ISCA Journal of Engineering Sciences ______________________________________ *ISCA J. Engineering Sci.*
Vol. **1(1),** 45-50, July **(2012)**

Characterization of the domestic wastewaters and dimensionality of a pilot treatment station by lagooning at Abomey Calavi city- Benin

Aina M.P.[1,3*], Djihouessi B.[1], Vissin E.W.[2], Kpondjo N.M.[1], Gbèdo V.[1] and Sohounhloué K.C.D[3]
[1]Lab. des Sciences et Techniques de l'Eau de l'Ecole Polytechnique d'Abomey Calavi, UAC, Cotonou, BENIN
[2]Lab. Pierre Pagney, Climat, Eau, Environ., Dévelopement (LACEEDE) /DGAT/FLASH, Université d'Abomey-Calavi, BENIN
[3]Lab. d'Etude et de Recherche en Chimie Appliquée, Ecole Polytech. d'Abomey/Calavi, UAC, Cotonou, BENIN

Available online at: www.isca.in
Received 2nd July 2012, revised 16th July 2012, accepted 19th July 2012

Abstract

This study has been conducted to characterize the household wastewaters rejected by the populations of Tokpa-Zoungo, a populous district of the city of Abomey-Calavi in Southern Benin. The laboratory analyses on samples of wastewaters taken from the cesspools, and near several compounds (houses) in the study area, revealed that the average load of polluting effluents to be treated is important (36O mg / l COD, 180 mg / l for BOD_5). The results show that the wastewaters rejected by the inhabitants are perfectly biodegradable. A treatment by lagooning, using microphyte with three stabilization basins yielded good results with the targeted purifying output being about 88%. The water thus treated is susceptible to be in conformity with discharge standards in sensitive areas such as the lake Nokoué which is the receiving medium in this case. The study also suggested a network for the collection of wastewaters rejected by the populations of the study zone. Wastewater treatment plant (WWTP) therefore will be the primary waste water receiving entity. Two phases have been achieved during the course of the present study, the first one being the topographic surveys that have been conducted to measure the slopes and the pressure drops to the WWTP, and the second. The dimensioning of the pipes to insure drainage of waters to the wastewater treatment plant WWTP.

Keywords: Wastewater, treatment, characterization, lagooning.

Introduction

Several systems of collective purification of wastewaters have already been put in place in West and Central African countries; in 1993, a study showed that 155 purification plants have been built[1]. The processes of purification by activated muds represented nearly 75% of these recorded plants and almost all have either stopped working, or need repair[1,2]. This failure comes from the fact that the purification techniques by activated sludge are very expensive both for construction and maintenance, and very rigid in exploitation they fit in the realities of African countries characterized by limited financial and human resources. The other WWTPs are exploited beyond their capacity.

Considering these reports, several researchers propose a treatment by the processes of extensive type[3-6]. Indeed, the extensive processes are simple systems to implement, inexpensive to operate and easy to maintain and thus fit perfectly the socioeconomic context of West and Central African countries. The most known of the extensive processes is the lagooning.

Recently, many authors proved that the method of lagooning gives good efficiency and shows good perspectives for its implementation in sub-Sub-Saharan Africa[7,8]. However, no station has really functioned yet on a large scale, for economic reasons and a lack of political support. The insufficiency of training and educational support and the lack of research study in that field are also reasons that justify this situation.

Therefore, the main objectives of the current study are the characterization of the wastewaters from the city of Abomey-Calavi and the contribution to the improvement of the life conditions of the populations from the districts in Benin. The pilot WWTP once set up can serve as a case of study and practical experience for the characterization of wastewater and can also help in proposing better solutions for the treatment of wastewater.

Material and Methods

Presentation of the study zone: For this work, we were interested in the Tokpa-Zoungo district that is situated in the center of the precinct of Abomey-Calavi in the Atlantic Department. This very dense district represents the old town of the Abomey-Calavi city. It shelters big domestic concessions subdivided in small houses where cohabit several households. Tokpa-Zoungo is situated along the Lake Nokoué and doesn't have sewage system.

