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The impact of sewage disposal and tanning waste on the vegetation of Khartoum South, Sudan

Entsar Abushenab Rizgalla Hammad *

Department of Biology, Faculty of Science, Al-Makhwah 65931, Al-Baha University, Saudi Arabia.

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Abstract

This study examined the effects of tanning waste and sewage disposal on Khartoum South's vegetation. The floristic composition, density, frequency, and species diversity of the vegetation were the factors under investigation. Chemical analyses for the elements Ca, Mg, K, Cr, Cd, and Zn were performed on soil and plant samples.

Soil samples were collected from three locations in the study area at two depths: 0-5 cm and 10-15 cm. Plant samples of different species were collected for chemical analysis of the same elements mentioned above. Statistical analysis included analysis of variance (5% level) and correlation between soil and plant elements in addition to T- and F-tests. The results showed that elements Ca and Mg had a positive correlation between plant species and soil samples, while elements Cr and Cd had a negative correlation between soil and plant samples. The results of T-test and F-test showed no significant differences between element concentrations at two soil depths and three locations in the study area. The study concluded that the drastic change in the vegetation of the area was caused by sewage and tanning.

Keywords: Waste Water; Sewage; Vegetation; Tanning; Khartoum South

1. Introduction

The vegetation and soil in urban green spaces determine the capacity of the urban environment to support biodiversity. Additionally, the elements that humans may modify the most readily through disturbance and direct management measures include soil and green space vegetation [1, 2, 3]. Water pollution occurs when the water quality gets impaired or when the ecological balance is disrupted. The greatest source of pollution comes from organic materials that end up in the freshwater systems [4].

Heavy metals (HMs) exist naturally in rocks, but human activity has increased their accumulation. Heavy metals in soil can be found in biosolids, manure, agrochemicals, wastewater, and sewage sludge used excessively [5, 6]. HMs build up in the soil and trigger serious health issues for plants, livestock and humans [7, 8]. Heavy metal contamination in soil has influenced about 10 million individuals globally [9]. As a result, HMs accumulate in crops through the soil-root contact and present a severe risk [10]). The two most important natural resource foundations for agriculture's long-term success and civilizations' longevity are soil and water [11]. Further, anthropogenic and natural activities have also lead to the contamination of soil and water [12]. This study deals with one of the problems that has greatly affected species composition and growth vigor of the vegetation in the area close to the tannery and sewage disposal unit in Khartoum South. This area receives huge amounts of sewage water and tannery waste on daily bases. Bearing in mind the chemical composition of sewage water and tannery waste, there is a pressing need for studying short and long term effects of these wastes on the area's vegetation. Nature is a closed cycle. Matter and energy cannot be destroyed. The sewage materials are resources that should be transformed to a useful product which fits into the closed cycle of nature

* Corresponding author: Entsar Abushenab Rizgalla Hammad.

[13]. Khartoum Green Belt area, which was a live shelter belt situated 10 Km South of Khartoum, was under construction. The concept of using sewage effluent as an irrigation source was inspired by the presence of the Green Belt area.

Khartoum sewage station is located at El Rimaila area on the east bank of the White Nile about 5 Km South of Khartoum. It has a capacity of 3.2 million gallons per day, to irrigate 700 Feddans which constituted the original area of the western part of the Belt area. However, the continuous increase in flow rates to that limited area, created many problems, such as the creation of water-logged areas, increase of salinity [14]). Khartoum tannery, established in 1962, is one of the oldest public sector investment for leather products of tanned hides which are exported or used locally for shoes, bags and belts. The White Nile tannery is located just behind Khartoum tannery with an effluent treatment plant for the use of both tanneries [15]. This system of disposal is no longer working now because the effluent treatment plant needs rehabilitation. The untreated effluent is discharged on the open space near the tannery. In the sphere of material use, the creation of waste products is generally accepted as inevitable: food becomes sewage, automobiles become junked cars, while farms become dry land. Wastes of all kinds may be regarded either as sources of raw materials or ignored if too costly or technically unsuitable to recycle [16].

Heat energy-related materials and wastes that are presently not or cannot be recycled are released into the environment through disposal. Sewage is about 99.9% water and 0.02-0.04% solids, of which proteins and carbohydrates, each comprise 40-50% and fats 5-10%. According to Simmons [16], the processing of hides and skins into leather, has been an important industrial activity since time immemorial [17]. The various materials developed as replacement or substitutes for leather are unlikely to have much effect on its importance. Pollution from tanneries, as from any major industry, has a negative long-term impact on the development potential of a country irrespective of immediate economic benefits of the production [18]. The vegetation in Khartoum State had witnessed drastic changes in recent years which necessitate a thorough investigation to determine the contributing factors to these vegetational changes. This study was conducted to investigate the effect of sewage disposal and tanning waste on the vegetation of Khartoum South area, Sudan.

