J. Mater. Environ. Sci. 6 (6) (2015) 1692-1698
ISSN : 2028-2508
CODEN: JMESCN

Characterization and valorization of drinking water sludges applied to agricultural spreading

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Received 8 May 2014; Revised 22 November 2014; Accepted 02 December 2014.

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Abstract

Our study delved into drinking water sludges at the treatment plant of Bouregreg. Two sampling campaigns were carried out at the S2 station's sludge bed decanter during the months of May and June 2012. The Sludges were limed at different concentrations to increase their agronomic value in landfarming. The analysis of the sludges physico-chemical characteristics showed an important increase in dryness after liming which facilitates their handling and management. On the other hand, liming allowed a stabilization of organic matter. In fact, the increase in pH gave drinking water sludge a very good calcium amendment status by increasing the calcium level. Trace element levels are still below the recommended MTE limits for agricultural spreading. Moreover, these sludges reveal a very high hygienisation in terms of pathogens. Thus, these results demonstrated that drinking water sludges at the station of Bouregreg showed significant agronomic characteristics that are perfectly suitable for agricultural spreading.

Keywords: Bouregreg, drinking water sludge, liming, agricultural spreading, dryness

1. Introduction

During the production of water for human consumption, waste of various kinds takes place, gathered in the vast majority of cases in more or less concentrated suspensions referred to as " sludges " [1]. The common characteristic of all these sludges is to constitute very liquid waste of generally low or zero value added [2]. According to regulations, drinking water sludges are classified as " non-hazardous waste " also known as " banal industrial waste " (BIW) . That implies that they are not submitted to the heavy constraints of "hazardous waste ". However, traceability is required by regulations starting from their withdrawal from the drinking water plant until the end of the recovery channel [3].

To master sludge management technically and economically, communities must move towards more flexible and frequently multi-channel solutions [4]. Landfarming remains privileged in three out of five cases, but other answers ecologically exist as shown in the decision guide [5, 6]. This guide suggests solutions like monitored spreading, regulated and controlled, not only on agricultural lands but also on road embankments, in the mountain, in the forest, in swamp or areas affected by erosion [7].

Sludges once spread, increase crop yields thanks to their composition. They contain nutrients for crops and serve as calcium and organic amendment to improve the physical and chemical properties of the soil, especially if they are limed or composted [8]. Microorganisms present in large numbers in the soil digest organic matter in part provided by sludges and turn it into minerals for the plant. Another part of organic matter is incorporated into the soil and contributes to the maintenance of a favorable structure for root growth [9]. Thus, the purpose of this study focuses on the characterization of raw and limed drinking water sludges in order to study the impact of liming on the sludges' treatment process as well as on their recovery [10].

Present practice is commonly to dewater the sludge up to about 30% DM and then pay to send it to a commercial landfill. However, this practice is becoming more and more expensive. Consequently, National Office of electricity and drinking water initiated a research project on alternative methods for use of mill sludges. Various options were identified, of which using the sludge on agricultural land seemed one of the most promising [11].

The sludges vary in composition from mill to mill, but they are normally extremely low in potentially toxic components. It was thought that they might therefore be useful as soil-conditioning agents, whose use may in fact increase crop yield [12]. (They also contain modest levels of N, P and K.).

2. Experimental procedure

This study focused mainly on the treatment plant of Bouregreg. The two sampling campaigns were carried out at the S2 station sludge bed decanter during the months of May and June 2012. In each of the two campaigns, sludges were limed with different concentrations in order to evaluate their agronomic value in agricultural spreading.
The main parameters of the quality of the sludge were analyzed using different samples according to standard methods in vigor and compared to predefined standards [13]. The methods of physico-chemical and microbiological analyses used are summarized in Tables 1 and 2.

