Cleaner Engineering and Technology 2 (2021) 100045

Contents lists available at ScienceDirect

Cleaner Engineering and Technology

journal homepage: www.journals.elsevier.com/cleaner-engineering-and-technology

Assessing impacts of sand mining on water quality in Toutsang locality and design of waste water purification system

Ypolit Kemgang Lekomo [a,b,2], Clautaire Mwebi Ekengoue [a,b,2,*], Aurel Douola [c,1], Rodrigue Fotie Lele [a,c,1,2], Guedjeo Christian Suh [b,d], Samuel Obiri [a,e,2], Armand Kagou Dongmo [a,b,2]

[a] African Scientific Association for Innovative and Entrepreneurship (ASAIE), Yaoundé, Cameroon
[b] Department of Earth Sciences, Faculty of Sciences, University of Dschang, Dschang, Cameroon
[c] Green Heart International (GHI), Headquarter Building Waffo Pierre, Street Africa Construction Ndiandam, P O Box: 1450, Bafoussam, Cameroon
[d] Department of Geology, Higher Teacher Training College, University of Bamenda, Bambili, Cameroon
[e] Environmental Chemistry Division, Council for Scientific and Industrial Research (CSIR), Water Research Institute, Achimota, Ghana

ARTICLE INFO

Keywords:
Sand mining
Toutsang locality
Toutsang water quality
Physico-chemical analysis
Sedimentation tank
Indoor purpose and household use

ABSTRACT

This paper focuses on assessing and development of water purification system for addressing water quality effects associated with sand mining in Toutsang locality, West-Cameroon. The study approach involved field investigations, laboratory analysis and design of waste water treatment system. Water samples were randomly collected from the study into well-labeled containers and conveyed to *Unité de Recherche d'Analyse des Sols et Chimie de l'Environnement, Faculté d'Agronomie et des Sciences Agricoles (FASA)* at the University of Dschang for analysis. Results from the physico-chemical analysis show elevated levels of total suspended solids (TSS), magnesium (Mg), turbidity and iron (Fe) in water samples collected downstream of the River close to the mining site, which exceeds the World Health Organization (WHO) standards. Based on the results of the physico-chemical analysis, a waste water treatment comprising of sedimentation tanks is proposed to treat waste water from the sand mining site. The designed water treatment system can be used to treat contaminated water from sand mining sites for domestic use. The proposed model tank needs to be implemented to restore Toutsang Water quality for indoor purpose and household use.

1. Introduction

1.1. Context and justification

Sand is an indispensable natural resource for any society [Gavriletea, 2017]. This comes from the fact that, after fresh water, sand represents the highest volume of raw material used on earth. Sand is found either in marine or terrestrial environments. The latter include residual soil deposits, River channel deposits, and floodplain alluvial deposits [Gavriletea, 2017].

Sand has been used as an aggregate material for different civil construction since times [Padmalal et al., 2014]. For instance, the mortar used for bounding Egyptian pyramids blocks was a mixture of clay and sand or a mixture of mud, lime and sand. Sand is still been used in the construction industry and many other industries such as cement, glass, adhesives, ceramics, abrasives and filters in water treatment [Padmalal et al., 2014] as well as playing an important role in the processing of chemicals and metals and plastics.

The multiple utilization of sand has resulted in its increase demand and this trend is expected to continue due to population increase and the increasing standard of living. However, the exploitation of this resource causes many environmental impacts [Ekengoue et al., 2018]. Several adverse effects of sand mining on the immediate and extended environment have been widely reported in literature [Bhattacharya et al., 2019]. Sand mining and dredging operations have the tendency to worsen downstream water quality which may adversely affect aquatic life.

In Cameroon, like in many other African countries, studies conducted so far on sand mining have primarily focused on assessing both the

* Corresponding author. African Scientific Association for Innovative and Entrepreneurship (ASAIE), Yaoundé, Cameroon.
E-mail addresses: clautaire.mwebiekengoue@yahoo.fr, clautaire.mwebi@gmail.com (C. Mwebi Ekengoue).
[1] www.ghiafrica.org.
[2] www.asaie.org

https://doi.org/10.1016/j.clet.2021.100045
Received 4 August 2020; Received in revised form 14 December 2020; Accepted 28 January 2021

