Chemistry Research Journal, **2021, 6(6):111-118**

Available online www.chemrj.org

Research Article

ISSN: 2455-8990
CODEN(USA): CRJHA5

Characterization of Raw Sludge Dumped in the City of Niamey (Republic of Niger)

Abdou GOUMAR*, Haoua AMADOU, Mahaman Sani LAOUALI et Abdou Salam MANZOLA

Laboratoire de Chimie de l'eau, Faculté des Sciences et Techniques, Université Abdou Moumouni de Niamey, BP 10662 Niamey, Niger
*Author correspondent Email: goumarabdou@yahoo.fr ; Tel: (+227) 96899054

Abstract In Niamey, the majority of the population does not have access to the sewerage system (0.5%), which is very weak and often non-functional, clogged with waste of all kinds. Autonomous drainage works are the most used. These generate sludge that needs to be drained and treated in order to avoid health and environmental pollution. The risks are real as the sludge is discharged directly to the various dumping sites (sometimes even in the city) without any treatment. The characterization of these sludges that are produced and dumped has never been supplemented in order to allow the appropriate choice of treatment methods. This study fills this gap.

The objective of this work is to highlight the different characteristics of the fecal sludge of the city. For this purpose, physic-chemical and bacteriological parameters were measured according to French standards. The results of these analyses show that the Chemical Oxygen Demand (COD) and the Biochemical Oxygen Demand (BOD5) have respective average values of 1144.4 and 700mg / L. As for nutrients, nitrates and ortho-phosphates have mean values of 234.40 and 28.18 mg / L, respectively.

Keywords Characterization, Dumping, Fecal sludge, Environmental pollution, Niamey-Niger

Introduction

The management of wastewater and excrement is a major problem in large African cities [1]. To meet the need for wastewater treatment facilities, the choice is preferably made for stand-alone systems for their more accessible costs compared to the sewer system, despite the health risks associated with managing the sludge from these facilities [2]. Currently, the management methods of this sludge have negative impacts on the environment and expose populations to various health risks, and wastewater and excreta management is not currently a concern for many developing countries. Indeed, the actions carried out focus on the creation of latrines without worrying about the future of the products generated. Thus, for the management of fecal sludge, the problems still remain unresolved because fecal matter is generally perceived as repugnant and must be discreetly disposed of and its management is often a taboo subject.

In recent decades, various countries, including Burkina Faso, Cote d'Ivoire, Senegal, Ghana, and recently Niger, have made efforts to improve their sanitation infrastructure. Further efforts are still needed to develop appropriate sanitation facilities. In general, the technologies used fall within the scope of non-collective sanitation with very few wastewater collection networks in place, even in large urban areas.

According to the World Health Organization (WHO), there are 2.6 billion people in the world without access to adequate sanitation systems and nearly 1.1 billion people continue to defecate in the open air [3]. Open defecation by part of the population puts the whole community at risk, given the increased risk of diarrhoeal diseases, cholera, verminous infestations, hepatitis and other associated diseases [3].

Materials and Methods

Presentation of the Study Site

Capital of Niger, Niamey is located in the West of Niger between latitudes 13°20' and 13°35' North and longitudes 2°00' and 2°24' East. It is built on the banks of the Niger River, which crosses it for about 15 km, thus constituting the structuring element of its landscape.

The city of Niamey was established as an Urban Community by decree N°88-393/PCMC/MI of 24 November 1988. In 2002, it was subdivided by the Decentralization Act into five (5) communal districts (Figure 1) composed of ninety-nine (99) surrounding districts and villages, giving the city both urban and rural aspects [4]. The city has a Sahelo-Sudanian climate characterized by irregular rainfall during a short wet season and a long dry season. Most of the rainfall occurs regularly between June and September with a concentration between July and August. The average annual temperature of the city is around 29°C but can reach 45°C at the height of the dry season, especially on some April days. This temperature can be below 15°C in cold periods, especially between January and February [5]. The city's hydrographic network consists of temporary and permanent watercourses.

