



## CHARACTERIZATION OF DISSOLVED ORGANIC MATTER IN SELECTED WETLANDS FROM NORTHERN NIGERIA



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**Abstract:** The molecular composition of dissolved organic matter (DOM), collected from Baturiya, Nguru, Matara-Uku, Jebba and Lokoja wetlands of the Northern Nigeria were characterized using Fourier Transform Infra-Red (FTIR) and Gas Chromatography-Mass Spectrometry (GC-MS). FTIR results indicated that the DOM of these wetlands contain the phenolic hydroxyl groups, hydroxyl group, conjugated double bond of aromatic family (C=C), amino, amide and free carboxyl groups. The major components identified in all DOM samples analyzed using GC-MS were phenol, 2,4-Bis(1,1-dimethylethyl)phenol, 1-Methyl-4-propan-2-ylbenzene, methyl esters, 2-Myristinoyl pantetheine, 2,2,4-Trimethyl-3-carboxyisopropyl, isobutyl ester, 1,1-Bis(dodecyloxy) hexadecane, Stearic acid hydrazide, 3-Trifluoroacetoxytetradecane, Rhodopin, 2-hydroxy-2-octylsebacic acid, alkenes, alcohols, amines and cyclocompounds. The large carbonyl, phenyl hydroxyl and amine functional groups could explain that DOM from these wetlands might have a strong reactive potential with inorganic and organic pollutants. Phenol hydroxyl groups, conjugated double bonds, amino and carboxylic groups have been implicated for the formation of disinfection by-products like trihalomethane and trihaloacetic acids which are carcinogenic.

**Keywords:** Characterization, dissolved organic matter, FTIR, GC-MS, wetlands

### Introduction

Dissolved organic matter (DOM) is ever-present in all natural waters and is known to play vital roles in the global carbon and nitrogen cycles, (Seitzinger *et al.*, 2002; Lu *et al.*, 2004; Lennon, 2004) the fate, mobility and transformation of contaminants and nutrients, (Ravichandran *et al.*, 2004). It is recognized that dissolved organic matter (DOM) is the principal precursor of disinfection byproducts (DBPs) in water treated with chlorine (Gibert *et al.*, 2013). Trihalomethanes (THMs) and haloacetic acids (HAAs) are the two major groups of DBPs, which are potentially carcinogenic (Lennon, 2004; Kaiser *et al.*, 2001). The substances that compose the DOM have the ability to retain and transport organic and inorganic pollutants in the environment (Ohlenbusch and Frimmel, 2001), and it is the type and nature of the functional groups present, like carboxyl (-COOH), phenol (benzene-OH), alcohol (-CH<sub>2</sub>-OH), and methoxyl (-OCH<sub>3</sub>), that can influence its interaction ability with the different pollutants (Ravichandran, 2004). Thus, there is a great need to further understand the composition, variability and reactivity of dissolved organic matter in the environment.

The array of molecules that make up the DOM and their low concentration in water systems make their characterization complex (Kaiser *et al.*, 2001; Rochelle-Newall and Fisher, 2002). Therefore, to facilitate their study it is often necessary to isolate and concentrate them by methods such as reverse osmosis, evaporation under reduced pressure, or freeze-drying (Luet *et al.*, 2004; Kaiser *et al.*, 2001; Puddu *et al.*, 2000), and then fractionate them according to their polarity using fractionating resins like Amberlite XAD or by molecular size through techniques like ultrafiltration, ultracentrifugation, and high performance size exclusion chromatography (Marschner and Kalbitz, 2003; Hedges, 2002). The recording of FTIR spectra of freeze dried water samples is another possibility to investigate the DOM composition of water sample (Benke *et al.*, 1998). This was also done by Capriel (1997) with bulk soil. When DOM is analyzed by <sup>13</sup>C-NMR, Fourier Transform Infra-Red (FTIR), fluorescence, UV-Vis, and Gas Chromatography-Mass Spectrometry (GC-MS) techniques, they provide information related to the components of the DOM, and these are used as its fingerprints (Ohlenbusch and Frimmel, 2001; Aluwihare and Repeta, 1999), characteristics

that allow predicting its behaviour in the environment and its effect on a variety of pollutants (Kim *et al.*, 2003).

