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Physical Characterization of River Sands Used in Central and Northern Regions Togo

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Abstract In this article, it is determined the characteristics of river sands used in the central and northern regions Togo in order to know their skills as building materials and as water filtration materials. Samples of these sands are taken and subjected to identification tests such as particle size analysis, apparent and absolute densities, sand equivalent test. The sand characterization parameters (fineness modulus, uniformity and curvature coefficient, effective diameter, etc.) were evaluated. It appears that most of river sands of central and northern regions Togo are suitable for being used to make good concrete. These river sands are suitable, with regard to the physical parameters studied, for use, in the raw state, as filtration materials on wastewater treatment units. For the needs of use on a wide range of sand filters for drinking water production stations, a granular correction by sieving and calibration is necessary, as for all natural sand, in order to make effective diameters and uniformity coefficients of materials studied conform to standards.

Keywords river sand, concrete, filtration material, building material

1. Introduction

The most widely used material on earth after water, sand is mainly used in civil engineering in the manufacture of mortars and concretes but also for other applications such as water filtration in wastewater treatment or drinking water treatment units. There are two main categories of sands: natural sands from rivers, mountains, sea or extracted from quarries and artificial sands from the crushing of slag blocks in blast furnaces. Different types of sands are used in Togo mainly for the construction of civil engineering works: silty quarry sand, crushed sand and rolled river sand. In the center and the north of the country, river sand is often used to carry out construction, given the multitude of rivers of different sizes existing in these regions.

The purpose of this study is to map river sands in central and northern Togo and to carry out their physical characterization in order to deduce possible uses, in particular in the field of construction and water filtration. For this, sand samples are taken and subjected to identification tests. This study will make it possible to define the potential of these sands with regard to the standards and directives in force for each targeted application and to improve the state of current knowledge on these local materials.

2. Materials and Method

Togo is a country in West Africa located between the 6th and 11th degrees north latitude and 0- and 1.6-degrees east longitude. The country is divided into five administrative regions which are, from south to north: the “Maritime” region, the “Plateaux” region, “Centrale” region, the “Kara” region and the “Savanes” region.

This study focuses on rivers sands in the “Centrale”, the “Kara” and the “Savanes” regions. A total of 43 sampling sites were identified in these regions and distributed as follows: 12 sites in “Centrale” region, 15 sites in the “Kara” region and 16 sites in the “Savanes” region as shown in Table 1. Figure 1 shows the distribution of sampling sites on the map of Togo. These sites were chosen taking into account their importance in the targeted localities where they are known as the main points of sampling of sandy materials by the populations, with a view to satisfying their different needs.

Table 1: Sampling sites

Region	Sampling sites	Latitude (°North)	Longitude (°East)
The "Savanes" region	Sissiak-Haut	10.760017	0.122867
	Tambangou	10.729067	0.1919
	Warkanbou-centre	10.802083	-0.014817
	Tami-centre	10.84885	0.034183
	Biankouri	10.97325	0.033533
	Sintoti	10.952167	0.01215
	Korbongou-centre	10.915917	0.308883
	Kpadjenta	10.952267	0.22115
	Nadoti	10.306967	0.415267
	Nataré	10.81215	0.419233
	Djiyéga	10.8499	0.578517
	Safobè	11.041833	0.124733
	Boadé-centre	11.122817	-0.06405
	Dapaong	10.85	0.21
	Cinkassé	11.1039	0.009444
	Mandouri	10.85	0.816667
The "Kara" region	Kpéloudè	9.6196	1.162183
	Kawa	9.626883	0.999517
	Pya	9.6452	1.1418
	Kpinzinde	9.509933	1.279217
	Kanté-centre	9.958483	1.041817
	Kamaka	10.193867	0.926983
	Mô	9.017717	0.689617
	Soudou	9.357533	1.35285
	Gnata	9.322333	1.068783
	Koumea	9.72278	1.1825
	Kéran	10.0833	1.00
	Pagouda	9.7525	1.32778
	Bafilo	9.35	1.26667
	Kara	9.55083	1.183583
	Sarakawa	9.630833	1.0225
"Centrale" region	Blitta	8.3236	0.982217
	Aouda	8.734397	1.050558
	Kpankyo	8.913117	1.12135
	Agbandaoude	9.249133	1.3613
	Défalé	8.9819	1.561767
	Goubi	8.6524	1.468033
	Mono	8.428067	1.25005
	Tchamba	9.02	1.41
	Talabo	8.06667	0.683333
	Sokodé	8.99	1.15
	Komah	8.92	1.12
	Kpaza	9.223661	1.323047

