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RESEARCH ARTICLE

SOCIO-SANITARY AND ENVIRONMENTAL IMPACT OF THE SANITATION NETWORK DYSFUNCTIONS ON NIANGON NORD AND TOIT ROUGE INHABITANTS (YOPOUGON- ABIDJAN)

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ABSTRACT

The dysfunction of the sanitation works in Niangon Nord and Toit Rouge, districts of Yopougon (Abidjan), results in the flow and stagnation of domestic wastewater in the households and in the streets. In contact with these kinds of water, the population is exposed to some diseases. The objective of this work is to highlight the socio-sanitary and environmental impacts of wastewater from the dysfunction of the sanitation network on the inhabitants of these districts. In order to do so, the register of customers' requests of the *DRANA* maintenance and repair service was consulted, and a sample survey of households in the two districts was carried out. The data collected showed that the dysfunction of the sanitation works in Niangon Nord and Toit Rouge is caused by the bad behavior of the populations on these infrastructures. The wastewater analysis has shown high concentrations of physico-chemical and bacteriological pollutants. There is an average of 204.08 mg/L of Suspended Solids , 8.57 mg/L of (NO_3^-), 38.76 mg/L of de (NH_4^+), 2.46 mg/L of (PO_4^{3-}), $1.73.10^8$ UFC/100 mL of total coliforms, 07.10^7 UFC/100 mL of fecal coliforms, and $2.39.10^7$ UFC/100 mL of fecal streptococci. These waters near residential areas which are also playgrounds for children constitute a health risk for these families. The bacteriological contamination from these waters, as well as the odors they emit, would particularly cause malaria, typhoid fever, and diarrhea. On the other hand, the presence of nitrogen compounds would constitute a minor risk to human health in case of ingestion of these waters.

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INTRODUCTION

The 1970s urban development plan established by the Ivorian government led to the construction of numerous socio-economic housing units in many townships in the district of Abidjan (Bohoussou, 2008; Gnamba, 2014). These houses have been endowed with a separative sanitation system. Since the houses have been delivered to their occupants by the Ivorian government, considerable attempts of the sanitation and drainage systems are observed. This fact is due to demographic growth and land pressure. The uncontrolled constructions, done on manholes and other sewerage network, result in a collapse of the domestic wastewater pipes. Domestic wastewater streams and stagnates in streets, roadways and drains; causing obnoxious odors (Wayou, 2010). Domestic wastewater consists mainly of water from households and sewage. Their composition is fairly uniform and depends on the habits of each house. Organic compounds (detergents, grease, solvents, and organic debris…), suspended particles, nutrients (phosphorus and nitrogen), fecal germs are among the main pollutants (Huang *et al.,* 2010, Thongtha *et al.,* 2014; Verlicchi *et al.,* 2013). The dysfunction of sanitation works makes the population be in

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contact with domestic wastewater (Soro *et al.,* 2010, Ba, 2011); Exposing them to some possible diseases. People are thus exposed to the contaminants these waters by a direct contact with the skin, eyes and mucous membranes; by inhalation or ingestion (Ba, 2011). The frequency, the extent and the probability of exposure are very important criteria to assess the risk associated with a given contaminant (WHO, 2003). On the basis of this observation, we have put the focus on the particular case of two districts in Yopougon: Niangon Nord and Toit Rouge. This work aims at studying the socio-sanitary and environmental impacts of the dysfunction of the sanitation network on the inhabitants from Niangon Nord and Toit Rouge. More specifically, it is a physico-chemical and bacteriological analysis of domestic wastewater resulting from the dysfunction of the sewerage network in the above mentioned districts and of the socio-sanitary and environmental impact.

