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Impact of Waste Management on Surface Water and Soil Pollution on the Right Bank of the Congo River in the Brazzaville Agglomeration (Republic of Congo)

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Abstract

Situated on the right bank of the Pool Malébo, in the Congo River basin, the city of Brazzaville is rich in potential water resources. This resource is being polluted by human practices that are deteriorating the quality of the soil and, consequently, the quality of the water. The aim of this study is therefore to list the activities carried out by the population around watercourses in order to get an idea of how waste is managed and its impact on water and soil quality. The survey sample was selected on the basis of zones of influence located between 250 m and 750 m around watercourses. The survey form was drawn up using Sphinx Plus2-Edition Lexica-V5. The data from the surveys was entered into the same software, then transferred to Excel for processing in order to produce the graphs. 880 people were surveyed, the most dominant age group being between 25 and 48 years old, i.e. a rate of 66%; the female sex being the most representative with a rate of 54%. The average age of the respondents was lower secondary school, and they were generally employed in the private sector. Commercial activities (restaurants/bars, pharmacies, grocery stores/butchers, markets, etc.) are the most common economic activity, with a rate of around 70%; 59% of these activities are located close to or very close to the watercourse (750 - 1000 m). The activities that contribute to soil degradation, and consequently water degradation, in the city of Brazzaville are: 59% the dumping of household waste and/or wastewater on the ground and 32% uncontrolled urbanization. The study shows that soil and water pollution in Brazzaville is caused by poor management of household waste and uncontrolled urbanization.

Keywords: Survey, waste management, pollution, water, soil, Brazzaville

1. Introduction

The exponential development of most African cities, accompanied by very rapid population growth, poses the problem not only of the availability of water resources, but also of their quality (Nwamo *et al*., 2016). This population growth is accompanied by an equivalent need for food production, exploitable land and water (Nwamo *et al*., 2016). The Congo has enormous water potential, but is not immune to water quality problems (Ofouémé-Berton 2010). For several decades, the country has experienced significant demographic growth, caused by a massive rural

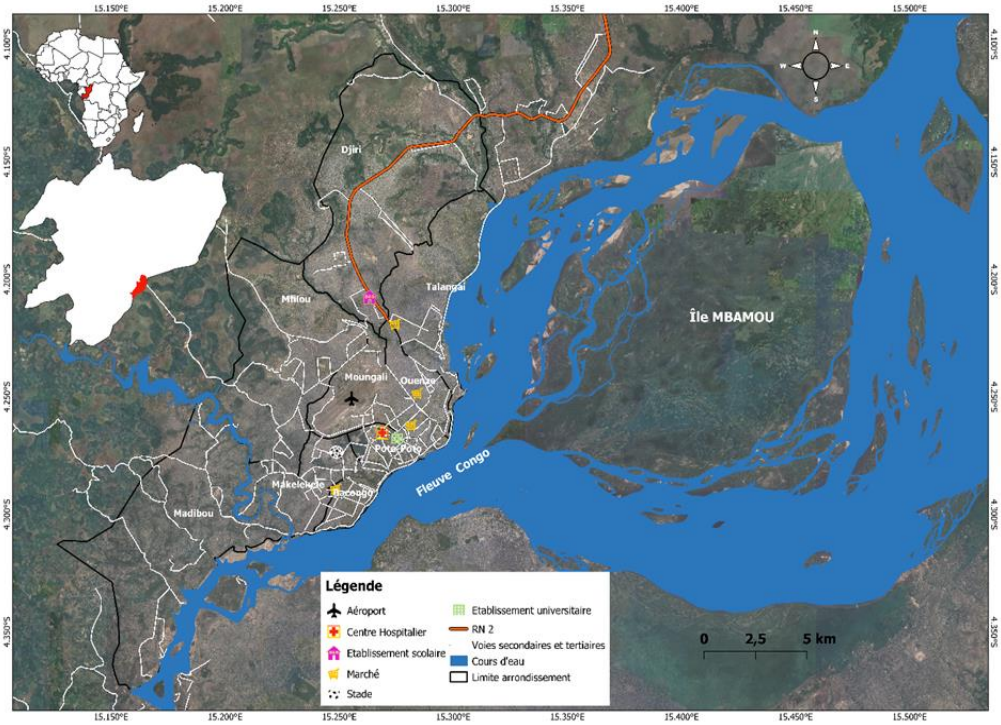
exodus resulting in an increase in urban density and anarchic occupation of the land, which is then subject to multiple anthropogenic actions and effects (Essouli *et al.*, 2020). Socio-economic human activities (agriculture, industry, livestock farming, fishing, household activities, medical care, etc.), coupled with processes due to natural phenomena (soil erosion, rainfall, evaporation, runoff, etc.) put surface water resources undegreat pressure, and accelerate their degradation (Hawa *et al.*, 2011; Aw *et al.*, 2011; Adjagodo *et al.*, 2016; Dovonou *et al.*, 2022). Consequently, the discharge of untreated industrial and urban wastewater, the presence of informal landfill sites and human activities are the main sources of deterioration in water quality (Laffite, *et al.*, 2016; Poté, *et al.*, 2008; Mubedi J., *et al.*, 2013). Several factors, including poor waste management and the uncontrolled installation of latrines, influence the quality of soil and water resources in general, and surface water in particular. Surface water is often enriched with organic matter and suspended solids as a result of human activity, which accelerates its degradation (Hawa *et al.*, 2011). Their composition is more variable and they are sensitive to pollution from the external environment. The aim of this study, based on surveys of urban populations, is to identify the various human activities that influence soil and surface water quality in the city of Brazzaville.

2. Materials and methods

2.1. Study area

The city of Brazzaville is located on the right bank of the majestic Congo River, the second most powerful river in the world after the Amazon in terms of flow (40.000 $m^3 s^{-1}$). It is 30 km long and covers an area of 263.9 km^2. It is bounded to the north-east by the Batéké plateau and the Djiri river, to the south and east by the Congo River, and to the west by the Maloto river (Figure 1). It lies between latitudes 4°10' and 4°17' South and longitudes 15°16' and 15°45' East. The city of Brazzaville has nine (09) arrondissements: Makélékélé (1), Bacongo (2), Poto-Poto (3), Moungali (4), Ouenzé (5), Talangaï, (6), M'filou (7), Madibou (8), and Djiri (9). The climate of Brazzaville is currently influenced by climatic variations. It is marked by two main seasons: a rainy season that extends over a period of eight (08) months (from October to May) with average annual rainfall of 1,343.77 mm between 2003 and 2010 (Louzayadio, 2019). Brazzaville is part of the vast hydrogeological complex of the Batéké plateaux, and is crossed by several watercourses forming a dendritic network. These waters flow over three types of ferrallitic soil, depending on the material on which they were formed. There are ferrallitic soils on weathering material from the Inkisi sandstones, ferrallitic soils on Batéké sands and ferrallitic soils on material of alluvial origin. These soils

all belong to the subclass of highly desaturated, depleted ferrallitic soils, which means that the sum of exchangeable bases (Ca, Mg, K, Na) is very low in the B horizon (of the order of 1 cmol (+)/kg of soil) and that the saturation rate of the absorbent complex is less than 20% (Schwartz,1986, Essouli *et*



al., 2020).