Table 1: Methodes of analysis of physico-chemical parameters

Parameters	Method of analysis	Unit
pH	pH Metry	-
Decantability test	H=f(t)	cm/h
Suspended matter (SM)	Membrane filtration	mg/l
Volatile matter (VM)	Ashing at 550 ° C	%
Dry matter(DM)	Freeze-drying	%
Moisture content(MC)	Calculation	%
Total nitrogen (TN)	KCL extraction+colorimetric determination	mg N/Kg
Total nitrate ($TNO_3^{-)}$	KCL extraction+colorimetric determination	mg N/Kg
Total ammonium (TNH_4^+)	KCL extraction+colorimetric determination	mg N/Kg
Total phosphorus(TP)	ICP	mg /Kg
total potassium(TK)	ICP	mg /Kg
total magnesium(TMg)	ICP	mg /Kg
total calcium(TCa)	ICP	mg /Kg
MTE: Fe, Al, Cd, Cu, Ni, Pb, Cr, Zn	ICP	mg /Kg

Tableau 1 : Analytical methods for the microbiological parameters

Parameters	Method of analysis	Unit
Helminth eggs	MPN(Most probable number)	MPN/ 10 g SM
Salmonella	Counting and viability	Unit/ 10 g SM

3. Results and discussion

3.1 Physico-chemical and microbiological analyses results

3.1.1 Physico-chemical parameters

A. pH

pH measurement is used to indicate the acidity or alkalinity of raw sludges and sludges conditioned with lime [14]. The results of pH measurement are shown in Table 3. The addition of lime with different concentrations induces an increase in pH value that goes from 6.91 to 11.5.

Table 3 : Variation of the pH of raw and limed sludges at the treatment plant of Bouregreg during the months of May and June 2012

	Raw sludge May (S1)	Raw sludge June (S2)	Limed sludge to 10% (S3)	Limed sludge to 15 % (S4)	Limed sludge to 25% (S5)	Limed sludge to30 % (S6)
pH	*6 .91*	*6.38*	*9.38*	*9.47*	*11*	*11.5*

*S: Sample

B. Decantability test

This test characterizes the ability of sludge to undergo a static thickening, with or without conditioning. It allows the choice of product and the optimal dose for conditioning as well as thickener dimensioning [15]. Raw and limed sludges decantation results during the months of May and June 2012 are shown in both Figures 1 and 2. Thus, we notice an increase in the decantation speed with the injection of lime in the sludges. It should be noted that the added coagulant does not have any real influence. In fact, the polyelectrolyte and the alginate show comparable efficacy.