Sampling and analytical methods: The choice of sampling points for physical and chemical parameters analysis of wastewaters was based on getting a compromise between the possibility of sampling and the necessity to have gathering wastewaters coming from all the households reflecting life standing. Therefore, we have selected five (5) cesspools which take into account the household activities and there life standings in the study area.

The samples are taken with great care to effectively represent water discharged from the households and to reflect the best characteristics of the effluents under study. For this an automatic portable sampler (SIGMA type) containing 24 small bottles of 1 L each was used for sampling. Every bottle is previously cleaned in the laboratory, and at the sites of sampling, they were rinsed once with the wastewater prior to the sampling.

At every sampling point, we have taken 96 samples. Every 8 hours a volume of 250 ml of wastewater was taken to fill 24 containers of 1 liter each. A mixture of the 96 samples permitted to have an average sample that has been submitted to the different analyses. The samples are kept at 4°C before analysis in order to limit change in the parameter values to measure.

For each average sample obtained, we associated a number. Site I (low living standing: traditional toilet), site II (average living standing: modern toilet), site III (average living standing: modern toilet with high discharge), site IV (market activities), site V (poor living standing: No toilet). The sample A is a mixture of the samples from I to V, achieved proportionally to the debit of the rejected flow in each point of sampling. The physical and chemical analysis of different wastewater samples have focused on the following parameters: temperature, pH, dissolved oxygen, turbidity, COD, BOD_5 and nutrients such as nitrate, nitrite, ammonium, and phosphate[9].

The theoretical expected value at the time of the measurement of a parameter X of a given sample A was calculated using the following formula:

$$thX_A = \frac{Q_1 X_1 + Q_{II} X_{II} + \ldots\ldots + Q_V X_V}{\sum Q}$$

On every average sample, the following parameters have been measured in situ: temperature (using thermometer), pH (using pH-meter pH 3110 equiped with a glass electrode), dissolved oxygen (an oxymeter of inoLab Oxi 730 type, equiped with a cellOx 325 oxygen probe) and the turbidity (by using the 1100 IR turbiquant, including a white tungsten lamp and a reflected light detector). The determination of the concentration in phosphate is done on site with conditioned "Aquachek" strips. The determination of the nitrate and ammonium was made in the HACH Lange DR 2800 spectrophotometer in the laboratory.

The COD analyses were carried out according to the AFNOR standards (NFT 90 – 101). Measurements of dissolved organic carbon (DOC) were carried out by a carbon analyzer (OI analytical model 1010). After the sample acidification by phosphoric acid, mineral carbon (CO_2) is removed by nitrogen bubbling. The sodium persulfate is then introduced into the sample. This oxidant reacts with the organic carbon in the sample at 100°C to form CO_2. This is again purged from the solution and detected by IR analysis. The amount of CO_2 is proportional to the mass of carbon in the sample. The detection limit is estimated at 0,2 mg C. L^{-1}.

The determination of the BOD_5 has been done by means of the OxyTop system. The value of the theoretical BOD thus obtained allows us to have, thanks to the BOD abacus, the necessary sample volume to introduce in the Oxytop. This latter is then put in the thermostatic chamber and was agitated. After five days, we get, after reading on the Oxytop, the value of the biochemical oxygen demand BOD_5.

Topographic surveys: The surveys allowed us to have significant data about the site relief, which facilitated the design of the network for waste water collection. They also permitted to highlight the different slopes.

Determination of the water debits rejected by the populations: The determination of the water flows rejected by the populations is based on the water consumption per capita. The evaluation of water consumption has been proved to be difficult because few people in the study zone connect to the public network of potable water distribution service .Most of them use unsane well water and cannot give the quantity of water from the well that they consume. We proceeded then by investigation, interviews and table of assessment of waters by activity (kitchen, dishes, laundry, bath, toilets and drink). The average thus obtained is 50 L/inhabs/day. It is important to underline that the populations of Tokpa Zoungo are practically located in the same living standing; therefore the difference in their water consumption is low. We assume an overall rate of restitution estimated at 80% of the consumption of water in the house[10].