Figure 1. Location of the study area

2.2. Survey method

The areas to be surveyed were chosen along the seven (07) main rivers that irrigate the city of Brazzaville (Djiri, Tsièmé, Djoué, Mfoa, Maduku, Mikalou, M'Filou) and are all tributaries of the Congo River. The survey areas were chosen upstream, mid-slope and downstream of the rivers (Figure 2). The survey was carried out from 09 to 14 December 2022, by a group of ten (10) students from the University of Marien N'Gouabi in the Republic of Congo. It was carried out face-to-face with the respondent, using a questionnaire developed with the help of Sphinx Plus software[2] - Edition Lexica-V5. The sample of people to be surveyed was selected in concentric zones, starting from a central point in the middle of the watercourse. Three concentric zones were defined with an equidistance of 250 m, the furthest zone being 750 m from the river (Dieng *et al.*, 2016; Madzella, 2019). These concentric zones were delimited using Qfield

software and incorporated into the Smartphones for easy location of the zone of influence in the field. These survey zones were determined using a satellite image of the city of Brazzaville to cover the extent of the survey area. The questionnaire was submitted mainly in households and to people encountered in the survey area (shopkeepers, local players, farmers, etc.). The surveys were conducted in French and local languages, depending on the district and the social level of the population. In the field, people or households were chosen at random, while respecting the geographical representativeness of the survey area. The survey data were analyzed and entered into the Sphinx software and transposed into Excel to produce the graphs. A total of 880 people were surveyed, including 176 farmers.

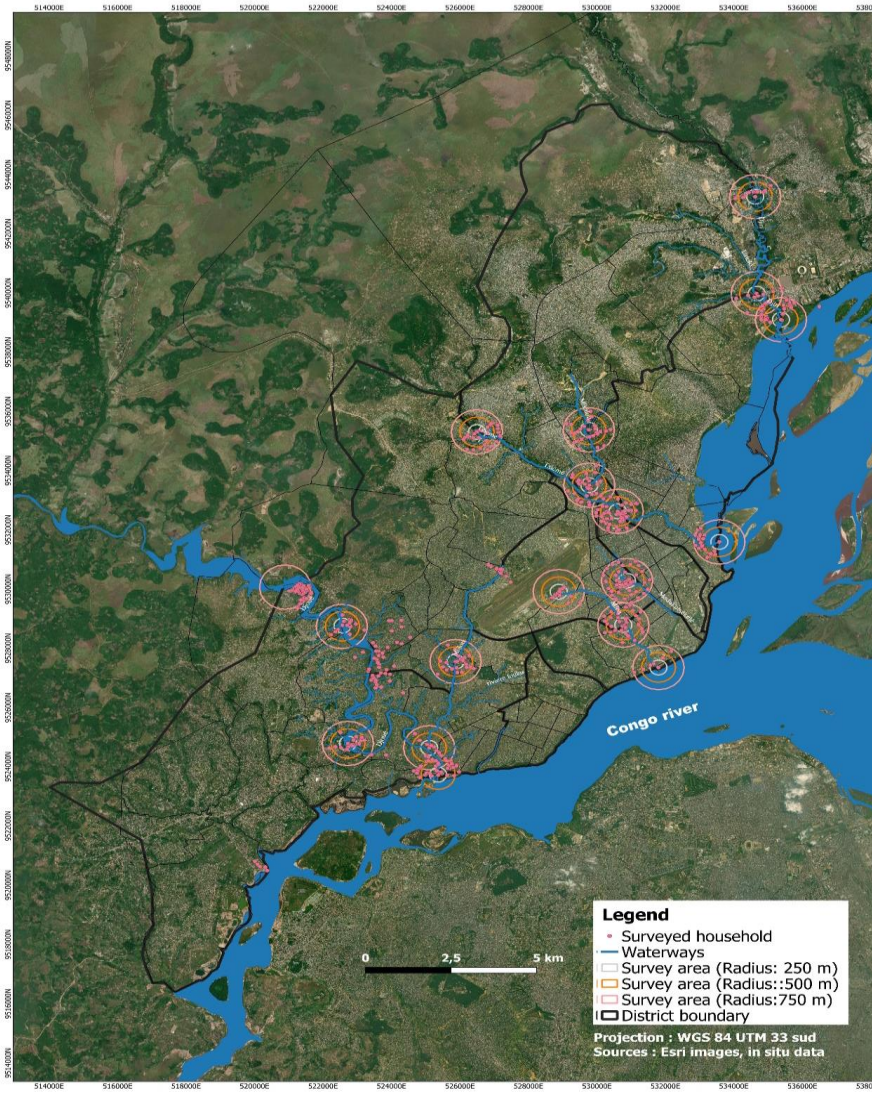


Figure 2. Survey area sites location

3. Results and discussion

The surveys were carried out in the eight (08) arrondissements of the city of Brazzaville through which the following rivers flow: *the Djoué*, *the Mfilou*, *the Mfoa*, *the Madutkutsékélé*, *the Tsiémé*, *the Mikalou* and *the Djiri*. The highest proportions of respondents were found in the Djiri, Mfilou and Madibou arrondissements, which are crossed by the largest rivers, *the Tsiémé*, *Djiri*, *Mfilou* and *Djoué* respectively (Figure 3). The most representative household size, representing nearly 30% of those surveyed, is between 6 and 8 people (Figure 4).