Documentary Research

This study benefited from a combinatorial and multidisciplinary methodological approach. It is the result of a methodology that combines documentary research, direct field observations, sampling and analysis of samples of Fecal sludge discharged at the disposal sites. The surveys carried out at the level of households, heads of households, drains (manual and mechanical), semi-direct interviews with managers of urban planning, sanitation and environmental protection services, identified four (04) types of autonomous sanitation facilities (traditional latrines, modern latrine, Sanplat latrine, VIP latrine) within households, the distribution of which varies from one municipality to another. The quantities of sludge produced the various disposal sites, health risks, environmental impacts and constraints related to the current management of fecal sludge were also identified.

Material

Drainage Sludge

In general, the term Fecal sludge refers to liquid sludge or undigested or partially digested solids resulting from the storage or treatment of black water in so-called on-site sanitation systems such as septic tanks, latrines, cesspools, dry toilets, public toilets etc [6].

Indeed, Fecal sludge from fast filling and low water use structures such as traditional latrines, VIP latrines and public toilets are highly concentrated and fermentable, while sludge from septic tanks after a more or less long stay of 4 to 15 years [7], are partially mineralized during anaerobic digestion processes, they are biologically more stable.

There are two (2) types of emptying in the city of Niamey, namely manual emptying, which mainly concerns latrines, and mechanical emptying, which concerns septic tanks and all-water tanks. In the first case, the sludge is more concentrated and in the second case it is diluted, which facilitates emptying. Indeed, Blunier et al, [8], Defo et al, [2], report that the septic tank is a modern structure for the pretreatment (settling and digestion) of Fecal sludge, which justifies lower pollutant concentrations than in latrines.

The sludge discharge sites for manual drains are the excavation dug either near the drained pit, the street or the gutters built for storm water drainage. It should be noted that the spill on the street and in gutters is clandestine. As for mechanical drains, they generally discharge into abandoned earth extraction quarries and fields around the city of Niamey.

The figures below (figures 2 and 3), illustrate the two (2) emptying modes (manual and mechanical) carried out in the city of Niamey.

Sample Collection and Packaging Equipment

Samples of the sludge were taken as indicated by Klinger et al [9], directly during the landfill at the disposal site to ensure their representativeness. At each site, four 0.5L sub-samples are collected at different locations. The four sub-samples are then combined to form a composite sample. Each sampling vial shall bear indications relating to the name of the sampler, the date, time, place of sampling, and the values of the parameters recorded in situ. Samples are placed in a cooler at a temperature of 15°C (±5°C) and transported to the laboratory where they are stored in a refrigerator at a maximum temperature of 4°C.

Our samples were taken from the various discharge sites of the sludge identified during our investigations. Table 1 provides us with the contact information for these sites (Table 1).

Methods of Analysis of Samples

Temperature (T), Hydrogen Potential (pH), Electrical Conductivity (EC), and Redox Potential (Eh) were measured in situ with the Multi Parameter HI 9828 pH/ORP/EC/DO equipped with several sensors. The readings are made after stabilizing the display on the device's screen. The method complies with AFNOR 90 008 [10].

The dry matter and total volatile matter are determined in accordance with procedure NF T 90-029. 50ml sample is evaporated in a water bath, then its residue is dehydrated in an oven at 150°C for 24 hours. The dehydrated sample is then acclimatised to laboratory conditions in a desiccator and weighed to determine the M.S. content (dry matter in mg/L). The dehydrated sample is then calcined in the oven at 550°C (± 20°C) for 2 hours, then the resulting ash is acclimatised (for 1 hour in a desiccator) to laboratory conditions, before being weighed. Total volatile matter (TVM) is obtained by removing the mass of the dehydrated sample, that of the residual ash.

Chemical Oxygen Demand (COD) is determined by oxidation with an excess of potassium dichromate in an acid medium at 150°C, in the presence of silver sulphate as catalyst and mercury sulphate to avoid interference from chloride ions, in accordance with the AFNOR standard. The value is read by JICA DR/890 spectrophotometry at the appropriate wavelength according to the COD range selected.