List of abreviations

Ca	Calcium
EC	Electrical Conductivity
Fe	Iron
HNO_3	Nitric Acid
K	Potassium
Mg	Magnesium
Na	Sodium
PH	Potential of Hydrogen
SS1	Sample Site 1
SS2	Sample Site 2
SS3	Sample Site 3
SS4	Sample Site 4
TDS	Total Dissolved Solid
TSS	Total Suspended Solid

economic benefits as well as its attending environmental challenges such as water and environmental pollution, destruction of aquatic and vegetation, thereby leading to the disappearance of certain vegetative and animal species [Manga et al., 2013]. However, not much work has been done in designing a waste water treatment system for purification of water downstream of sand mining concession for human consumption or other domestic or agricultural uses. It is within this context that, this study focuses on assessing the impacts of sand mining on water quality in Toutsang locality and further design water purification system to aid in addressing the water quality issues.

1.2. Geographical setting of the study area

Toutsang is an agglomeration of Dschang town, a locality of Menoua Division (West Region of Cameroon) geographically located between 5°25′ to 5°27′ latitude North and 10°02′ to 10°05’longitude East. Menoua Division spans from Santchou at an altitude of 600 m through Dschang (1500 m) and topping on the plateau of Djuttitsa at an altitude of 2200 m. The Division experiences an annual average rainfall of 1717.17*mm* and temperature ranges between 13.66°*C* and25.35°*C*. In the region and particularly in Toutsang, the main activities are agriculture and sand harvesting (Fig. 1).

2. Materials and methods

2.1. Sampling techniques and samples collection

Purposive sampling techniques were adopted in selecting 2 sites upstream of the River and 2 sites downstream of the River where sand mining takes place. A total of four (4) samples were collected from four (4) locations from the River Toutsang. Two (2) samples each in the upstream and downstream of the River Toutsang were collected using plastic sampling bottles of 1.5 L by dipping the bottles 15 cm below the water level at designated sampling stations and capped under water to avoid air bubbles. Prior to sample collection, all the plastic bottles were thoroughly washed with phosphate-free detergent, rinsed with 1:1 HNO_3 and distilled water and finally dried. Before collection, the plastic bottles were rinsed twice with the same water to be collected. At each of the

