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Mechanical Characterization and Impact Study on the Environment of Raw Sediments and Sediments Dehydrated by Addition of Polymer

A. Kasmi, N. E. Abriak, M. Benzerzour, I. Shahrour

***Abstract*—**Large volumes of river sediments are dredged each year in Europe in order to maintain harbour activities and prevent floods. The management of this sediment has become increasingly complex. Several European projects were implemented to find environmentally sound solutions for these materials. The main objective of this study is to show the ability of river sediment to be used in road. Since sediments contain a high amount of water, then a dehydrating treatment by addition of the flocculation aid has been used. Firstly, a lot of physical characteristics are measured and discussed for a better identification of the raw sediment and this dehydrated sediment by addition the flocculation aid. The identified parameters are, for example, the initial water content, the density, the organic matter content, the grain size distribution, the liquid limit and plastic limit and geotechnical parameters. The environmental impacts of the used material were evaluated. The results obtained show that there is a slight change on the physical-chemical and geotechnical characteristics of sediment after dehydration by the addition of polymer. However, these sediments cannot be used in road construction.

***Keywords*—**River sediment, dehydration, flocculation aid, characteristics, environmental impacts, road construction.

I. Introduction

SEDIMENTS are defined as a set of loose particles of clays, silt and sand, formed from the erosion of rocks and soils from organic activity, and from local discharges caused by human activity. The dredging operations of the sediment are necessary to maintain navigation in waterways and access to habours. Each year, this operation generates a considerable quantity of sediments, about 250 Mm^3 in Europe [1] and 50 Mm^3 in France [2] more than 6 Mm^3 are fluvial sediments [3]. However, the industrial and the anthropogenic activities bring a multitude of inorganic pollutants (heavy metals) and organic ones (hydrocarbon, PAH, PCB ...) in sediments [2], [4]. The beneficial of use in the civil engineering domain consumes over 450 Mt of granular materials each year, and 80% of such materials are annually consumed in the field of road construction [5]. Over 96% of these aggregates are mainly provided by natural accumulation. However, only 5% of the materials generated from recycling operation are used in public works at present [5]. Thus, the use of sediments in the construction sector may represent a new source of supply of aggregates and the valorization of dredging sediments brings, despite the difficulties, socio-economic and environmental benefits. In the road construction, the characteristics of dredged materials could be similar to those of currently used materials [6], from grain size distribution (fine to coarse aggregates) often have inadequate mechanical properties to be used in Civil Engineering. The dredged sediments are often fine materials with high moisture content. The determination of the mechanical properties of these sediments often has inadequate to be used in Civil Engineering. Several ways of valorisation of dredged sediments in combination with treatment (hydraulic binders, granular corrector…) have been explored: in road construction [3], [7]-[15]; in aggregates [16], [17] in concrete [13], in brick [18]-[20] and cement production [21]. This water content depends on the nature of the sediments and the dredging method. There are several techniques used for sediment dehydration as for example: natural drying, mechanical adding of chemical reagents (flocculation aid / polymer) and thermally techniques [22]. It should be noted that, the use of flocculation aid leads to: 1) facilitate the separation of liquid-solid phase, 2) improve the quality of the rejected water and 3) increase the concentration of sludge produced. This polymer aid favors the agglomeration of destabilized particles, forming flocculates which can be easily separated from the water by way of decantation or filtration [23]-[27]. The choice of used polymer and its dose is based on laboratory optimization tests. These optimization tests are linked to the material type and the dehydration method [28]. The optimal determination of the polymer proportioning is essential taking into account to facilitate dehydration, and to obtain a high dry matter content of the dewatered sludge cake and low conditioner dose of polymer [25], [29], [30].

This work presents the comparison of physical-chemical, mineralogical, geotechnical and environmental properties of raw sediment and dehydrated sediments by the addition the flocculation aid (will be denoted as flocculated sediment in this study).

II. Materials and Methods

The rive sediments use in this study were dredged from river Bure in Norfolk situated in England.

The used polymers for dehydration in this study are anionic, cationic and non-anionic. These polymers were provided by

A. Kasmi, N. E. Abriak, Mahfoud Benzerzour Abriak, and Issam Shahrour are with the Laboratoire Génie Civil et géo-Environnement de Lille Nord de France, Laboratoire Génie Civil & Environnemental, Ecole des Mines de Douai, 941, rue de Charelbourseul, Douai, France (phone: 00.33.3.27.71. 24.10; e-mail: Abdelhafid.kasmi@mines-douai.fr, nor-edine.abriak@mines-douai.fr, Mahfoud.benzerzour@mines-douai.fr, isam.shahrour@polytech-lille.fr).