The five-day Biochemical Oxygen Demand (BOD_5) was determined by the five-day incubation method at darkness and temperature of 20°C using a "LovibondOxiDirect" device, measured by resistant electronic pressure sensors.

Ammoniacal nitrogen (NH_4^+), nitrates (NO_3^-), nitrites (NO_2^-) and orthophosphates (PO_4^{3-}) were determined by the colorimetric method with a HACH DR/3900 spectrophotometer reading.

As for Faecal Coliforms (CF), E packages, and Faecal Streptococci (SF), their determination is based on the research method and the counting of bacterial colonies by membrane filtration and deep seeding in appropriate culture media (specific Chromocult Agar agar for CF and specific M Entrecoccuse Agar for SF), followed by incubation at 44°C (±0.5) for CF and 37°C (±0.5) for SF, for 24 and 48 hours respectively. This method complies with the French standard.

Results

The results of the analyses of the sampled fecal sludge are given in Table 2.

By comparing the average values of the parameters with the standards for the discharge of waste into the natural environment set in Niger (Order No. 140/MSP, 2004), it appears that certain parameters such as pH, temperature, ammonium ions and nitrite ions comply with these standards.

The conductivity varies between 1354 and 9950 µS/cm with an average of 3017.5 µS/cm while the standard is set at a value less than or equal to 1000 µS/cm. The content of ortho-phosphate ions varies between 6.5 and 130 mg/L at the various depot sites, while the standard allows only a value less than or equal to 5 mg/L. The nitrate ion content ranges from 42.00 to 520.0mg/l, whereas the standard only requires a value below 11.4 mg/l. These undesirable substances (NO_3^-, PO_4^{3-}) which are at the root of eutrophication [8], exceed discharge standards extremely well.

For carbonaceous pollution, the Chemical Oxygen Demand (COD) and the Five-Day Biochemical Oxygen Demand (BOD_5) gave values ranging from 440 to 3550 mg/L on the one hand and 200 and 1800mg/L on the other hand. Although these values are low compared to the values obtained by other authors in other countries, they are well above the release standards of 150 and 50mg/L respectively.

The conductivity values, COD, BOD_5, and MS, MVS on the one hand and nitrogen and ortho-phosphates on the other hand are very variable and these often refer to the origin of the sludge deposited. In any case, these values are well above the accepted standard for releases to nature or for reuse in agriculture [3]. This shows the need to treat this sludge properly in order to reduce health and environmental risks.

The bacterial species of the sludge are recorded in Table 2. The number of E. coli changes in the range [28.10^3 - $1.5.10^6$ CFU/100mL] and the average number is $1.60.10^6$ CFU/100mL, fecal coliforms have numbers varying in the range [30.10^3 - $1.5.10^6$ CFU/100ml] with $3.28.10^6$ CFU/100mL as the average number, and finally fecal Streptococci whose number varies in the interval [70.10^4 - $10.4.10^6$ CFU/100mL] with an average of $14.8.10^6$ CFU/100mL.

Table 1: Physical and chemical characteristics of the raw Fecal sludge deposited

	Road career Torodi	**Road career kouaratagui**	**Road career Nord faisceau**	**Road carer Banizoumbou**	**Career Koubia**	**Road career Aéroport**	**INFORMAL SITE 1**	**INFORMAL SITE 2**	**INFORMAL SITE 3**
T (°C)	30.1	33.1	34.2	35.1	31.5	34.2	32.8	33.8	36.2
pH	8.04	7.99	9.1	8.91	8.38	9.01	7.84	7.94	8.81
C (US/CM)	4950	9950	1354	2413	1532	2121	1134	2415	1289
Eh (MV)	-81.7	-34.8	-17.5	-1.4	41.6	-39.3	-44.3	-5.7	-68.1
Sal (MG/L)	3.16	0.76	0.66	0.36	0.71	0.51	0.52	0.54	0.79
TDS (MG/L)	2917	757	667	375	713	521	527	565	792
MS (MG/L)	3044	3246	42136	1654	7954	1228	656	1500	908
MVS (MG/L)	1014	2150	21088	936	5744	612	394	868	856
NH_4^+ (MG/L)	101.0	18.1	13.0	57.2	6.5	23.5	34.4	62.0	82.0
NO_2^-(MG/L)	0.14	0.72	1.17	0.14	2.30	0.019	0.02	0.15	0.24
NO_3^-(MG/L)	158.0	340.0	514.0	107	520.0	42.0	43.0	143.0	261.0
PO_4^{3-}(MG/L)	26.0	11.5	35.0	18.1	16.0	6.5	16.2	21.3	103.0
DCO (MG/L)	860	740.0	2400	530	3550	450	700	630	440
DBO_5(MG/L)	200	650	1800	400	1650	150	500	600	350
DCO/DBO	4.3	1.14	1.33	1.32	2.15	3.00	1.40	1.05	1.25