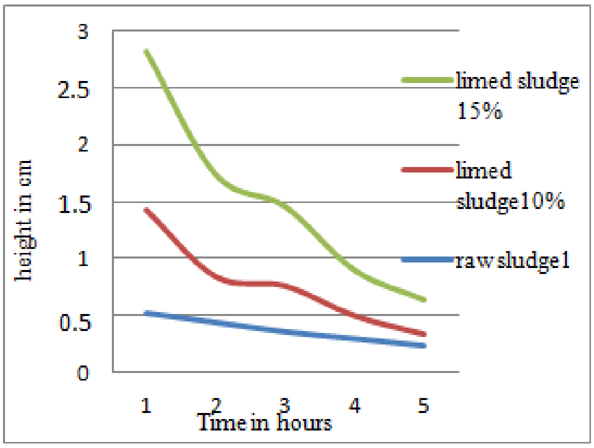

Fig. 1: Raw and limed sludges decantation results during the month of May 2012

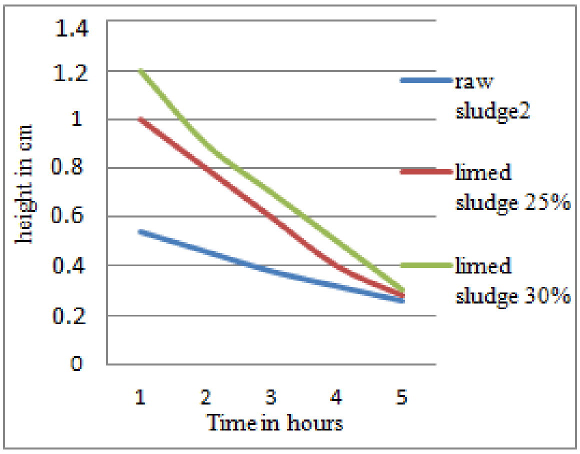

Fig.2: Raw and limed sludges decantation result during the month of June 2012

C. Suspended matter (SM)

Suspended matter equals the insoluble content. Its presence in significant concentration influences the physico-chemical and biological characteristics that are reflected on the nature of sludge treatment [16]. The evolution of SM content of raw and limed sludges during both campaigns (May and June) is shown in Figure 3.

The addition of lime increases the SM rate of different samples that goes from 23.6 to 32 mg / l, which facilitates sludge treatment and management.

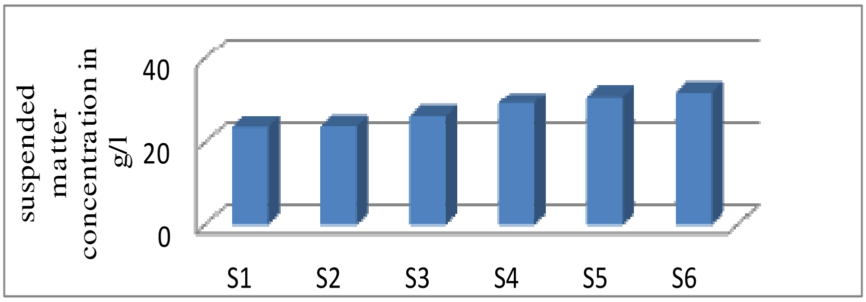

Fig.3: Evolution of SM content of raw and limed sludges during both Campaigns (May and June)

D. Dry matter and moisture content (DM and MC)

The concentration in DM is used to determine the sludge dryness [17]. The evolution of DM and MC in the two sampling campaigns is shown in Figure 4. DM content measured in raw and limed sludges is located on a beach varying between 8.81 and 13.41%. This represents an increase in sludge dryness, which automatically translates to a decrease in moisture content going from 91.8 to 86.58%, which promotes sludge drying.

E. Volatile matter (VM)

This parameter provides an indication of the degree of stabilization of sludge and its ability in different treatments and recovery (dehydration, incineration ...).

The VM results of different samples are shown in figure 5.

The obtained results vary between 20 and 27%. The values are inferior to 30%. This low VM content gives the sludge the stabilization ability, which facilitates their thickening and dehydration [18].

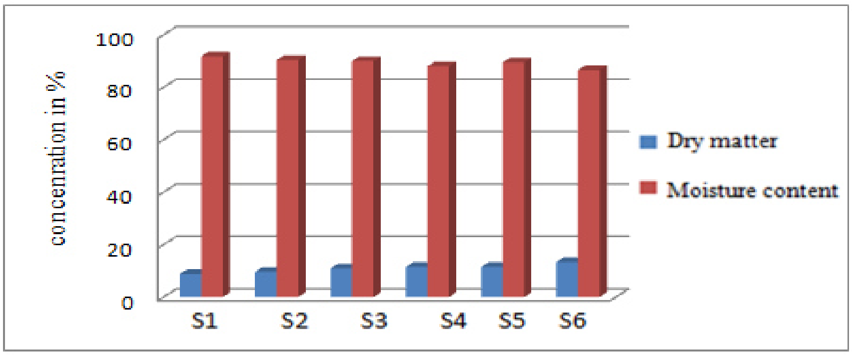

Fig.4 : Evolution of DM and MC of raw and limed sludges during. The months of May and June 2012