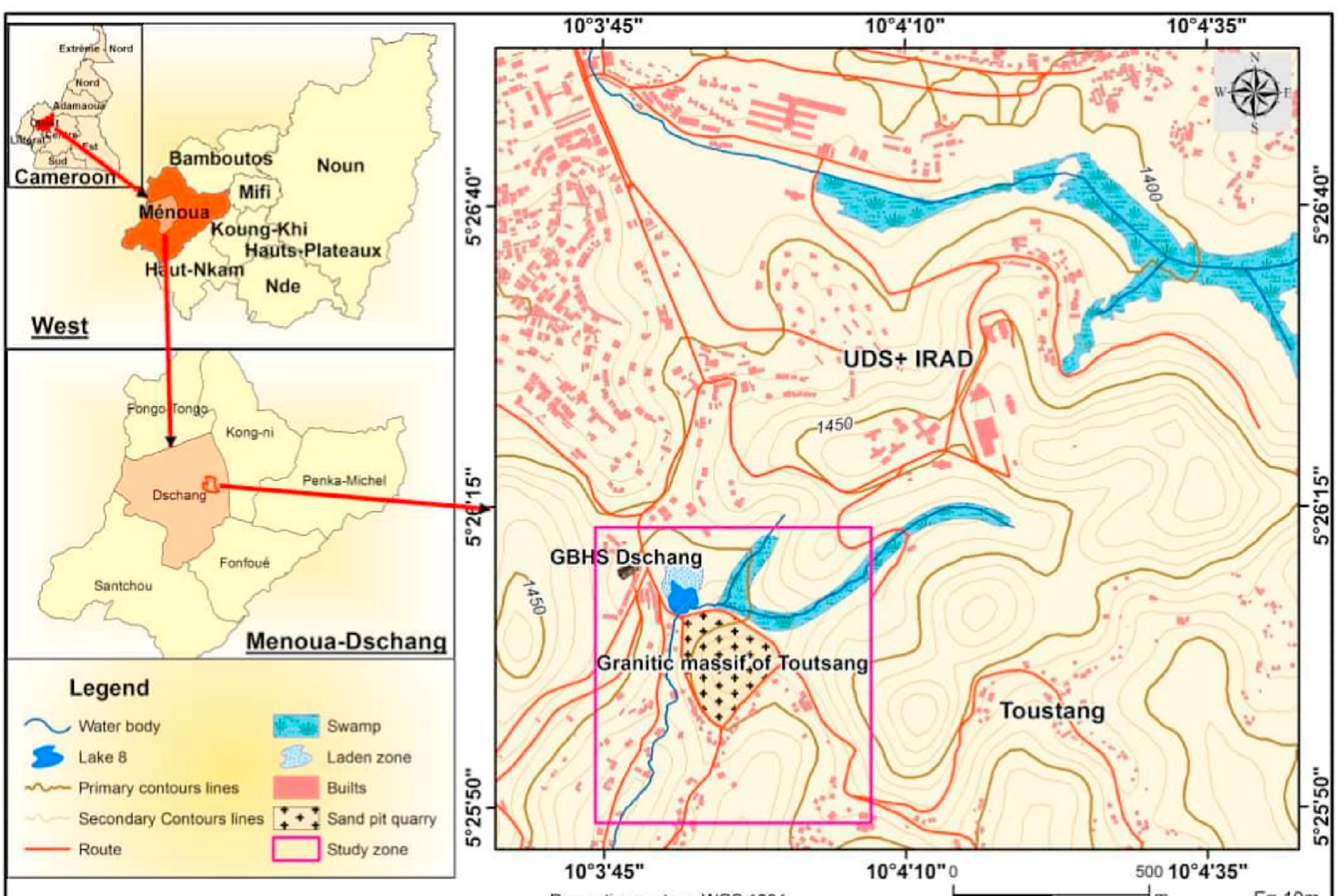

Fig. 1. Location map of the Toutsang sandpit. The color frame indicates the area where we carried field investigations in Toutsang locality.

Table 1
Standard laboratory methods used in estimating physico-chemical parameters of the water samples.

Parameter	Materiel	Laboratory method	Observation
Bicarbonates	Glassware	Determination with phenolphthalein, carbonates, Bromocresol orange/green methyl and acids (HCl/H_2SO_4)	Color changes from orange yellow to red or blue to yellow
Ammoniacal nitrogen (mg/l)	Glassware and distillator	Determination with phenolphthalein, magnesium oxide, Devarda, boric, chloridric and sulphuric acids	Pink coloring of the solution
Nitric nitrogen (mg/l)	Glassware	Determination with phenolphthalein, magnesium oxide and boric, chloridric and sulphuric acids	Pink coloring of the solution
Calcium (mg/l)	Atomic Absorption Spectrometer (AAS)	Direct reading	Value displayed
Magnésium (mg/l)	Atomic Absorption Spectrometer (AAS)	Direct reading	Value displayed
Potassium (mg/l)	Atomic Absorption Spectrometer (AAS)	Direct reading	Value displayed
Sodium (mg/l)	Flame Spectrometer (FS)	Direct reading	Value displayed
Iron (mg/l)	Atomic Absorption Spectrometer (AAS)	Direct reading	Value displayed

sampling point, the Global Positioning System (GPS) coordinates were taken in order to map the location of sand mining activity. To avoid cross contamination, the sampling container was washed with distilled water after each sampling. The samples were stored in an ice-chest at 4 °C and conveyed to the laboratory for analysis.

Physical parameters such as temperature, potential of hydrogen (pH), cleanness, salinity, electrical conductivity (EC) and total dissolved solid (TDS) were directly measured on the field with the help of a multiparameter borer model waterproof IP57, following the recommendations of [APHA, 1999] and [Rodier et al., 2009]. While other parameters involved in the analysis such as Sodium (Na), Potassium (K), Calcium (Ca) and Fe to cite a few were estimated in the laboratory using standard laboratory methods. Table 1 indicates standard laboratory methods used in estimating physico-chemical parameters of the water samples.