MATERIALS AND METHODS

Presentation of the study area

Niangon Nord and Toit Rouge are districts in the suburb of Yopougon. Yopougon is one of the thirteen (13) suburbs of the district of Abidjan and it is located in the South-West of Abidjan. Niangon Nord and Toit Rouge are planned urban communities from Yopougon. They have been built by two real estate companies, SICOGI and SOGEFIHA in the 1970s (Gnamba, 2014). Niangon Nord is located in the south-west of Yopougon (Figure 1) with an estimated population of 39,831 inhabitants with 5251 households (INS, 2014). Toit Rouge is located in the south-east of Yopougon (Figure 1), with an estimated population of 52307 inhabitants with 12623 households (INS, 2014). These districts are equipped with a separative sanitation network.

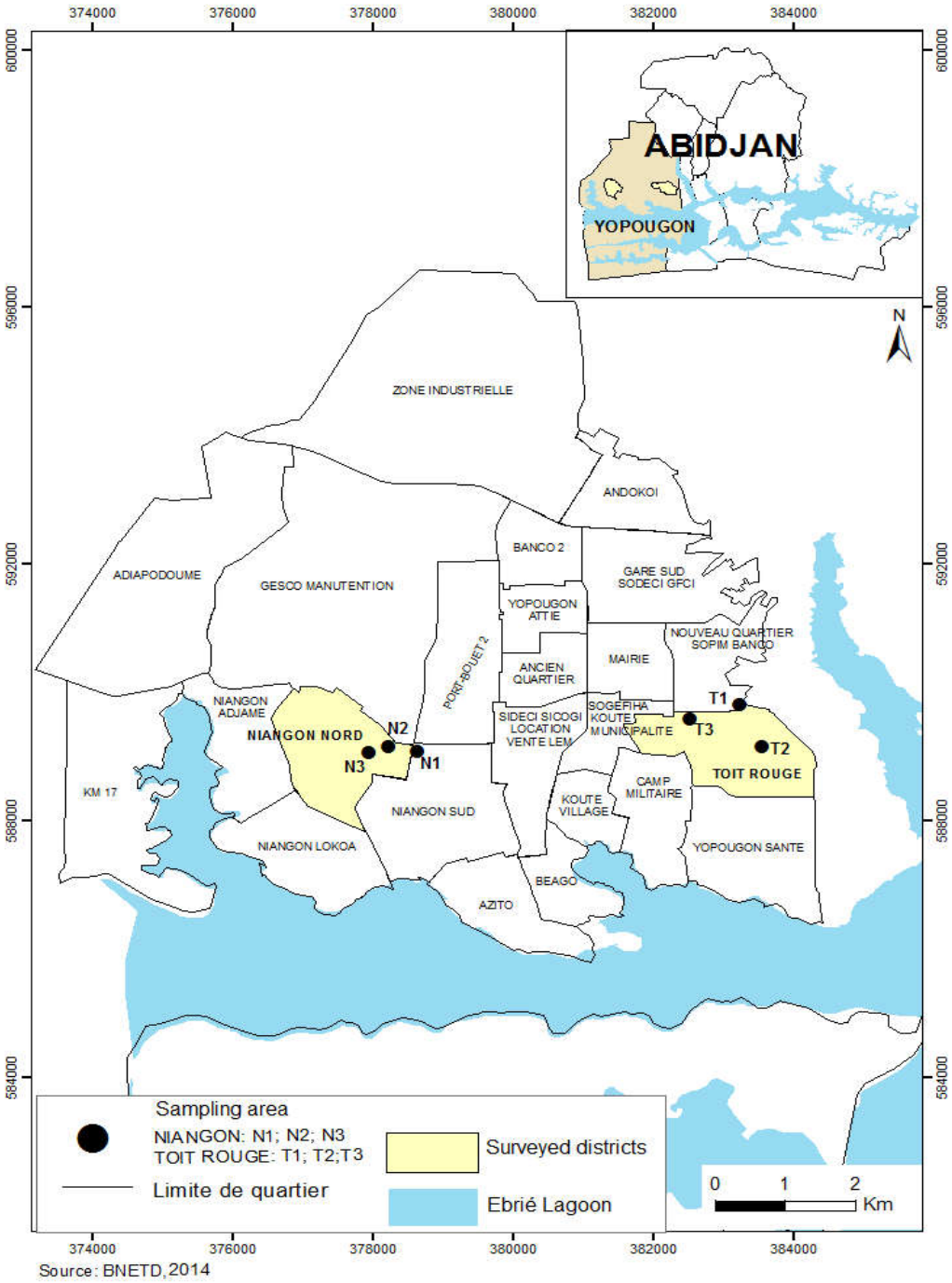

Figure 1. Yopougon map

The choice of the study area

The choice of the districts was made on the basis of the following criteria:

- Good coverage in terms of sanitation network;
- High recurrence of dysfunctions in the sanitation network.

Sampling

Three (3) sampling points of domestic wastewater from the dysfunctions of the sewer system were selected per districts (Figure 1). These points are located in the areas of dysfunction which are close to households (degraded manholes, stagnant domestic wastewater which streams from the sewer network). The sampling was carried out by four campaigns (April 2016, July 2016, September 2016, and November 2016). Each campaign has permitted to collect 12 samples, for a total of 48 samples. The sampling, the transport and the storage of samples have been in accordance with the protocol defined by AFNOR (2001) and Rodier (2009).

Socio sanitary diagnosis

Customers' requests register viewing: The register of customers' requests for the maintenance and repair service of *DRANA*[1] is the register in which are recorded, every working day, the requests of customers from the dysfunctions of the sanitation network in households or in the public domain. The data from this register helped to make statistics on the dysfunction of the sanitation network of domestic wastewater in the two study areas.

Households sample survey

The households sample survey in the two districts was carried out over a period of two months (November-December 2016). It aimed at sorting out the level of functioning of the household sanitation network, the level of households' sanitation knowledge, the management of households' sanitation network dysfunction, and the sanitary aspect linked to the dysfunction of the sanitary network. Households were randomly selected; avoiding any possibility to choose neighboring houses.

Determination of the number of households to be surveyed

The survey was conducted with a sample of 384 households spread over the two districts (Niangon North 112 households) and Toit Rouge: 272), which are connected to the suburb collector. The survey questionnaire was given to the household heads or to their representatives, for each zone. The sample size (Table 1) corresponds to the number of individuals in the sample. The population of these districts is estimated to 92138 inhabitants. The size of the population is known from the last general population census in 2014. In this case, the most appropriate sample formula is as follows (OMS, 1991):

$$N = \frac{T^2 - P\,(1-P)}{M^2}$$

N = Required sample size
T= Confidence to 95% (Standard value of 1.96)
P = Proportion of the population producing wastewater.
M= 5% margin of error (Standard value of 0,05).

Determination of physico-chemical and bacteriological parameters

Physico-chemical analyzes: The in situ pH measurements have been carried out by the *HACH HQ 40d* multi-parameter. Turbidity was measured with the HACH Lange 2100Q turbidimeter in laboratory. The Suspended Solids (SS) were determined by filtration of a volume of waste water on the basis of 0.45 µm cellulose filter (AFNOR, 2001). Nitrites (NO_2^-), nitrates (NO_3^-), ammonium (NH_4^+) and orthophosphates (PO_4^{3-}) were analyzed by colorimetry using the QW324A, UV2700 spectrophotometer according to AFNOR (2001) and Rodier (2009).

Bacteriological Analysis

The total coliforms, fecal coliforms, fecal streptococci were counted using the surface spreading seeding method (AFNOR, 2001). The followings were used: Violet Red Bile Lactose (VRBL) for the total coliforms and the fecal coliforms, Esculin Bile and Sodium Azide for facal streptococci. Results from all determinations were expressed as colony forming units per 100 mL (UFC/100 mL).

Data processing

The data processing was carried out using the *SPHINX* software. The *Statistica 7* software was used, as for the data from the analyzes, as well as the production of figures and tables.