Results and Discussion

Characterization of the sewage: Temperature, pH, and Dissolved Oxygen (DO) values obtained for various samples are summarized in table -1.

As can be seen from the table, the temperature values of the different samples vary from 26,9°C to 29,2°C. This parameter is important for the performances expected from the extensive process types; usually the temperature has to be greater than 20°C so that the resort to the anaerobic lagooning is considered to be interesting, because temperatures greater than 20°C favor an optimal microbiological activity development[5,8].

The different pH values (7,5 - 8,5) indicate basic medium, and match the normal pH of household sewage[11].

The low DO values indicate the presence of a great quantity of oxidizable matter. These values are correlated with the pH values, thus demonstrating that the oxidizable matter could be linked to the organic matter contained in the wastewaters. However, the value observed in sample IV seems not to be correlated with the results, certainly influenced by the temperature of the area, but especially due to the factor of diffusion of the membrane of the oxygen probe that would be affected by the presence of Cl_2, sulfurous hydrogen, ammonia or Bromine. Organic matter content in the sewages is appreciated by the measure of the COD and the BOD_5 on each sample. The results are reported in table-2.

The COD values show that the organic pollution is considerable in the analyzed samples. However these values, except the one of sample III, remain low compared to the 600 to 1000 mg/l generally admitted as normal for the wastewaters[10].

The value of the COD in sample III is higher than those of the other samples, and could be explained by the fact that the water coming from the septic faucet of the compounds is mixed with water coming from a fish processing factory. It is important to note that one of the main economic activities of housewives in the study area is fish retail after cleaning and smoking for conservation. The waste water from the fish cleaning activities get mixed up with the household waste water. The concentrations of the BOD_5 of the analyzed samples vary with a yearly average of 180 mg/l, a maximum of 240 mg/l and a minimum of 45 mg/l.

The theoretical value calculated for the BOD_5 is: the COD_A = 173,41 mg/l. This value is very close to the value obtained experimentally.

For the samples I, II, IV, V and A the COD/ BOD_5 values are very close to 2. These values are consistent with those generally given for urban residuary waters which are between 2 and 2,5 in entry of the treatment plant. The corresponding sewages are biodegradable[12]. On the other hand, the report from sample III is 4,07. This value is comparable to the one of 4,5 obtained by[13]. This high value indicates a strong content in non biodegradable organic matter. This could be due to especially to the organic carbon but unfortunately we did not measure the total organic carbon (TOC) to provide more explanation. However, it is important to notice that the mixture of the samples (Ech A) gives a COD/BOD_5 value of 1,99. The biological treatment of the set of the disposals should not raise any problem.

It would also be judicious to measure, in this case, the SUVA indication to have some information on the fragrance of the sewages.

$$SUVA = \frac{AbsUV_{254}}{COD}$$

The concentration of Kjedhal nitrogen generally admitted for the urban wastewater is 75mg/l[10]. This concentration is greater than those obtained by[7] which is 69,9 mg N/ls (at the pilot treatment plant of the University A M in Niamey) and[14] that is of 59 mg N/l (for the yearly characterization of the influential of the anaerobic lagoon, in Mèze in France). This value combined to the contents in nitrate and in ammonium obtained after the analysis of the samples, yields the global nitrogen NGL values reported in table-3.

The NGL obtained for the different samples are in the limit of the values indicated by the water and purification code in Benin (permitted highest value of 200 mg/l).

Network and distribution of discharge: The proposed connection plan takes in account 30 concessions. We have considered 700 inhabitants equivalent to quantify the pollution generated by the households and the market activities of the city of Abomey – Calavi.

