0.1	2.2 ± 0.2	2.0 ± 0.2	1.0 ± 0.1
Alkalinity (˚F)	4.80 ± 0.20	4.90 ± 0.20	4.75 ± 0.20	4.70 ± 0.20	4.18 ± 0.20	4.23 ± 0.20	4.00 ± 0.20
Total hardness (˚F)	2.35 ± 0.10	2.10 ± 0.10	3.30 ± 0.10	6.50 ± 0.10	5.90 ± 0.10	6.50 ± 0.10	3.00 ± 0.10
Organic matter (mg/L)	1.49 ± 0.10	2.83 ± 0.10	1.42 ± 0.10	1.65 ± 0.10	2.76 ± 0.10	1.35 ± 0.10	1.78 ± 0.10
NO_3^- **(mg/L)**	26.10 ± 0.50	21.1 ± 0.50	28.2 ± 0.50	102 ± 0.50	62.0 ± 0.50	56.76 ± 0.50	52.8 ± 0.50
NO_2^- **(mg/L)**	0.57 ± 0.10	0.64 ± 0.10	1.85 ± 0.10	0.90 ± 0.10	0.60 ± 0.10	0.56 ± 0.10	0.59 ± 0.10
Cl^- **(mg/L)**	28.89 ± 1.50	27.60 ± 1.50	31.93 ± 1.50	42.8 ± 1.50	32.6 ± 1.50	33.72 ± 1.50	21.3 ± 1.50
PO_4^{3-} **(mg/L)**	0.12 ± 0.05	0.25 ± 0.05	0.30 ± 0.05	0.30 ± 0.05	0.20 ± 0.05	0.35 ± 0.05	0.70 ± 0.05
SO_4^{2-} **(mg/L)**	1.00 ± 0.10	1.00 ± 0.10	1.50 ± 0.10	0.50 ± 0.10	6.50 ± 0.10	1.00 ± 0.10	5.00 ± 0.10

Table 3. Physico-chemical characteristics of surface waters.

Parameters	Samples						
	S_1	S_2	S_3	S_4	S_5	S_6	S_7
pH	4.6 ± 0.2	4.8 ± 0.2	4.9 ± 0.2	5.0 ± 0.2	5.1 ± 0.2	5.8 ± 0.2	5.9 ± 0.2
Dissolved oxygen (mg/L)	3.20 ± 0.10	3.30 ± 0.10	3.00 ± 0.10	3.10 ± 0.10	3.30 ± 0.10	3.00 ± 0.10	3.30 ± 0.10
Conductivity (μS/cm)	248 ± 12	197 ± 22	166.5 ± 9.5	162 ± 8	291.5 ± 19.5	163 ± 14	165 ± 17
Turbidity (NTU)	0.4 ± 0.1	0.6 ± 0.1	5.6 ± 0.5	4.6 ± 0.5	7.0 ± 0.50	7.8 ± 0.50	10.7 ± 0.50
Alkalinity (˚F)	4.00 ± 0.20	3.30 ± 0.20	3.40 ± 0.20	3.20 ± 0.20	3.60 ± 0.20	3.50 ± 0.20	3.50 ± 0.20
Total hardness (˚F)	2.40 ± 0.10	2.10 ± 0.10	1.90 ± 0.10	1.90 ± 0.10	3.40 ± 0.10	2.00 ± 0.10	2.10 ± 0.10
Organic matter (mg/L)	0.50 ± 0.10	4.00 ± 1.20	4.40 ± 1.20	4.40 ± 1.20	3.50 ± 1.20	12.50 ± 2.50	12,87 ± 2.50
NO_3^- **(mg/L)**	25.66 ± 2.50	23.17 ± 2.50	23 ± 2.50	28 ± 2.50	33 ± 2.50	1.30 ± 0.60	1.40 ± 0.60
NO_2^- **(mg/L)**	0.4 ± 0.10	0.4 ± 0.10	0.5 ± 0.10	0.35 ± 0.10	0.40 ± 0.10	0.15 ± 0.10	0.20 ± 0.10
Cl^- **(mg/L)**	41.3 ± 1.50	35.12 ± 1.50	29 ± 0.50	28.50 ± 0.50	36.23 ± 1.50	27 ± 0.50	27.5 ± 0.50
PO_4^{3-} **(mg/L)**	0.24 ± 0.05	0.10 ± 0.05	0.32 ± 0.05	0.14 ± 0.05	0.14 ± 0.05	0.24 ± 0.05	0.26 ± 0.05
SO_4^{2-} **(mg/L)**	0.20 ± 0.10	0.20 ± 0.10	0.20 ± 0.10	0.50 ± 0.10	0.20 ± 0.10	0.50 ± 0.10	0.50 ± 0.10

