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RESEARCH ARTICLE

Characterization of sludge waste products from wastewater treatment plant of Khenifra city in Morocco

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ABSTRACT

To promote the utilization of sewage sludge as alternative building materials, a study was carried out to examine the characteristics of sewage sludge from wastewater treatment plant of khenifra city, Morocco. Experiments were performed for determining the mineralogical composition, chemical properties, loss of weight, the rate of the calcium carbonate and moisture. Furthermore, the geotechnical parameters deal with the Atterberg limits, water content and Sand equivalent of the sewage sludge material. The purpose of this paper is to present the available information on the various components of sewage sludge to explore the possibility of exploiting this waste in building materials

Results show that sewage sludge has neutral pH value around 6.93 and contains organic matter. Moreover, the sludge is composed of a significant amount of oxides and metals. The value of net calorific value (NCV) is 1888.91 Kcal kg^{-1}. As well as, the mineralogical composition of sludge has been determined by X-rays diffraction (XRD) show the presence of quartz (SiO_2), hematite (Fe_2O_3), aluminum oxide (Al_2O_3) and calcite (CaO_3).The result of the geotechnical properties of sewage sludge obtained indicates a very high value for a liquid limit of 126%, a plastic limit of 100% and the plasticity index of 25% and 128% water content.
Based on the data obtained from the characteristics of sewage sludge produced by wastewater treatment plant in the Khenifra city, the utilization of sewage sludge into building materials such as in brick making, ceramics making and in the manufacture of cement are possible, because sludge composition is similar to the raw to construction materials.

Keywords: Characterization, recycling, sewage sludge, wastewater treatment plant

1. INTRODUCTION

Rapid increase in industrial development, population growth and improvements in life style are among the factors leading to higher wastewater production. Consequently, the wastewater treatment results in generating huge amount of sewage sludge worldwide [1]. In Morocco, the annual production of sewage sludge exceeds 2 million tons of dried sludge in 2015. While the amount of sewage sludge produced in 2025 is estimated to reach 3.4 million tons as a result of the rapid progress of urbanization and the continuous improvement of sewage treatment facilities [2.3]. Among all the sewage sludge disposal methods at present, the most common techniques to discard of sludge are sanitary landfills, in addition to some being used in agriculture as organic fertilizer and for soil management [4, 5]. In the meantime, more stringent environmental regulations which govern the disposal of sewage sludge have resulted in limitations on sewage sludge disposal options [6]. These methods of managing the sewage sludge might have adverse impacts on the environment. As a consequence of these problems related to the disposal of sewage sludge, another a new technique of sewage sludge

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disposal is based on the utilization of sludge in construction materials. However, the physicochemical characteristic and mineralogical property of the sludge is similar to the construction material investigated in literature [7]. Several research work has been done on the use of this waste in construction materials, to make filler in asphalt concrete applications [8], in brick making [9, 10, 11], in ceramic making [12, 13], and in the manufacture of cement [14, 15, 16], cementitious materials [17, 18], or for the manufacture of aggregates and lightweight aggregates [19, 20].

The main objective of this study is to evaluate the characteristics of sewage sludge such as the properties mineralogical, characterization of the physicochemical and also the geotechnical parameters to solve the problem of sludge disposal due to the growing amount of sludge as well as environmental protection issues and to reduce costs of the handling of sewage sludge is becoming one of the most significant challenges in wastewater management, therefore, reuse or recycling of sewage sludge to develop sustainable construction materials as proved to be a practical solution for disposal and environmental problem.

2. MATERIALS & METHOD

The sample of the sewage sludge used in this work was sampled from the wastewater treatment plant (WWTP) located in the Khenifra city, Morocco. The WWTP is a sewage treatment plant by processes biological according to standardized conditions of AFNOR EN 1085 [21].