In recent years research work related with DOM has increased considerably, because of its effect of retention and transport of organic and inorganic pollutants in different natural substrates (Leenheer *et al.*, 2004; Peuravuori, 2005).

In Nigeria there are very few studies aimed at the characterization of basins of great significance to agriculture, such as the wetlands, lakes and Rivers. The Hadejia-Nuru, Baturiya, Matara-Uku, Lokoja and Jebba wetlands in Northern Nigeria have not been characterised and this call for concern. Still, there is little information about the DOM in the wetlands of Northern Nigeria, though their characterization is of great importance given that, it can change the fate of the pollutants present in the water.

The Lokoja and Jebba wetlands (Fig. 2) are part of the Lower Kaduna-Middle Niger wetlands which are located on the extensive floodplain of the mid-section of River Niger (in Nigeria) and the lower course of one of its main tributary, River Kaduna. The wetlands extend from Jebba (9°00'N 4°50'E) to Baro (8°35'N 6°25'E) along the Niger, and from Wuya Bridge on the River Kaduna, along the Jebba – Bida (9°00'N 6°00'E) road downstream to Pategi (8°45'N 5°37'E) on the south bank of the Niger. The Hadejia-Nguru wetlands (Fig. 1) are located between latitudes 12°15'N and 12°55'N, and between longitudes 10°E and 11°E in the Sudan savanna of Nigeria, Baturiya wetland (Fig. 3) occupies an area of approximately 101,095 ha and is located between latitude 12°31'N and longitudes 010°29'E. Over half a million people depend upon the lake and the surrounding wetlands for their livelihoods, especially for water supply. Majority of the people living around the lake are either fishermen, or processors and marketers of fish. The land around the lake is irrigated in both dry and wet season for vegetables and rice production. The lake is also used for livestock grazing, recreation and research, since it has a large biodiversity of birds, insects, wildlife and flowering plants. In fact the lake and the surrounding wetlands is a particularly good representative of natural wetlands, which embodies all the diverse flora and fauna at both the Sahel and the Sudan savannah in a single location; hence the area is important for ecotourism. Hadejia-Nguru wetlands are designated as a Ramsar site by the Ramsar Convention; it is presently the only Ramsar site in Nigeria. All this confirms the importance

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of evaluating the presence of DOM and its characteristics, as well as the effect that it can have on the pollutants present in the wetlands.