ND : Not determined

Table 2: Characteristics of bacteriological parameters

	Road career Torodi	**Road careerkouaratagui**	**Road career Nord faisceau**	**Road carer Banizoumbou**	**Career Koubia**	**Road career Aéroport**	**INFORMAL SITE 1**	**INFORMAL SITE 2**	**INFORMAL SITE 3**	**Moyenne**	**Normes**
C.F (UFC/100ml)	30.10^3	$1.4.10^6$	$3.5.10^5$	$1.5.10^6$	$1.8.10^6$	$1.2.10^6$	$1.6.10^5$	$5.7.10^6$	$4.6.10^6$	$1.81.10^6$	2.10^3
E-Colis (UFC/100ml)	28.10^3	$1.3.10^6$	2.10^5	$1.3.10^6$	1.310^6	$7.8.10^5$	1.3310^5	$4.9.10^6$	$4.4.10^6$	$1.60.10^6$	ND
S.F (UFC/100ml)	70.10^4	$2.1.10^6$	$10.4.10^6$	$1.8.10^6$	$7.7.10^5$	$9.5.10^5$	$9.8.10^4$	4.10^6	$14.1.10^6$	$3.88.10^6$	10^4
œuf d'helminthes (Œuf/L)	3360	5320	360	378	7600	900	680	912	1000	2278.8	

ND : Not determined

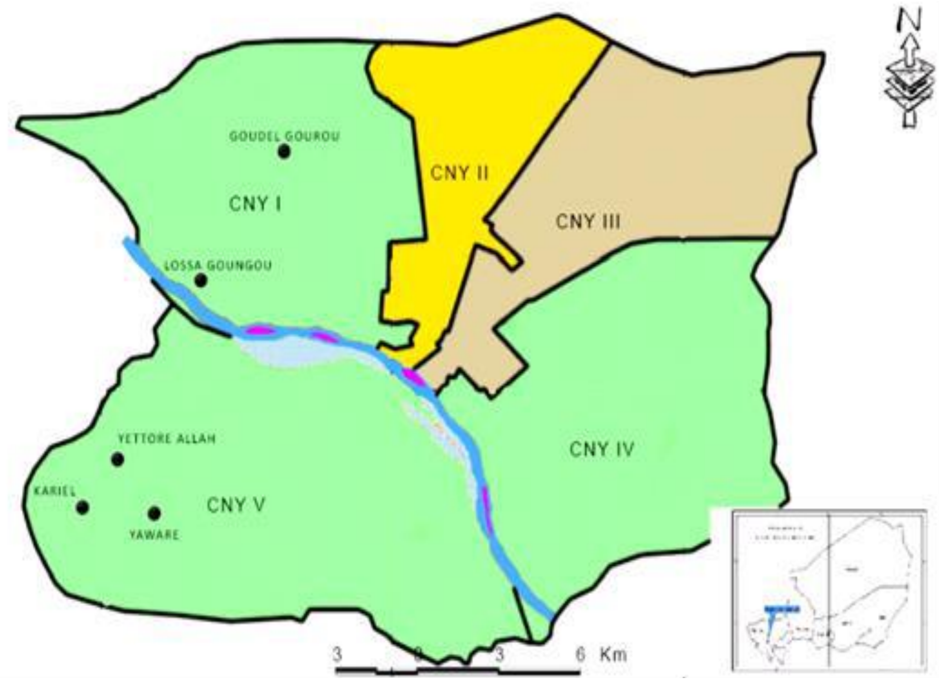

Figure 1: Municipal division of the city of Niamey [4]

