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Impact of sewage sludge on plant diversity in the Nomayos area, in the central regions of Cameroon

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ABSTRACT

Waste management in urban areas remains a major concern in African cities, particularly in Cameroon. The aim of this study was to assess the impact of sewage sludge on floristic diversity in the Nomayos area. To achieve this objective, a floristic inventory was carried out at the various study sites based on surface surveys in four types of land use. A total of 100 quadrats of 1 m² were set up at the various sites. The floristic inventory carried out at the various sites identified 60 species belonging to 58 genera and 20 families. The most frequent, abundant, and diverse families are Poaceae, Asteraceae, Solanaceae, Papilonoidae and Cyperaceae. However, low species richness was observed in the sewage sludge accumulation area. This low richness is thought to be due to high nitrate content, which can cause certain species to disappear in favour of others that are able to adapt to a polluted environment (*Echinocloa pyramidalis, Echinocloa cruis-parvonis*). These results highlight the influence of sewage sludge disposal on the flora of the discharge areas.

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INTRODUCTION

Africa is rapidly urbanizing (Förster and Ammann, 2018). Its urbanizing rate rose from 15% in 1960 to 40% in 2010, and will reach 60% by 2050 (Ongonkoa and Song, 2019). This rapid urbanizing, coupled with a population explosion, is leading to the production of all kinds of waste, with harmful consequences for aesthetics and the environment. Indeed, waste production has been inherent in human activities, whether domestic, agricultural, industrial or commercial (Ouattara *et al.*, 2022; N'gouran *et al.*, 2023). According to Ngambi (2015), rapid and uncontrolled urbanizing generates enormous quantities of waste, which could inevitably lead to environmental imbalance. With increasing urbanizing, population growth and lifestyle changes, waste production has reached unprecedented levels (Zulfiqar *et al.*, 2019). Other studies have revealed that around 50% of known biodiversity (plant and animal species) is negatively affected by human activities in urban areas (Mckinney and Lockwood, 1999).

Boucher and Fontaine (2010) add that urbanizing explains the loss of species, especially plant species, and their ecosystem services that are useful to city dwellers. According to Djousse Kanouo *et al.* (2023), the uncontrolled disposal of this waste in the natural environment inevitably leads to the degradation of the environment and resources. The city of Yaoundé, like other Cameroonian cities and the second largest city in Cameroon in terms of population, is not spared from poor waste management. Waste management in urban areas therefore appears to be one of the most important development challenges of the 21st century, especially in African cities. In urban areas of many developing countries, the location of excreta disposal is dramatic. Every day, around the world, thousands of tonnes of sludge from on-site sanitation systems, such as traditional latrines, public toilets and septic tanks, are disposed of without prior treatment (Carr, 2005), Pre-treatment (Carr, 2005; Delville and Boucher, 1996; Ingallinella *et al.*, 2002). In most cities in Cameroon, as in most African cities, there is no sewerage system. Excreta are collected in individual sanitation systems installed in homes (Montangero *et al.*, 2002). Autonomous sanitation facilities such as septic tanks, latrines and public toilets are devices that store sewage sludge, which must be removed regularly (Strauss *et al.*, 2003). If this sludge is not collected regularly, transported and treated at a treatment plant, it can cause serious damage to the environment and public health (Kinglee *et al.*, 2004). Studies show that in urban areas, collected effluent, whether pre-treated or not, is stored in sealed or unsealed pits, from which the sludge is then removed manually or mechanically by various operators. These operators, often faced with a lack of suitable sludge treatment facilities, frequently dump the sludge directly into the environment, near homes or on the outskirts of urban areas, thus causing serious health and environmental problems (Defoe *et al.,* 2015; Ouattara *et al.*, 2022; N'gouran *et al.*, 2023). However, few studies to date have focused on the impact of sewage sludge on the flora of sewage sludge disposal sites. According to Savoy (2005), urban biodiversity has been recognized as an important issue for the future. Furthermore, the conservation of this biological diversity could improve human health in cities around the world. Unfortunately, more than 50% of known plant and animal species are believed to be negatively affected by human activities in urban areas (Mckinney and Lockwood, 1999; UN, 2012). However, the city of Yaoundé, Cameroon's second largest city in terms of population, is not spared from poor liquid waste management. Sewage sludge from the city's autonomous sanitation systems is collected mechanically by private or public operators, transported and dumped in an uncontrolled manner in the city and its suburbs without prior treatment on vegetation. Based on this observation, the present study aims to assess the impact of sewage sludge dumping on urban and peri-urban flora in the city of Yaoundé. More specifically, this study will analyse the floristic diversity of the various sewage sludge disposal sites and determine the influence of sewage sludge on the diversity of the residual flora at the various disposal sites.