Studies show that the daily water f consumption in Benin is 60 liters by inhabitant - equivalent. We have estimate, employing the installation of the washers in the households that waste water disposal is about 80% of the total water use. So, each inhabitant - equivalent produces daily 48 L of waste water out of the 60 L used.

The collection network, is a network branched out to the gravitary out-flow, under permanent out-flow regime with circular pipelines filled up to 80%.

Then, the conception of the network is based on the law

$$Q = VS$$

Where: Q is the known flow m^3/s; S is the wet section; V is the average speed expressed as it follows; $V = K.R^{2/3}.I^{1/2}$ for a gravity outflow conduct with; K, the coefficient of roughness; R, the hydraulic radius ratio of the wet section over the wet perimeter) in meters; I , the hydraulic gradient necessary for the outflow at a given flow Q. Table-4 represents the basic technical parameters of the network collection.

Purification efficiency and dimensionality of the pilot WWTP: The dimensioning of a lagooning path must take into account several factors that must be hierarchized according to the purifying objectives. For this study, the issue is about a disposal in a sensitive environment namely lake Nokoué. That is why, the exhaustion of nutrient (nitrogen, phosphorous), of the carbonated pollution and the indicators of fecal contamination, is considered as a priority objective.

Considering the values that are obtained after the characterization of the rejected waste waters and complying with the constraints for disposals in sensitive surroundings; the minimum outputs of 65% for the COD, 85% for the BOD_5 must imperatively be reached. These outputs are consistent with the quality for residuary waters in the Republic of Benin standards.

Then, the system of lagooning with microphytes (anaerobic basin + optional basin + basin of maturation) presents good perspectives for implementation. The efficiencies of such a system are remarkable at the level of the output. A survey implemented over four months on the pilot station of the University A.M in Niamey gave the following results: in terms of performance, the levels of exhaustion of the organic pollution are located between 60 and 90%, and the elimination of the TKN parameters, $N\text{-}NH_4$ and $P\text{-}PO_4$, give the respective average outputs of 65, 72 and 82%[7]. These results are similar to those obtained by[8] in a similar study concerning five stations in Tunisia.

For the dimensioning of the anaerobic basins[15], suggested to calculate the volumic load using the following the formula:

$$\lambda_V = \frac{CiQ}{V} = \frac{Ci}{t}$$ With:

λv : the volumic load in $g/m^3.j$; Ci: the influential concentration (mg BOD5/l); Q : is the waste water flow (m^3/j); V : the volume of the basin (m^3); V/Q = t is the residence time of the waste water (days).

Many authors suggested to evaluate the admissible maximal organic load in a basin according to the average temperature of the coolest month of the year as follow :

$$\lambda_{appl} = 20T - 120$$

Then, these same authors used a more appropriate equation for the dimensioning of the optional basins:

$$\lambda_{app} = 350(1{,}107 - 0{,}002T)^{T-25}$$

Where: λ_{appl} is the admissible load of BOD_5 by unit of surface in BOD5/ha/j kg, T is the minimal temperature of the air of the coolest month of the year.

Volumic loads between 100 and 400 g/m3.j are recommended to insure good working conditions. [15]suggested a BOD load of about 150 $g.m^{-3}.j^{-1}$ in the anaerobic basin and a surface load of about 350 kg $BOD.ha^{-1}.j^{-1}$ for a working temperature greater than 25°C. The WWTP of the University Abdou Moumouni in Niamey is proportioned according to these criteria[7]. The one in Mèze in France functions with an organic load of 83 g $BOD/m^3.j$[14]. The volumic organic load recommended by the Ministry of Health in Israel is 125 $g/m^3.j$ quoted by Effebi R[8].

The water flow to take in account at the entry of the water treatment plant is based on the water consumption per capita. One supposes a global percentage of restitution estimated to 80% for the water consumption in the house, because it is excessively important if the system of collection and contains some losses[10].

