

FIRST DOCUMENTATION OF PLANT SPECIES DIVERSITY IN KHARTOUM REFINERY, SUDAN

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Abstract. This is the first record data of plant species diversity in the new ecosystem after the establishment of Khartoum Refinery (KRC), a new ecosystem was appeared due to processing, operation of oil refining. Khartoum Refinery (KRC) is located north of Khartoum State, Sudan. This work aim to assess the impact of treated water from KRC on plant diversity; twelve field trips were carried out to cover dry and wet seasons. Plant specimens were collected, pressed, dried, identified, mounted according to the standard methods and then incorporated in the herbarium. Scientific names were updated from the website of the international plant list version. Sixteen (16) plant species belonging to nine (9) families were recorded in Khartoum refinery. This study concludes that treated water has indeed effect the biodiversity since many plant species growing and dominating. The study recommended periodic monitoring of vegetation and soil in KRC to study the accumulative impact of treated water on soil properties and plant diversity.

Keywords: *oil refining, treated water, plant specimens, periodic monitoring, plant diversity*

Introduction

Biodiversity is a widely used term having no unified definition (El Tahir and Vishwanath, 2015). It is an issue which is defined globally by different authors. It is a short form for biological diversity which is to describe the total number, variety and variability of living organisms as well as the diversity of the ecosystem they are living in. In this definition, diversity can be assessed at three levels: Genetic variation which encompasses genetic variability among the populations and the individuals of the same species. Species variation this encompasses variability among species at plot or field levels. It is one of the important specifications of bio-societies that are measured in different ways. Ecosystem variation within an area, biome, or planet this encompasses diversity at a higher level of organization. At this level the indicator of diversity is species dominance (El Tahir and Vishwanath, 2015).

The concept of biodiversity is considered to be the integration of biological variability across the above mentioned three scales to the landscapes that they form, or are part of, and the ecological processes that support them. Generally, biodiversity measurement focuses on the species level and species diversity is one of the most important indices which are used for the evaluation of ecosystems at different scales (Wilson, 1988). Problem statements there are different residues that remain after produced water treatment which include oil, free metal and other toxic components of treated produced water. When these toxic components accumulate in the soil they can change soil chemical and physical properties which directly affect plant growth and composition. Objective of this research is to determine the member of plant species component of the new ecosystem diversity in Khartoum refinery.

Materials and Methods

Study area of Khartoum refinery

The study area landscape is located in the semi desert zone north of Khartoum State (Figure 1), at latitude range between 16.4023N to 16.1157N, as well as longitude range between 32.4609E to 32.2086E. According to Andrews (1950), as well as Harrison and Jackson (1958), the area is the semi desert grassland on sand in places with a thin scatter of *Acacia raddiana*, *A. mellifera* and *Commiphora* spp. The rainy season begins in July the end of September. The dry season begins in December and last June. The rainfall is about 164 mm per year. The annual minimum temperature average is 29.6°C and maximum is 38°C.