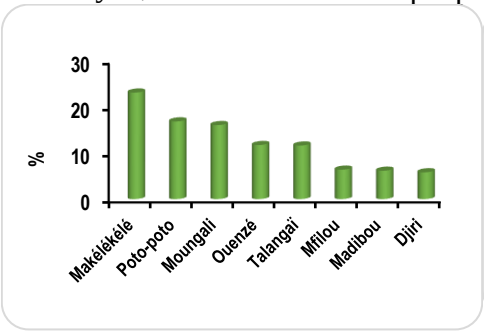


Figure 3. Frequency (%) of respondents in each arrondissement

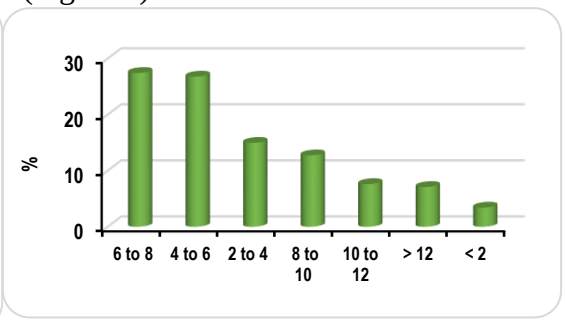


Figure 4: Frequency (%) of household sizes

According to the breakdown of respondents by gender, women are the most represented with a percentage of 54% (figure 5). The most represented age groups were 25-30 and 37-42 (Figure 6), which shows that the people interviewed in this study are mostly young and of age. Similar results were obtained by Nkounkou *et al*, (2017) who worked on drinking water in the city of Brazzaville

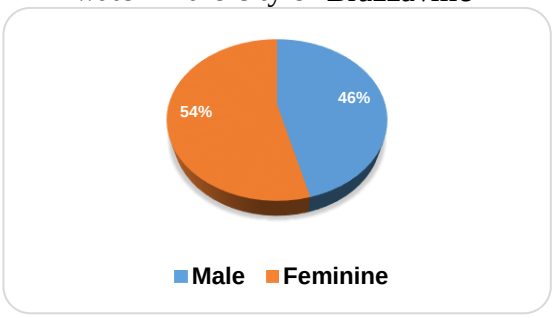


Figure 5. Breakdown of respondents by gender

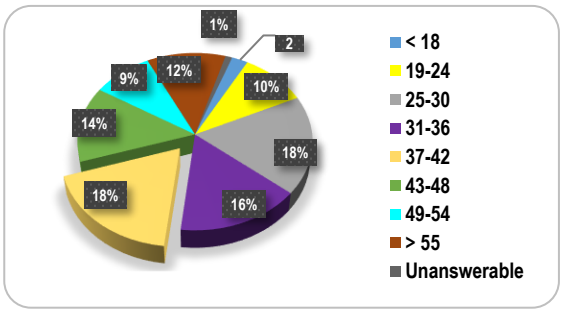


Figure 6. Breakdown of respondents by age group

According to the respondents of activity sector, 60% of them were employees, 54% of them in the private sector and 6% in the public sector (Figure 7). The majority of respondents (56.93%) had a secondary education and 26.48% had a higher education (Figure 8).

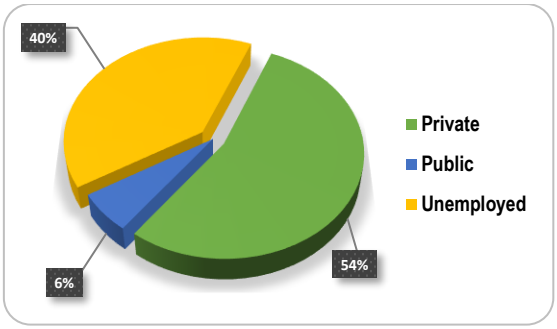


Figure 7. Respondents sector of activity

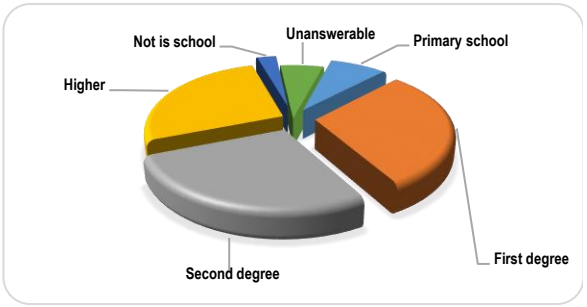


Figure 8. Level of education of respondents

Most households (79%) have a source of water supply, which in this case is the Congolese water distribution company (LCDE). A further 15% have boreholes, 7% wells and 8% springs (Figure 9). The majority of households that do not have a water supply source on the plot (87% of those surveyed) travel a distance of less than 100 m to obtain water, and sometimes more than 600 m (Figure 10). These results differ from those found by Nkounkou, (2017), where water supply was a chore for people. This can be explained by population growth, which encourages people to have a source of supply in their neighbourhoods.

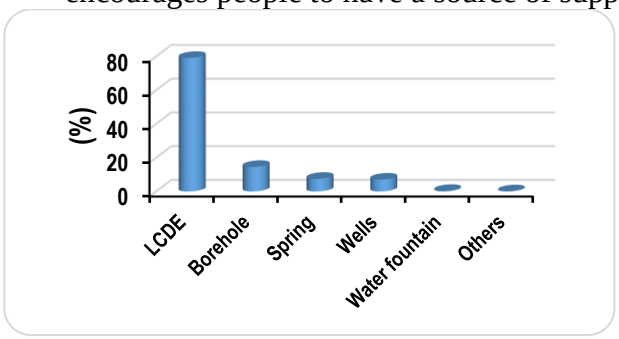


Figure 9. Water supply method

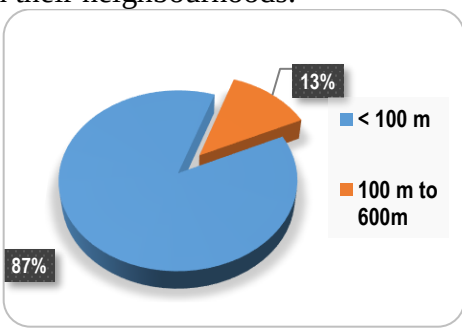


Figure 10. Distance travelled by households to obtain water

With regard to solid waste management, 40.60% of households store their waste in dumps, 21.45% leave it in the open air, 14.04% burn it, 13.39% have it collected by collection companies, 14.24% is buried and the rest is either recycled or dumped in watercourses (Figure 11). These results are in line with those found by Nwamo *et al* (2016) in the city of Douala in Cameroon, where the majority of people said they dumped their waste in rubbish bins, and a small proportion in and around watercourses. Dumping waste in this way stresses the watercourse in which it is dumped.