Therefore for dimensioning our water treatment plant the parameters and specification we recommend are summarized in table-5 bellow.

Thus, we obtained the physical characteristic of the different basins presented in table-4.

Conclusion

This integrated study is part of an approach of research - action, considering the involvement of the populations in the investigations, in the interviews and in the search of sustainable solutions. The decision makers met during the course of the present study are fully aware of the sanitation needs of their people and are carrying out reflections to find sustainable solutions to those needs. The implementation of a pilot WWTP at Topka Zoungo is one of the solutions that is considered. Lagooning is the kind of purification way that offers the best perspective for implementation. It is a low-cost system that is simple, and doesn't require a big technicity for maintenance and monitoring. The analyses at the laboratory, the sampling done at the cesspools of the study zone have allowed us to have a characterization of the domestic wastewaters of the locality. Monitoring of the pilot WWTP will allow research and the development of better solutions for the treatment of the domestic wastewaters in Benin.

Table-1
Temperature, pH and dissolved oxygen values of different samples

	T°C ±0,1	**pH ±0,01**	**DO (mg/l) ±0,1**
Sample I	26,9	7,82	0,16
Sample II	28,8	8,31	0,12
Sample III	29,2	9,12	0,09
Sample IV	27,9	8,09	0,06
Sample V	28,6	8,12	0,11
SampleA	**28,6**	**8,04**	**0,08**

Table-2
Values of the conventional pollutant parameters

	Turbidity (NTU)	**COD (mg/l)**	**BOD_5 (mg/l)**	$\frac{DCO}{DBO_5}$	**Nitrate (mg/l)**	**Ammonium (mg/l)**	**Phosphate (mg/l)**
Sample I	48,92	85	45	1,89	2,9	2,3	5
Sample II	82,77	416	240	1,73	13	11,5	12
Sample III	140,2	732	180	4,07	58	53	45
Sample IV	232,1	394	200	1,97	8	6,9	15
Sample V	106,8	307	145	2,12	~	~	14
Sample A	**170,0**	**359**	**180**	**1,99**	**~**	**~**	**18**

Table-3
Likely content in global nitrogen

	Nitrate (mg/l)	Ammonium (mg/l)	TKN (mg/l) (Bourrier, 2008)	NGL obtained (mg/l)
Sample I	2,9	2,3	75	80,2
Sample II	13	11,5	75	99,5
Sample III	58	53	75	186
Sample IV	8	6,9	75	89,9
Sample V	~	~	~	~

Table-4
Basic technical parameters of wastewater collection

Sections of the network	***Q* (l/s) to select**	**Selected Ø (mm)**	**Suppressed slope**
P1-P7	0,19	200	0,045
P7-P10	0,27	200	0,025
P10-P14	0,38	200	0,004
P14-P21	0,50	200	0,004
PI-P22	0,61	200	0,002
P22-P27	0,84	200	0,002
P27-P32	0,92	200	0,002
P32-P38	1,27	200	0,002
P38-P45	1,34	200	0,002

Table-5
Recommended dimensioning parameters and specification:

Parameters	**Specification**
In-coming flow	33,6 m^3/day
Evaporation	60 mm/m^2/d
Concentration in BOD_5 at the entry l'entrée	200 g/ m^3
Microphytes	1 anaerobic basin + 1 optinal basin + 1 basin of maturation
Height of the different basins	Anaerobic basin 3 m ; optional basin 1,5 m ; basin of maturation 1 m.
λ_v : volumic charge	100 g/m^3
Volume anaerobic basin requested anaérobie	V= [BOD]* Q_{EU} /λ_V (Mara and Pearson, 1998)
Load per surface unit	$\lambda_{appl} = 20T - 120$ (Mc Garry et Pescod, 1970)
Exit Ncf of the WWTP	3 Ulog
Minimal temperature °C	25°C
Folding	Anaerobic basin 60% ; optional basin 70% ;
Retention time for the maturation basin	4 days