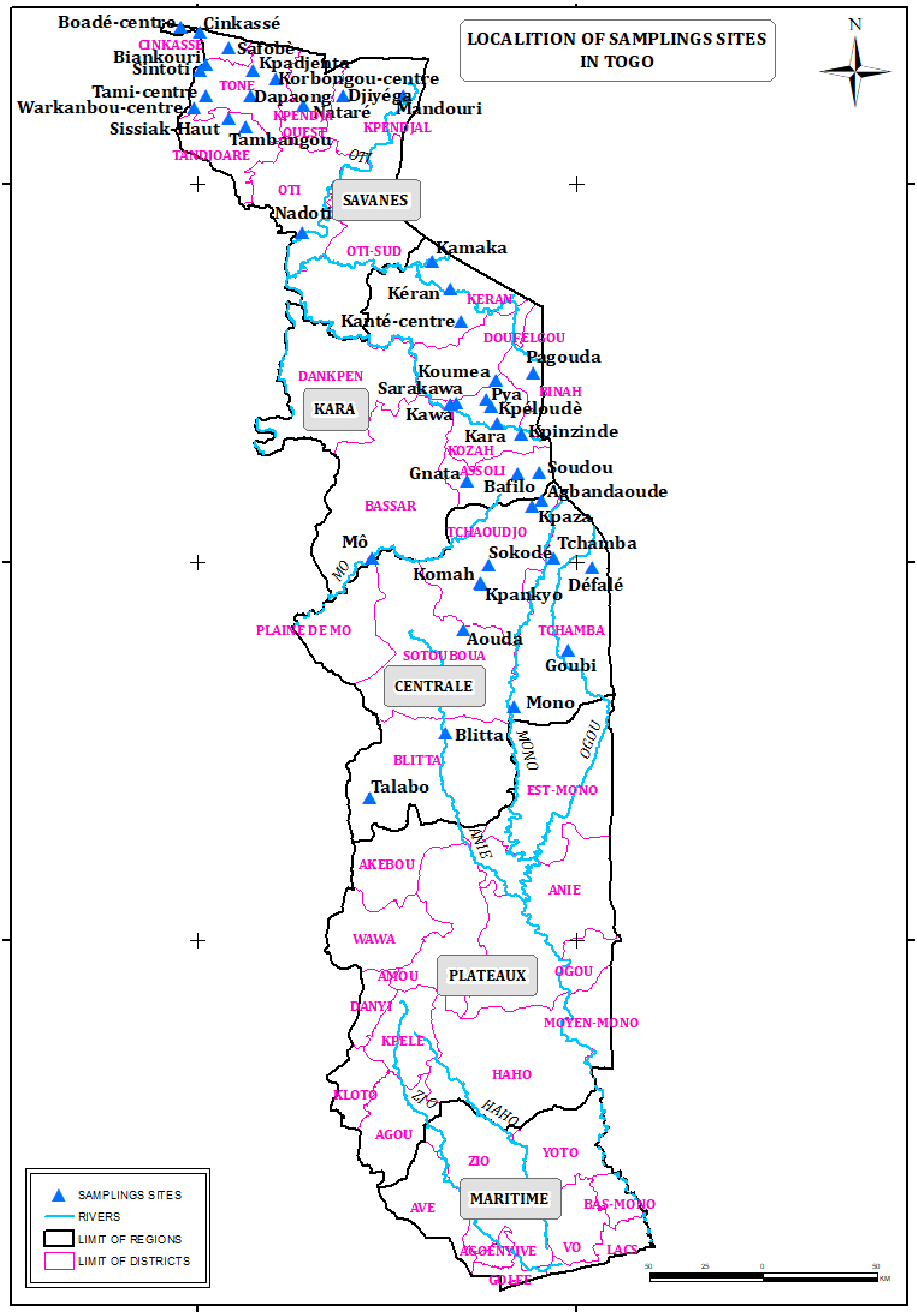

Figure 1: Location of sampling sites on the map of Togo

Sand samples are taken from each site and subjected to identification and physical characterization tests:

- particle size analysis according to standard NF EN ISO 17892-4 [1];
- the measurement of the apparent densities according to standard NF EN 1097-3 [2];

- the measurement of the absolute density according to standard NF EN 1097-6 [3];
- the sand equivalent test according to standard NF EN 933-8 + A1 [4].