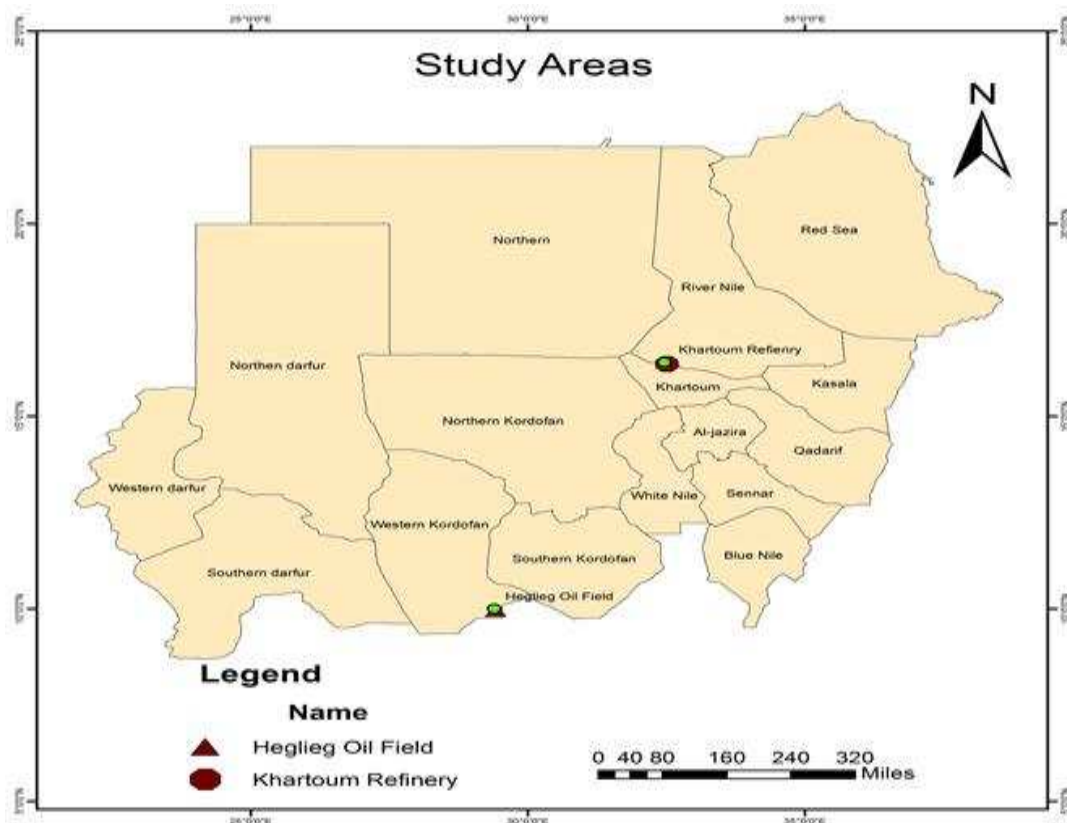


Figure 1. The study area of Khartoum Refinery.

Natural vegetation

According to White (1984), the area is located in the zone of Sahel semi-desert grassland transition to Sahara and grassland is the prevalent vegetation on deep sandy soils. It usually contains mixture of bushes and small bushy trees, the density of which is partly determined by local conditions. The woody species are *Acacia tortilis*, *Comiphora Africana*, *Balanites aegyptiaca*, *Boscia senegalensis* and *Tamarix* sp on the wet areas. The desert grass land is dominated by *Aristida adscensionis* and *Panicum turgidum*.

Soil

The soil type is loam and sand dry (moist plus darker) sandy clay loam with very few small and large rock fragments. The structure is less except for the surface 2 cm clear wavy boundary, and the pH is 7.2.

Khartoum refinery treated waste water system

Physical oil removal: this concerns all mechanical processes which do not use any reagent. Physical-chemical oil removal is done by adding chemical reagents and biological treatment (alge and fungi) finally the treated water is fed into large forest area.

Sample collection

Direct observations and primary surveying were used to assess environmental conditions and plant community type. Plant specimens were collected from different sites of the study area at different times of the year in 2016. Collection procedure followed the methods described. The whole plant was collected in case of herbs and twigs with leaves and flowers and /or fruits in case of shrubs and trees. The sample size is all the plant in the study area was collected.

Preparation of specimens

The specimens collected were stretched to dry between newspapers and firmly pressed inside a herbarium press. Newspapers were continuously changed during drying to avoid rotting of material. Specimens were identified and verified using keys in the taxonomic references, namely: Broun and Massey (1929), Andrews (1956; 1952; 1950) and El Amin (1990). The specimens were mounted, labeled and deposited at the herbarium of the Environmental and Natural Resources and Desertification Research Institute (ENRDRI), National Centre for Research (NCR), Khartoum. Field observations were recorded including, habit, habitat, distribution and colors of flowers during the collection trips. In the herbarium further classification analysis and /or identification were carried out initially by examining the various parts of the specimens collected using a hand-lens. Fine floral characters were examined under Mbc-10 dissection microscope. Preliminary species identification was carried out using a set of keys (Andrews, 1956; 1952; 1950), Hutchinson et al. (1963), and Braun et al. (1991). Specimens were matched with identified and authenticated herbarium specimens in the herbarium of ENRDRI and the Herbarium catalogue of the Kew Royal Botanic Gardens (2021) for confirmation. The synonyms of the identified species were extracted from many references such as Hutchinson et al. (1963), Cronquist (1965), Wickens (1976), Sahni (1968), El Awad (1995), Elghazali (1985) and El Amin (1990).

Updating of plant names was taken into account according to recent literature namely: The Plant List (2021) and Kew Royal Botanic Gardens (2021). The list of clades and orders covered in this study was arranged according to APG (2008) and the families were arranged according to the Haston et al. (2009) while subfamilies, genera and species are arranged alphabetically. The vernacular names of species were recorded from local inhabitants within the study area and also extracted from Broun and Massey (1929) as well as Andrews and Tothill (1948), for citation of species only the oldest reference cited was (Sp. Pl. in most cases), in addition to Andrews (1956; 1952; 1950). Economic uses given were compiled from local people and available literature. The life-forms of plants were formulated according to Raunkiaer (1934).