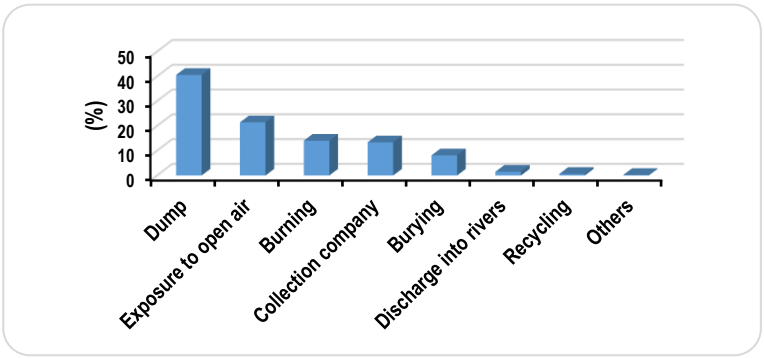


Figure 11. Waste management by households

Faecal sludge from households is mostly buried (52%) or transported by vacuum trucks (40%). Only 4% of households dump their waste in composting pits, and 3% dump it in watercourses (Figure 12).

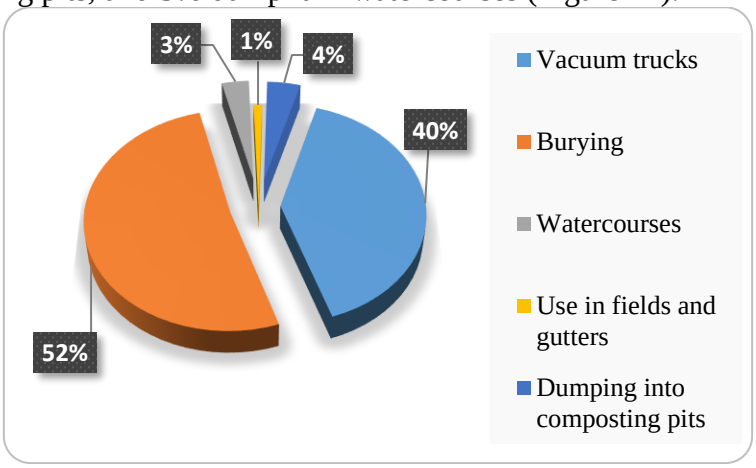


Figure 12. Management of faecal sludge by households

Several methods are used to manage domestic wastewater (Figure 13). In fact, 56% of households surveyed evacuate domestic wastewater in the street, 18% in plots and 11% in gutters. Only 9% of respondents discharge their wastewater into individual sanitation facilities (septic tanks and cesspools), which are collected by tanker trucks. Unfortunately, this water is not treated before being discharged into the environment. Controlling the quality of the water before it is discharged helps to maintain a low-pollution environment, while guaranteeing health of people (Mbaka *et al.*, 2017; Pambou *et al.*, 2022). Wastewater often contains micropollutants and other pathogenic organisms dissolved in water, which are responsible for waterborne diseases and the pollution of aquatic ecosystems (Pritchard, *et al.*, 2009; WHO, 2011).

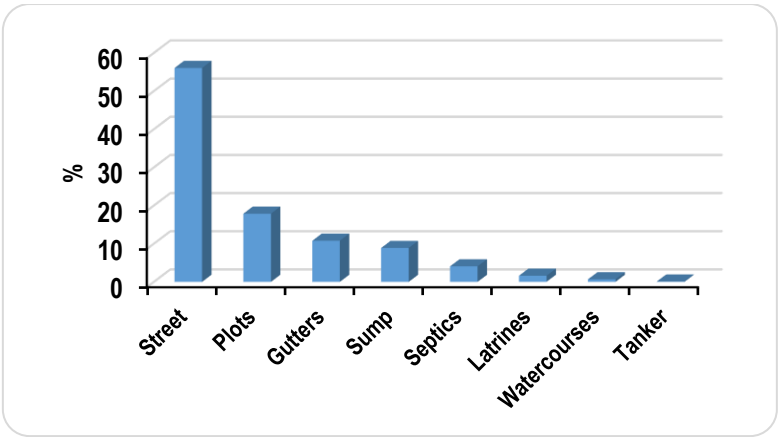


Figure 13. Wastewater disposal in households

In the city of Brazzaville, more than 80% of the population does not practise livestock farming (Figure 14); of those who do, 40% of waste is buried or left in the plots, 32% is used in the fields and/or gardens, 20% is dumped in the open in the street and 8% is sold (Figure 15).

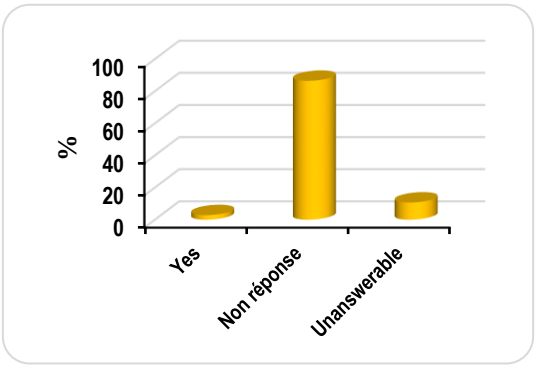


Figure 14. Frequency of livestock farming in the survey area

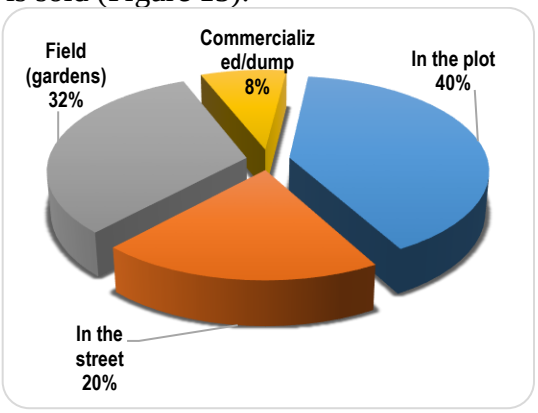


Figure 15. Frequency of livestock waste management

Regarding the link between waste management and environmental pollution, nearly 91% of households surveyed said that their environment was polluted by household waste (Figure 16). Plastic waste is the most common pollutant. This shows that the biggest source of water and soil pollution in Brazzaville is household waste.

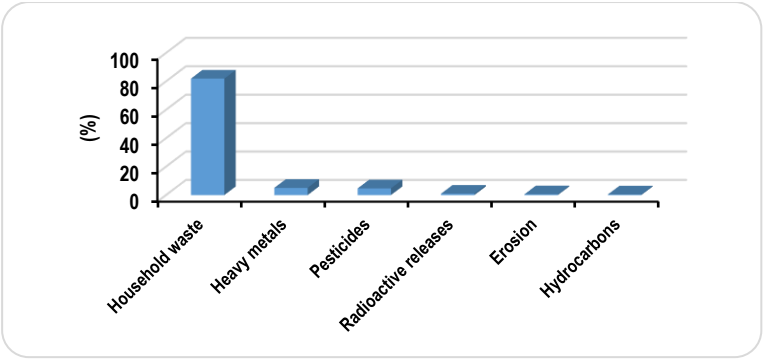


Figure 16. Sources of environmental pollution in the city of Brazzaville

According to Figure 17, the most common illnesses linked to environmental pollution in the city of Brazzaville are, in descending order, malaria (53%), diarrhoea (20%), stomach ache (16%), typhoid fever (4%) and dermatitis (3%). Cholera and urticaria were marginal. These results can be explained by the fact that these are diseases that have plagued tropical areas for millennia (INSERM, 2015).