SNF Florger society. The selection of polymers and their dosage is determined by the jar-test. After the Jar-test, the flocculated sediments were filtered for 5 minutes, in order to determine the final moisture content. Sediment dewarting was realized by using a drying bed on raw sediments, and flocculated sediments as determined by the Jar-test. The physical characteristics of the raw sediment and flocculated sediment with the addition of polymer such as the organic matter content, the specific gravity and the grain size distribution, are determined according to European and French test standards. The mineralogical composition of these sediments was investigated using X-ray diffraction (XRD Bruker D8 with Co Kα radiation at 1.78 Å).

To assess the environmental impacts of the sediment, leaching tests were performed on three samples, in accordance with the European test standard EN 12457-2. The leaching tests were conducted with a liquid-to solid ratio (L/S) of 10 (100 g of solid in 1 l of deionized water). The mixture was stirred at a rate of 60 cycles / min for 24 h. The leachate was separated from the solid phase by centrifugation and filtered using a 0.45-µm membrane filter for inductively coupled plasma-atomic emission spectroscopy (ICP-AES) measurements. The metallic elements were analysed by ICP-AES. Chloride, nitrate and sulphate contents were measured by means of ionic chromatography. To evaluate the potential of dredged fine sediments for use in road construction, comparisons to specific thresholds defined in the guide published by French authorities are made [31].

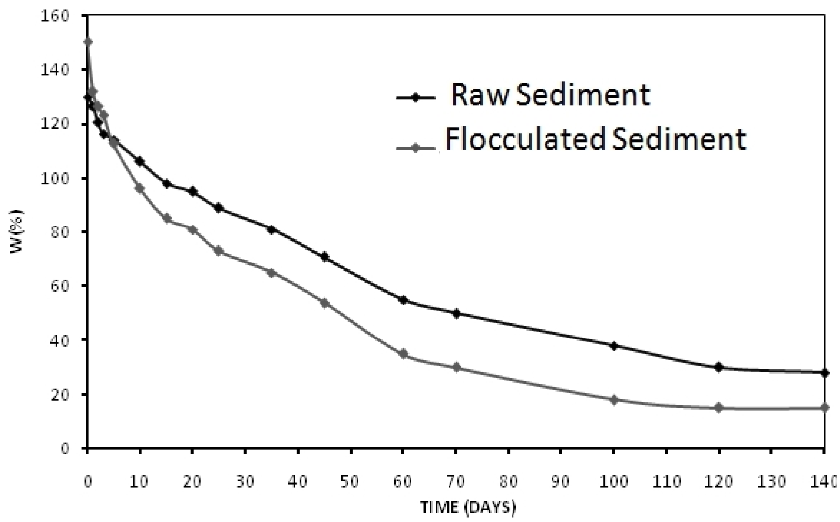

Fig. 1 Evolution of the water content in function of time for raw sediment and sediment flocculated by the addition of polymer

III. Results and Discussion

A. Physical Characterization

In this work, the used polymer is cationic polymer, and the optimum dosage for this polymer was determined at 4 kg/ton dry sludge. This optimal dose has allowed to obtain the effective results for its clarity and high dry matter of dewatered sludge cake. According to standard NF P94-050, the water content monitoring for raw sediment and flocculated sediment are measured as a function of time. The set obtained results are shown in Fig. 2. It appears that a decrease in water content for the flocculated sediment compared to raw sediment. The addition of polymer allows the saving of 30-60 days to obtain the same water content. Consequently, the use of polymer reduces the dehydration time and liberates the site of dehydration.

Table I presents the test results of physical characteristics of the studied sediments. From this table, it appears that a 1% increase in the organic matter after dehydration of the sediment with a polymer. This increase was related to the presence of organic compounds in the polymer chain and by the elimination of the organic soluble or not soluble particles (acid humic and acid fulvic) by the polymeric chain [29], [30], [32]. It also appears an increase in the liquid limit (LL (%)), Plastic limit (PL (%)) and VBS after dewatering the sediment with a polymer. The organic matter increases the plastic limit, liquid limit [33], [34] and also the capacity of fixing by adsorption [35]. For illustration, Fig. 3 shows the difference between raw sediment and flocculated sediment after addition of cationic polymer.