RESULTS

Socio-sanitary and environmental diagnosis due to the dysfunction of the sanitation network

Distribution of requests per month

The consultation of the different interventions of SODECI in Niangon Nord and Toit Rouge throughout 12 months, has helped to construct the diagram (Figure 2) which represents the number of requests in these two areas per month. Sanitation problems were the most observed in May in the two districts; with 37 and 26 requests respectively in Toit Rouge and Niangon Nord.

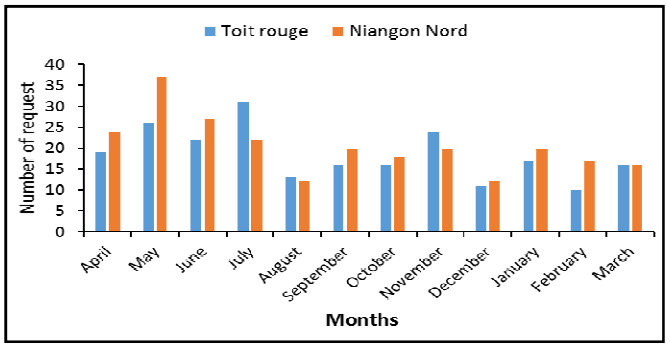

Figure 2. Frequency of requests processed by SODECI from April 2016 to March 2017 (Niangon Nord and Toit Rouge, Yopougon)

The interventions of SODECI in Toit Rouge are more considerable than those of Niangon Nord. DRANA data indicate that an average of 18,5 requests per month is recorded while in Toit Rouge, an average of 20,5 per month is received.

Households raising recurring sanitation problems

The Figure 3 shows the households that raise sanitation problems. In fact, all the people that we encountered are formal; they have no problem of rainwater draining. But their major problem remains the evacuation of wastewater. 53% of Toit Rouge households and 56% in Niangon Nord evoke problems of wastewater evacuation.

People enumeration per household

The Table 1 shows the number of inhabitants in the surveyed households. There is an average of 9 people living in accommodation in Niangon Nord and Toit Rouge. The number of inhabitants reaches a peak of 17 and 23 people per household respectively in Niangon Nord and Toit Rouge.

Knowledge of the sanitation network

The results of Figure 5 show that many respondents know what a sanitation network is. Indeed, 67% of Toit Rouge surveyed households and 41% of Niangon Nord's actually know what a sanitation network is; they define it as all the facilities and equipments set for the evacuation of Wastewater and rainwater. On the other hand, 33% of Toit Rouge households and 59% of Niangon Nord's do not know the concept of sanitation network. These people either give an incorrect definition or they have no idea of what it is.

Solicited structures to solve the network sanitation dysfunctions

Private individuals are the most solicited to solve the dysfunctions of sanitation works. 64% of Toit Rouge households and 50% of Niangon Nord's resort to them. 47% of households in Toit Rouge and 44% in Niangon Nord call for SODECI. In Niangon Nord, 6% of the households and 1% in Toit Rouge carry out repairs themselves without using any structure (Figure 6).

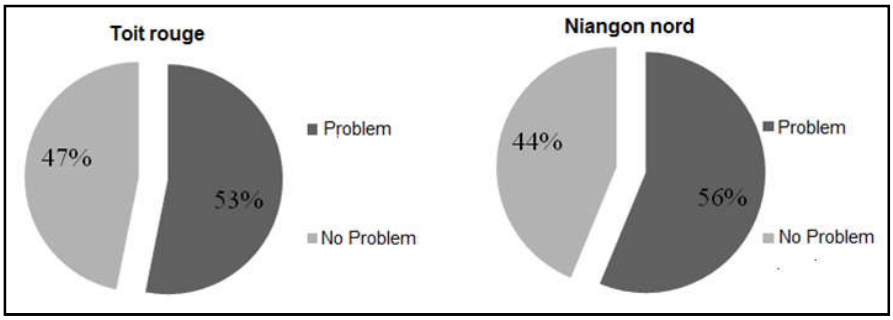

Figure 3. Proportion of households with wastewater drainage problems (Niangon Nord and Toit Rouge, Yopougon)

Table 1. Enumeration of persons per household in Niangon Nord and Toit Rouge (Yopougon)