MATERIALS AND METHODS

Presentation of the study area

The study was conducted in Nomayos, 25 km south-west of Yaoundé, in the Méfou-et-Akono Division of Central Region Cameroon's (Fig. 1).

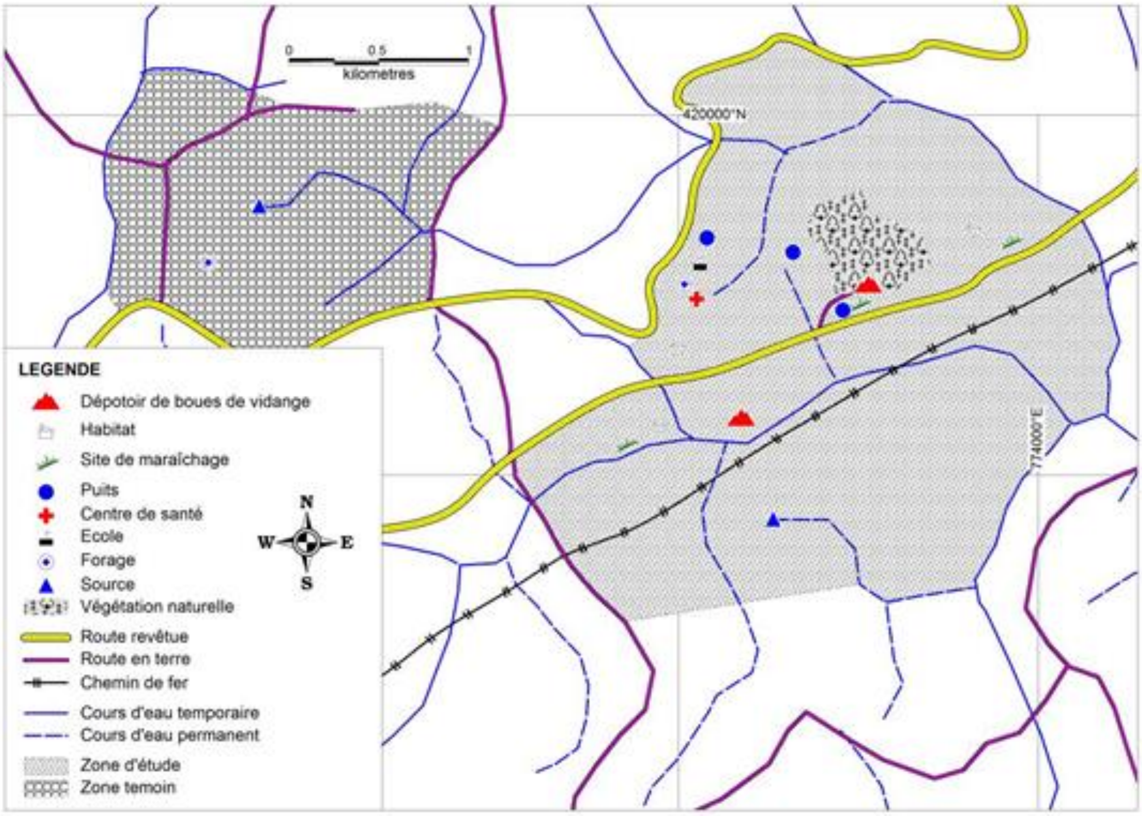

Fig. 1. Location of the sewage sludge dump

Despite the climate changes observed in recent decades, the Central Region is characterised by a Guinean-type equatorial climate. It is a cool and mild climate, with constant temperatures and average rainfall varying between 1,500 and 2,000 mm (Suchel, 1972 and 1988, INS, 2010). This climate has four seasons, including a short dry season from July to August, a long dry season from December to March, a short rainy season from March to June and a long rainy season from September to November. The hydrographic network of the Central Region is very dense and belongs to two major river basins (Nyong and Sanaga). The Nyong River, 800 km long, has as its main tributaries the Mfoumou, Mefou, So'o, Kéllé and Afamba, which flow through the departments of Nyong and Mfoumou, Mefou and Afamba, Mefou and Akono, Nyong and So'o, Nyong and Kéllé and Mfoundi (Olivry, 1986). This work was carried out along the banks of two rivers in Nomayos, a town near Yaoundé that serves as a site for the indiscriminate dumping of sludge collected by sewage trucks from the sanitary facilities of Yaoundé-Yaoundé (Fig. 2). The site covers an area of approximately 300 m² and receives around 1,350 m³ of untreated sewage sludge per week (Fig. 2)

a: waste at the sewage sludge disposal site b: sewage sludge disposal

Fig. 2. Study site

Flora inventories were carried out on four selected land use types (fields, grassland, sewage sludge disposal areas and sewage sludge accumulation areas). These flora inventories took the following criteria into account:

1. Vegetation on hydromorphic soil and dry land;
2. The presence of human activity;

3. Accessibility of the environment;
4. Presence of the watercourse (Avo'o).