2.2. Collection of hydromorphometric parameters

Hydromorphometric parameters such as water's velocity, water's flow and depth were investigated on the field. Determination of Toutsang water's flow was made using volumetric method. Doing it, we needed a 10 L container and a stopwatch. The filling time of the container has been evaluated several times in order to minimize errors due to the filling time investigation. From both quantities (container's volume and filling time), Toutsang water's flow was estimated easily by Eqn (1) where $Q(m^3/s)$, $V(m^3)$and $t(s)$ represent respectively Toutsang water's flow, container's volume and container's filling time.

$$Q = {}^{V}\!/_{t}. \tag{1}$$

With respect to the velocity of Toutsang River, the float method was used. The use of this archaic method was related to lack of financial means and adequate measuring equipment. A floating object was thrown in the center of Toutsang River. After having covered a predefined distance (10 m), the time taken to cover the distance was noted. As with the water flow, several tests were carried out in order to minimize errors in journey time. Based on Eqn (2) where $d(m)$ is the distance covered by the float and $t(s)$ the time needed by the float to cover such a distance, Toutsang water's velocity was assessed. Toutsang water's depth was simply investigated using a long graduated ruler, introduced to the bottom of the water following the width and the length for a distance of 10 m respectively.

Table 2
Analytical results of physical and chemical parameters of Toutsang water samples and corresponding standard World Health Organization (WHO) values.

Measured parameter	SS1	SS2	SS3	SS4	Standard values (WHO, 1996; EPA, 2001)
Distance from mining site (m)	440	430	800	810	/
Solid, suspended (mg/l)	4000	6000	69 000	83 000	50
PH	6.75	7.05	6.65	7.8	6.5–8.5
Electrical conductivity ($\mu s/cm$)	40.4	49.2	31.2	37.6	1.000
Temperature (°C)	19.9	20.1	20.1	20.5	25
TDs (ppm)	28.8	34 .9	10.4	26.3	500 (mg/l)
Salinity (%)	26.1	28.2	15.8	23.6	≤ 40
Turbidity (NTU)	7.9	8.6	153.5	156.6	5
Bicarbonates (meq/l)	53.68	51.24	48.8	53.68	/
Ammoniacal nitrogen (mg/l)	3.64	3.64	2.8	2.8	50
Nitric nitrogen (mg/l)	1,4	1.4	0.28	0.28	0–18
Calcium (mg/l)	3	6	10	10	75
Magnesium (mg/l)	175	177	180	184	100
Potassium (mg/l)	4.01	4.01	4.01	4.00	/
Sodium (mg/l)	2.44	2.44	2.44	2.42	0.4–1900
Iron (mg/l)	0.826	0.826	9.952	11.98	0.7–1

$$v = \frac{d}{t}. \tag{2}$$

2.3. Design of waste water purification system

The purification system proposed in this study to improve the quality of wastewater following the sand mining activity in the Toutsang locality is a rectangular reservoir made of banked concrete which measure $350Kg/m^2$, and irons of 10 including water repellent adjuvants. With slab base, made of large concrete, the system is equipped with an emptying cofferdam, an open channel leading the wastewater to the setting tank and an overflow that will allow to evacuate the treated waters downstream. Since the dimensions of the settling tank are a function of the water flow and the size of particles to be settled, the height H and length L do link by Eqn (3) while the basis $S_n(m^2)$ is given by Eqn (4). In the later, $V_d(m/s)$ is the rate of particle deposition or rate of sedimentation.

$$5H \leq L \leq 10H, \tag{3}$$

$$S_n = \frac{Q}{V_d}. \tag{4}$$

3. Results, discussions and recommendations

3.1. Physico-chemical analysis of Toutsang water

Results of the laboratory analysis of Toutsang water samples are presented in Table 2 for upstream and downstream samples analysis

(a)

(b)

Fig. 2. (a) polluted water due to sand harvesting, standing as the only source of useable water for indoor and outdoor household purposes by habitants of the Toutsang locality; (b) transportation of fine particles by water due to sand exploitation in the Toutsang locality.

respectively. The values of the analytical results provide a clear distinction between the upstream (SS1 and SS2) before mining and downstream (SS3 and SS4) after mining site, showing for instance water pollution effect, as compared to their standard values [EPA, 2001]. The result shows that Toutsang River is particularly rich in fine sediments (74 400 mg/l) and organic particles, which stand as the major factor of sedimentation of the water body.