2. Material and methods

2.1. The vegetation of the study area

A survey of the dominant plant communities in the study area was carried out in October 2021 and the checklist of the flora in the study area was prepared. The plant species' frequency and density were also determined using quadrats of two sizes: a 0.5x0.5 m quadrat for determining the density and frequency of grasses and herbaceous species while a quadrat of 10x10 m was used for determining the density and frequency of shrubs and trees. The percent frequency of the species of the plant in the area was determined by the following equation:

Frequency $= \frac{No.of\ a\ given\ species\ x\ 100}{Total\ No.of\ species}$

The density of the plant was calculated as follows:

$$Density\ = \frac{Number\ of\ plants}{Area}$$

2.2. Chemical analysis of soil and plants

The chemical analysis of soil and plants in this research was conducted following the guidelines recommended by Allen [19]. Calcium, potassium, magnesium, zinc, cadmium, and chromium were determined with an atomic absorption spectrophotometer.

2.2.1. Chemical analysis of soil

Collection of soil samples

The soil samples were collected from depths of 0-5 cm and 10-15 cm, the depths that represent the soil's ability to supply most of the essential nutrients and pollutant elements for the plant. Three locations, each five meters apart, were used to gather six soil samples from each depth. The samples were collected from the area of sewage disposal in January 2021, placed in plastic bags, and stored in the laboratory at room temperature.

Determination of ash content

The method used by Abdurhaman [20] was adopted here. The ash content of the oven-dried soil samples was determined as follows: A suitable crucible was pre-heated in a muffle furnace to about 550°C, then cooled in a desiccator and weighed. Approximately 1 gm of the dried sample was transferred to the crucible and weighed. The crucible containing the dry sample was placed in a cold muffle furnace and the temperature was raised to 55°C. The crucible was taken out after two hours, let to cool, then moved to a desiccator, weighed, and the amount of ash was determined.

Preparation of soil solution for analysis

The extraction techniques were used for the measurement of exchangeable nutrients in the soil. In these methods, the ions of soil nutrients are displaced from adsorption sites by other replacing ions applied in gr excess [19]. The displaced ions are then estimated quantitatively Various studies have been carried out comprising the effectiveness of extraction methods, including those by Simmons [16]). In this ammonium acetate at pH 7 was used for extraction of K, Ca, Mg, and Zn. The extractant was prepared as follows: 575 ml of glacial acetic acid and 600 ml of ammonia solution were added to about two liters of de-ionized water. The mixture was diluted to 10 liters and the pH was adjusted to 7.0±0.1by adding acetic acid or ammonia solution. The extraction solution was prepared by mixing a representative amount of the soil sample (5 g) and 100 ml of the extractant in a conical flask. The mixture was shaken for 30 minutes, filtered and the filtrate was used for ion determination. The extraction for total Cr and Cd determination was prepared by acid digestion for plant materials.

2.2.2. Preparation of plant material

Sample collection

For a sufficient indication of nutrient status, samples of the newly photosynthetic tissues of *Calotropis procera, Prospis africana, Xanthium spinosum, Brachiaria eruciformis, Trianthema portulacastrum,* and T.*pentoudra* were collected in porter bags and immediately taken to the laboratory to avoid contamination or change in mineral composition.

Drying and grinding

The plant samples were oven-dried at 45°C for several hours until the samples were sufficiently dry to be ground. The dried materials were ground to produce a homogenous sample suitable for analysis.

Preparation of solutions for chemical analysis

To prepare a solution suitable for total elemental analysis of plant material, an oxidation process is necessary for the destruction of the organic matter. In this research, the digestion was done by acid oxidation using a sulphuric acid-hydrogen peroxide mixture. The digestion mixture was prepared as follows: 0.42 g of selenium (Se) and 14 g of Lithium sulfate ($Li_2SO_4.H_2O$) were added to 320 ml of 100-volume hydrogen peroxide (H_2O_2). The solution was thoroughly mixed and 420 ml of concentrated sulphuric acid was carefully added under cooling. To prepare sample solutions suitable for analysis, the digestion was done as follows: 2 ml of the digestion mixture was added to 0.15g of the dry ground plant sample in a digestion tube. The plant material was digested first at 60°C until the initial reaction subsided, then the temperature was increased to 200°°C and almost a colorless solution was obtained. The cold digestion mixture was filtered and diluted to 100 ml to give a 10% concentration of H_2SO_4.