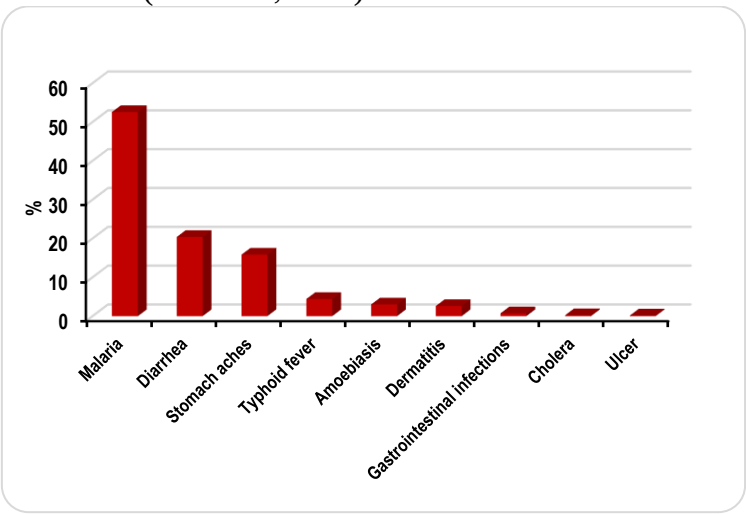


Figure 17. Type of deseases prevalent

In terms of human activities that are sources of pollutants, commercial activities (restaurants/bars, pharmacies, grocery stores/butchers, markets, etc.) are the most common, accounting for around 70%, followed by agricultural activities (17%). Other human activities (livestock farming, fishing, crafts, pharmacies and industry) are, on the whole, very little represented in the areas surveyed (6%) (Figure 18). These results highlight the predominance of commercial activities in the districts of the city of Brazzaville in Congo, as in some countries such as Gabon (Mombo and

Edou, 2005) and the Democratic Republic of Congo (Makuku *et al.*, 2018). On the other hand, the results found by Nwamo *et al* (2016) in the city of Douala in Cameroon showed that agricultural activities (82.5%) and livestock rearing (17.5%) predominate and are used for household subsistence. The most widespread agricultural practices (Figure 19) are market gardening (vegetables, chives, spinach, etc.) (41%), maize (20%), groundnuts (11%), cassava (12%), fruit trees (8%) and sweet potatoes (2%).

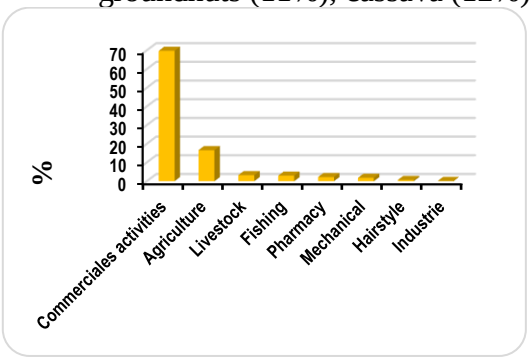


Figure 18. Human activities in the surveyed areas

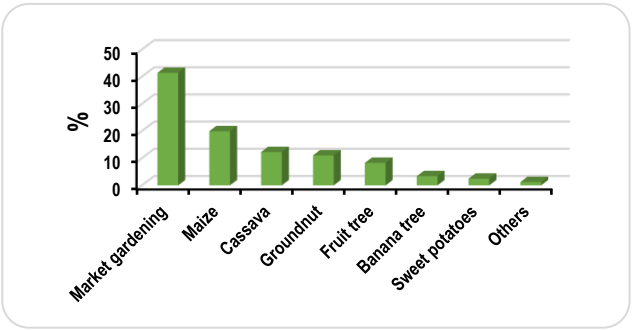


Figure 19. Type of culture produced

The assessment of the distances of the sources of pollution showed that most of these activities (59%) are located close to or very close to the watercourse (Figure 20). This can be explained by the fact that the majority of anthropogenic activities are carried out on the banks of watercourses (Aziz Assaad, 2014).

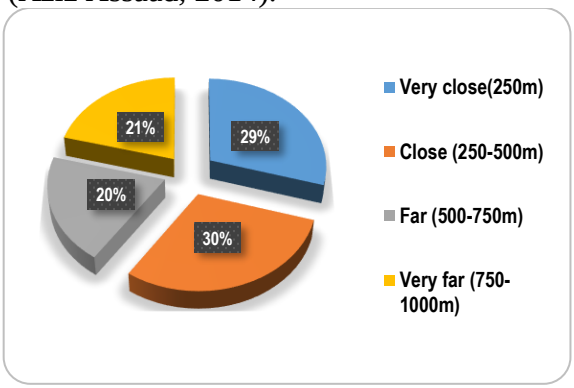


Figure 20. Distance of sites where activities are carried out from the watercourse

50% of people who practise agriculture think that the soil is fertile, whereas 40% of those surveyed said the opposite (Figure 21). The main criterion for recognising the level of soil fertility used by farmers is yield (figure 22).

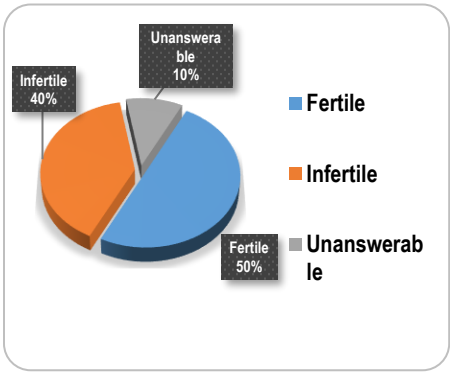


Figure 21. Soil fertility status

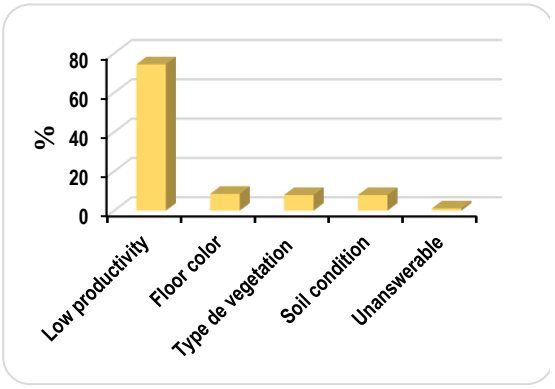


Figure 22. Warning signs of soil fatigue

To improve soil productivity, almost 60% of those surveyed use fertilisers (chemical fertilisers and organic amendments), particularly for market gardening (Figure 23); the rest of the population fallow and grow shifting cultivation. Organic soil improvers are used more often than chemical fertilisers in Brazzaville (Figure 24). Chemical fertilisers and organic soil improvers are used empirically, without any official recommendation of an optimal dose; this leads to soil and water pollution and the bioaccumulation of heavy metals in crops (Malmqvist and Rundle, 2002; Nwamo *et al.*, 2016; Nzila *et al.*, 2018).