The World Health Organization [WHO, 1996] recommended standard values for surface water parameters and they are depicted in Table 2. Based on analytical results in one hand and standard values in the other hand, it well appears that only TSS, EC, Ca, Mg, Fe and turbidity are considerably different compared to their respective standard WHO values. In addition, the EC of water is diminished (45.85–31.9$\mu S/cm$). We interpreted such a difference as the consequence of sand mining in the locality. The varied difference in EC between the upstream and downstream of the site indicated that sand exploitation is a source of precipitation of dissolved ions in the water. This shows a potential water quality problem. Results also show that Mg, Sodium (Na), and Fe vary significantly between upstream and downstream of Toutsang River. Therefore, for both Mg and Na, these variations do not depend on sand mining activity. In fact, well-illustrated in Table 1 shows that although the variation in value observed, for Mg, the value is higher (176 mg/l) than the WHO standard value (100 mg/l) in the upstream samples. Furthermore, in case of Na, no matter by how much the value is reduced (2.44–2.43 mg/l), we cannot talk about water quality, since the value is still found in the permissible zone (0.4-1.900 mg/l) imposed by [WHO, 1996].

In contrast, water quality problem arises if one considers results based on Fe. It's well mentioned that [EPA, 2001] Fe is present in significant amounts in soils and rocks and principally in insoluble form. However, being introduced into the River, Fe dissolved and one attend to high value of Fe in River body. This process is that which explains the significant amount of Fe (10.966 mg/l) observed in the downstream of Toutsang River samples. Severe problem may occur by the presence of Fe although there are normally no harmful effects on persons consuming waters with significant amounts of Fe [EPA, 2001]. Rather, the problem is primarily aesthetic, as the soluble ferrous (Fe^{++}) Fe is oxidized in air to the insoluble ferric (Fe^{++}) form, resulting in color change (Fig. 2a) or increase of turbidity. The water with such a color cannot even be used for indoor and outdoor household purposes, since laundry becomes stained if washed in water with excessive Fe. Likewise, vegetables become discolored while cooking, they contain high amounts of Fe. Taste problems may also occur [EPA, 2001].

The high value turbidity may be attributed to the presence of suspended particles related to sand activity and present in Toutsang River (Fig. 2b). This result also corroborates with that of [Arimoro, 2009] and [Meme et al., 2014]. This high level turbidity degrades water quality and reduces light penetration within the River, which affects the photosynthesis rates and the primary production rate of the River. It also affects fish population in the River. These particles do rely on high turbidity water, which can directly affect aquatic ecosystem or relay to other diseases. Thus, as mentioned above, siltation, which causes high turbidity in the water, has depleted fishes' population and is, sadly, the origin of extinction of certain local species. The silt becomes clogged in the fishes' gills, causing physiological stress on the fishes [Phua et al., 2004]. This clogging can lead to infections and the death of the fishes. The sedimentation may affects the water body up to a distance of 11 km from the extraction site, since very fine sand may be carried up to 11 km from the site, fine sand may be carried up to 5 km, medium sand may be carried up to 1 km, while coarse sand may be carried up to a distance less than 50 m. All these results obtained are in accordance with the study of [Ngameni et al., 2017]. Additional impacts of the activity (sand mining) in the Toutsang locality are mentioned by [Ngameni et al., 2017], who also investigated laboratory analysis on heavy metals which are present in the downstream, where sand exploitation activity takes place, and mentioned harmful effects on persons and macro invertebrates consuming water with significant amounts of those heavy metals.

3.2. Hydromorphological measurement of River Toutsang

Toutsang River hydromorphological parameters obtained are depicted in Table 3 below.

Table 3
Toutsang River hydromorphological parameters.

Toutsang River Hydromorphological parameters	Water flow (m^3/s)	Water velocity (m/s)	Water depth (m)
Values obtained	8844985.5×10^{-9}	203333×10^{-9}	1.04