2.2.3. Determination of elements in soil and plants

All elements in this study were determined using the analytical technique of atomic absorption spectrophotometer (AAS). This technique was recommended as being rapid and easy to apply [21].

3. Results

3.1. The vegetation of the study area

A vegetational survey was carried out in the study area. Vegetational parameters such as frequency and density have been studied. The results are shown in Table (1).

Table 1 Frequency (%) and density (plant/m^2) of plant species in study area

Plant species	Frequency	Density
Abutilon pannasum (Frost.) Schlecht.	2.4	3.2
Solanum dubium Fresen.	0.3	0.4
Glinus lotoides L.	0.3	0.8
Xanthium brasilicam Vell.	6.99	9.6
Brachiaria eruciformis Sm.Griseb	72.9	100
Amoranthus viridis L.	0.28	0.8
Trianthema portulacastrum L.	6.12	8.4
T.pentandra L.	10.5	14.4
Calotropis procera(Ait.)Ait. F.	41.5	0.14
Acacia nilotica subsp.nilotica Benth.	4.9	0.016
Borassus aethiopum Mort.	2.43	0.008
Prosopis africana (Guill) Perr.	48.8	0.16
Balanites aegyptiaca (L.)Lam.	2.43	0.008

Table 2 Percentage of certain elements of some plant species collected from the study area

Sample No.	Species	Percent of elements in plant species					
		Ca	Mg	K	Zn	Cd	Cr (6μg/g)
1	*Calotropis procera* (Ait) Ait. F.	0.11	0.06	0.43	0.018	0.0002	0.0008
2	*Prosopis africana* (Guill) Perr.	0.004	0.04	0.64	0.005	0.002	0.0008
3	*Xanthium spinosum* Vell.	0.004	0.05	0.64	0.01	0.0002	0.0006
4	*Brachiaria eruciformis* Sm.Griseb.	0.01	0.04	0.51	0.016	0.0003	0.001
5	*Trainthema portulacastrum* L.	0.20	0.05	0.41	0.052	0.0001	0.0005
6	*Trianthema pentondra* L.	0.009	0.04	0.48	0.005	0.0001	0.001

Table 3 Chemical analysis of soil samples collected from the study area

Site	Soil depth	Sample No.	Percent of elements in soil samples					
			Ca	Mg	K	Zn	Cd	Cr (6μg/g)
1	A	1-A	0.85	0.53	0.30	0.031	0.28	12.0
1	B	1-B	0.90	0.61	0.83	0.026	0.22	16.0
2	A	2-A	0.78	0.48	0.28	0.030	0.18	8.0
2	B	2-B	0.81	0.58	0.32	0.026	0.16	16.0
3	A	3-A	0.75	0.48	0.12	0.021	0.25	12.0
3	B	3-B	0.68	0.41	0.36	0.028	0.14	8.0

Table 4 Quadrat samples in the study area (frequency %)

Plant species	Family	Quadrats									
		1	2	3	4	5	6	7	8	9	10
Abutilon pannasum (Frost.) Schlecht	Maluaceae	34.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solanum dubium Fresen.	Solanaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0
Glinus lotoides L.	Molluginaceae	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.1	0.0
Xanthium brasilicam Vell.	Compositae	0.0	4.9	11.1	61.1	14.2	2.3	2.3	3.4	0.0	5.9
Brachiora eruciformis Sm. Griseb	Gramineae	4.3	73.8	88.9	38.9	50.0	88.4	93.0	89.7	0.0	74.5
Amoranthus viridis L.	Amoranthaceae	0.0	0.0	0.0	0.0	0.0	0.0	1.2	3.4	0.0	0.0
Trianthema portulacastrum L.	Ficoidaceae	56.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	88.9	0.0
T. pentaudra L.	Ficoidaceae	0.0	21.3	0.0	0.0	35.7	11.6	3.5	0.0	0.0	-
Calotropis procera (Ait.) Ait. F.	Asclepiadaceae	70.0	66.7	60.0	0.0	31.5		-	-	-	-
Acacia nilotica subsp. nilotica Benth.	Mimosaceae	10.0	0.0	0.0	14.3	0.0	-	-	-	-	-
Borassus aethiopum Mort.	Palmae	10.0	0.0	0.0	0.0	0.0	-	-	-	-	-
Prosopis Africana (Guill) Perr.	Mimosaceae	10.0	33.3	20.0	85.7	68.8	-	-	-	-	-
Balanites aegptiaca (L.)Lam.	Balanitaceae	0.0	0.0	20.0	0.0	0.0	-	-	-	-	-

Figure 1 A general view showing the effect of human activities on the vegetation of the study area.