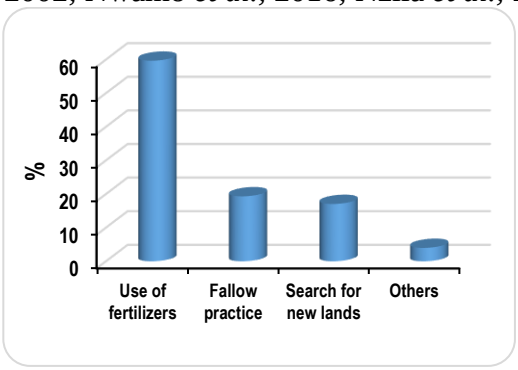


Figure 23. Measures taken in the event of soil fatigue

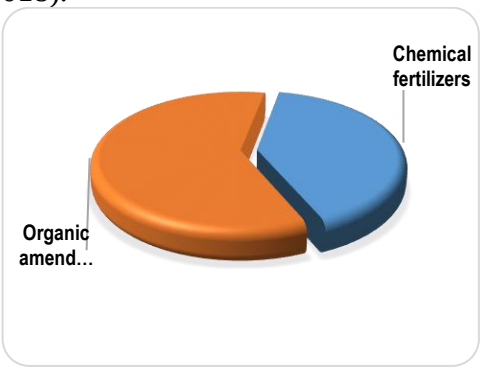


Figure 24. Type of fertiliser used

The most commonly used chemical fertilisers are NPK and urea, with less than 7 kg for NPK and 7 ml for urea on a 20 m^2 plot (Figure 25). These fertilisers are applied to the plants using various methods (Figure 26) : broadcast (30%), around the plant (28%), as a base dressing (25%) and in patches (18%).

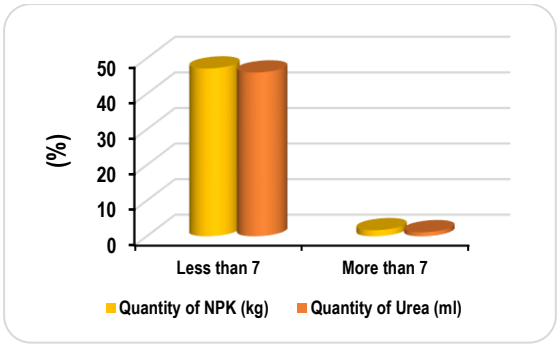


Figure 25. Amount of fertiliser used on crops

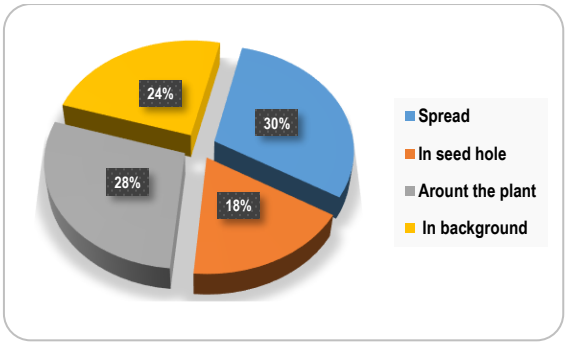


Figure 26. Methods of applying fertilisers to crops

The organic soil improvers used (Figure 27) are compost (33%), poultry droppings (28%), pig droppings (22%) and household waste (16%).

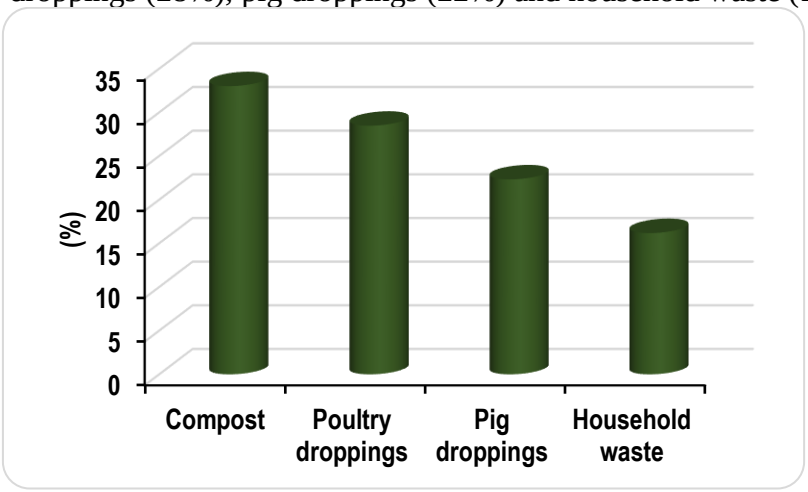


Figure 27. Types of organic amendments used on crops

Pesticides are used on 47% of crops (figure 28). Figure 29 shows that the most commonly used pesticides are insecticides (42%), herbicides (29%) and fungicides (21%). We are therefore witnessing an intensification of farming practices characterised by regular and unsustainable inputs of organic fertilizers (household waste sludge and compost, livestock manure, agro-industrial by-products, sewage sludge), mineral fertilizers and the use of various pesticides (Compaoré and Nanéma, 2010; Nzila *et al.*, 2018).