Table 4. Microbiological characteristics of groundwater.

Parameters	Samples						
	W_1	W_2	W_3	W_4	W_5	W_6	W_7
Escherichia coli **(UFC/mL)**	192,000	256,000	128,000	192,000	256,000	64,000	64,000
Klebsiella **spp (UFC/mL)**	0	320,000	0	320,000	320,000	192,000	128,000
Enterococus **spp (UFC/mL)**	1600	0	0	32,000	0	0	0
Serratia **spp (UFC/mL)**	128,000	192,000	0	128,000	0	0	0
Aéromonas **spp (UFC/mL**	192,000	256,000	0	0	0	0	0
Asppergillus **spp (UFC/mL)**	0	0	0	32,000	0	0	0

Table 5. Microbiological characteristics of surface waters.

Parameters	Samples						
	S_1	S_2	S_3	S_4	S_5	S_6	S_7
Escherichia coli **(UFC/mL)**	28,000	320,000	320,000	116,000	320,000	256,000	320,000
Klebsiella **spp (UFC/mL)**	0	160,000	0	98,000	0	320,000	320,000
Vibrio cholerae **(UFC/mL)**	0	8000	0	0	16,000	32,000	32,000
Enterococus **spp (UFC/mL)**	0	3200	32,000	0	0	4800	4800
Serratia **spp (UFC/mL)**	64,000	64,000	128,000	0	128,000	320,000	192,000

that pH of water sample was acidic. Total alkalinity of water varied from 4.18˚F to 4.90˚F for groundwater and 3.20˚F to 4.00˚F for surface water. The values of total alkalinity were comparatively moderate. Total hardness measured was found in the water samples in the ranges of 2.10˚F to 6.50˚F for groundwater and 1.90˚F to 3.40˚F for surface water, which shows that water is very soft [4,14].

Chloride content of the water samples was low. According to WHO standards, maximum acceptable limit for chloride is 500 mg/L. The values observed in the present study are between 21.3 and 42.8 mg/L [14,15]. The sulphate content varies between 0.50 mg/L and 6.50 mg/L for groundwater, 0.20 mg/L and 0.50 mg/L for surface water. The specific conductivity of water samples varies between 166 and 687 µS/cm. The maximum permissible limit of this parameter for drinking water is 300 µS/cm. However, the average specific conductivity exceeds this limit for wells W_4 (687 µS/cm), W_5 (556 µS/cm) and W_6 (530 µS/cm).

The water samples concentration of dissolved oxygen varies between 2.50 mg/L and 3.8 mg/L. These values are lower than the maximum recommended limit for dissolved oxygen which is 8 mg/L [4]. The turbidities of groundwater samples are weak and varies between 1.4 NTU and 2.3 NTU. The turbidities of surface water samples (S_1 and S_2) are also weak and equal to 0.5 NTU, but the samples S_3 to S_7 are more turbid, they contained more colloidal particles. Indeed, their turbidities varies between 4.6 and 10.7 NTU. The dissolved organic matters of groundwater are weak enough. However the water samples of the wells W_2 and W_5 contain more organic matters because these wells are not covered. Indeed, the polyethylene buckets used by people to take water could be also source of water enrichment in organic matters as the seal is often in contact with the soil. The dissolved organic matter of surface water was above 3 mg/L which represented the permissible limit [4] except the sample W_1. This water sample was taken probably from a stream.