Figure 2 *Prosopis africana* is the most dominant in the study area.

Figure 3 *Brachiaria eruciformis* dominant grass in the study area.

3.2. Results of chemical analysis

3.2.1. Chemical analysis of plant samples

Plant samples of the species*: Calotropis ptocera, Prosopis africana, Xanthium spinosum, Brachioria eruciformis, Trianthema portulacastrum,* and *Trainthema pentandra* were collected from the study area nearby ElRemala town. The collected samples were analyzed to determine the plant content of certain elements which include: calcium (Ca), Potassium (K), Magnesium (Mg), Cadmium (Cd), Chromium (Cr), and Zink (Zn). The results were expressed as the percentage dry weight of the plant material (Table 2). The percentage of each element was calculated according to the following equation by Allan [19].

$$E\ (\%) = \frac{C\ mg/L \times sample\ volume}{10^4 \times weight\ of\ sample}$$

Where:

E = Element
C = Concentration of element in mg/L
Sample volume = Final dilution of the sample after digestion
Weight of sample = Weight of sample in grams before ashing

3.2.2. Chemical analysis of soil samples

Soil samples were collected from three sites in the study area, each site lying within a distance of 5 m from the other. For each site, 2 soil depths (A=0-5 cm and B=5-10 cm) were chosen for sample collection. The collected soil samples were analyzed for the following elements: Ca, Mg, Cd, Cr, and Zn) as previously mentioned for plant samples. The results of chemical analysis of soil samples are shown in Table (3). It is worth mentioning that the elements Cd and Cr, with low concentrations, were calculated according to the following equation:

$$E\ (\mu g g^{-1}) = \frac{C\ (\mu g) \times sample\ volume\ (mL0}{Aliquot\ (mL) \times weight\ of\ sample\ (g)}$$

Where:

C = Concentration of element in µg
Sample volume =Final dilution of the sample after digestion
Weight of sample = Weight of sample in grams before ashing

3.3. Statistical analysis of chemical analysis of plant and soil samples

3.3.1. Correlation between mineral content of soil and plant

The species *Prosopis africana* (Guill) Perr. was the key species in the study area. In order to determine the correlation between the concentrations of elements in the soil and those in the important species in the study area, the correlation coefficient was computed. Here is a summary of the correlation studies: - The amount of the element Ca in the soil and that in *Prosopis africana* showed a positive correlation. Regarding Mg, the correlation was likewise positive. A negative correlation was observed for Cd and similarly for the element Cr.

3.3.2. Analysis of variance for soil samples at two depths

Two depths of the soil of the study area($A = 0.5$cm, $B = 5 - 10$cm)were examined for the elements Ca, Cd, Mg, Zn, and Cr. The results were statistically analyzed using both a t-test and F-test (Variance ratio test). The significance of variance was determined at the 5% level ($P = 0.05$). The following represents a summary of the results of the statistical analysis for the two soil depths for each element. It is evident that for every element listed above, there were no statistically significant variations in the depths' elemental concentrations at the 5% level. This suggests that the elements under investigation have a uniform spatial distribution between the two soil depths.

3.3.3. Analysis of variance for soil samples from three sites in the study area

Three sites in the study area were chosen and soil samples were taken from each site and analyzed for the following elements: Ca, Cd, Cr, K, Mg, and Zn. The sampling results were statistically analyzed using a t-test and F-test. The significance of variance between the sites was determined at the 5 level. The summary of the statistical analysis is presented as follows: It is evident that the concentrations of the elements under investigation in the three study sites did not differ significantly (at the 5% level). The only exception to this generalization is the element potassium where the F-test showed significant differences between sites 1 and 3 on one hand, and sites 1 and 2 on the other hand. This exception could be explained based on the very low variance of site 1 as compared to the other two sites. It is more likely that site 1 is highly alkaline, a finding which is closely reflected in the significance of the F-test between site 1 and the other two sites.