The results of the particle size analysis made it possible to determine the following parameters:

- passers-by in the 80 µm sieve;
- the minimum and maximum sand diameters;
- the effective diameter which is the diameter allowing 10% of the grains to pass;
- the fineness modulus which is 1/100 of the sum of the cumulative rejections (cumulative distributions), expressed as a percentage, on the sieves of the series 0.125 mm, 0.25 mm, 0.5 mm, 1 mm, 2 mm and 4 mm [5];
- the coefficients of uniformity and curvature given by [6–7]:

$$c_u = \frac{d_{60}}{d_{10}} \quad (1)$$

$$c_c = \frac{(d_{30})^2}{d_{10} \times d_{60}} \quad (2)$$

Where
Cu is the coefficient of uniformity
Cc is the coefficient of curvature
d_{10}, d_{30} and $d_{60}$are diameters allowing respectively 10%, 30% and 60% of the grains to pass

The different samples were assessed on the basis of the criteria indicated below.

2.1. Assessment criteria for sands as construction materials

Tables 2 to 5 give the criteria for assessing the sands according to the fineness module, the sand equivalent and the coefficients of uniformity and curvature.

Table 2: Sand assessment according to fineness modulus [5]

Use in concrete	Nature of sand	fineness modulus	Observations
Unauthorized sands	Sand too fine	<1.8	
Eligible sands	Sand a little too fine	1.8 to 2.2	Sands usable if one seeks in particular the ease of implementation to the probable detriment of resistance
	Medium sand (preferential)	2.2to2.8	Sands which are well suited to obtain satisfactory workability and good resistance with limited risks of segregation
	Sand a little too coarse	2.8 to 3.2	Sands that can be used to find high strengths, but poor workability and risk of segregation
Unauthorized sands	Too coarse sand	> 3.2	

Table3: Sand assessment according to sand equivalent [5]

Sand Equivalent (SE)	Nature of sand	Sand appreciation
SE<30	Purely clay sand	To be rejected for making concrete.
30<SE<60	Clay sand	Risk of shrinking or swelling. To be rejected for quality concrete.
60<SE<70	Slightly clay sand	Permissible property for standard quality concrete when there is no particular fear of shrinkage.
70<SE<80	Clean sand	Low percentage of fine clay. Suitable for high quality concrete.
SE>80	Very clean sand	Almost total absence of fine clay. Risk of causing a plasticity defect.

Table 4: Sand assessment according to uniformity coefficient [6]

Appreciation	Intervals
very tightly grained material	Cu < 2
tight-grained material	2 ≤ Cu < 5
semi-tight grain material	5 ≤ Cu < 20
spread grain material	20 ≤ Cu < 200
very wide grain size material	Cu ≥ 200

Table 5: Appreciation of sand graduation [6-7]

Appreciation	Intervals
well graded sand (SW)	Cu > 6 et 1 < Cc < 3
poorly graded sand (SP)	Cu ≤ 6 ou Cc ≤ 1 ou Cc ≥ 3

2.2. Assessment criteria for sands as filter materials

In general, the sandy materials used in water filtration are evaluated according to several parameters related to the particle size, density and physical resistance measured through friability and acid loss tests. We will focus here on the parameters related to particle size and density for which the assessment criteria relate to the effective diameter d_{10}, the uniformity coefficient Cu, the apparent density and the absolute density.

Several uses can be made of sands, in water filtration (purification of waste water as treatment of drinking water), according to the value of the effective diameter of the material, in accordance with the following table.

Table 6: Use of sand as a filtration material according to its effective diameter [8]

Use	Intervals of effective diameter d_{10}
Slow filtration and very rapid pressure filtration (25 m/h or even 50 m/h) of swimming pools, lightly loaded water, coagulation on filter	d_{10} between 0.1 mm and 0.5 mm
Filtration without prior settling with or without coagulation on filter: speed of 7 m/h (lightly charged water)	d_{10} between 0.6 mm and 0.8 mm
Direct filtration of lightly loaded raw water, floor filter washable with water and air, speed from 15 m/h to 20 m/h	d_{10} between 0.9 mm and 1.35 mm
Roughing of industrial water, pre-filtration before slow filtration	d_{10} between 1.35 mm and 2.5 mm
Use as a support or roughing layer	d_{10} between 3 mm and 25 mm

Concerning the coefficient of uniformity of filter sands, for a use relating to the production of drinking water, its maximum value must be between 1.5 and 1.8 [9–10]. For the purification of wastewater, this threshold is raised to 3 or even 6 [11].