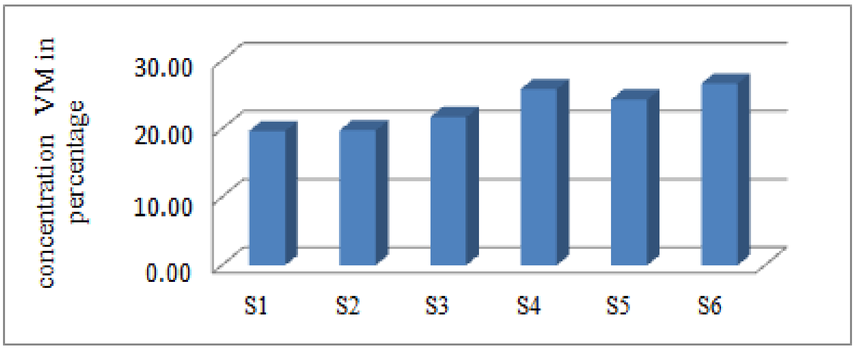

Fig.5: Volatile matter percentage of raw and limed sludges during the months of May and June 2012

F. Total nitrogen, nitrate and ammonium

The availability of these fezrtilizing elements in the sludge gives them a very interesting agronomic value. They can also improve the characteristics of the soil, especially in the case of limed or composted sludges [19].

The concentrations of nitrogen, nitrate and ammonium of different samples (May and June) are shown in Figure 6. Nitrogen is primarily present in organic form in sludges. The mineral fraction comes down to the ammonium form. We notice that the concentration of nitrogen goes from 232.5 mg / kg in raw sludge to 592.5 mg / kg in limed sludge "no degradation", which shows that the organic matter in limed sludges characterized by a stability superior to that of non-limed sludges plays an important and non-negligible role in physical fertility. We can explain this stability by the low water content and elevated pH in limed sludges.

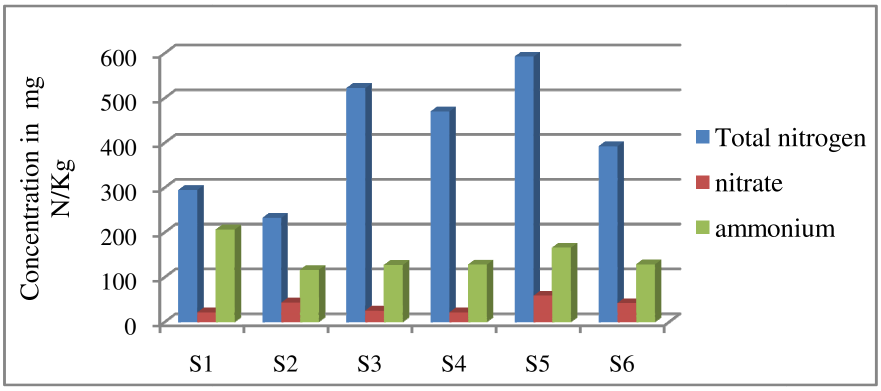

Fig.6: Concentrations of nitrogen, nitrate and ammonium of raw and limed sludges, During the months of May and June 2012

G. Total phosphorus (P), total calcium (Ca), total magnesium (Mg) and total potassium (K)

These parameters are interesting elements for sludge landfarming since they represent an important agronomic value in microelements.

Concentrations of P, Ca, Mg and K in raw and limed sludges at the drinking water treatment plant of Bouregreg are shown in Table 4.

The evolution of the calcium concentration of 570 mg / kg in raw sludges to 5563 mg / kg in limed sludges gives them a very important calcium amendment status for agricultural spreading.

Potassium content is important and increases from 1978 mg / kg in raw sludge to 4735 mg / kg in limed sludge.
Phosphorus and magnesium content is always low with almost constant values in raw and limed sludges. This is explained by the mineral nature of drinking water sludges.