The abbreviations

The abbreviations can be includes: (1) C=Central Sudan; (2) D=Darfur; (3) Es=Eastern Sudan; (4) Kh=Khartoum State; (5) Kd=Kordofan; (6) KRC=Khartoum Refinery; and (7) N=Northern Sudan.

Results and Discussion

The results showed that the flora of Khartoum refinery is composed of 16 species which belong to 9 families (Table 1). Updated classification of these;

Table 1. Plant species of Khartoum Refinery.

No.	Family	Scientific name
1	Amaranthaceae	<i>Aerva javanica</i> (Burm.F.) Juss . ex Schult
2	Apocynaceae	<i>Calotropis procera</i> (Aiton)
3	Compositae	<i>Aaronsohnia pubescens</i> (Desf.) K. Bremer &Humphries
4	Cucurbitaceae	<i>Cirtullus coloyntis</i> (L.) Schrd
5	Leguminosea	<i>Acacia seyal</i> Delile
6	Leguminosea	<i>Acacia tortillis</i> (Forsk.) Hayne.Sp <i>spirocarpa</i> Hochst. Ex A. Rich
7	Leguminosea	<i>Rhynchosia memnonia</i> (Del.) DC
8	Leguminosea	<i>Tephrosia uniflora</i> Pers
9	Leguminosea	<i>Senna alexandrina</i> Mill
10	Malvaceae	<i>Crochours depressus</i> (L.) Stocks
11	Poaceae	<i>Aristida adscensionis</i> L
12	Poaceae	<i>Chloris virgata</i> Sw
13	Poaceae	<i>Panicum turigdum</i> Forsk
14	Tamaricaceae	<i>Tamarix senegalensis</i> DC
15	Zygophyllaceae	<i>Fagonia cretica</i> L
16	Zygophyllaceae	<i>Seetzenia orientalis</i> Decne

Clade: Monocots/Commelinids

Order: Poales

Family: Poaceae. Subf. Arundinoideae

Scientific name: *Aristida adscensionis* L. (Figure 2), Sp. Pl.:82 (1753);

Andrews, Flowering plants of the Sudan, VolIII: 395 (1956).

Synonym: *A.abysinica* Tin & Rupr., Sp. Gram. Stipac. 1:34 (1842).

Local name: Gao

Uses: Fodder.

Distribution: C, D, Es, Kd, Kh, N



Figure 2. *Aristida adscensionis*.

Family: Poaceae. Subf.Chloridoideae

Scientific name: ***Chloris virgata*** Sw. (*Figure 3*), Fl. Ind. Occid. 1: 203 (1797),
Andrews; Flowering plants of the Sudan, VolIII: 418 (1956).

Synonym: *Chloris alba* J.Pres, L.Reliqu. Haenk.1: 289 (1830).

Agrostomia barbata Cerv., Naturaleza (Madrid) 1870: 346 (1870).

Local name: Afn

Life form: Therophytes

Uses: Fodder.

Distribution: C, D, Es, Kd, Kh, N.



Figure 3. *Chloris virgata* Sw.

Family: Poaceae. Subf.Panicoideae

Scientific name: ***Panicum turgidum*** Forssk. (*Figure 4*), Fl. Aegypt.-Arab. 18 (1775);
Andrews, Flowering plants of the Sudan, VolIII: 504 (1956).

Synonym: *Panicum frutescens* Mez, Bot. Jahrb. Syst. 57: 186 (1921).
Local name: Tomam
Distribution: C, D, Kh.
Life form: Therophytes
Uses: Fodder and medicinal



Figure 4. *Panicum turgidum* Forssk.

Clade: Eudicots/Eurosids I
Order : *Zygophyllales*
Family: *Zygophyllaceae*. Subf. *Seetzenioideae*
Scientific name: *Seetzenia lantana* (Wild) Bullock. (Figure 5), Kew Bull. 19: 204 (1965).
Synonym: *Zygophyllum lanatum* Willd., Sp. Pl. 2. 2(1): 564. (1799).
Seetzenia orientalis Decne., Ann. Sci. Nat., Bot. II, 3: 281 (1835);
Andrews, Flowering plants of Anglo-Egyptian Sudan Vol I: 124 (1950).
Local name: Hyben
Life form: Therophytes
Distribution: C., D., Kh.
Uses: Fodder and medicinal



Figure 5. *Seetzenia lantana*(Wild) Bullock.