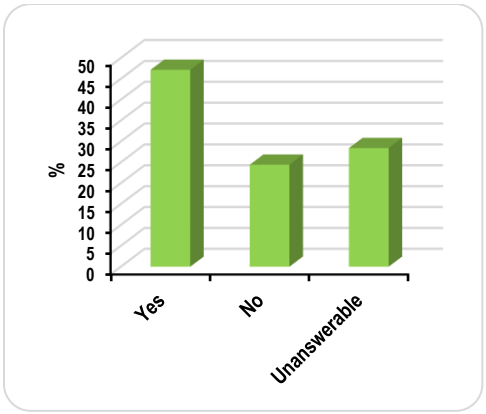


Figure 28. Frequency of pesticide use on crops

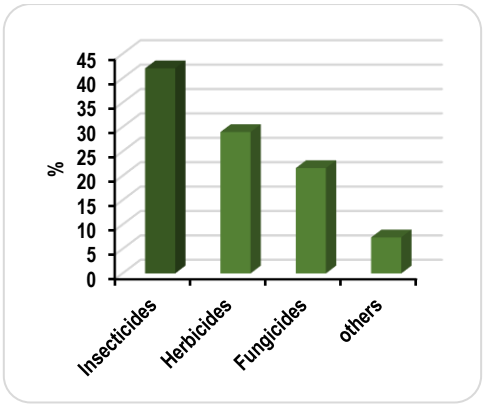


Figure 29. Types of pesticides used

Almost half of residents of Brazzaville (45%) own their own home (Figure 30). By contrast, 24% of residents rent, 21% live in family housing and only 1% live in social housing. The majority (65%) of plots are purchased from landowners, which explains why most people live in their own homes (Figure 31).

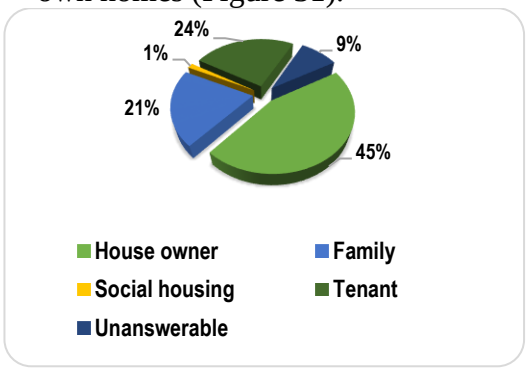


Figure 30. Housing situation of residents in surveyed areas.

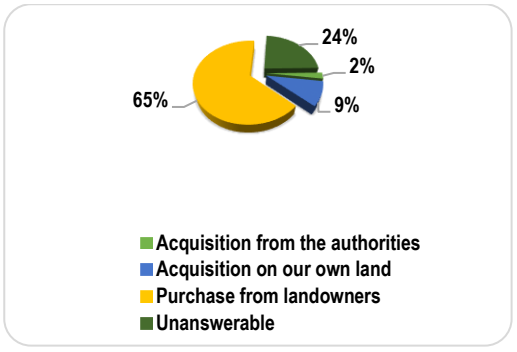


Figure 31. Land acquisition method

According to the people surveyed (Figure 32), the activities that contribute to soil degradation in the city of Brazzaville are the dumping of waste on the ground (59%) and anarchic urbanisation (32%) (Rebouh, 2019). Indeed, the city of Brazzaville includes thousands of household waste dumps that are either in the streets or in vacant lots (Zmirou *et al.*, 2003, PARSEGD, 2008; Nzila *et al.*, 2010; Mukuku *et al.*, 2018).

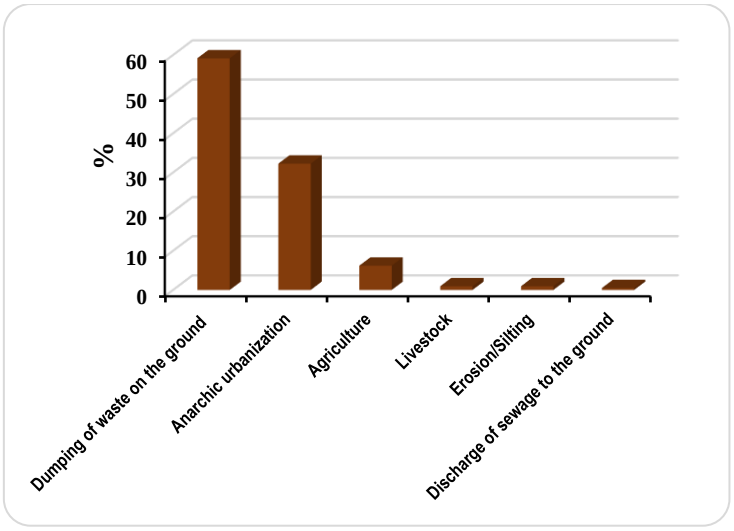


Figure 32. Causes of soil degradation in the areas surveyed

Conclusion

The Brazzaville surveys were conducted in eight (08) districts (Makélékélé, M'Filou, Talagaï, Ouenzé, Poto-Poto, Djiri, Madibou and Moungali). The most dominant age group is between 25 and 48, representing 66% of respondents. 54% of respondents were women. The average age of respondents was lower secondary school level, and they were generally employed in the private sector. The population generally uses water supplied by the national water distribution company (LCDE). 56% of domestic wastewater is discharged into the streets, resulting in a high prevalence of malaria (73%). Commercial activities (restaurants/bars, pharmacies, grocery stores/butchers, markets, etc.) are the most common economic activity, accounting for around 70%; 59% of these activities are located close to or very close to the watercourse. Farmers use organic amendments and chemical fertilizers to improve fertility and obtain satisfactory harvests. However, organic soil improvers are most commonly used by market gardeners (mainly compost). To combat plant diseases and pests, these market gardeners use pesticides, the most commonly used of which are insecticides. The activities contributing to soil degradation in the city of Brazzaville are mainly dumping waste on the ground (59%) and uncontrolled urbanization (32%). This study shows that soil and water pollution in Brazzaville is caused by poor management of household waste and uncontrolled urbanization.

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References:

1. Adjagodo A., Agassounon Djikpo Tchibozo M., Kelome N. C., Lawani R. (2016). Flux des polluants liés aux activités anthropiques, risques sur les ressources en eau de surface et la chaine trophique à travers le monde: synthèse bibliographique *Int. J. Biol. Chem. Sci*. Vol. 10 No. 3. Pp. 1459-1472.
2. Aw S. E., N'goran B. Z., Siaka S., Parinet B. (2011). Intérêt de l'analyse multidimensionnelle pour l'évaluation de la qualité physico-chimique de l'eau d'un système lacustre tropical: cas des lacs de Yamoussoukro (Côte d'Ivoire). *J. Appl. Biosc., vol.* 38, pp. 2573-2585
3. Aziz Assaad. (2014) Pollution anthropique de cours d'eau : caractérisation spatio-temporelle et estimation des flux. Thèse Université de Lorraine, *HAL open science*, 227 p.
4. Compaoré E., Nanéma L. S. (2010). Compostage et qualité du compost de déchets urbains solides de la ville de Bobo-Dioulasso, Burkina Faso. *Tropicultura* Vol. 28, No. 4, pp. 232 – 237
5. Dieng S. D., Diop M., Goudiaby A., Niang-Diop F., Faye L. C., Guiro I., Sambou S., Lykke A. M., Sambou B. (2016). Caractérisation des services écosystémiques fournis par *Cordyla pinnata* dans la périphérie de la Forêt classée de Patako au Sénégal. *VertigO*, vol. 16, No. 2, 18 p.
6. Dovonou F. E., Mivodjo Alladassivo E., Martial Koukpo J., Sintondji, L., Yalo N. (2022). Evaluation de la qualité physico-

chimique et bactériologique de l'eau du lac Azili dans la commune de Zangnanado au centre du Bénin *Internationa Journal of Biological and Chemical Science.* Vol. 16, No. 2, pp. 867-877.