TABLE I
Physical and Geotechnical Properties of River Sediment

Parameters	Raw sediment	Flocculated sediment
Organic matter content (%) at 450°C (NF EN 15169-2007)	7	8
Specific density (ρs) (ASTM D5550-06)	2.45	2.43
Methylene blue value (NF P94-068-1998	2.9	3.2
Plastic limit - PL (%) (NF P94-051-1993)	85	93
Liquid limit - LL (%) (NF P94-051-1993)	42	48
Plasticity index - PI (%) (NF P94-051-1993)	43	45

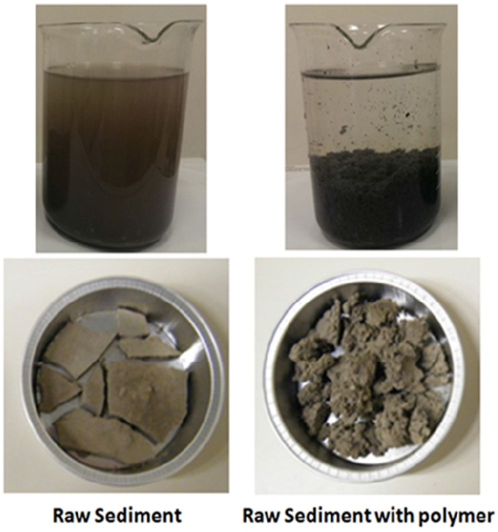

Fig. 2 Visual appearance for raw sediment and flocculated sediment

The grain size distribution, obtained using the laser diffraction technique, was carried out on raw sediments and flocculated sediments with agitation for 5 minutes and 20 minutes. The set obtained results are reported in Fig. 4. It observed that the polymer addition provokes an agglomeration of particles. Indeed, 20 minutes of agitation causes the rupture of the connections between the agglomerated particles and generates the deflocculating of flocculated sediment.

In general, the polymer leads to create the flocs, which acts as a glue between the particles by adsorption or by bridging. These actions can be realized in a reversible way [27], [36].

It is noted that the raw sediment and flocculated sediment could be classified as an F11-A4 type of material according to the Frenchguide for materials classification for road construction. This type of material, depending on the bearing capacity and the consistency index, could not be used in embankment construction work.

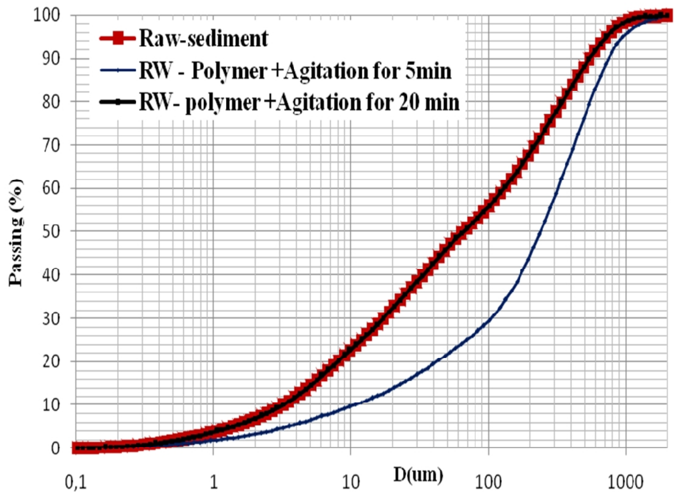

Fig. 3 Grain size distribution of raw sediment and flocculated sediment agitation for 5 and 20 minutes

B. Geotechnical Characterization

The IPI (%) CBR index is used to measure the bearing capacity of a compacted material. The test consists of applying a static load with a piston and to follow the penetration of this piston into a material. This test is preceded by the compaction of sample according to Proctor test, which are necessary to evaluate the water content, allowing the highest level of compaction at a field site.

The obtained results of raw sediment and flocculated sediment are reported in Figs. 4 and 5. The measured values of the optimum moisture content and the optimum dry are shown in Table II.

The obtained results show a decrease of the dry density with an increase in the optimum water content after the addition of polymer. This result could be explained by an increase in the organic matter after polymer addition[33].