	Minimum number of people per household	Average number of people per household	Maximum number of people per household	Total population of the visited households
Niangon Nord	3	9	17	770
Toit Rouge	4	9	23	1379

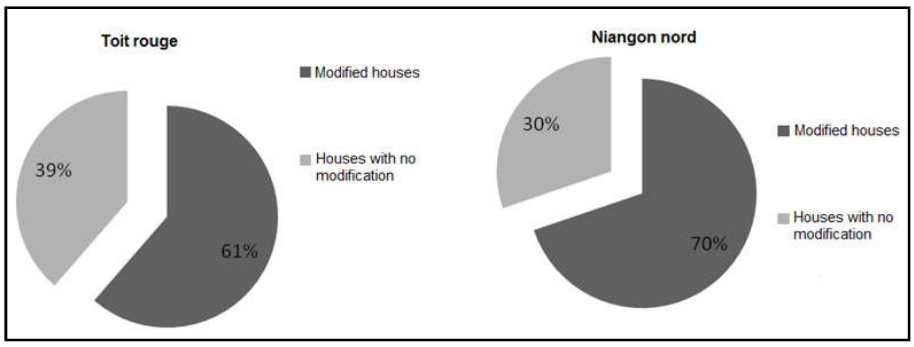

Figure 4. Proportion of households having modified their houses (Niangon Nord and Toit Rouge, Yopougon)

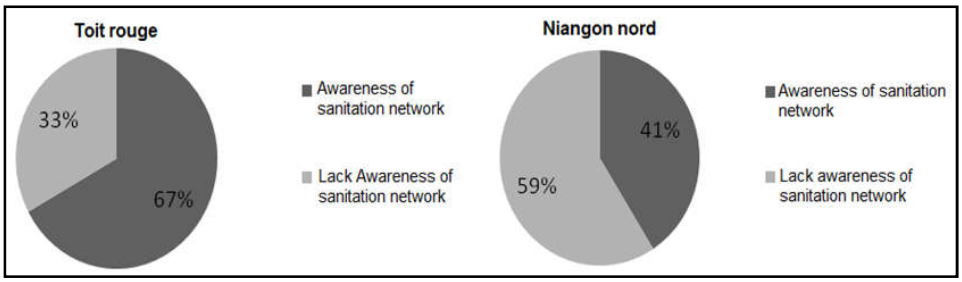

Figure 5. Knowledge of the concept of sanitation network (Niangon Nord and Toit Rouge, Yopougon)

Housings modifications

Our survey revealed that 61% of Toit Rouge households and 70% of Niangon Nord's have modified their living space. On the other hand, 39% of houses in Toit Rouge and 30% in Niangon Nord Have not been modified (Figure 4).

Households raising health problems due to poor sanitation

Figure 7 shows that within period a two-month (November-December), 45% of Niangon Nord's reported having at least one family member suffering from poor sanitation-related sicknesses or water-linked vectors ; Including cholera, typhoid fever, diarrhea and malaria.

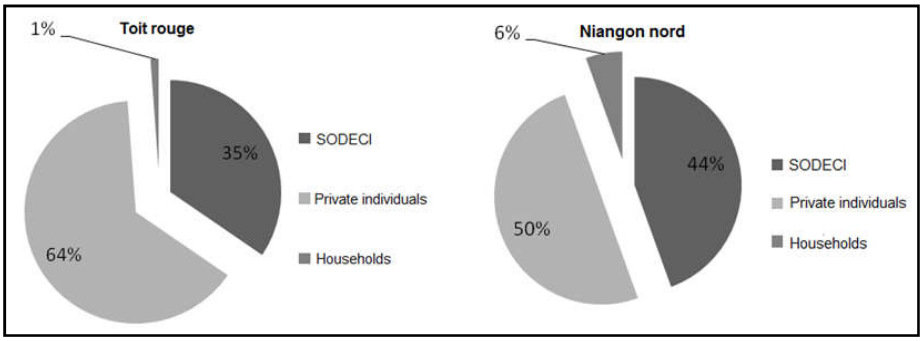

Figure 6. Solicited structures to solve the malfunctions of the sanitation network (Niangon Nord and Toit Rouge, Yopougon)