The concentration of nitrate in the analyzed samples ranges between 21.1 and 102 mg/L for the well water when it was 1.30 to 28 mg/L for the surface water. The relatively higher concentration range of NO_3^- (52 at 102 mg/L) for the wells W_4, W_5, W_6 and W_7 clearly indicates contamination of the waters with domestic waste water or with waste water from leaking septic tanks built near these wells. The concentration of nitrite is weak enough and varies between 0.56 mg/L and 1.87 mg/L for the groundwater when it varies from 0.2 mg/L to 0.4 mg/L for the surface water. The concentration of sulphates and phosphates in the analyzed samples are very low.

The results shown in **Tables 4** and **5** indicate that the analyzed waters were polluted by various microorganisms such as: *Escherichia*, *Klebsiella*, *Enterococus*, *Serratia*, *Aeromonas*, *Asppergillus*. In the groundwater samples, the number of *E. coli* varies between 64,000 UFC/mL and 256,000 UFC/mL, that of *Klebsiella* varies from 128,000 UFC/mL to 320,000 UFC/mL. Those of *Enterococcus*, *Serratias and Aeromonas* varies between 1600 UFC/mL and 32,000 UFC/mL, 128,000 UFC/mL and 192,000 UFC/mL, 192,000 UFC/mL and 256,000 UFC/mL respectively. In the surface water samples, the number of *E. coli*, *Klebsiella*, *Vibrio*, *Enterococcus* and *Serratia* varies between 28000 UFC/mL and 320,000 UFC/mL, 98,000 UFC/mL and 320,000 UFC/mL, 8000 UFC/mL and 32,000 UFC/mL, 3200 UFC/mL and 4800 UFC/mL, 64,000 UFC/mL and 320,000 UFC/mL respectively. The consumption of drinking water contaminated with pathogenic microbes of faecal origin has a significant risk on human health in the developing countries, especially in rural and industrial areas [1,16-18]. All analyzed water samples are not potable.

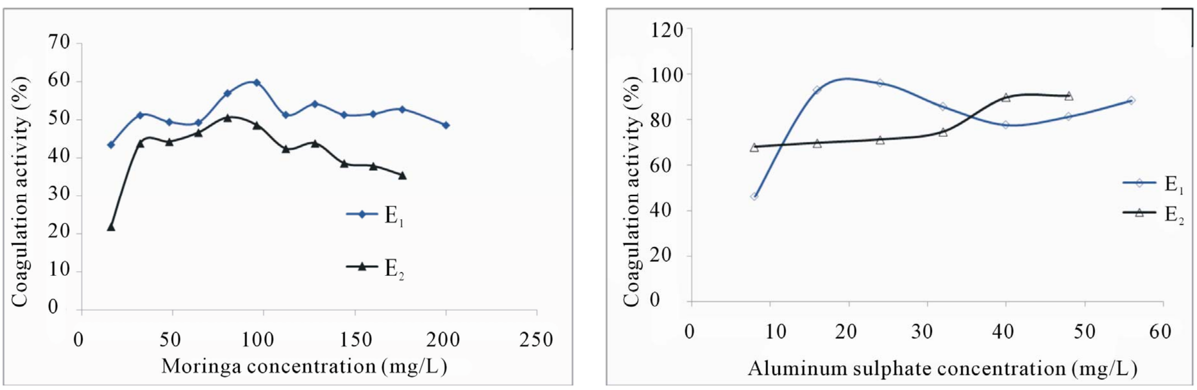
3.2. Water Treatment

Two samples (E_1 and E_2) of River water S_7 having initial turbidities 14.4 NTU and 7.2 NTU and which the dissolved organic matters were 12.37 mg/L and 5.60 mg/L respectively were treated by the aqueous extracts of *Moringa*. The obtained results were represented on **Figures 1** and **2** and the **Table 6**.