The apparent density of filter sands is generally between 1.4 and 1.7 and the absolute density between 2.5 and 2.8 [9].

3. Results and discussions

Table 6 gives the results of the characteristics (effective diameter, fineness module, sand equivalent, passing through the 80µm sieve, apparent and absolute densities, uniformity and curvature coefficients) of the different sands.

Table 6: Sands studied characteristics

Region	Sampling sites	passers-by at 80 µm	d_{10}	d_{min}	d_{max}	Cu	Cc	FM	dap	dabs	SE
The "Savanes" region	Sissiak-Haut	3.95	0.18	0.08	12.5	3.78	1.12	2.44	1.51	2.65	68
	Tambangou	1.10	0.17	0.08	10.0	7.65	0.88	2.80	1.41	2.63	63
	Warkanbou-centre	1.50	0.28	0.08	12.5	4.19	0.85	2.88	1.47	2.64	87
	Tami-centre	0.90	0.36	0.08	12.5	4.72	0.85	3.48	1.60	2.62	93
	Biankouri	1.40	0.30	0.08	12.5	4.33	0.50	2.53	1.42	2.65	92
	Sintoti	20.00	0.25	0.16	8.0	3.12	0.95	2.53	1.40	2.64	83

	Korbongou-centre	1.20	0.33	0.16	12.5	3.22	0.94	2.62	1.46	2.64	82
	Kpadjenta	1.66	0.25	0.08	12.5	4.00	0.88	2.91	1.54	2.57	80
	Nadoti	1.99	0.32	0.08	12.5	3.13	0.78	2.95	1.58	2.68	78
	Nataré	2.22	0.25	0.08	16.0	6.40	0.73	3.29	1.58	2.66	85
	Djiyéga	1.25	0.28	0.08	12.5	4.64	0.80	2.94	1.43	2.61	80
	Safobè	1.50	0.28	0.08	12.5	4.64	0.66	3.11	1.46	2.62	79
	Boadé-centre	2.30	0.22	0.08	10.0	4.55	1.09	2.85	1.46	2.64	89
	Dapaong	20.00	0.18	0.16	0.63	2.44	0.99	1.73	1.47	2.61	88
	Cinkassé	10.00	0.29	0.16	5.0	3.72	1.00	2.93	1.42	2.64	90
	Mandouri	0	0.36	0.16	12.5	3.14	0.83	3.13	1.55	2.64	83
The "Kara" region	Kpéloudè	1.81	0.17	0.08	12.5	2.65	0.88	1.82	1.40	2.63	72
	Kawa	4.31	0.27	0.16	8.0	3.07	0.88	1.75	1.42	2.64	78
	Pya	0	0.34	0.16	8.0	2.65	0.75	2.90	1.48	2.65	88
	Kpinzinde	0.50	0.18	0.08	8.0	2.11	0.91	1.61	1.43	2.66	92
	Kanté-centre	1.00	0.23	0.08	10.0	4.35	1.04	2.76	1.46	2.64	90
	Kamaka	0.40	0.18	0.08	6.3	2.39	0.94	2.12	1.63	2.67	84
	Mô	6.50	0.23	0.13	10.0	3.02	0.94	2.20	1.50	2.64	74
	Soudou	0	0.21	0.16	5.0	2.86	1.09	2.32	1.44	2.65	90
	Gnata	1.02	0.2	0.08	20.0	2.40	1.00	2.09	1.43	2.66	92
	Koumea	10.00	0.17	0.16	5.0	3.13	0.72	2.09	1.62	2.63	63
	Kéran	0	0.22	0.16	5.0	3.00	0.91	2.58	1.45	2.64	91
	Pagouda	0.80	0.20	0.08	20.0	3.20	0.75	2.32	1.58	2.7	90
	Bafilo	1.51	0.18	0.08	12.5	2.67	1.26	1.90	1.42	2.62	81
	Kara	10.00	0.22	0.16	20.0	2.48	0.84	2.73	1.45	2.64	81
	Sarakawa	0.99	0.18	0.08	31.5	2.89	1.09	2.09	1.50	2.65	72
"Centrale" region	Blitta	0	0.19	0.16	8.0	3.16	1.01	2.33	1.47	2.64	84
	Aouda	40.00	0.13	0.16	0.63	3.46	0.90	1.70	1.4	2.6	95
	Kpankyo	5.00	0.27	0.16	12.5	2.75	0.82	1.80	1.48	2.64	87
	Agbandaoude	10.00	0.18	0.16	5.0	4.00	1.00	2.45	1.59	2.63	83
	Défalé	10.00	0.25	0.16	5.0	3.60	1.02	2.75	1.58	2.64	77
	Goubi	1.07	0.24	0.08	12.5	3.83	0.84	2.86	1.53	2.65	79
	Mono	0.87	0.34	0.16	10.0	2.37	1.05	2.87	1.43	2.67	90
	Tchamba	0	0.18	0.16	8.0	2.78	1.21	2.08	1.49	2.64	82
	Talabo	0	0.27	0.16	5.0	6.15	0.73	3.22	1.54	2.64	81
	Sokodé	0	0.23	0.16	5.0	3.57	1.07	2.37	1.42	2.64	80
	Komah	10.00	0.22	0.16	5.0	2.64	1.07	2.25	1.52	2.65	80
	Kpaza	0.01	0.20	0.16	5.0	6.25	0.74	2.93	1.55	2.65	83