Table4: Concentration of P, Ca, Mg and K in raw and limed sludges during the months of May and June 2012

Element	Concentration in mg/kg					
	Raw sludge May (S1)	Raw sludge June (S2)	Limed sludge to 10% (S3)	Limed sludge to 15 % (S4)	Limed sludge to 25 % (S5)	Limed sludge to 30 % (S6)
Ca	570	909	1173	1229	4302	5563
K	1978	2404	2543	3271	3341	4735
Mg	106	171	227	288	341	373
P	58	62	69	77	83	88

H. Metal Trace Elements (MTE)

Whatever the final destination of sludges, knowing metal trace element contents is crucial, especially in the case of recovery. Moreover, these MTE were kept as indicators for the quality of agricultural soils.
MTE contents in raw and limed sludges of both campaigns are shown in Table 5.
The results reveal a high abundance of aluminum in raw and limed sludges with concentrations varying between 66.666 and 192.708 mg / kg. These high concentrations can be explained by the regular use of aluminum sulfate as a coagulant in water treatment. Sludge liming contributes to an increase in pH, which causes a drop in soil aluminum uptake in the case of drinking water sludges agricultural spreading.
For iron, its evolution fluctuates between 14.633 and 28.593 mg / kg. The strong presence of this element in the sludge gives it a non-negligible amendment status in trace element for agricultural spreading.
Copper and zinc content in different samples remains very low and does not exceed 29.26 mg / kg for Cu and 98.78 mg / kg for Zn. Both are categorized as trace elements and strict non-contaminants.
As for strict contaminants Cd, Ni, Pb and Cr, their concentrations in different raw and limed sludges do not exceed the recommended limits in MTE for sludge agricultural spreading [13].
The addition of lime in sludge primarily allows the complexation of MTE which induces a modification in their chemical speciation. This modification has a tendency to move elements of the most labile forms to more stable forms.

Table 5: MTE results in raw and limed sludges of May and June 2012

Element	**concentration in mg/kg**					
	Raw sludge May(S1)	Raw sludge June(S2)	Limed sludge to 10%	Limed sludge to 15 %	Limed sludge to 25 %	Limed sludge to 30 %
Al	121951	66666	115000	192708	115625	111940
Fe	20243	14633	24550	28593	25781	20000
Cd	1.158	0.566	0.854	0.833	0.43	0.44
Cu	29.26	15	20.5	20.31	11.87	11.94
Ni	29.26	15.33	20.5	20.31	11.25	11.94
Pb	73.17	33.66	20.5	50	26.87	29.85
Cr	35.97	33.66	46	25	14.06	12.31
Zn	98.78	53.333	52.5	54.68	28.12	29.10

3.1.2 Microbiological Parameters

A. Salmonella and helminth eggs research

Sludge is considered sanitized when it meets the requirements of article 16 of the decree of December 8, 1997, the decree of January 8, 1998 and article 12, which set limit values for salmonella, enteroviruses and helminth eggs [14].
The research results for salmonella and helminth eggs of different samples are shown in Tables 6 and 7. They show that sludges at the treatment plant of Bouregreg perfectly meet the basic rules of hygiene for sludges to be used in landfarming.

Table 6: results for salmonella of different samples of May and June 2012

Concentration in MPN/10 mg MS						
Samples	S1	S2	S3	S4	S5	S6
Salmonella	0	0	0	0	0	0

Table7: Results for helminth eggs of different samples of May and June 2012

Concentration in unité OH /10 mg SM						
Samples	S1	S2	S3	S4	S5	S6
Helminthes Eggs	0	0	0	0	0	0

3.2 Physico-chemical parameters correlational study

The main purpose of this study is to evaluate the correlation between different analyzed parameters in raw and limed sludge. The obtained results were used to explain the existing variations between the analyzed elements in correlation with the liming process. In this analysis, the correlative study between the physico-chemical parameters gave relationships with strong correlation, average correlation and weak correlation [20].

We can therefore conclude that we have:

-A very strong correlation between the addition of lime and the increase in pH.

-Suspended matter increases with the addition of lime.

-Strong inverse correlation of moisture content with $CaCO_3$ (moisture content decreases with the addition of $CaCO_3$).

-Average correlation with $CaCO_3$ with different nutrients in sludge.

-Inverse correlation of MTE with $CaCO_3$.

We can conclude that the liming of drinking water sludges facilitates their management by increasing their dry matter content and decreasing their moisture content, thus signaling that the liming process gives sludges a calcium amendment status and organic matter and MTE stability with the increase in pH.