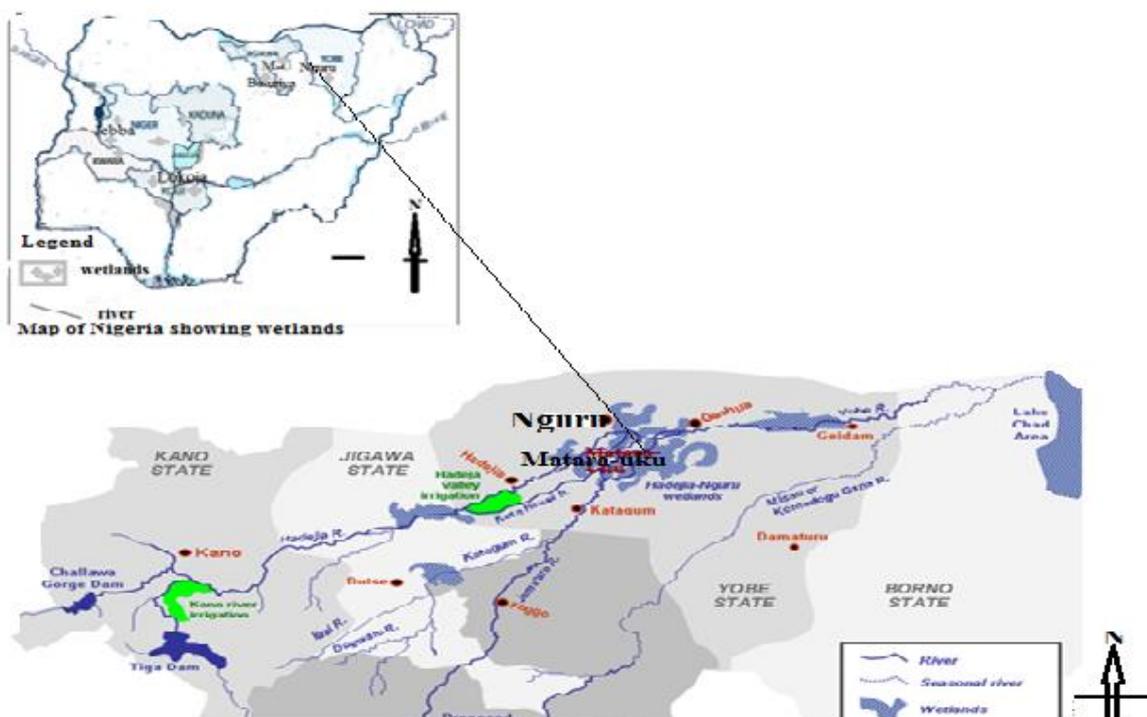


Fig. 1: Hadejia-Nguru wetlands showing Nguru and Matara-Uku wetlands

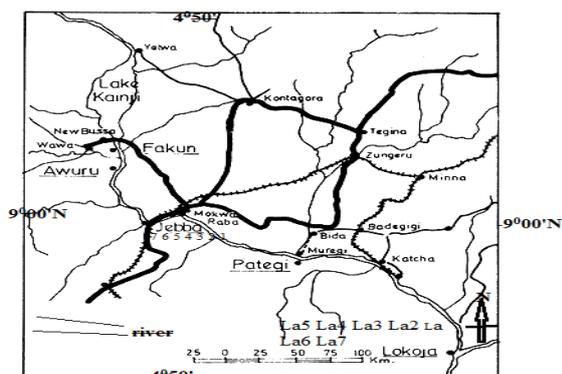


Fig. 2: Map of Jebba and Lokoja wetlands showing sampling sites

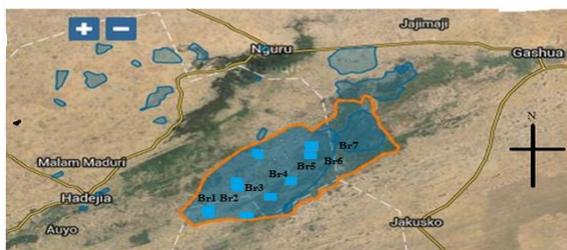


Fig. 3: Map of Baturiya wetlands showing sampling sites

The aim of this study is to characterize the DOM and then compare the structural and chemical characteristics of the DOM from the various wetlands. The study involves the use of FTIR and GC-MS techniques, which to the best of our knowledge have not been used in the characterization of DOM in these wetlands. This will provide new information on the characteristics of DOM from different sources. Such

knowledge can assist in our understanding of the composition and chemical properties of DOM samples in aqueous environments.

### Material and Methods

#### Sampling and sample treatment

Surface-water samples were collected using standard water sampling procedure in 2 L white, low-density polyethylene bottles from 35 sites spread across five sampling locations during the early part of the dry season and the wet season. In Jebba wetland samples were collected from sites J1, J2, J3, J4, J5, J6 and J7, in Matara-Uku wetland samples were collected from sites M1, M2, M3, M4, M5, M6 and M7, while in Baturiya wetland sites Br1, Br2, Br3, Br4, Br5, Br6 and Br7 were sampled. Likewise, in Lokoja wetlands sites L1, L2, L3, L4, L5, L6 and L7 were also sampled. Similarly, samples were also collected from sites N1, N2, N3, N4, N5, N6 and N7 in Nguru wetland. Composite samples were collected 200 m apart from each sampling location. The samples were kept at about 4°C and taken to the laboratory for analysis. The bottles were washed by soaking in 0.5 molL<sup>-1</sup> HCl followed by 0.1 molL<sup>-1</sup> NaOH for 24 h each. Six (6) L of water samples from each sampling location were filtered through precombusted (470°C for 4 h) 0.7-µm GF/F glass fiber filters (Whatman International), passed through Dowex 50 W x 8 column, rotary evaporated and freeze-dried for FTIR and GC-MS analyses (Lu *et al.*, 2003).