The sludge was dried in air are brought to the laboratory, for to characterize the physical properties, chemical analysis, and geotechnical parameters. For this purpose, the collected samples were dried at a temperature equals of 105°C for 48 hours, the sludge dried has undergone a pulverization in a porcelain mill and it sieved to obtain a particle size less than 200 µm using a metallic sieve. In the laboratory basic physical parameters was determined; pH was determined by pH meter, moisture content was determined according to NF EN 13037 standard [22], and conductivity ratio was determined according to the standard LST EN 1745 [23].

The major chemical compounds such as (Cr, Co, Cu, Zn, Pb, and Cd) of the dry sludge have been analyzed by inductively coupled plasma-atomic emission spectrometry (ICP-AES) equipment. The net calorific value (NCV) is determined by calorimetric bomb type 6100 calorimeter.

The mineralogical composition is determined by X-ray diffraction (Bruker X-ray diffractometer equipment) in a radiation of half an hour scanning, which explores in the interval of 2Θ angles from 10° to 90°.

The particle size distribution was measured by conventional sieving for the 63 to 2000 µm fractions sieves, according to NLT 104/91 standard [24] and ASTM standard [25].

Limits of Atterberg corresponding to the thresholds of the passage of the solid state in a plastic state and to the plastic state in the liquid state. The interval between these two limits allows to obtain the index of plasticity. These limits were determined by the Casagrande method [26, 27, 28, 29].

The water content is defined as the ratio of the mass of the pore fluid to the mass of the solid particles, expressed as a percentage. The water content was determined using the oven-drying method BS1377 [29]. The mass of the solid particles in the sludge specimen equals the residual mass after drying in an oven at a temperature of 110 ± 5°C for a period of 8–16 h according to ASTM D2216 standard [30, 31]. The sand equivalent was determined according to NLT 113/87 standard [24], a quick procedure for determining the percentage of fines elements contained in a material [32].

3. RESULTS & DISCUSSION

3.1. Physical characteristics

Table 1 shows the physical characteristics such as pH, moisture content, net calorific value, volatile matter, loss on ignition and rate of the calcite of the sewage sludge.

Table 1. Physical characteristics of the sewage sludge

Parameters	Content	Literature results [7]	Literature results [33]	Literature results [34]
pH	6.93	6.82	6.85	7-7.5
Conductivity (mS m^{-1})	4.51	-	3.27	-
Moisture[a] (%)	23.33	2.35	-	74
NCV (Kcal kg^{-1})	1888.91	-	-	-
Volatile matter[b] (%)	51.90	2.66	-	-
Loss on ignition[c] (%)	44	8.96	-	-
Rate of the $CaCO_3$	16.55	-	-	5.98

[a]Heated at 105±5 °C for 24 hours [b]Combusted at 550±5 °C for 2 hours [c]Combustedat 550±5 °C for 4 hours

The results of pH (6,93) indicated that the average near the neutrality, this value is close to those found in literature; Ahmad et al.[7], Naamane et al. [33] and Malliou et al. [34] found respectively 6.82, 6.85, 7 as a values of pH in their studies. The moisture content of dried sample is 23.33, the same result was found by Modolo et al. [35]. The volatile matter present in the sludge is 51.9 % indicates that the sludge is inorganic in nature, whereas loss on ignition is 44 %. The rate of carbonate found is 16.55%, which is the same result obtained by Aadraoui et al. [36]. NCV found is 1888Kcal.kg-1, the value of NCV compared with results found in other studies; Husillos-Rodriguez et al. [37] found 1999 Kcal kg^{-1}, Zhang et al.[38] found 5972 Kcal kg^{-1}, Samolada et al. [39] found 3487 and Zhao et al. [40] found 4497 Kcal kg^{-1}. This can be explained by the presence of significant amounts of soil in the sludge. Indeed, the mineral matter influences the NCV of a material. The Fig. 1 shows the result of particle size distribution of the sludge.