Figure 2: Manual emptying of a latrine

Figure 3: Mechanical emptying

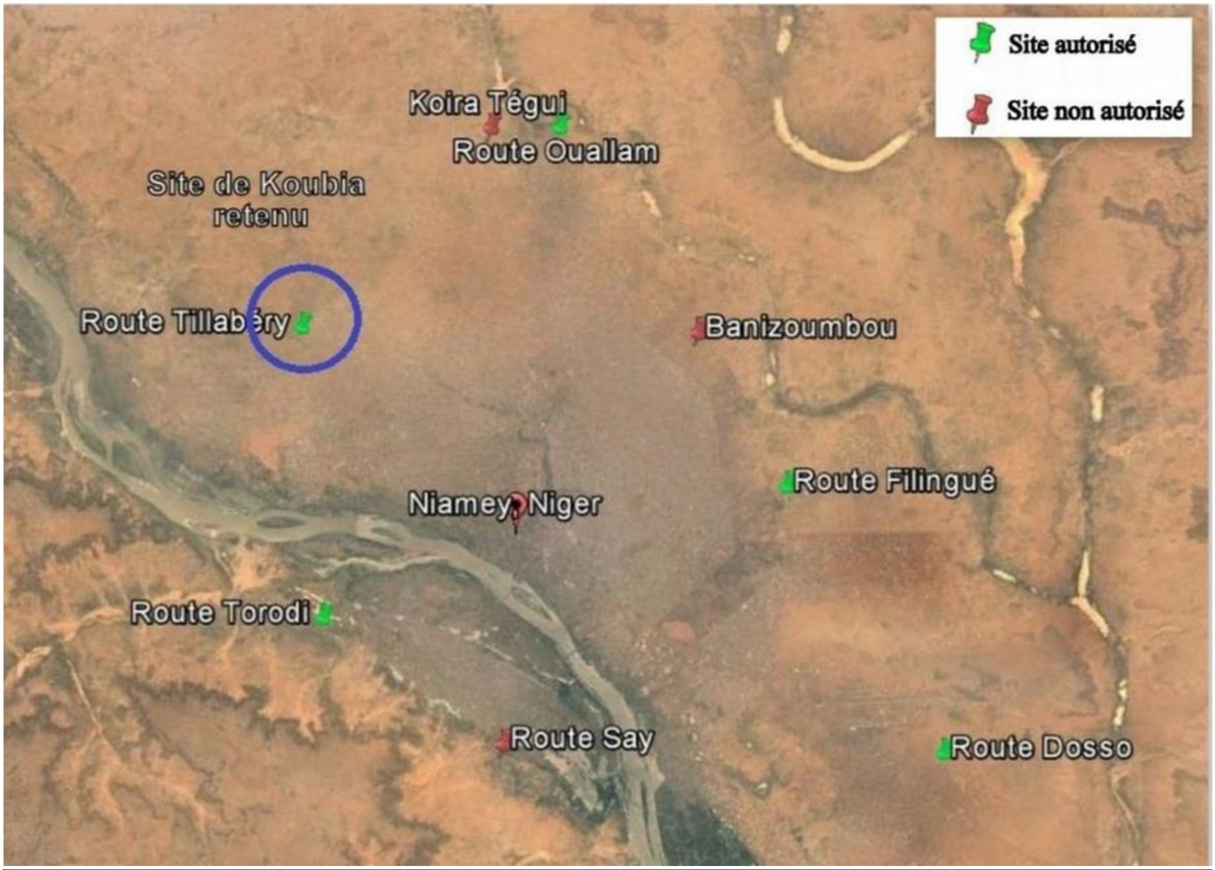

Figure 4: Sampling locations and their contact details

Discussions

The maximum and minimum temperatures of the recorded Fecal sludge are 36.1 and 30.1°C respectively with an average of 33.4°C. These values are in accordance with the discharge standards set in Niger (Order No. 140/MSP, 2004). As an important parameter, the temperature favors the microbial activity of mineralization at the disposal sites, or basins (case of a treatment plant). It is not insignificant to evaluate the characteristics of a treatment plant. However, the biological activity is more important in hot weather than in winter, because the temperature plays an important role on the kinetics of the reactions.