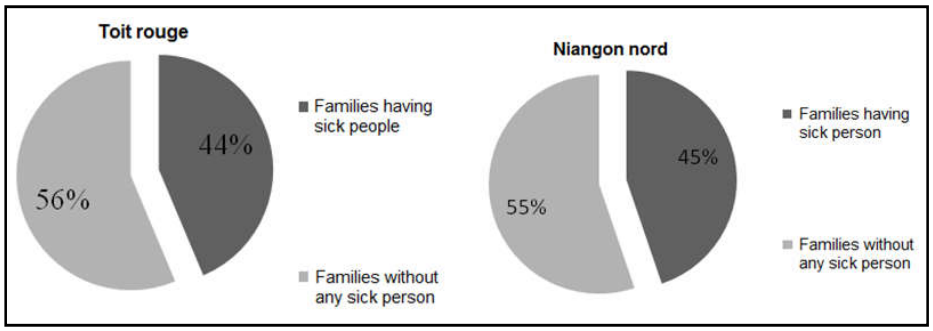

Figure 7. Households raising health problems due to poor sanitation or due to water-linked vectors (Niangon Nord and Toit Rouge, Yopougon)

Table 2. Physico-chemical parameters of domestic wastewater resulting from sewerage network dysfunctions in Niangon Nord and Toit Rouge (Yopougon)

	pH	*SS (mg/L)*	*Turbidity (NTU)*	NO_2^- *(mg/L)*	NO_3^- *(mg/L)*	NH_4^+ *(mg/L)*	PO_4^{3-} *(mg/L)*
Minimum	7.51	90	130	0.64	3.67	18.20	1.08
Average	7.61	204.08	289.13	1.62	8.57	38.76	2.46
Maximum	7.71	360	512	2.55	12.16	67.80	6.80
Standard deviation	± 0.065	± 108.86	± 151.53	± 0.76	± 2.83	± 19.03	± 2.18

Table 3. Bacteriological parameters concentrations of domestic wastewater from sewerage system dysfunctions in Niangon Nord and Toit Rouge (Yopougon)

	Total coliforms (UFC/100 mL)	Fecal coliform (UFC/100 mL)	Fecal Streptococci (UFC/100 mL)
Minimum	$5.6.\ 10^7$	$1.27\ .10^7$	$9.63\ .10^6$
Average	$1.73\ .10^8$	$6.07\ .10^7$	$2.39\ .10^7$
Maximum	$3.37\ .10^8$	$1.16\ .10^8$	$3.87\ .10^7$
Standard deviation	$\pm\ 0.9.10^8$	$\pm\ 3.81\ .10^7$	$\pm\ 1.1.10^7$

Physico-chemistry and bacteriology of resurgent and streaming domestic wastewater

Physico-chemical parameters

The Table 2 shows the results of physico-chemical analyzes obtained from the Niangon Nord and Toit Rouge. The pH values of domestic wastewater from sewerage system dysfunctions in these two districts range from 7.51 to 7.71 with an average of 7.61 The concentration of Suspended Solids varies between 90 mg/L and 360 mg/L with an average value of 204.08 mg/L. As for the turbidity, domestic wastewater values range from a minimum of 130 NTU to a maximum of 512 NTU with an average of about 289.13 NTU. There was a variation in nitrite concentrations of 0.64 to 2.55 mg/L, with an average of 1.62 mg/L. Nitrate concentrations are between 3.67 and 12.16 mg/L with an average of 8.57 mg/L. Those of ammonium are between 18.2 and 67.8 mg/L with an average of 38.76 mg/L. Finally, phosphate ion concentrations in domestic wastewater in the two districts range from 1.08 to 6.80 mg/L, with an average of 2.46 mg/L.