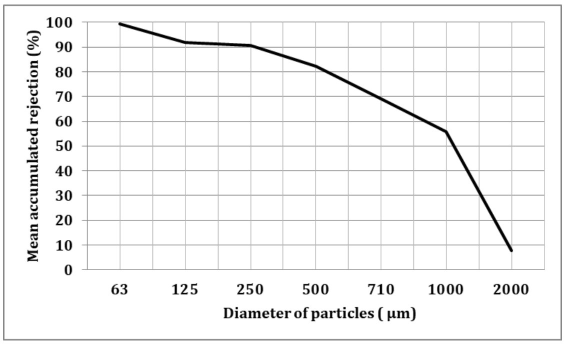

Fig 1. Sludge grain size distribution

About 78% of sand (distributed as follows, coarse sand is 25%, medium sand is 17% and fine sand is 36%) ranging between 150-75µm and also around 22% for clay and silt fractions its diameter is lower than 63 µm, are constituted principal composition of the sludge of this study. Furthermore, it was similar to that of fine agglomerate according to results obtained in the study by Valls et al. [41].

3.2. Chemical characteristics

The Table 2 shows the ICP–AES analysis results for the sewage sludge. The results indicated the presence of high quantity of Ca, Fe, Mg, Na and K. In general, the concentration of these elements was the same result obtained by Naamane et al. [42, 43, 44], Tantawy et al. [45] and Cyr et al. [46]. The high concentration of the calcium and iron in the sewage sludge is owing to the utilize of ferric salts during wastewater treatment. Thus, these results provided a presence of heavy metals such as Zn, Cu, Pb, Cd and Co. these toxic elements may be due to domestic detergents (may be which contain several chemical elements such as linear alkylbenzene sulfonates, nonylphenol and alkylphenol ethoxylates), or by the erosion of the system of piping or by pluvial waters [47]. On the other hand, the sludge tends to accumulate high concentrations of heavy metals, because of the physical-chemical processes that are involved in wastewater treatment plant [48, 49].

Table 2. Results of Heavy metal in sewage sludge

Non-toxic elements			Toxic elements		
Elements	Content (mg kg^{-1})	Literature results [42]	Elements	Content (mg kg^{-1})	Literature results [42]
Fe	14860	34.16	Zn	1386.67	3.82
Ca	64633.33	657.245	Cu	211.33	1.84
Mg	6833.33	69.422	Ba	337.93	0.53
Al	3942.53	-	Pb	100.88	1.04
K	1435.66	18.966	Cr	31,52	0.79
Na	1600.66	79.239	Cd	131.18	0.04
Mn	156.56	0.33	Co	3.106	0.02

3.3. Oxide composition

The results of the X-ray diffraction (XRD) patterns of the sewage sludge are shown in Fig 2. The major chemical composition of the sludge is present in figure 2, showed the presence of calcite ($CaCO_3$) and quartz (SiO_2), aluminum oxide (Al_2O_3) and hematite (Fe_2O_3) are the main components of the sludge, same results obtained by Al-Sharif et al. [50], De-Lima et al. [51] and Aadraoui et al. [52]. This component produces during wastewater treatment because of the using of coagulant as the aluminum oxide and iron oxide [47], it is noted that components of the waste sludge which is similar to the primary components found in the ordinary Portland cement and also in the silty fractions of clays [53, 54].

3.4. Geotechnical parameters

Some geotechnical properties of sewage sludge tested are listed in Table 2. The plasticity characteristics assessed using the Atterberg limit tests, indicated a liquid limit of 126.08% and a plastic limit of 100.49 %. The plasticity index of 25%, based on those results on the classification of Casagrande, it can be concluded that the sewage sludge mostly a similar behavior within soils elastic silts and organic clay of very high plasticity [32, 55]. In addition, the liquidity index about -1.42 % was given that this sewage sludge is largely solid [52], according to the result of the consistency index about to 3.72 %, this sewage sludge is solid. However, the equivalent of sand around to 15% was confirmed the sewage sludge sample is plastic, this result correlated with those of the plastic soil [52], according to the classification of Casagrande, the sewage sludge is the similar composition with of soils elastic silts clays to high plasticity. Laboratory test results demonstrated that the sludge was high in water content near at 128.45%.