Family: Zygophyllaceae. Subf. Zygophylloideae
Scientific name: ***Fagonia cretica*** L.,Sp. (*Figure 6*) Pl. 386 (1753);
Andrews, Flowering plants of Anglo-Egyptian Sudan, VolII: 124(1950).
Synonym: *Fagonia deflexa* Moench, Suppl. Meth.: 82 (1802).
Local name: Um shoeka
Distribution: C, D, Kh.
Life form: Chamaephytes
Uses: Fodder and medicinal



Figure 6. *Fagonia cretica* L.

Order: *Fabales*
Family: Fabaceae (Leguminosae). Subf: Caesalpinoideae (syn. Caesalpinaceae)
Scientific name: ***Senna alexandrina*** Mill. (*Figure 7*), in Lock, Kew Bull.43: (1988);

Synonym: *Cassia senna* L., Sp. Pl: 377(1753); Andrews, Flowering plants of the Anglo-Egyptian Sudan Vol II: 118(1952). *C. lanceolata* Forssk., Fl. Aegypt.-Arab.:85 (1775). *C. acutifolia* Delile., Fl. Aegypte: 219(1813).

Local name: Sana, Sanya, Sanamaka.

Life form: Chamaephytes.

Uses: Medicinal used in the form of senna pods, or as herbal tea made from the leaves, as a laxative. Fodder.

Distribution: C, D, Es, Kd, Kh, N



Figure 7. *Senna alexandrina* Mill.

Family: Fabaceae (Leguminosae). Subf.: Mimosoideae (syn. Mimosaceae)

Scientific name: *Acacia seyal* Delile (*Figure 8*), Fl. Aegypte: 286 (1813);

Andrews, Flowering plants of the Anglo-Egyptian Sudan Vol II: 144 (1952).

Synonym: *Acacia fistua* Schwenif., Linnaea 35: 344. (1867).

Local name: Talih

Life form: Phanerophytes

Uses: An important source for gum (talha gum) and wood. Fodder and medicinal.

Distribution: C, D, Es, Kd, Kh, N



Figure 8. *Acacia seyal* Delile.

Scientific name: *Acacia tortilis* subsp. *spirocarpa* (A.Rich.) (Figure 9)
Brenan, Kew Bull.1957:88(1957).

Synonym: *A. Spirocarpa* Hochst. ex A. Rich., Tent. Fl. Abyss. 1:239(1847).
Acacia tortilis (Forssk.) Hayne, in Andrews, Flowering plants of the Anglo-Egyptian
Sudan Vol II:142(1952).

Local name: Sumer

Life form: Phanerophytes

Uses: Fodder, medicinal and charcoal.

Distribution: N, C



Figure 9. *Acacia tortilis* subsp. *spirocarpa* (A. Rich.) Brenan.

Family: Fabaceae (Leguminosae). Subf.: Papilionoideae (syn. Papilionaceae)

Scientific name: *Rhynchosia minima* var. *memnonia* (Delile) (Figure 10) T.Cooke.
In Tackholm, St.F.E.:284, Pl.89 (1974).

Synonym: *Glycine memnonia* Delile, Descr. Égypte, Hist. Nat. (1813)
Rhynchosia memnonia (Delile) DC., Prodr. 2: 386 (1825); Andrews, Flowering plants
of the Anglo-Egyptian Sudan Vol II: 228 (1952).
Local name: Adanelfar, Adna.
Life form: Chamaephytes.
Uses: Fodder and medicinal.
Distribution: Widespread



Figure 10. *Rhynchosia minima* var. *memnonia* (Delile) T. Cooke.

Scientific name: ***Tephrosia uniflora*** Pers., Syn. Pl. [Persoon] 2(2): 329. (1807);
Andrews, Flowering plants of the Anglo-Egyptian Sudan Vol II: 236 (1952).
Synonym: *Tephrosia quartiniana* Cufod., Bull. Jard. Bot. État Bruxelles 25(Suppl.):
283 (1955). *Tephrosia transjubensis* Chiov., Fl. Somala 2: 161 (1932).
Tephrosia vicioides A. Rich., Tent. Fl. Abyss. 1: 188 (1847).
Local name: Hemera
Life form : Chamaephytes.
Uses: Fodder



Figure 11. *Tephrosia uniflora* Pers.

Clade: Eurosids I

order: *Cucurbitales*

Family: Cucurbitaceae. Subf.Cucurbitoideae

Scientific name: ***Citrullus colocynthis*** (L.) Schrad., Linnaea 12: 414 (1838).