To better assess the impact of the sewage sludge dump on the flora. Phytodiversity plots of 5 m x 5 m were established in each site. Each plot was subdivided into 25 sub-plots measuring 1 m x 1 m; Five sub-plots were selected at random without replacement to record the number of times each species appeared on the sub-plots (1 m x 1 m) (N'gouran *et al.*, 2022). Thus, in each of these 4 m² plots, the surface inventory consisted of collecting all species (trees, shrubs, vines and grasses). The itinerant survey consisted of walking through the 25 m² plots to complete the list of plant species inventoried at the various study sites. In each 1 m² plot, the following were identified and recorded. In these quadrats, the abundance coefficient was determined according to Braun Blanquet's classic scale (+, 1, 2, 3, 4, 5) (Fonkou, 2006). Plant identification was done directly in the field by the assistance of a plant botanist who had knowledge in identifying plant species of the area using common identification criteria such as leaf type and arrangement, trunk and morphology. Unidentified plant species were harvested and taken to be compared with those of the National herbarium in Yaounde, Cameroon for further identification.

RESULTS

Floristic composition

The 125 quadrats, covering an area of 125x10-4 hectares, comprise a total of 60 species belonging to 58 genera and 20 families identified upstream and downstream of the sewage sludge disposal site. Among these families, 18 have at least 30 species. Overall, this diversity varies depending on the sampling sites. A high number of families and species were observed at the SM site (sewage sludge discharge area) with 18 families and 30 species, and at the SAV site (site located downstream of the sewage sludge disposal site) with 12 families and 20 species, compared to 6 families recorded in SP with approximately 8 species (the sewage sludge accumulation area). At the SAM site (located upstream of the sewage sludge dump), 11 families and 26 species were recorded (Fig. 3).