#### Chemicals and reagents used

Hydrochloric acid, sodium hydroxide, dichloromethane and Dowex 50 W x 8 column were purchased from BDH, England. 0.7-µm GF/F glass fiber filters (Whatman International) were obtained from sigma-aldrich and distilled deionised water was used.

**Characterization of DOM**

The freeze-dried DOM samples were analyzed for their structural and chemical characteristics. Fourier Transform Infrared (FTIR) spectrometer and GC-MS (Agilent Technologies) were used for the characterization of DOM. The spectra resolution was 8 cm<sup>-1</sup> and 32 scans were averaged for FTIR. GC-MS was carried out with Agilent 7890-A having an MS detector 5975-C, ionization for MS is electron ionization. Mass analyzer was Quadrupole. The peaks were analyzed using data analysis software NIST-2011. The analysis was carried out in column HP- 5 ms, dimensions- 30 m length, 0.25 mm ID.0.25 μm film thickness. The initial temperature ramp was maintained at 40°C, for 2 min. At the end the temperature ramp was 310°C and hold time was 10 min. The rate of temperature ramp was 10°C/min. The experiment was programmed with total run time 41 min, helium was used as a carrier gas at a constant flow rate of 1.0 ml/min, split less flow 1 ml/min. Injection volume was 1 μl with scan mass range 30 m/z – 600 m/z having positive polarity.

**Results and Discussion**

**FTIR spectra of DOM from wetlands**

The results of the FTIR analysis of the DOM for both the wet and dry seasons are presented in Figs. 4 and 5 for the five sampling locations. The spectra show agreement among the spectroscopic profiles of the different DOM, indicating that

the structures and functional groups are similar. The main signals are seen in the ranges between 3312-3350 cm<sup>-1</sup> corresponding to the H-bonded of OH stretching of carboxyl, phenol and alcohols. This band may also be attributed to stretching vibration of N-H in amines and amides; stronger intensity signals ranging between 1618 and 1640 cm<sup>-1</sup> are attributed to the C=O stretching of COO<sup>-</sup>, ketonic C=O, and aromatic C=C; signals ranging from 1400 -1454 cm<sup>-1</sup> are attributed to C-H of carbohydrates; and strong signals ranging from 1000-1068 cm<sup>-1</sup> are assigned to the C-O group of polysaccharides; and strong signals between 1313 and 1383 cm<sup>-1</sup> are attributed to polyhydroxylated phenols and C-N stretching of aromatic amines. The IR spectra obtained for the DOM from the five sampling locations agree with the IR spectrum of humic acids (Shin and Monsallier, 1999). Lower intensity signals ranging from 1722 to 1737 cm<sup>-1</sup> are found in J, Br, Ng and M (Figs. 4 and 5) corresponding to carboxylic and carbonyl stretching vibrations. More so, lower intensity signals are also observed between 1566 and 1581 cm<sup>-1</sup>, which correspond to aromatic C=C, N-H bending and C=N stretching at sites J, L, and Br (Figs. 4 and 5). In the spectra profile of all the wetlands studied, there were also minor peaks at 2065, 2080, 2087, 2091, 2120, 2542, 2549, 2851 and 2,918 cm<sup>-1</sup>, which were ascribed to the C-H stretching of methyl and methylene groups of aliphatic chains.