Synonym: ***Colocynthis vulgaris*** Schrad.(*Figure 12*), Index Seminum (GOET) 1833: 2 (1833); Andrews, Flowering plants of the Anglo-Egyptian Sudan Vol I: 166 (1950). *Cucumis colocynthis* L., Sp. Pl. 1011 (1753).

Local name: Handel

Life form: Therophytes.

Uses: Medicinal.

Distribution: C, D, Es, Kd, Kh, N



Figure 12. *Cirtulluscoloynthis* (L.) Schrad.

Clade: Eurosids II

Order: *Malvales*

Family: Malvaceae. Subf. Grewioideae

Scientific name: ***Corchorus depressus*** (L.) Stocks (*Figure 13*), Proc. Linn. Soc. London 1:367 (1848).

Synonym: *Antichorus depressus* L., Mant. Pl. 1: 64 (1767). *Corchorus depressus* (L.) C. Chr., Dansk Bot. Ark. 4(3): 34 (1922); Andrews, Flowering plants of the Anglo-Egyptian Sudan Vol I: 217 (1950).

Local name: Um takasho

Life form: Therophytes.

Uses: Fodder, food and medicinal.

Distribution: C, D, Es, Kd, Kh, N



***Figure 13. Corchorus depressus* (L.) Stocks.**

Clade: Eurosids I

Order: *Caryophyllales*

Family: Tamaricaceae

Scientific name: ***Tamarix senegalensis*** DC. (*Figure 14*), Prodr. 3: 96 (1828).

Synonym: *Tamarix nilotica* (Ehrenb.) Bunge, Tent. Gen. Tamar. 54 (1852);

Andrews, Flowering plants of the Anglo-Egyptian Sudan Vol I: 161 (1950). *Tamarix arabica* Bunge, Tent. Gen. Tamar. 55 1852.

Local name: Tarffa.

Uses: Medicinal.

Life form: Phanerophytes

Distribution: C, D, Es, Kd, Kh, N



Figure 14. *Tamarix senegalensis* DC.

Clade: Eurosids I

Order: *Caryophyllales*

Family: *Amaranthaceae*. Subf. *Amaranthoideae*

Scientificname: *Aerva javanica* (Burm. f.) Juss.exSchult. (*Figure 15*), Ann. Mus. Hist. Nat.11: 131 (1808); Andrews, Flowering plants of the Anglo-Egyptain SudanVol I: 113 (1950).

Synonym: *Achyranthes alopecuroides* Lam.,Encycl. 1: 548 (1785).

Local name: Raselshayib

Life form: Chameaphytes.

Uses: Fodder and medicinal.

Distribution: C, D, Es, Kd, Kh, N



Figure 15. *Aerva javanica* (Burm. f.) Juss.exSchult.

Clade: Euasterids I

Order: Gentianales

Family: Apocynaceae. Subf. Asclepiadoideae

Scientific name: *Calotropis procera* (Aiton) Hortus (*Figure 16*), Kew. 2: 78 (1811);
Andrews, Flowering plants of the Anglo-Egyptain Sudan Vol II: 402 (1952).

Synonym: *Asclepias procera* Ait., Hort.Kew.I:305(1789).

Local name: Usher

Life form: Nanophanerophytes.

Uses: Medicinal, Fodder.

Distribution: C, D, Es, Kd, Kh, N



Figure 16. Calotropis procera (Aiton) Hortus.

Clade: Euasterids II

Order: *Asterales*

Family: Asteraceae

Scientific name: *Aaronsohnia pubescens* (Desf.) K. Bremer & Humphries (*Figure 17*), Bull. Nat. Hist. Mus. London, Bot. 23(2):157 (1993).

Synonym: *Cotula pubescens* Desf. Fl. Atlant. 2: 284 (1799). *Chamomilla pubescens* (Desf) Alavi., Fl. Libya 107: 150 (1983).

Local name: Sefera

Life form: Therophytes.

Uses: Medicinal.

Distribution: C, Kh, N



Figure 17. *Aaronsohnia pubescens* (Desf.) K. Bremer & Humphries.

Conclusion

This study concludes that treated water has indeed effect the plant diversity since many plant species are growing and dominating. This 16 species are the first members' components of the new ecosystem. The study recommended periodic monitoring of vegetation and soil in KRC to study the accumulative impact of treated water on soil properties and plant diversity.

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Conflict of interest

The authors declare that there is no conflict of interest for this article.

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