The pH values revealed comply with the release standards (6.5-9.0). In general, the development of the bacteria that ensure the purification of the sludge is carried out in a medium having a favorable pH of between (5.0-9.0). Their abrupt variations (pH, T) can have considerable impacts on the behavior of the purifying bacteria of the medium.

The conductivity varies between 1354 and 9950µS/cm with an average of 4666.7µS/cm. These show that the dumped fecal sludge is highly mineralized and that there is a high presence of mineral salts in the environment.

The degradation of organic nitrogen to ammonium is an integral part of the nitrogen cycle in nutrient production. The ammonium values recorded at the depot sites are below the standard of 60.0mg/L except for the Torodi road quarry, which is 101mg/L. The average nitrate concentration is 236.00 mg/l. These show a good nitrification process during sludge dewatering. These values are higher than the discharge standards, justifying the need for sludge management to avoid the risk of pollution of surface water and groundwater [11]. These results may be explained by the quality of the structures (septic tank or latrine) and the frequency of emptying. Indeed, fecal sludge with a long stay in the pit generally has a higher mineralization rate. Nitrites range from 0.019 to 1.17mg/L with an average of 0.55mg/L. These values are below the standard of 0.9mg/L except at the Nord faisceau quarry where a value of 1.17mg/L was recorded. Being an oxidized form of nitrogen, nitrite ions are not stable and can evolve into nitrates in an aerobic environment in the sludge dewatering process. Phosphorus in sludge in different forms (organic phosphorus, ortho phosphate) can come from food but also from natural or anthropogenic sources. They are nutrients that can be used in agriculture, but at high levels they can contribute to the eutrophication of surface waters, which is a real danger to aquatic flora and fauna. The ortho-phosphate ion values recorded have an average of 28.50 mg/L while the standard provides a value less than or equal to 5mg/L. The average values of Chemical Oxygen Demand (COD) and Biological Oxygen Demand after five days (BOD_5) are 1144.4 and 700.00 mg/L respectively. The COD/BOD_5 ratio is between 1 and 5 for all samples studied, those that show that these sludge is still biodegradable. They remain fermentable, which will make it possible to consider the need for adequate treatment and percolate treatment before release into the environment in order to bring them into compliance with discharge standards.

Table 2 provides the results of the microbiological parameters for the determination of fecal coliform and fecal streptococcus concentrations. The presence of these bacteria in the sludge indicates a possibility of encountering other pathogenic micro-organisms.

The results of this work show a great variability in the characteristics of Fecal sludge within the city itself, which could be explained by various reasons, including the types of structures used, the residence time of the sludge, the type of emptying used (manual or mechanical). These confirm the various studies carried out by Koné et al (2016), Blunier et al (2004), Mahamane, (2011). [8, 11-12].

Conclusion

The physico-chemical and bacteriological analyses thus determined show that this sludge discharged into the environment without any treatment is rich in organic matter, nutrients (PO_4^{3-}, NO_3^-) and bacteria (fecal coliforms, and fecal streptococci). The management of by-products of this type of sanitation is a necessity to reduce the impact of their impacts on health and the environment. It is important to comply with certain standards to reduce the risk of disease transmission, by avoiding their release into the environment and their use in agriculture without prior treatment; at the end of this work, given the consistency and chemical and microbiological characteristics of the sludge, it is important to consider the possibility of treating it advantageously with other rustic technologies such as planted beds, which promote leachate infiltration and faster dehydration.

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