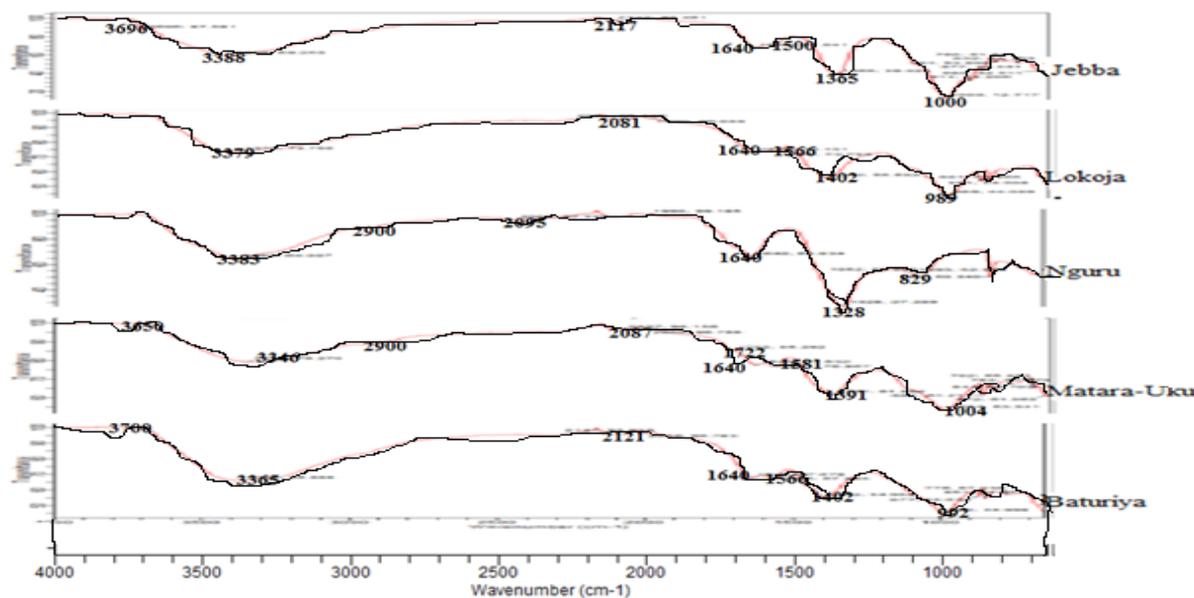


Fig. 4:FTIR spectra of DOM obtained from wetlands during the wet season

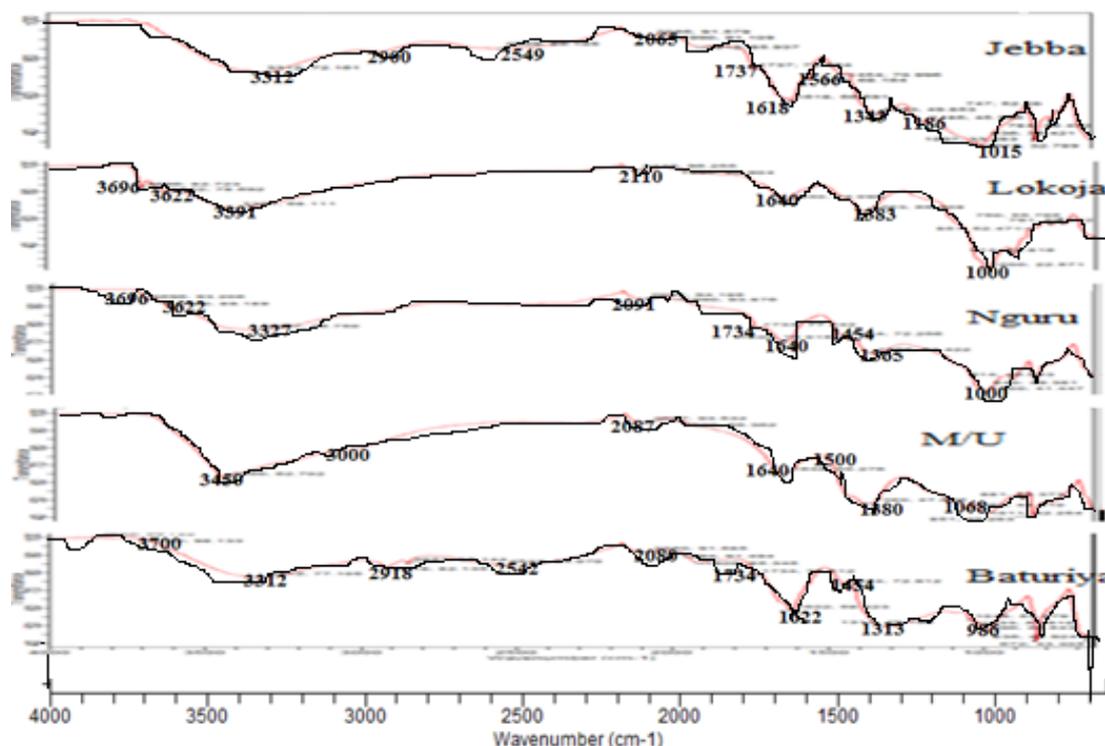


Fig. 5: FTIR spectra of DOM obtained from wetlands during the dry season

These results indicated that the DOM of these wetlands contain the phenolic hydroxyl groups, hydroxyl group, conjugated double bond of aromatic family (C=C), amino group and free carboxyl groups. However, phenolic hydroxyl and conjugated double bonds have been implicated for the production of trihalomethane (THM) and trihaloacetic acids. It had been reported that some aromatic halogenated DBPs can decompose to form haloacetic acids (HAAs) and THM. From the IR spectra of J and Br (Fig. 5) in the dry season, weak signals were observed at 2918 and 2851  $\text{cm}^{-1}$ . These bands which revealed the presence of aliphatic chain; at 2918  $\text{cm}^{-1}$  with a small shoulder (C-H asymmetric stretching in  $\text{CH}_2$  and  $\text{CH}_3$ ) and at 2851  $\text{cm}^{-1}$  (C-H symmetric stretching in  $\text{CH}_2$ ) were absent in the spectrum of L (Fig. 5). This could be due to photodegradation of these compounds, as some parts of the Br, N, M and J sampled were covered with vegetation. However, these peaks were also seen during the wet season in the spectra of DOM from sites J, N and M (Fig. 4). Likewise, signals were observed at 1737, 1734 and 1734  $\text{cm}^{-1}$  in J, Br and N (Fig. 4), respectively; these signals are absent in L and M (Fig. 5) during the dry season. This may be attributed to the binding between metals and  $\text{COO}^-$  group. But in the wet season, this peak was observed in M (Fig. 4). Also, a weak peak was seen in the spectrum of DOM from J (Fig. 5), at 1566  $\text{cm}^{-1}$ , this peak is absent in the other sampling locations during the dry season, though it was