TABLE II
DRY DENSITY, WATER CONTENT AND CBR INDEX FOR THE HIGHEST LEVEL OF COMPACTION

River Sediments	Raw	With polymer
WOPM (%)	18	20
ρd (g/cm³)	1.64	1.61
IPI (%)	19	25

C. Mineralogy and Environmental Characterization

Using the XRD pattern, see Fig. 5, shows that the studied sediment contains: Quartz, Calcite and other minerals such as Pyrite, Halite, Illite. Consequently, the dehydration of sediment using polymer has no effect on mineral phases.

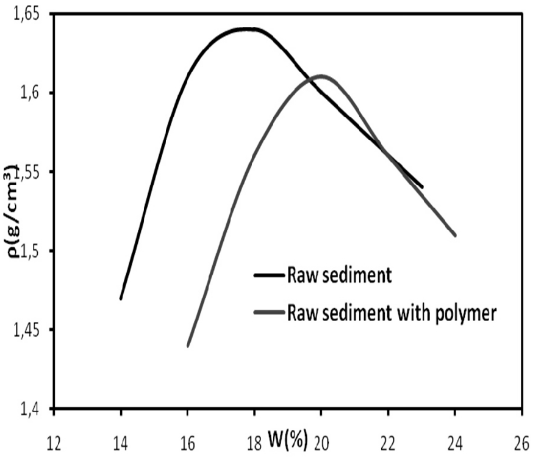

Fig. 4 Compaction of the studied sediments

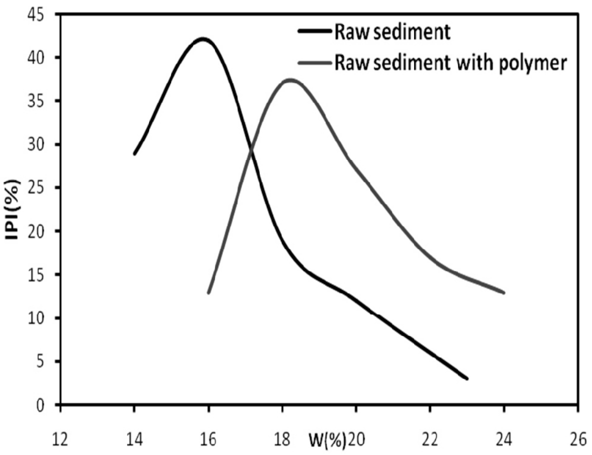

Fig. 5 IPI index of studied sediments

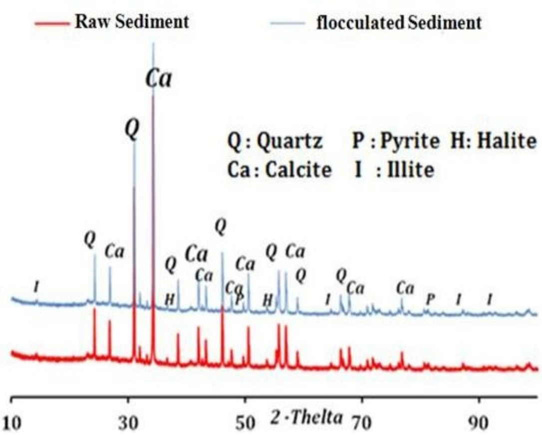

Fig. 6 X-ray patterns of raw and flocculated sediment showing of different mineral

According to the European test standard EN 12457-2, the environmental impacts of the raw sediment and flocculated sediment were performed. The set obtained results are listed in Table II. It appears that the measured values are lower than the limit values for use in road threshold [31]. From this table, it also observed that the dehydration of the sediment by polymer has no effects on the environment, and the chemical properties of these sediments are therefore considered acceptable for valorization in road construction.