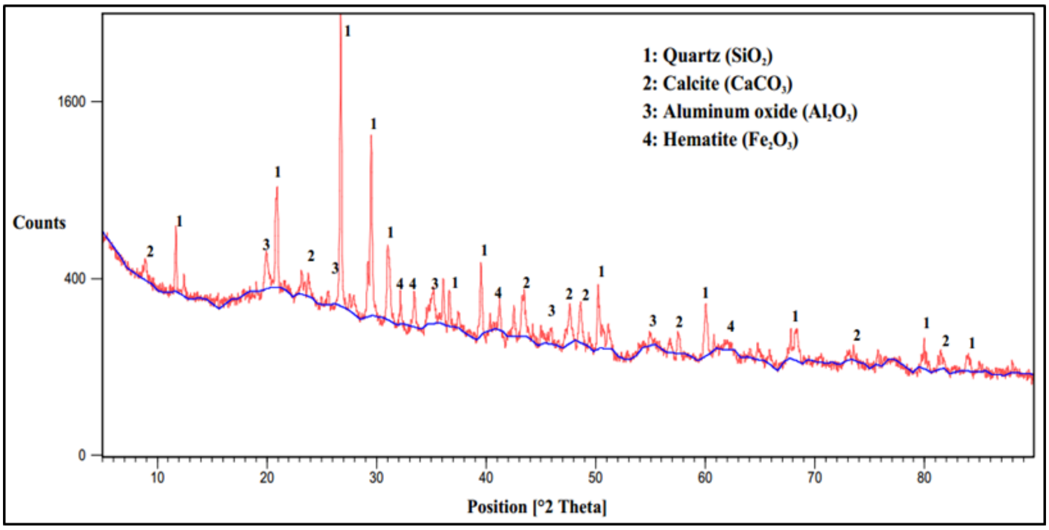

Fig 2. XRD patterns of sewage sludge

Table 2. Geotechnical properties of the sewage sludge

Parameters		Mean (%)
Limits of Atterberg	Liquid limit (L_L)	126.08
	Plastic limit(P_L)	100.49
	Plasticity Index (P_I)	25.60
	Liquidity index (L_I)[a]	-1.42
	consistency index(C_I)[b]	3.72
Equivalent of sand		15
Water content (W) (%)		128.45

[a] $L_I = \frac{(W-P_L)}{(L_L-P_L)}$ [b] $C_I = \frac{(L_L-W)}{(L_L-P_L)}$

4. CONCLUSIONS

The results of this research are the first step in the study of the characterization of the sewage sludge generated by wastewater treatment plants of Khenifra City. Since the calorific value is low and the sewage sludge contains the mineral material it may be used as raw materials in construction. The following conclusions can be made from the studies carried out:

1. This sewage sludge contains high organic substances and heavy metals;
2. This sewage sludge composes of SiO_2, Al_2O_3, and small amounts of Fe_2O_3, the sum of SiO_2, Al_2O_3, and Fe_2O_3 satisfies requirements stated for pozzolanic;
3. This sewage sludge mainly contains Ca, Fe, Mg, Na, P and K, and as minor constituents, it contains Zn, Pb, Cu, Ti, Ba, Cr, Mn, and Ni;
4. The geotechnical parameters according to the classification of Casagrande showed that the sewage sludge consisted of high values of liquid limits and plastic limits.

Based on these results, the next step in our work (which will be the subject of the next publication) is the use of this waste sludge as an additive in construction materials (in the manufacture of cement, manufacture of brick and of aggregates), to assess the effect of this sludge on the cement and also know about the added sludge dose that would be ideal and similar to the standards of building materials.

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