4. Discussion

This study revealed that Khartoum South vegetation had witnessed, during the last two decades several drastic vegetational changes as compared to previous studies carried out in the study area. The changes included plant cover, density, diversity, and frequency of species. Six new species have invaded and taken over the area since Mohamed [22] examined the floristic composition of the vegetation in the study area and produced a check-list of 80 species, 73 of which had vanished (91%) over the previous 20 years, for example, *Brachiaria eruciformis* (Fig. 3). Moreover, some species such as *Calotropis procera* and *Prosopis Africana* (Fig. 2) have increased greatly and became dominated species. The latter two species are indicators of soil deterioration. Other species that have invaded the study area, but in smaller densities, are *Abutilou fannasum, Xanthrum spinosum, Trainthema pertulacastrum,* and *Borassus aethiopicus.* Another vegetational change is the disappearance of the thickets of *Mimosa pigra* in the area. Many factors have collaborated and induced these vegetational changes including sewage and tanning wastes, human activities, and climatic factors. The sewage and tanning waste had a very little impact as shown by the results of chemical analysis of plants and soils and their statistical analysis. At present, the sewage effluent is contained in Khartoum sewage system which collects, disposes, treats, and reuses the liquid waste. The effect of the tanning waste was utmost before 1999 when the tanning waste was spilled over a large area. Since the fruits of *Mimosa pigra* were used as a tanning material, the area used to be a domain of this tree species, and heavy thickets of it could be seen all around the area near Khartoum tannery. However, in late 1999 the tanning waste was contained and treated internally in Khartoum Sewage System. The heavy thickets of *Mimosa pigra* are now cleared. This study suggested that the main factor responsible for the vegetational changes in the study area is the human activities of this heavily populated area. This finding is consolidated by Suliman [23] who reported that Mayo village emerged in the past 10 years and had a census of about 44,864 persons; the population of Soba Elmahata area was estimated as 2500 persons, while that of Elsalama area and IdHussein area together were estimated as 8,216 persons. It is worth mentioning that the population has increased greatly in the past few years. The human activities included the felling of trees and shrubs for fuel and charcoal. Moreover, the study area has been cleared for building construction and a large industrial area has been established at the expense of the existing vegetation as shown in Figure (1). Similar population figures were reported by Mohammed [22]. Other human activities such as goat grazing and accidental fires contributed to the elimination of most plant species. Other factors responsible for vegetational changes are the recent climatic changes in the study area. This affected the species diversity and density in the study area, as shown by Figure 3. These climatic effects (Table 4) are in line with Mohammed [22] who reported that the discrepancy in species diversity might be attributed to recent changes in climatic conditions. From the results of chemical analysis of the plants and soil, it is observed that for each of the aforementioned elements, there were no statistically significant differences (5% level) between the concentrations of Ca, Cd, Mg, Zn, and Cr in the two soil depths, indicating a homogeneous spatial distribution of the examined elements between the two soil depths. The concentrations of the elements under examination (Ca, Cd, Cr, K, Mg, and Zn) in the three study sites did not differ significantly (at the 5% level). The element potassium (K) is the lone exception to this generalization, as the F-test revealed a significant difference between sites 1 and 2, as well as between sites 1 and 3. The extremely low variance of site 1 in relation to the other two sites may help to explain this exception. The significance of the F-test between site 1 and the other two sites indicates that it is more likely that site 1 is highly alkaline. Many authors [24, 25, 26] have studied the efficiency of some plants in removing minerals from soils irrigated with tanning and sewage wastes. Proctor and Woodels [27].) and Abdurhman [20] had already recovered high levels of Cr in soils from tanning sites. According to the current study, plant species and soil minerals for the elements Ca and Mg have positive correlations. Plants and soil elements have been found to negatively correlate with other elements, such as Cr and Cd. This is in line with the findings of Hayati et al. [28] in England and Yahia [29] in Sudan, which showed that there is little correlation between an element's uptake by a plant and its concentration in the soil. This is in line with the findings of Srivastava et al. [7] and Alizadeh-Kouskuie et al. [8]. According to a chemical analysis of the study area's soil and plant minerals, tannery wastes and sewage effluents did not significantly pollute the area. This is consistent with research done by Allen [19]), which examined the range of element concentrations in soil and vegetation, as indicated by Table 4. The sewage effluent has been contained and treated in Khartoum Sewage system since its establishment. However, the tanning wastes have not been contained and treated internally by Khartoum sewage system until 1999. So the tanning wastes are partially responsible for the vegetational changes mentioned above.

5. Conclusions

The results of this study indicate that the study area has undergone a number of vegetational changes, including the extinction of 91% of the plant species, an increase in the frequency of *Calotropis procera* and *Prosopis africana*, which indicate deteriorating soil, the emergence of six new species, and no discernible differences in the concentrations of elements between the two soil depths and the three study area sites. The ecological factors that caused these changes were sewage and tanning wastes, human activity, and climatic variations. The study recommended a need for restoration and rehabilitation of the original vegetation in the study area.

Compliance with ethical standards

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Disclosure of conflict of interest

The author declares that here is no conflict of interest.

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