d_{10}: effective diameter; dmin: minimum diameter; dmax: maximum diameter; Cu: coefficient of uniformity; Cc: curvature coefficient; dap: apparent density; dabs: absolute density; FM: fineness modulus; SE: sand equivalent

Table 7 gives the assessments of the various sands studied for possible use as building materials.

Table 7: Sands studied appreciation as building materials

Region	Sampling sites	Sand equivalent	Fineness modulus	Uniformity coefficient	Graduation
The "Savanes" region	Sissiak-Haut	SCS	MS	TGM	SP
	Tambangou	SCS	MS	STGM	SP
	Warkanbou-centre	VCS	SLC	TGM	SP
	Tami-centre	VCS	STC	TGM	SP
	Biankouri	VCS	MS	TGM	SP
	Sintoti	VCS	MS	TGM	SP
	Korbongou-centre	VCS	MS	TGM	SP
	Kpadjenta	CS	SLC	TGM	SP
	Nadoti	CS	SLC	TGM	SP

	Nataré	VCS	STC	STGM	SP
	Djiyéga	CS	SLC	TGM	SP
	Safobè	CS	SLC	TGM	SP
	Boadé-centre	VCS	MS	TGM	SP
	Dapaong	VCS	STF	TGM	SP
	Cinkassé	VCS	SLC	TGM	SP
	Mandouri	VCS	SLC	TGM	SP
The "Kara" region	Kpéloudè	CS	SLF	TGM	SP
	Kawa	CS	STF	TGM	SP
	Pya	VCS	SLC	TGM	SP
	Kpinzonde	VCS	STF	TGM	SP
	Kanté-centre	VCS	MS	TGM	SP
	Kamaka	VCS	SLF	TGM	SP
	Mô	CS	MS	TGM	SP
	Soudou	VCS	MS	TGM	SP
	Gnata	VCS	SLF	TGM	SP
	Koumea	SCS	SLF	TGM	SP
	Kéran	VCS	MS	TGM	SP
	Pagouda	VCS	MS	TGM	SP
	Bafilo	VCS	SLF	TGM	SP
	Kara	VCS	MS	TGM	SP
	Sarakawa	CS	SLF	TGM	SP
"Centrale" region	Blitta	VCS	MS	TGM	SP
	Aouda	VCS	STF	TGM	SP
	Kpankyo	VCS	SLF	TGM	SP
	Agbandaoude	VCS	MS	TGM	SP
	Défalé	CS	MS	TGM	SP
	Goubi	CS	SLC	TGM	SP
	Mono	VCS	SLC	TGM	SP
	Tchamba	VCS	SLF	TGM	SP
	Talabo	VCS	STC	STGM	SP
	Sokodé	VCS	MS	TGM	SP
	Komah	VCS	MS	TGM	SP
	Kpaza	VCS	SLC	STGM	SP