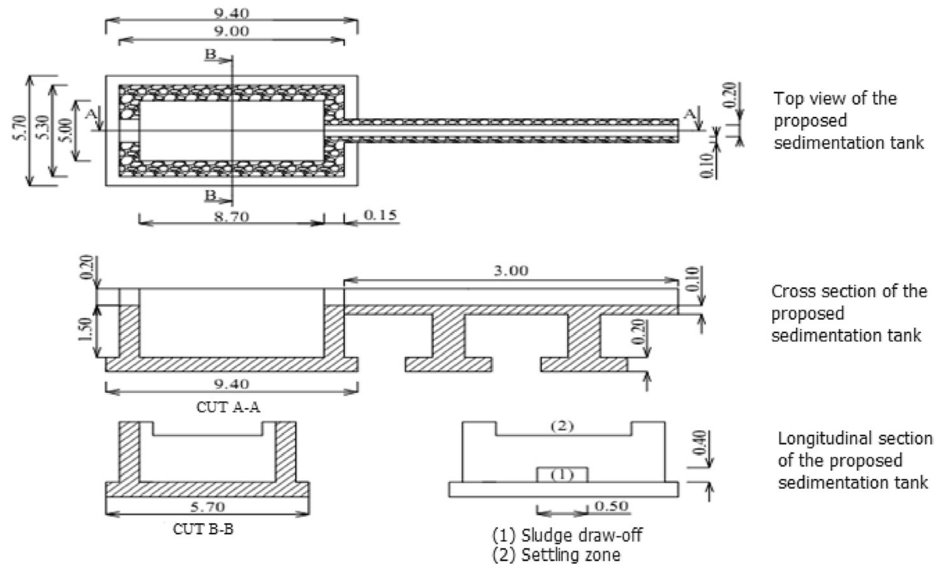

Fig. 3. Proposed model sedimentation tank for Toutsang waste water purification.

3.3. Recommendations

Results of water samples analysis has shown that the suspended solid in Toutsang River at the downstream of the mining site is completely different to it WHO standard value. This means that, Toutsang River contents very important amount of fine sediments in suspension, which is the origin of it brownish coloration (Fig. 2). Thus, proper management of Toutsang River consist on removing those sediment in suspension from the water in order for it to be clean and appropriate to be use at least for indoor and household purposes. Fig. 3 depicts therefore the practical model proposed in this study. The proposed model is a settling sedimentation tank. The sedimentation of water is a phenomenon which consists of the separation of suspended particles that are present in the water. Theoretically, the system is based on the gravity force from differences in density between particles and water [Jover-Smet et al., 2017]. Globally, the aim of the tank is to remove all suspended particles, such as sand, which are present in the water in order for it, as mentioned above, to become clean and appropriate for indoor and household purposes. The model tank proposed is a rectangular settling basin of length and width calculated according to the waste water parameters, particularly the water's velocity and water flow rate (Table 3). The bottom of the tank is slightly sloped to facilitate sludge scraping. In some few meters at the exit of the primary settling tank, two additional small basins are located prior for additional sedimentation process. Their aim being to stop all particles which are not removed in the primary settling tank. Practically, the model can be implemented in the study area. No matter it financial coast (XAF 8 millions), such a model can be implemented by miners. This is because sand mining activity generates important values of daily and monthly incomes to miners in the locality.

Sand mining, as a sector, needs to be regulated in order to balance economic development and environmental management in the quest to achieve sustainable development. We recall that sand mining activity in Toutsang generates water pollution. Proper management of sand mining in Toutsang as in other sand mining sites requires important elements that determine the environmental sustainability. Therefore, the following additional recommendations have to be considered:

- Sand mining site rehabilitation after exploitation. The rehabilitated site could be converted to ecotourism ventures where indigenous species are grown. This will encourage biodiversity development and earn foreign exchange for the locality in particular and the country in general through tourism.
- Promote studies to generate information based on environmental impacts due to mining activities.
- Proper implication of the government in artisanal sand mining activity. Sand harvesting activity has to be taken into consideration by the government, and not to be regarded as a poor sector or activity.

4. Conclusion

Toutsang is a locality of Dschang town. The locality undergoes sand mining activity which contributes to the construction of buildings and infrastructural development and provides both economic and social benefits. However, the activity is a source of severe environmental impacts including destruction of landscape, reduction of farm and grazing land, collapsing river bank, deforestation and particularly water pollution. Meaningly, sand mining lessened water quality with significant effect on both physical and chemical water's parameters. Physico-chemical analysis of Toutsang water samples has shown that Toutsang sand mining modifies water quality thereby increases the levels of some physico-chemical parameters such as total suspended solids (TSS), magnesium (Mg), turbidity and iron (Fe) downstream of the River close to the Mining site as compared to the WHO standards. In addition, Toutsang River contents very important amount of fine sediments in suspension which is the origin of it brownish coloration. Toutsang sand mining strongly contributes to the sedimentation and siltation of the River bank. Investigating Toutsang River hydromorphological parameters including water flow, water velocity and water depth, we design a water purification system, a sedimentation tank to improve Toutsang waste water quality. The practical model proposed stands as the more appropriate model for waste water purification, in order for the water to become clean and appropriate for indoor and household purposes. The finding in this research work ends up with a perspective that the model has to be implemented practically in order to verify theoretical hypothesis labeled above. In addition, detailed study with particular interest on geochemistry analysis is necessary in order to have lucid idea on the concentration of elements such as Lead, Arsenic, Cupper, Silver, Mercury, Nickel, Cadmium to cite a few. These supplementary researches may help to fully document changes in water quality due to sand mining in Toutsang locality.