Pearson's correlations are highly significant (p>0.44;p=0.00<0.01). It allowed us to reinforce quantitative experimental results in terms of sludge improvement with respect to drinking water sludges regarding their handling and agronomic quality.

Table 8: Correlation between physicochemical parameters and $CaCO_3$ limed sludge treatment plant Bouregreg (R> 0.82, P <0.05)

	Correlation between physicochemical parameters and $CaCO_3$ of limed sludge treatment plant Bouregreg with a risk α = 5% (R> 0.82, P <0.00).
	[$CaCO_3$]
pH	(r=0.97;p=0.01<0.05) D.S
[SM]	(r=0.98;p=0.00<0.05) D.S
[VM]	(r=0.90;p=0.01<0.05) D.S
[DM]	(r=0.94;p=0.00<0.05) D.S
[MC]	(r=0.82;p=0.04<0.05) D.S
[NT]	(r=0.63;p=0.17<0.05)N.S
[PT]	(r=0.98;p=0.00<0.05) D.S
[Mg]	(r=0.97;p=0.00<0.05) D.S
[K]	(r=0.92;p=0.00<0.05) D.S
[Ca]	(r=0.92;p=0.00<0.05) D.S

Table 9 : Correlation between the concentrations of **MTE** and $CaCO_3$ of limed sludge treatment plant Bouregreg with a risk α = 5% (R**>** 0.70, P **<0.00).**

	Correlation between the concentrations of MTE and $CaCO_3$ of limed sludge treatment plant Bouregreg with a risk α = 5% (R> 0.70, P <0.00).
	[$CaCO_3$]
[Al]	(r=0.25;p=0.01<0.05) D.S
[Fe]	(r=0.43;p=0.00<0.05) D.S
[Cd]	(r=-0.67;p=0.01<0.05) D.S
[Cu]	(r=-0.68;p=0.00<0.05) D.S
[Ni]	(r=-0.70;p=0.04<0.05) D.S
[PB]	(r=-0.49;p=0.17<0.05)N.S
[Cr]	(r=0.98;p=0.00<0.05) D.S
[Zn]	(r=0.97;p=0.00<0.05) D.S

ISSN : 2028-2508
CODEN: JMESCN

Conclusion

The purpose of this study is to characterize drinking water sludges at the treatment plant of Bouregreg in order to evaluate their agronomic value in landfarming and thus come up with recommendations for low-cost management. The obtained experimental results showed that these sludges are perfectly suitable for landfarming after the addition of lime. In fact, liming gives them a calcium amendment status. The pH going from 6.9 in raw sludge to 11.5 in limed sludge. Moreover, we noticed an increase in the decantation speed from 0.5 cm / h to 3 cm / h and an increase in dryness from 8.81% in raw sludge to 13.41% in limed sludge which automatically translates to a decrease in moisture content from 91.8% in raw sludge to 86.58% in limed sludge. The low VM content in sludges which does not exceed 30% facilitates their thickening and dehydration. On the other hand, the analyses of the elements NT, PT, K and Mg showed stability in limed sludge organic matter, compared to non-limed sludge. The microbiological results show that sludges at the treatment plant of Bouregreg perfectly meet the basic rules of hygiene for sludges to be used in agricultural spreading. Thus, drinking water sludges at the station of Bouregreg can be spread on agricultural land without specific constraints, under the term “decantation lands”, averaging, most of the time, an addition of lime giving them a calcium amendment status and a better rheological quality.

Acknowledgement-This study was conducted in the laboratory of quality control, Drinking water treatment plant of Bouregreg .The authors acknowledge support from National Office of Hydrocarbons and Mines and laboratory for Materials, Nanomaterials and environment, Faculty of Science University Mohamed V. Authors would like to thank “National Office of electricity and drinking water” Company for supplying the drinking water sludge.

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(2015) ; http://www.jmaterenvironsci.com