7. Essouli O. F., Miyouna T., Essouli Kessimpou P., Boudzoumou F., Matini L., Faye S. (2020). Hydrochimie des eaux de surface et souterraines de la partie Nord de Brazzaville: origine et processus de minéralisation. Revue *RAMReS –Sci. Appl. & de l'Ing*., Vol. 2, No. 1, pp. 1-15.
8. Hawa S. (2011). Analyse physico-chimique et bactériologique au L.N.S. des eaux de consommation de la ville de Bamako durant la période 2000 et 2001.Thèse de Doctorat d'état en Pharmacie, *Faculté de Médécine de Bamako*, 77 p.
9. INSERM (2015). Dossier d'information sur le paludisme, unité de recherche 1135 Inserm/UPMC, Centre d'immunologie et des maladies infectieuses, Paris) - janvier 2015
10. Koua O. J., Nzaou S. (2011). Perspective de la population congolaise de 2007 à 2020, CNSEE, 11 p.
11. Laffite A., Kilunga P., Kayembe J., Devarajan N., Mulaji C., Giuliani G., Poté J. (2016). Hospital effluents are one of several sources of metal, antibiotic resistance genes, and bacterial markers disseminated in sub-saharan urban rivers. Frontiers in Microbiology, vol. 7, pp. 11-28.
12. Madzella Mbiemo M. (2019). Biens et services écosystémiques associés à la forêt de la Djoumouna, Brazzaville (Congo). Mémoire de Master d'enseignement en Sciences de la Vie et de la Terre, *Université Marien Ngouabi, Ecole Normale Supérieure*. 87p.
13. Malmqvist B., Rundle S. (2002). Threats to the running water ecosystems of the world. *Environmental Conservation*. 29 p.
14. Mbaka P., Mwangi J., Kiptum C. (2017). Assessment of water quality in selected shallow wells of Keiyo Highlands, Kenya. *African Journal of Science Technology Innovation and Development*, vol. 9, No. 3, pp.1-10.
15. Mombo JB., Edou M. (2005). La gestion des déchets solides urbains au Gabon. *Geo-Eco-Trop*. Vol. 29, pp. 89-100.
16. Mubedi J., Devarajan N., Le Faucheur S., Mpuku J., Atibu E. Sivalingam P., Poté J. (2013). Effects of untreated hospital effluents on the accumulation of toxic metals in sediments of receiving system under tropical conditions: case of South India and Democratic Republic of Congo. *Chemosphere*, vol. 93, No. 6, pp. 1070-1076.
17. Mukuku O., Musung J. M., Samba C. K., Tshibanda C. N., Mavuta C. Z., Bamba M. M., Luboya N. O. (2018). Évaluation de la gestion des déchets ménagers dans la commune de Katuba à Lubumbashi

(République Démocratique du Congo). *Revue de l'Infirmier Congolais*. Vol. 2, pp. 50-56.
18. Nwamo R. D., Ba'ana Etoundi M. L., Tchoumbougnang F., Dibong D. S. (2016). Impacts des actions anthropiques sur les zones humides de la ville de Douala et solutions de gestion durable: cas de la rivière Kondi. *Journal of Applied Biosciences* vol. 99 pp. 9423-94321.
19. Nzila, J. D., Watha-Ndoudy N., Kinzounza J. R., Abia J. B. (2010). Caractérisation et quantification des déchets solides dans les décharges brutes de la ville de Brazzaville (Congo). In: Annales de la Faculté des Arts, Lettres et Sciences Humaines, *Université de Ngaoundéré*. Vol 11, 22 p.
20. Nzila J. D., Salisou Yallo M., Watha-Ndoudy N., Nguila-Ntsoko D. P., Gakosso N. V., Banzouzi Ntondélé O. C., Kampé J. P., Louembé D., Kimpouni V. (2018). Spatial distribution of metallic trace elements in the soils of Mayanga market garden sites in Brazzaville (Congo). *Journal of Applied Biosciences.* Vol. 132 pp. 13413 – 13423.
21. Ofouémé-Berton Y. (2010). « L'approvisionnement en eau des populations rurales au Congo Brazzaville », *Les Cahiers d'Outre-Mer* No. 249, pp. 7-30. DOI: 10.4000/ com.5838
22. Pambou Y., Apinda Legnouo E. A., Alankila Otélé A., Massolou A. M., Ngayila N., Madoungou Ndjeunda G. M., Zinga C. R., Mavoungou J. F. (2022). Variabilité saisonnière de la qualité des eaux du bassin versant de Nzeng-Ayong dans le sixième arrondissement de la commune de Libreville (Gabon*). Journal of Applied Biosciences*, vol. 169, 17559-17574.
23. PARSEGD (2008). Etude de la gestion des déchets solides de Brazzaville diagnostic et plan directeur de gestion. Vol. 1, 141 p.
24. Poté J., Haller L., Loizeau J. L., Garcia Bravo A., Sastre V., Wildi W. (2008). Effects of a sewage treatment plant outlet pipe extension on the distribution of contaminants in the sediments of the bay of Vidy, Lake Geneva, Switzerland. *Bioressource Technology*, vol. 99, No. 15, pp. 7122-7131.
25. Pritchard M., Mkandawire T., O'Neill J. (2009). Groundwater pollution in shallow wells in Southern Malawi and a potential indigenous method of water purification. *Appropriate Technologies for Environmental Management in the Developing World*, pp. 169-179.
26. Rebouh D. (2019). Gestion des déchets de constructions en Algérie. *Mémoire de Master Université Mouloud Mammeri Tizi-Ouzou.* 90 p.
27. WHO (2011). Guidelines for drinking water quality (4th Ed). Geneva, World Health Organization, Switzerland: 541p.

28. Zmirou D., Beausoleil de Coninck P., Déportes I., Dor F., Empereur-Bissonet P., Hours M., Keck G., Lefebvre L., Rouisse L. (2003). Déchets et sols pollués. In : Environnement et santé publique – Fondements et pratiques, *Edisem / Tec et Doc, Acton vale / Paris*, pp. 397-440