Bacteriological parameters

The Table 3 shows the bacteriological parameters concentrations of domestic wastewater from sewerage system dysfunctions in Niangon Nord and Toit Rouge. The followings are counted: $5.6\ .10^7$ to $3.37\ .10^8$ UFC/100mL of total coliforms with an average of $1.73\ .10^8$ UFC/100mL; $1.27\ .10^7$ to $1.16\ .10^8$ UFC/100mL of fecal coliforms with an average of $6.07\ .10^7$ UFC/100mL; and $9.63\ .10^6$ to $3.87\ .10^7$ UFC/100mL of fecal streptococci with an average $2.39\ .10^7$ UFC/100 mL.

DISCUSSION

Data from DRANA show that Niangon Nord and Toit Rouge register respectively an average of 9 and 17 requests due to the sanitation network dysfunction every month. The sanitation problems are more noticeable in may which corresponds to the great rainy season (Halle and Bruzon, 2006). They are about 26 and 14 requests respectively in Toit Rouge and Niangon Nord. Also, more than 53% of households in these two districts raise recurring problems of sanitation. The causes of these dysfunctions are numerous, but the most significant are the bad behavior of the populations on sanitation infrastructures. These bad behaviors consist in the occupation of the sewage servitudes which is the result of ignorance and demographic pressure (Boni *et al*., 2009; Wayou, 2010). Indeed, according to the household survey, 33% of Toit Rouge households and 59% of Niangon Nord's do not know the concept of sanitation network. In addition, 61% of Toit Rouge households and 70% of those of Niangon Nord have modified their accommodations. This situation could be due to the increased poverty of the populations. According to the survey, the average number of inhabitants per household is 9 people in the two districts. This number can reach a maximum level of 17 and 23 people respectively in Niangon Nord and Toit Rouge. Moreover, the households' demographic pressure is a source of the network dysfunction because the infrastructures set to pipe wastewater into the network had not been designed for such a population. The consequences of these dysfunctions are the resurgence, the flow and stagnation of domestic wastewater from manholes in the households and in the streets which are also children's playgrounds, insalubrity, obnoxious odors, causing a lot of damage. These problems are namely nuisances on people living places and on the environment (Wethé *et al*., 2003; Ba, 2011).

Private individuals are the most requested to solve the dysfunctions of sanitation works, even though they are not qualified for this task. In fact, 64% of Toit Rouge households and 50% of Niangon Nord's call for private individuals while 47% of households in Toit Rouge and 44% in Niangon Nord resort to *SODECI*. This could be explained by the fact that SODECI can not satisfy all requests for intervention or sometimes lags in the execution of its task. This could also be explained by *SODECI* engines' breakdown that makes the latter immobile, the lack of dredges or the extension of the population areas to the technical corridors of servitude, as reported by Assemian (2007) and Wayou (2010). The physico-chemical analysis of domestic wastewater from sewerage network dysfunctions in Niangon Nord and Toit Rouge has showed pollutant concentrations, characteristic of domestic wastewater (Thongtha *et al.,* 2014, Saizonou an al., 2014 Gnagne *et al.,* 2015). The presence of nitrogen compounds in general, and nitrates in particular, with values between 3.67 and 12.16 mg/L, would present a minor risk to human health in case of indigestion. Nitrates are not toxic to humans by themselves. They are only dangerous under these two conditions: if there is massive ingestion of their compounds or if they are transformed into nitrites by the digestive microflora within the organism (Idrissi, 2006). Cases of massive indigestion of nitrates can occur when there is an accidental intrusion of wastewater into the drinking water system, as has recently been reported in January 2017 in *Serge Kassy* district in the suburb of Port-Bouët in Abidjan (Touré, 2017).