We noticed on the graphs 1a and 1b of **Figure 1**, that

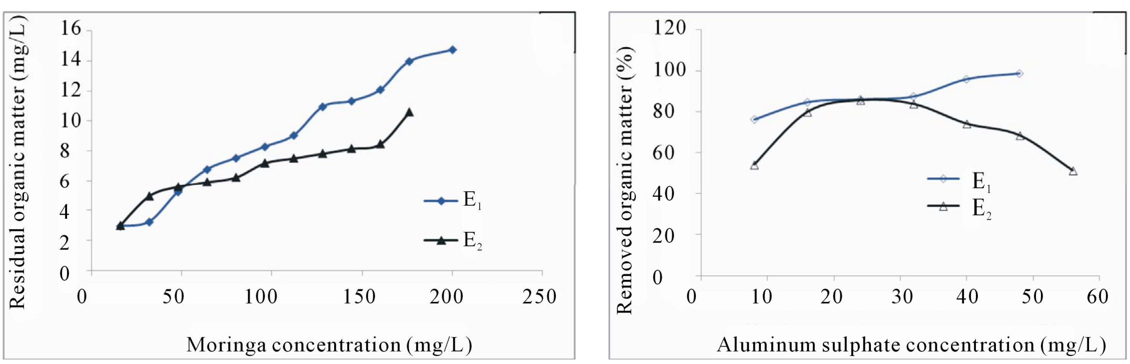
Table 6. Microbiological characteristics of the treated water by *Moringa* .

	Moringa concentration (mg/L)								
Parameters	0	80	96	112	128	144	160	176	200
***Escherichia coli* (UFC/mL)**	256,000	0	0	0	0	0	0	0	0
***Klebsiella* spp (UFC/Ml)**	320,000	6400	6200	6200	6000	5400	5000	4600	4000
***Vibrio cholerae* (UFC/mL)**	32,000	1600	1600	1500	900	800	800	700	700
***Enterococus* spp (UFC/mL)**	4800	0	0	0	0	0	0	0	0
***Serratia* spp (UFC/mL)**	320,000	0	0	0	0	0	0	0	0



(a) (b)

Figure 1. Variation of coagulation activity as function of coagulant concentration.



(a) (b)

Figure 2. Variation of organic matter as function of coagulant concentration.

the rate of turbidity reduction of treated water increase with the concentrations of each coagulant until it has reached a maximum value. The turbidity reduction depends however on the nature of the coagulant used and the initial turbidity of raw water. Turbidity reduction rate was 60% and 50% for samples E_1 and E_2 during the treatment with *Moringa oleifera* seeds and 88% and 96% when using aluminum sulphate. The optimal doses of the coagulants are respectively 96 mg/L and 80 mg/L for *Moringa* then 40 mg/L and 24 mg/L for alum.

On the graphs of **Figure 2(a)**, there is an increase of dissolved organic matter in treated water by *Moringa oleifera*. This enrichment of the treated water by organic matter is proportional to doses of *Moringa* used. The addition of organic matter rate is 20% and 89% for E_1 and E_2 and could be responsible for the treated water smell and color [19-22].

On the graph 2b, we observe a gradual increase of reduction rate of dissolved organic matter. The maximum rate of organic matter removed was 95% for E_1 and 85% for E_2. The slight decrease of reduction rate of organic matter beyond the dose of alum equals to 32 mg/L for E_2 sample (**Figure 2(b)**) it can be due to a restabilization of colloidal particles.

During the water treatment with the aqueous extract of *Moringa oleifera*, we noted an almost total elimination of microorganisms (**Table 6**). *Escherichia coli*, *Serratia* spp and *Enterococus* spp were eliminated completely but a reduction of 98.75% of *Klebsiella* spp and 97.82% of *Vibrio cholerae* were noted. The antimicrobial effect of *Moringa* is due to the molecule 4 (α-L-Rhamnosyloxy) benzyl isothiocyanate contained in its seeds [23-25].