TABLE III
LEACHATE TEST ON RAW SEDIMENT AND FLOCCULATED SEDIMENT (CUMULATIVE AMOUNT LEACHED L/S = 10 L/KG

Elements	Raw Sediment	Flocculated Sediment	Leaching limit values Validation for use in road
As	0.944	0.143	2
Ba	0.556	0.461	100
Cd	0.004	0.004	1
Cr	0.029	0.029	10
Cu	0.348	0.254	50
Hg	<0.001	0.010	0.2
Mo	0.178	0.160	10
Ni	0.088	0.089	10
Pb	0.060	0.060	10
Sb	0.058	0.058	0.7
Se	0.071	0.071	0.5
Zn	0.129	0.083	50
Fluorides	15	18	150
Chlorides	8140	6900	15000
Sulfates	1540	1100	20000
S F	18886	14200	60000
PH	7.950	8.200	[5.5-13]

IV. CONCLUSION

In this paper, the ability of river dredged sediment to be used as a sub-bas material is explored. After the dehydration by polymers, we obtain:

- A reduction of water content, between 30 - 60 days of difference, to obtain the same moisture content
- An increase inorganic matter causes a slight change in Atterberg limits and VBS and there is an increasing in the optimum moisture content with a decrease in the maximum dry density.
- No effect in the Mineralogy characterization and environmental impact.
- Raw sediments and flocculated sediments are classified as F11A4 on GTR and cannot be used in foundation layer.

To use this type of material in the road foundation, generally it is recommended to treat this type of material by lime and/or hydraulic binders and granular corrector.

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REFERENCES

[1] Sednet, "«European Sediment Network» site: http://www.sednet.org," European Sediment Network, 2011. (Online). (Accessed 2012).

[2] C., Alzieu, Dragages et environnement marin: état des connaissances: Ministère de l'aménagement du territoire et de l'environnement, Vols. 2-84433-014-2, Paris, 1999.

[3] NT., Tran, "Valorisation de sédiments marins et fluviaux en technique routière," Thèse de Doctorat, Ecole Mines de Douai, 2009.

[4] L. Hecho, État de l'art des tests de traitabilité d'une pollution, Les cahiers techniques, Pôle de compétence Sites et sédiments pollués en région Nord-Pas-de-Calais. Pôles de compétence Sites et sédiments pollués, 2-9517290-1-4, 2001, p. 37.

[5] Unicem, Carriére de Granulats et Developpement Durable 2011, 2009.

[6] V., Dubois, "Caractérisation physico-mécanique et environnementale des sédiments," Thèse de Doctorat à l ' Ecole des Mines de Douai, Douai, 2006.

[7] R., Boutin, "Amélioration des connaissances sur le comportement des rejets en mer des produits de dragage type vase: phénomènes court terme champ proche," Thèse de doctorat à l'Institut national des sciences appliquées de Lyon, Lyon, 1999.

[8] M, Boutouil, "Traitement des vases de dragage par stabilisation/solification à base de ciment et additifs," Thèse de doctorat, Université du Havre, Université du Havre, 1998.

[9] D., Colin, "Valorisation de sédiments fins de dragage en technique routière," Thèse de Doctorat à l'Universite de Caen, Caen, 2003.

[10] P., Scordi, Caractérisation et valorisation des sédiments fluviaux pollués et traités dans les matériaux routiers, Lille: Thèse de doctorat à l'école centrale de Lille, 2008.

[11] M., Miraoui, "Prétraitement et traitement des sédiments de dragage en vue d'une valorisation dans le génie civil," Thèse Doctorat à l'école des Mines de Douai, Douai, 2010.

[12] M., Dia, "Traitement et Valorisation de Sédiments de Dragage Phosphatés en Technique Routière," Thèse de Doctorat à l'école des Mines de Douai &Universite d'Artois, Douai, 2013.

[13] R., Achour, "Valorisation et caractérisation de la durabilité d'un matériau routier et d'un béton à base de sédiment de dragage," Thèse de Doctorat à l'école des Mines de Douai et l'universite de Sherbrooke, 2013.

[14] W., Maherzi, "Valorisation des sédiments de dragage marins traites aux liants hydrauliques en technique routière," Thèse de Doctorat à l' Université de Caen basse Normandie. U.F.R: sciences Caen école Doctorale normande de chimie, Caen, 2013.

[15] M., Benzerzour, Mansi. R, Abriak. N-E and Becquart. F, "Mathematical model for beneficial use of dredged sediments in road construction.," Journal of Engineering and Innovative Technology (IJEIT), vol. 3, pp. 1-6, 2013.

[16] S., Brakni, "Première approche vers une valorisation de granulats artificiels à base de sédiments de dragage," Thèse de Doctorat à l'Ecole des Mines de Douai, Douai, 2008.