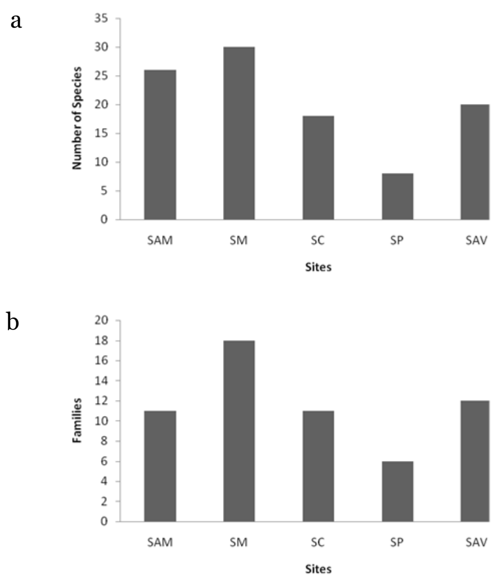

Fig. 3. Distribution of the number of species (a) and families (b) recorded according to site
SAM: site located upstream of the sewage sludge dump; SM: sewage sludge discharge area; SC: cultivated area; SP: lowest point of the sewage sludge dump; SAV: point located downstream of the sewage sludge disposal site.

Distribution of diversity of families in the cultivated site

In the cultivated site (SC), 11 families grouped into 18 genera and 18 species were inventoried, with a predominance of Solanaceae (5 species), Fabaceae (2 species), Sterculaceae (2 species) and Poaceae (2 species), with two species each (Fig. 4). The remaining families, representing 63.635% of the families recorded in this area, are represented by a single species. The characteristic species of this site are: *Zea mays, Musa paradisiaca, Xanthosoma sagitifolia* Schott*, Licopersicum esculentus* Mill*, Elaeis guineensis* Jacq*, Solanum nigrum* L.*, and Abelmoschus esculentus* L.

Distribution of diversity of families at the SAM site

At the site upstream of the sewage sludge dump, 26 species and 11 genera grouped into 11 families were identified. The families characteristic of this area are represented by Poaceae (9 species) and Asteraceae (4 species) (Fig. 5). The remaining families recorded in this area are each represented by a single species.

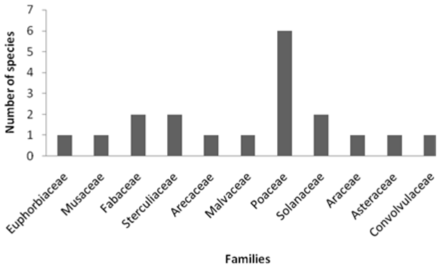

Fig. 4. Distribution of the most represented families (number of species) at the cultivated site

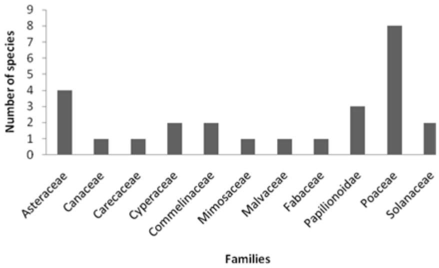

Fig. 5. Distribution of the most represented families at the SAM site

Distribution of species according to families in the sewage sludge discharge area

The SM site is the area where sewage trucks dump large quantities of sewage sludge. Once dumped, this sludge flows by gravity. Thus, 30 genera and 30 species grouped into 18 families were identified. Four characteristic families (Poaceae, Asteraceae, Solanaceae, Arecaceae) were identified, representing a total of 22.22% of the families listed. The remaining families, representing more than 75% of the families recorded in this area, are represented by a single species. These include Cyperaceae, Musaceae, Asteraceae, Costaceae and Curcurbitaceae (Fig. 6).

Distribution of diversity of families in the sewage sludge accumulation area

The sewage sludge accumulation site is considered a sewage sludge accumulation area because the sludge discharged by sewage trucks flows by gravity to the lowest point of the slope (swamp). The results reveal that very few species (8 species) belonging to 6 families were recorded in this area. The species are grouped in islands and form monospecific plant formations in some places (Fig. 7). The characteristic or most represented families in this area are Poaceae, Davalliaceae, Euphorbiaceae and Commelinaceae, accounting for 66.67% of the families recorded (Fig. 7). The remaining families are less diverse (only one species). Davalliaceae, Euphorbiaceae et Commelinaceae (Fig. 8).