Acknowledgments

Our appreciation goes to the Faculty of Science and particularly the

Department of Earth Sciences teacher team of the University of Dschang. We are grateful to Mr. Dongmo Solefack Patrick Mao for his technical assistance. Our thanks also go to the *Unité de Recherche d'Analyse des Sols et Chimie de l'Environnement, Faculté d'Agronomie et des Sciences Agricoles (FASA)* at the University of Dschang for analysis.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clet.2021.100045.

References

APHA (American Public Health Association), 1999. Standard method for Examination of Water and Wastewater, twentieth ed., vol. 20p. American Public Health Association, Washington, DC, ISBN 0-87553235-7.

Arimoro, F.O., 2009. Impact of rubber effluent discharges on the water quality and macroinvertebrate community assemblages in a forest stream in Niger delta. *C*hemosphere 77, 440–449. https://doi.org/10.1016/j.chemosphere.2009.06.031.

Bhattacharya, R.K., Chattergee, N.D., Dolui, G., 2019. Consequences of Sand Mining on Water Quality and Instream Biota in Alluvial Stream : a Case-specific Study in South Bengal River, India. Sustainable Water. resouces Management. Springer. https://doi.org/10.1007/s40899-019-00345-y.

Ekengoue, C.M., Lele, R.F., Kagou, D.A., 2018. Influence de l'exploitation artisanale du sable sur la santé et la sécurité des artisans et l'environnement : cas de la carrière de Nkol'ossananga, Région du Centre Cameroun. Eur. Sci. J. 4 (15), 246–268. https://doi.org/10.19044/esj.2018.v14n15p246.

EPA (Environmental Protection Agency), 2001. Parameters of Water Quality-Interpretation and Standard, vol. 132p. ISBN 1-84096-015-3.

Gavriletea, M.D., 2017. Environmental impacts of sand exploitation. Analysis of sand market. Sustainability 9 (7), 1–26. https://doi.org/10.3390/su9071118, 1118.

Jover-Smet, M., Martin-Pascual, J., Trapote, A., 2017. Model of supended solids removal in the primary sedimentation tanks for the treatment of urban waste water. Water 9 (6), 1–12. https://doi.org/10.3390/w9060448, 448.

Manga, E.V., Agyingi, C.M., Djieto-Lordon, E.A., 2013. In-channel Sand Extraction in River Mungo, Cameroon: Nature Effects and Concerns. Artificial Neural Network Modeling. https://doi.org/10.5675/ICWRER_2013.

Meme, F.K., Arimoro, F.O., Nwadukwe, F.O., 2014. Analyses of physical and chemical parameters in surface waters nearby a cement factory in North central, Nigeria. J. Environ. Protect. 5, 826–834. https://doi.org/10.4236/jep.2014.510085.

Ngameni, N.T., Asanga, P.F., Mpoame, M., Kenko, D.B.N., 2017. Impact de L'exploitation artisanale de La sabliere de Toutsang sur La structure des communautes de macroinvertebres du cours D'eau doulahang A Dschang (ouest cameroun). Eur. Sci. J. 13 (23), 254–274. https://doi.org/10.19044/esj.2017.v13n23p254.

Padmalal, D., Maya, K., 2014. Sand mining. Environ. Sci. Eng. https://doi.org/10.1007/978-94-017-9144-1.

Phua, C., Akker, V.D.S., Baretta, M., Dalfsen, V.J., 2004. Ecological Effects of Sand Extraction in the North Sea. University of Porto, Portugal. Accessed on 17th October 2019. URL. www.vliz.be/imisdocs/publications/154975.pdf.

Rodier, J., Legube, B., Merlet, N., 2009. L'analyse de l'eau. Dunod, 9e édition, Paris, p. 1579. ISBN: 9782100072460 2100072463.

WHO (Word Health Organization), 1996. Guidelines for Drinking-Water Quality, second ed. ISBN 92 4 154480 5 (v 2) (NLM Classification WA 675).