observed in the IR profiles of DOM from sites L, M and Br (Fig. 4) during the wet season. This may be attributed to the inflow of runoff into these wetlands. In addition, the spectrum profile of DOM from site M (Figs. 4 and 5) does not shows any peak at 1402  $\text{cm}^{-1}$  in both the wet and the dry seasons. This peak which corresponds to the C-H of carbohydrates was recorded in the spectra profiles from sites L, Br, J and N (Fig. 4). The bands 3696, 3622 and 3700  $\text{cm}^{-1}$  (Figs. 4 and 5) are all related to amides and amines which are characteristics of proteins and amino sugars (Leenheer and Rostand, 2007), thus explaining

the high nitrogen content previously determined in DOM from Lokoja, Baturiya, Matara-Uku and Jebba wetlands. The phenolic hydroxyl and conjugated double bonds are responsible for the disinfection byproducts of trichloromethanes and trichloroacetic acid formations while amino and carboxyl groups are the main precursors for the formation of dichloroacetic acids and dihalomethanes (Angzhen *et al.*, 2014).

#### GC-MS analysis of DOM from wetlands

The GC-MS chromatogram of the DOM from the five sampling locations showed the presence of sixty one (61) compounds (Figs. 6 to 15). The assignment of peaks were based on the comparison of mass spectra with the spectral library of National Institute of standard and Technology (NIST 11). The X-axis represents the retention time of each compound identified in minutes while the Y-axis represents the intensity. Tables 2 – 11 show the retention time, name of the compounds and their molecular weight. The 61 different compounds identified for GC-MS analyses show evidence for the presence of phenol derivatives, carboxylic acids, unsaturated esters, conjugated alkenes, haloalkanes, ethers, alcohols alkanes, alkanal, amines and ketones in the DOM samples.