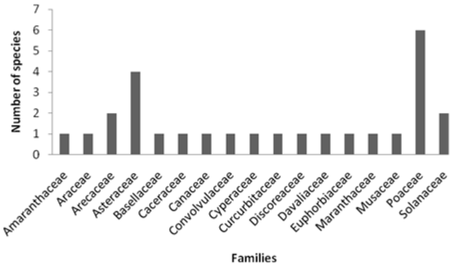

Fig. 6. Distribution of the most represented families in the sewage sludge disposal site

Fig. 7. Monospecific vegetation formation with *Acroceras zyzanoides*

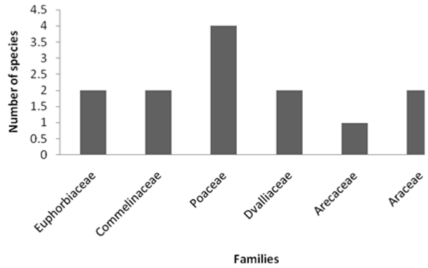

Fig. 8. Distribution of the most represented families in the sewage sludge accumulation area

Distribution of diversity of families downstream of the sewage sludge dump

Analysis of the diversity of families in this area shows a total of thirteen (13) families, with two

(02) of the families surveyed being the most represented. These are Poaceae (9 species) and Asteraceae (2 species). The remaining of the families present in this locality is represented by only one species. These include Amaranthaceae, Apocynaceae, Arecaceae, Asteraceae, Costaceae, Cyperaceae, Cucurbitaceae, Dioscoreaceae, Davalliaceae, Polygonaceae, and Solanaceae (Fig. 9).

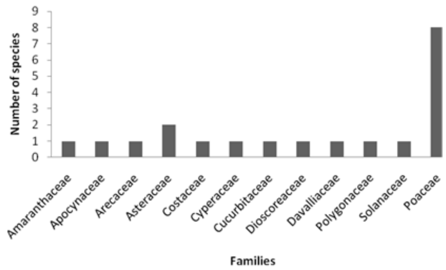

Fig. 9. Distribution of the most represented families downstream of the sewage sludge dump

Relative abundance of species according to site

Analysis of the different quadrats also shows that species abundance varies according to sampling site. At the site located upstream of the sewage sludge dump, 12 species, or 45% of the total number of individuals recorded, have a relative abundance greater than 2% (Fig. 10).

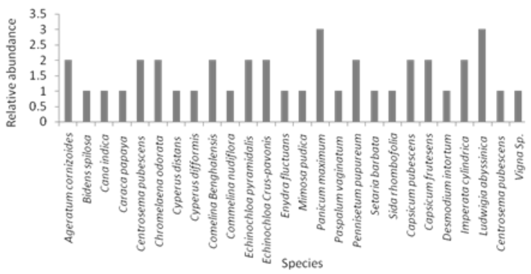

Fig. 10. Most abundant species upstream of the sewage sludge disposal site

These include *Ageratum cornizoides, Echinocloa pyramidalis, Echinocloa cruis-parvonis, Chromolaena odorata, Musanga cecropiodes, Carica papaya, Alchornea cordifolia, Amaranthus spinosus, Panicum maximum, Ludwigia abyssinica* and *Pennisetum purpurum*. The rest of the species identified in this area have a much lower relative abundance (≤1%). These include *Bidens pilosa, Carica papaya, Cyperus difformis, Imperata cylindrica*, and *Paspalum vaginatum*.