VCS : very clean sand; CS: clean sand; SCS: slightly clay sand ; STF : sand toofine ; SLF : sand a little too fine; MS : medium sand; SLC : sand a little too coarse; STC: sand too coarse; TGM : tight-grained material; STGM : semi-tight grain material; SP : poor graded sand

From Table 7, it can be seen that:

- 62.5% of the river sands of the “Savanes” region are very clean, 25% of these sands are clean and only 12.5% are slightly clayey: all these sands can, according to ES, be used to make concrete quality at least common and more. 81.25% of the sands in the “Savanes” region are eligible sands, 12.5% of the sands are coarse and the rest are very fine. The sands of this region are poorly graded and have a tight (87.5%) or semi-tight grain size. Apart from river sands taken at Dapaong, Tami-centre and Nataré, all the sands in this region are admissible for making concrete with the risk of loss of strength, shrinkage or segregation or defect in plasticity for certain sands.
- For the “Kara” region, the sands studied are mostly very clean (66.67%) or clean (26.66%). They are fine (53.33%) or medium (40%). They are poorly graded with a tight particle size. 86.67% of the river sands in this region are eligible to make concrete with most risks of loss of strength (40%).
- The river sands of “Centrale” region are all at least clean, poorly graded with a tight or semi-tight particle size. 41.67% of these sands are preferential. 83.33% of river sands in “Centrale” region are eligible for making concrete with the risk of probable loss of resistance and shrinkage for certain sands.

Most sands (83.72%) in central and northern regions Togoare eligible to make concrete. 39.53% of theses river sands can provide good concrete because they are medium or little fine or coarse, clean but poorly graded. They will help in the implementation of concrete but can affect the strength of the concrete. For sands that are too fine (9.30%) or too coarse (6.98%), a mixture with others sands is needed to make them medium before their use in construction. Screening of some of these sands is necessary before their use to remove coarse elements (diameters greater than 5mm).

Concerning the suitability of the sandy materials studied for use in water filtration, we note from the analysis of the characteristic values in Table 6 the following:

- The effective diameter of the materials varies between 0.13 mm and 0.36 mm with an average value of 0.24 mm. The river sands of central and northern regions Togo, with regard to this criterion, can be used in their natural state, in slow filtration and in very rapid filtration under pressure (25 m/h or even 50 m/h) on swimming pools and sparsely loaded waters with coagulation on a filter or for the treatment of waste water (typical value of 0.35 mm recommended [12]). Treatment of these natural materials by sieving and sizing may allow effective diameters adapted to other uses relating to water filtration, as shown in Table 6.
- All the sandy materials studied have, in the raw state, uniformity coefficients above the maximum threshold of 1.8 required for the production of drinking water. With values between 2.11 and 7.65 and an average of 3.61. 93% of these materials may however be well suited, for use as filtering sand, on wastewater treatment systems, for which the required uniformity coefficient threshold is between 3 and 6. For the use of these materials on drinking water production filters, granular correction by sieving and calibration is necessary in order to improve the uniformity coefficient.
- The values of the apparent densities of the materials studied, between 1.40 and 1.63 (average of 1.49) and those of the absolute densities between 2.57 and 2.70 (average of 2.64) are in accordance with specifications required for use as a filtration material.

With regard to the parameters studied, it appears that the river sands of central and northern Togo have aptitudes for their uses, in their natural state, as filtering materials, on wastewater treatment units. For use on a wider range of sand filters in drinking water production stations, granular correction by sieving and calibration is necessary, as with all natural sand, in order to improve the effective diameters and the coefficients of uniformity.

4. Conclusion

The objective of this study is to determine the physical characteristics of river sands of the “Savanes”, the “Kara” and “Centrale” regions of Togo. Samples of rivers sands in these regions are analyzed in laboratory to determine the possible use of these sands. All the sands studied are poorly graded with a predominantly tight particle size. Most of these sands are suitable for being used to make concrete. Some of them require improvement by adding other sands before their use as concrete sand because they are too fine or too coarse. The river sands of central and northern Togo are suitable, with regard to the physical parameters studied, for their uses, in a natural state, as filtration materials, on wastewater treatment units. For use on a wider range of sand filters in drinking water production stations, granular correction by sieving and calibration is necessary, as with all natural sand, in order to improve the effective diameters and the coefficients of uniformity.

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