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**Table 1:** Summarised FTIR Spectra of Dissolved Organic Matter from Wetlands

Wave number (cm <sup>-1</sup> )	region (cm <sup>-1</sup> )	Vibrational Assig.	functional group
3321(J), 3450(M) 3391(L), 3312(Br) 3327(N)	3500-3200	alcohol, phenols 1°, 2° amines, amides	O-H N-H
2900(J), 2900(M) 2900(L), 2918(Br), 2900(N)	3000-2850	alkanes	C-H
1618(J), 1640(M) 1640(L), 1622(Br), 1640(N)	1650-1580	carbonyl, 1° amines alkenes	C=O -C=C-
1566(J), 1581(M) 1566(L), 1566(Br), 1500(N)	1650-1450	aromatics	C-C
1454(J), 1450(M), 1402(L), 1454(Br), 1454(N)	1454-1400	Carbohydrates	C-O
1343(J), 1380(M), 1383(L), 1313(Br), 1365(N)	1383-1313	Polyhydroxylated phenols, C-N stretching of aromatic amines	C-N
1186(J), 1100(M) 1100(L), 1100(Br) 1100(N)	1250-1020	aliphatic amines	C-N
1037(J), 1068(M), 1010(L), 1048(Br), 1000(N)	1068-1000	Polysaccharides	-C-O
836(J), 881(M) 851(L), 836(Br) 840(N)	840-690	aromatic disubstituted	C-H

J= Jabba, M= Mataara-Uku, L= Lokoja, Br= Baturiya, N= Nguru

**Table 2** Identified Compounds in Jebba Wetlands During the Wet Season

S/N	t <sub>R</sub> (min)	Name of Compound	Molecular Weight
1	17.962	2-Methyldecane	156
2	18.331	2,6-dimethyldecane	170
3	20.907	(E)-2-Dodecene	168
4	30.255	1-Dodecanol	168
5	36.367	1-Hexadecanol	224
6	39.454	Cyclopropanebutanoic acid, 2-[[[2-[[2-(2-pentylcyclopropyl)- methyl]cyclopropyl]methyl]cyclo- propyl]methyl]-, methyl ester	334

**Table 3** Identified Compounds in Lokoja Wetlands During the Wet Season

S/N	t <sub>R</sub> (min)	Name of Compound	Molecular Weight
1.	13.115	Phenol	94
2.	17.577	2-Myristinoyl Pantetheine	484
3.	20.852	1,1-Bis(dodecyloxy)hexadecane	440
4.	27.655	3-Trifluoroacetoxytetradecane	196
5.	30.192	9-Hexadecanoic acid	236
6.	31.355	2,4-Bis(1,1-dimethylethyl)phenol	206
7.	33.704	2-Methylhexadecan-1-ol	238
8.	38.205	17-Pentatriacontene	490
9.	39.438	Methylhexadecanoate	270

**Table 4** Identified Compounds in Nguru Wetlands During the Wet Season

S/N	t <sub>R</sub> (min)	Name of Compound	Molecular Weight
1.	13.115	Phenol	94
2.	17.922	2-Myristinoyl Pantetheine	484
3.	18.315	2,6,10-Trimethyltetradecane	225
4.	20.884	1,1-Bis(dodecyloxy)hexadecane	440
5.	27.679	2-Methylhexadecan-1-ol	238
6.	31.355	2,4-Bis(1,1-dimethylethyl)phenol	206
7.	33.735	2,2,4-Trimethyl-3-carboxyisopropyl-, isobutyl ester	243
8.	37.985	3-acetoxy-7,8-epoxylanostan-11-ol	484
9.	38.213	17-Pentatriacontene	490
10.	39.446	Cyclopropanebutanoic acid, 2-[[[2-[[2-(2- pentylcyclopropyl) methyl] cyclopropyl]- methyl] cyclopropyl]methyl]-, methyl ester	334