Distribution of species abundance in the sewage sludge disposal area

In the sewage sludge disposal area, 15 species, or 50% of the total number of individuals recorded, have a relative abundance greater than 2% (Fig. 11). These include *Amaranthus spinosus, Physalis edulis, Carica papaya, Ageratum cornizoides, Thithonia diversifolia, Chromolaena odorata, Lycopersicum esculentum, Marantochloa pupurea, Esculenta grants, Elaeis guineensis, Raphia* sp*, Alchornea cordifolia*, etc. The remaining species, representing 47% of those identified in this area, have a much lower relative abundance (≤1%). These include *Setaria barbara, Panicum maximum, Costus afer, Nephrolepis* sp, and *Cyperus distans*.

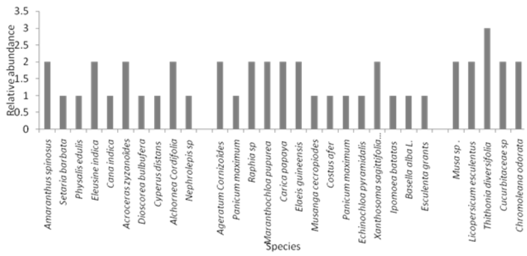

Fig. 11. Most abundant species in the sewage sludge discharge area

Distribution of relative abundance of species in the sewage sludge accumulation area

In the sewage sludge accumulation zone, two species identified, representing 10% of the total number of individuals counted, have a relative abundance greater than 2% (Fig. 12). These include *P. purpureum* and *A. zyzanoides*. The remaining species, representing 2% of the species identified in this zone, have a relatively low relative abundance. These include *Alchornea cordifolia, Pennisetum purpurum, Nephrolepsis bisserata, Raphia* sp, and *Eleusine indica.*

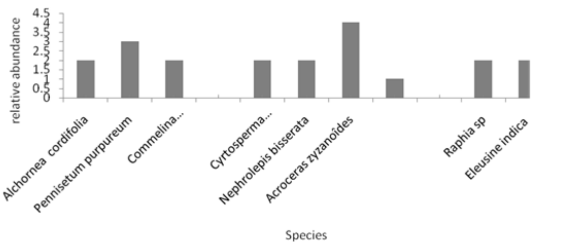

Fig. 12. Most abundant species upstream of the sewage sludge dump in the sewage sludge accumulation zone

Distribution of relative abundance of species downstream of the sewage sludge dump

However, downstream of the sewage sludge dump, 15 species identified, representing 75% of the total number of individuals recorded, have a relative abundance greater than 2% (Fig. 13).

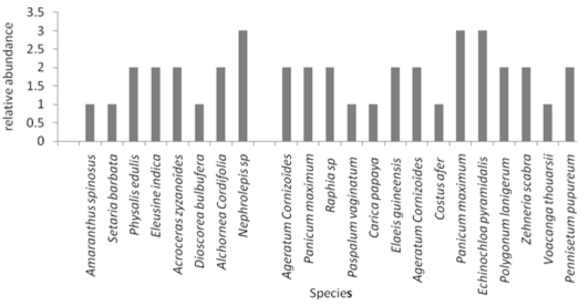

Fig. 13. Most abundant species downstream from the BV landfill site

These include *Echinochloa pyramidalis, Ageratum cornizoides, Elaeis guineensis, Musanga cecropiodes,* and *Panicum maximum*. The remaining species, representing 25% of the species recorded in this area, have a relatively low relative abundance. These include *Carica papaya, Eleusine indica, Voacanga* sp, *Costus afer,* and *Voacanga thouarsii.*

DISCUSSION

The floristic inventory at the various sites (04) identified 60 species divided into 58 genera and 20 families. The greatest species richness was recorded at the sludge disposal area, with 30 taxa belonging to 18 families. In contrast, the lowest diversity was recorded in the sludge dump accumulation zone, with 08 species grouped into 6 families. This study shows that the sewage sludge accumulation zone, considered to be highly polluted, contains few species compared to the sewage sludge discharge zone and the site upstream of the sewage sludge dump. This result is consistent with those of Fonkou (1996 and 2006), who showed that highly polluted swamps contain few macrophyte species compared to those that are less polluted. The sewage sludge disposal site is characterised by obligate hydrophytes such as: *Accroceras zyzanoides, Eleusine indica* and facultative hydrophytes that grow on dry land (*Pennisetum purpureum, Echinochloa pyramidalis, Alchornea cordifolia, Nephrolepis biserrata*) and plants with high organic matter absorption capacities (*Thithonia diversifolia*).