Vol. **1(1),** 45-50, July **(2012)**

Table-6
Physical parameters of the various basins

	Volume in m^3	Depth in m	Retention time
Anaerobic basin	67,20	3,00	2 days
Optional basin	99,75	1,50	4 days
Maturation basin	102,40	1,00	4 days

Figure-1
Aerial photograph of the study area (The zone delimited in red is the study area)

References

1. CIEH, Etude comparative des systèmes d'épuration collectifs dans le contexte africain, CIEH; Ouagadougou, 66 **(1993)**
2. UADE, OIEAU, Assainissement urbain en Afrique : Gestion des déchets liquides et solides dans les centres urbains d'Afrique, Rapport final du Séminaire Assainissement Urbain en Afrique, Ministère Français de la coopération **(1993)**
3. Charbonnel Y., Simo A., Procédé et systèmes de traitement biologiques d'eaux résiduaires, Université de Yaoundé, Brevet OAPI n° 8320, 11 **(1986)**
4. Pearson H.W., Mara D.D., Calwley L.R., Arridge H.M. and Silva S.A., The performance of an innovative tropical experimental waste stabilization pond system operating at high organic loadings, *Wat. Sci. Tech.*, **33 (7),** 63-73 **(1996)**
5. Koné D., Epuration des eaux usées par lagunage à Microphytes et à Macrophytes en Afrique de l'Ouest et au Centre : état des lieux, performances épuratoires et critères de dimensionnement, Thèse de Doctorat ès Sciences Techniques, Faculté Environnement Naturel, Architectural Et Construit / Ecole Polytechnique Fédérale de Lausanne (N° 2653), 170 **(2002)**
6. Aina M., Mama D., Yao B., Labanowski J., Moudachirou M., Matejka G., Feuillade G., Remediation of Wastewater From Paper Mill Industry by Ultrafiltration and Aerated Lagoon, *J. App. Sci. Res.*, **5(11),** 2035-2040, **(2009)**
7. SEIDL M., Mouchel J.M., Valorisation des eaux usées par lagunage dans les pays en voie de développement. Centre d'Enseignement et de Recherche Eau Ville Environnement, 43 **(2003)**
8. Effebi R., Lagunage anaérobie : modélisation combinant la décantation primaire et la dégradation anaérobie. Thèse de doctorat, Université de Liège Campus d'ARLON, 235 **(2009)**
9. Malick G. M.; Raval V.H., Zadyfia S. K.., Patej A.V., Idol immersion and Physico-Chimical properties of South Gujarat rivers, India, *Res. J. Chemical Sci.,* **2(3),** 21-25 **(2012)**
10. Bourrier R., Les réseaux d'assainissement, Cinquième édition, TEC et DOC, Lavoisier, Paris, 671 **(2008)**
11. Paing J., Bilan du carbone et du soufre dans le lagunage anaérobie : contrôle de l'émission d'H2S pour la réduction des nuisances olfactives. Thèse de doctorat, Université Montpellier I, 255 **(2001)**
12. Degrémont, Mémento Techniques de l'Eau. Dixième édition, Tome 1, Lavoisier, Paris, 785 **(2005)**
13. Echihabi L., Yagoubo M., Foutlane A., Bourchich L., Ychioui M. El., Jellal J., Etude des performances épuratoires de la station d'épuration des eaux usées de la ville de Boujaad- type lagunage naturel. Wat. Sci. Tech., **42 (10),** 9-16 **(2000)**
14. Picot B., Paing J., Sambuco J. P., Costa R. H. R. and Rambaud A., Biogaz production, sludge accumulation and mass balance of carbon in anaerobic ponds. 5th International IWA Specialist Group Conference on waste stabilization ponds, Auckland- New Zealand, **1**, 381-388 **(2002)**
15. Mara D.D., Pearson H.W., Design Manual for Waste stabilization ponds inmediterranean countries, Leeds, Lagoon International Technology Ltd, 112 **(1998)**