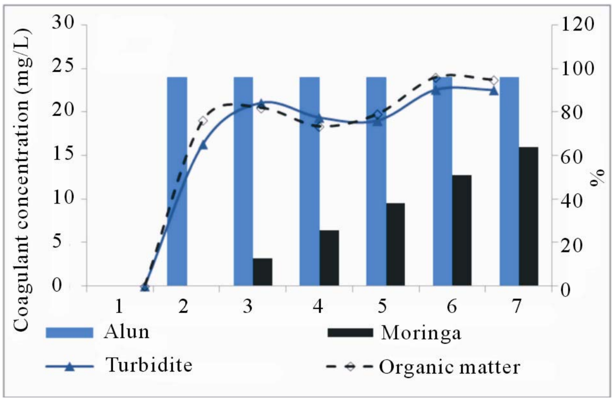
3.3. Moringa as Coagulant Aid with Alum

During the use of *Moringa oleifera* as a primary coagulant, we obtained that the rate of turbidity reduction is about 60% for both samples and an enrichment of water treated with organic matter. To improve the quality of treated water, we performed jar-test essays of water samples using *Moringa oleifera* as coagulant aid with aluminum sulphate. The optimum doses of alum for samples E_1 and E_2 (40 mg/L and 24 mg/L) were reduced by 40%. The amounts of removed alum are gradually replaced by various doses *of Moringa oleifera* in the proportions of 1/6, 2/6 to 6/6. The obtained results for the jar tests performed with samples E_1 and E_2 were shown in **Figure 3**.

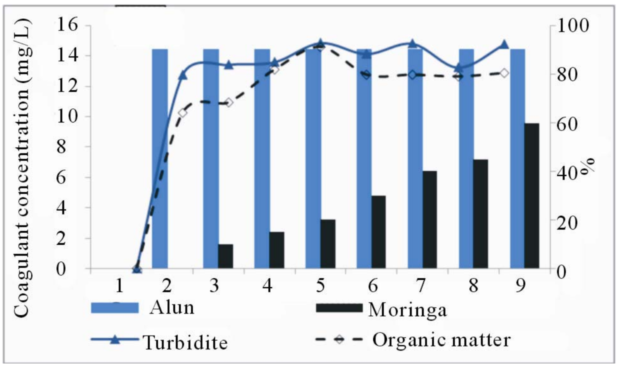
The doses of alum being constant, the variation of reduction percentages of turbidity and organic matter depends only on *Moringa oleifera* doses. On the graph 3a, 90% of turbidity and 96% of organic matter were removed from the sample E_1 with a combination of 24 mg/L of alum and 12.8 mg/L of *Moringa oleifera*. The replacement rate of alum by *Moringa oleifera* is 4/5. For a dose of alum equal to 40 mg/L and *Moringa oleifera* equal to 0 mg/L, the rate of turbidity reduction and organic matter are respectively 88% and 96%. For sample E_2 (Graph 3b), the rates of turbidity reduction and organic matter have reached their maximum value for the combination of alum 14.4 mg/L and *Moringa oleifera* 3.2 mg/L. For this combination, 93% of initial turbidity and 92% of initial concentration of organic matter in the sample E_2 were eliminated. The pH remained almost constant during the treatment.

4. Conclusion

The groundwater samples analyzed are contaminated by nitrate due to the proximity of septic tanks next to wells for which the waters are sampled. The surface water tur bidities were high in some places and mostly rich of organic matter. The groundwater and surface water presented a microbial pollution of faecal origin. These waters are not potable and cannot be consumed without adequate treatment. The water treatment with *Moringa oleifera* revealed a substantially reduction of all pathogenic microorganisms present in raw water and could be used in water treatment in rural areas since populations do not have distribution network of drinking water. The



(a)



(b)

Figure 3. Variation of removed turbidity and organic matter as a function of coagulant doses (a: E_1; b: E_2).

treated water with the combined coagulant (*Moringa* + alum) will be less turbid and dissolved aluminum, organic matter than in pump water.

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