Tita *et al.* (2008) showed that *Thithonia diversifolia*, *Pennisetum purpureum*, and *Chromaelaen aodorata* were abundant in fragments of the Nkoup River in Foumbot (West-Cameroon).

Furthermore, the most diverse families are Poaceae, Asteraceae and Solanaceae, with at least three species. Within these various botanical families, ruderal and cultivated species are present in considerable numbers at the five sites surveyed. Indeed, the large number of ruderal species at the various dumping sites could be explained by the anthropogenic activities. These annual and perennial ruderal formations are pioneer and post-pioneer herbaceous vegetation associated with disturbed and reworked areas (Maire *et al.*, 2020; N'gouran *et al.*, 2023). According to Saulais (2011), urban flora consists mainly of ruderal species. Ruderal species are characterised by their short life cycle and high dispersal capacity (Kowarik, 2011). For Bulllock *et al.* (2018), the dispersal of species is strongly influenced, directly or indirectly, by human activities. These activities can therefore alter the diversity and taxonomic composition of spontaneous plant communities, including dispersal mechanisms (Omar *et al.*, 2018; Vergnes *et al.*, 2017). Similar studies reveal that the dominance of Poaceae can be explained by the fact that species in this family are able to cope with harsh environmental conditions (Melon *et al.*, 2015; Kaou*et al.*, 2017). It is important to note that those involved in the septic tank emptying sector discharge sludge in an uncontrolled manner. This method of faecal disposal could therefore have a negative impact on plant development. The lower diversity recorded in the BV accumulation zone could be explained by a high pollutant load that prevents local species from adapting. Similar studies conducted in sub-Saharan Africa show that very high pollutant loads in sewage sludge could lead to the withering, death or even extinction of certain plant species at landfill sites (Labelle, 1995). A negative correlation between COD and toxicity in species such as *Daphnia pulex* Leydig and *Lactuca sativa* L. was established by Sánchez-Meza *et al.* (2007). Authors have also observed toxic effects of high N-NH_4^+ concentrations on plant growth (Jampeetonga *et al.*, 2012). However, other studies reveal that certain species identified in this study, such as *Echinocloa pyramidalis* and *Echinocloa cruis-parvonis*, adapt to pollution loads and can contribute to environmental purification. Fonkou *et al.* (2010) demonstrate that *E. pyramidalis* in the filter does indeed contribute to purification, as reductions of 80% for conductivity, 90% for colour, 79% for suspended solids, 60% for COD, 90% for BOD5 and 79% for nitrogen content were observed. Other studies reveal that the distribution of species in the BV landfill swamp is different from that observed in a swamp that receives only wastewater (Fonkou, 2006; Kidd *et al.*, 2006). According to Djousse Kanouo *et al.* (2023), the uncontrolled dumping of waste in the environment by local populations inevitably leads to the degradation of the environment and available resources.

CONCLUSION

This study was conducted in the locality of Manayos on the influence of sewage sludge dumps on the flora in the south-western zone of Yaoundé-Cameroon. The floristic inventory carried out at the various sites identified 60 species divided into 58 genera and 20 families.

The greatest species richness was recorded at the site that does not receive sewage sludge (control), with 30 taxa belonging to 18 families. The low species richness at the other sites, mainly in the sewage sludge accumulation zone, is thought to be due to high nitrate levels.

The most frequent and abundant families are Poaceae, Asteraceae, Solanaceae, Papilonoidae, and Cyperaceae. These different sites are characterised by the predominance of ruderal and/or cultivated species, which could be explained by the influence of anthropogenic activities.

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