As a reminder, the maximum concentration of nitrate recommended by the World Health Organization (WHO) in drinking water is 50 mg/ L (WHO, 2011). The main risk to human health associated with the indigestion of nitrates is due to the ability of the human body to transform nitrates into nitrites. Nitrites formed by nitrates reduction are likely to bind to hemoglobin. The latter is then oxidized into methaemoglobin. The conveyance of oxygen to the tissues that need it is no longer done. This disease is called methemoglobinemia or blue baby syndrome (L'hirondel and L'hirondel, 2002 ; Idrissi, 2006 ; El-Ouedghiri, 2014). Nitrite concentrations between 0.64 and 2.55 mg/L, with an average of 1.62 mg/L, are below the maximum concentration of recommended nitrite into drinking water estimated to 3 mg/L (WHO, 2011). On the other hand, the nutrients (nitrogen and phosphorus compounds) contained in these waters can bring about a series of symptomatic changes such as the development of plants *et al*gae biomass, which results in an increase of turbidity (Mama *et al.,* 2011). The high Suspended Solids values (with an average of 204.08 mg/L) are due to the type of mainly domestic effluent. Indeed, according to Baumont *et al* (2005), domestic wastewater contains suspended minerals from the washing of vegetables, food substances based on organic materials (carbohydrates, lipids, proteins) and detergents. In addition to causing obnoxious odors, the presence of nutrients and the high Suspended Solids contents of these wastewaters aesthetically tarnish the reputation of these two districts.

Moreover, pH values between 7.51 and 7.71 would be favorable for bacterial actions (Franck, 2002). As for bacteriological parameters, an average of 1.73 $.10^8$ (UFC/100 mL) of total coliforms; 6.07 $.10^7$ (UFC/100 mL) fecal coliforms and 2.39 $.10^7$ (UFC/100 mL) fecal streptococci are recorded. The bacteriological contamination far exceeds the standard (1000 CFU/100 mL) set by the World Health Organization for wastewater irrigation (OMS, 2012). The bacteria contained in these waters are indicative of contamination by bacteria or viruses, pathogens for humans (Abouelouafa *et al.,* 2002, Adjahouinou *et al.,* 2014, Some *et al.,* 2014). The stagnation of these waters near living places, as well as the odors they emit, would cause poor sanitation-related diseases such as diarrhea, typhoid fever, cholera, hepatitis, or Water-linked vectors (malaria, filariasis, dengue) (Cairncross and Feachem, 1983, Koné *et al.,* 2006, Sy *et al.,* 2011). Indeed, over a period of two months, 45% of households in Niangon Nord and 44% in Toit Rouge mentioned to have at least one member of their family suffering from diseases related to poor sanitation of wastewater or due to water-related vectors. Koné *et al.* (2014) have identified risk factors and behaviors that cause diarrhea among children under five living in such an environment. These are the fact that children in these areas eat without washing their hands, the presence of flies that swarm and cover the meals to be eaten, garbage cans without closure and covered with flies. In their work, Sy *et al.* (2011) confirm the spread of a number of diseases by the presence of unfavorable factors relating to the sanitation of the domestic and the peri-domestic space as well as the low Hygiene practices. And according to Hounga *et al.* (2015), risky factors are added to the causes. They consequently keep diseases recurrent, whenever they are treated or cured and have a socio-economic impact on families.

Conclusion

At the end of our work, it appears that the dysfunctions of the sanitation network in Niangon Nord and Toit Rouge, caused by

the occupation of the wastewater infrastructures due to the ignorance and the demographic pressure of the inhabitants has the following consequences: the resurgence, the flow and stagnation of domestic wastewater from manholes in the households and in the streets, causing a lot of damage. Among these damages, there are the nuisances on the population living places and on the environment. The physicochemical and bacteriological parameters analysis of wastewater resulting from the dysfunction of the sewage network in the two districts showed a significant pollution, characteristic of domestic wastewater. These waters near living places which are also the playground of children constitute a health risk for these families. Particularly, the bacteriological contamination of these waters, as well as the odors they emit would cause diseases linked to poor sanitation and due to water-related vectors (cholera, typhoid fever, diarrhea and malaria). On the other hand, the presence of nitrates and nitrites would present a minor risk in case of indigestion of children of more than four months; likely to play in or around these areas.

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