[17] A., Zri, "Mise en place d'une nouvelle approche de formulation d'une matrice cimentaire à base de sable de dragage: application aux bétons de sables et granulats," Thèse de Doctorat à l'école des Mines de Douai, Douai, 2010.

[18] M., Samara, "Valorisation des sédiments fluviaux pollués après inertage dans la brique cuite," Thèse de doctorat à L'école Centrale de Lille & Université des Sciences et Techniques de Lille, Lille, 2007.

[19] Z., Lafhaja, M., Samara, F., Agostini, L., Boucard, F., Skoczylas and G., Depelsenair, "Polluted river sediments from the North region of France: Treatment with Novosol process and valorization in clay bricks," Construction and Building Materials, vol. 148, pp. 606-612, 2007.

[20] L., Allal, M., Benammari, I., Frar, A., Azmani and N.E., Belmokhtar, "Caractérisation et valorisation des sédiments de dragage des ports de Tanger et Larache (Maroc)," Revue Paralia, vol. 4, pp. 5.1-5.13, 2011.

[21] JI., Dalton, KH., Gardner, TP., Seager; ML., Weimer; JCM., Spear; BJ Magee, "Properties of Portland cement made from contaminated sediments.," resources conservation recycling, vol. 41, pp. 227-241, 2004.

[22] D. Levacher and P. Dhervilly, "Déshydratation mécanisée in situ de sédiments fraîchement dragués ou mis en dépôts: le projet SEDIGATE I," XIèmes Journées Nationales Génie Côtier – Génie Civil, pp. 859-868, 22-25 juin 2010.

[23] W., Chen, D., Harbottle, Q., Liu and Z., Xu, "Current state of fine mineral tailings treatment: A critical review on theory and practice," Minerals Engineering, vol. 58, p. 113–131, 2014.

[24] Mikkelsen, L. Haugaard and K. Keiding, "Physico-chemical characteristics of full scale sewage sludges with implications to dewatering," Water Research, vol. 36, p. 2451–2462, 2002.

[25] V., Legrand, D., Hourdet, R., Audebert and D., Snidaro, "Deswelling and flocculation of gel networks: application to sludge dewatering," Water Research, vol. 32, no. 12, pp. 3662-3672, 1998.

[26] Örmeci, "Protocol to measure network strength of sludges and its implications for dewatering.," Journal of Environmental Engineering (enligne), pp. 131, 80-85., 2005.

[27] J., Gregory, "Polymer adsorption and flocculation in sheared suspensions," Colloids and Surfaces, vol. 31, p. 231–253, 1988.

[28] D., Chezau and P., Ginisty, "Floculation des boues: méthode d'essais pour l'optimisation de leur épaississement/déshydratation," Eau Industrie et Nuisance, no. 314, pp. 75-78, 2008.

[29] I., Baudin; j., Rodrigues, S., Huet, Optimisation du procédé de clarification Utilisation des Polymères Cationiques, 2005.

[30] Baudin, "Optimisation des procédés de clarification: Utilisation des polymères cationiques," Etude financée par l'Agence de l'Eau Seine Normandie, 2006.

[31] Setra, guide méthodologique: Acceptabilité de matériaux alternatifs en technique routière-Evaluation environnementale, 2012.

[32] YJ. Dong, YL. Wan and J. Feng, "Rheological and fractal characteristics of unconditioned and conditioned water treatment residuals," water research, vol. 45, pp. 3871-3882, 2011.

[33] R., Zentar, N-E., Abriak and V., Dubois, "Effects of salts and organic matter on Atterberg limits of dredged sediments," Applied clay science, pp. 391-397, 2008.

[34] H., Tremblay, "Amélioration mécanique et prédiction de la compressibilité des sols fins du Québec," Thèse de doctorat à l'Université Laval, QUÉBEC, 1998.

[35] M., Mustin, "Le compost: Gestion de la matière organique," Editions François Dubusc, Paris, 1987.

[36] M.E., Krapf, "Agrégation de cellules bactériennes par des polymères cationiques (polyéthylèneimine): influence de la masse moléculaire du polymère et de la présence/absence de surstructuresexopolymériques bactériennes sur la déshydratation des boues biologiques," Laboratoire Environnement et Minéralurgie - UMR 7569 - Université de Lorraine, Ecole Doctorale Sciences et Ingénierie des Ressources, Procédés, Produits, Environnement, Lorraine, 2012.