**Table 5.** Identified Compounds in Mataara-Uku Wetlands During the Wet Season

S/N	t <sub>R</sub> (min)	Name of Compound	molecular weight
1.	13.115	Phenol	94
2.	17.922	3,7,11-Trimethyldecane-1-ol	210
3.	18.307	2,6,10-Trimethyltetradecane	225
4.	20.876	(Z)-3-Dodecene	168
5.	30.208	1,1-Bis(dodecyloxy)hexadecane	440
6.	31.371	2,4-Bis(1,1-dimethylethyl)phenol	206
7.	33.350	Globuolol	222
8.	33.719	2-Methylhexadecan-1-ol	238
9.	38.213	(Z)-1-[2-[(Z)-octadec-9-enoxy]- ethoxy]oc-tadec-9-ene	562
10.	39.438	methyl 3-hydroxy-2-tetradecylocta- Decanoate	492

**Table 6.** Identified Compounds in Baturiya Wetlands During the Wet Season

S/N	t <sub>R</sub> (min)	Name of Compound	Molecular Weight
1.	18.417	Methyl-2-octylcyclopropane- Dodecanoate	366
2.	20.844	(Z)-3-Dodecene	168
3.	27.647	3-Trifluoroacetoxytetradecane	196
4.	31.355	2,3-dihydroxypropyl-2,4-Bis- (1,1-dimethylethyl)phenol	206
5.	33.138	(-)-Spathuleno	220
6.	33.696	Behenic alcohol Docosanol	308
7.	36.280	5-Octadecenal	252
8.	37.293	Methyltetradecanoate	242
9.	38.205	17-Pentatriacontene	490
10.	39.265	Rhodopin ol	536
11.	39.430	Methylhexadecanoate	270
12.	40.577	Methyl octadec-10-enoate	296
13.	40.718	Cyclopropanebutanoic acid, 2-[[[2-[[2-(2-pentylcyclopropyl)- methyl]cyclopropyl]methyl]cyclo- propyl]methyl]-, methyl ester	334

**Table 7.** Identified Compounds in Jebba Wetlands During the Dry Season

S/N	t <sub>R</sub> (min)	Name Of Compound	Molecular Weight
1.	18.339	2,6-dimethyldecane	170
2.	30.263	1-Dodecanol	168
3.	36.374	1-Hexadecanol	224
4.	39.462	methyl 3-hydroxy-2-tetra- Decyloctadecanoate	492

**Table 8.** Identified compounds in Lokoja wetlands during the dry season

S/N	t <sub>R</sub> (min)	Name of Compound	Molecular weight
1.	13.115	Phenol	94
2.	14.725	2-Ethylhexan-1-ol	112
3.	17.922	3,7,11-Trimethyldodecan-1-ol	210
4.	18.315	2,6-dimethyldecane	170
5.	20.876	(Z)-3-Dodecene	168
6.	27.671	2-Methylhexadecan-1-ol	238
7.	31.355	2,4-Bis(1,1-dimethylethyl)phenol	206
8.	31.748	Methyl-10-methylundecanoate	214
9.	33.719	2-Methylhexadecan-1-ol	238
10.	36.312	5-Octadecenal	252
11.	37.301	Methyl tetradecanoate	242
12.	38.213	17-Pentatriacontene	490
13.	39.438	Methyl -14-methylpentadecanoate	270
14.	40.548	Rhodopin	536
15.	40.718	Oleic acid, eicosyl ester	562

**Table 9.** Identified compounds in Nguru Wetlands during the dry season

S/N	t <sub>R</sub> (min)	Name of Compound	Molecular weight
1.	17.915	4-Methyl decane	156
2.	18.300	3,6-Dimethyl decane	170
3.	18.425	Stearic acid hydroxide	298
4.	20.868	3-Dodecene	168
5.	31.363	2,4-Bis(1,1-dimethylethyl)phenol	206
6.	39.438	Methylhexadecanoate	270
7.	40.577	Methyl-10-octadecenoate	296
8.	40.719	Dodecanoic acid, 1a,2,5,5a-, 6,9,10,10a-,octahydro-5a-hydroxy-4- (hydroxymethyl)-1,1,7,9-tetramethyl-6,11- dioxo-1H-2,8a-methyl	528

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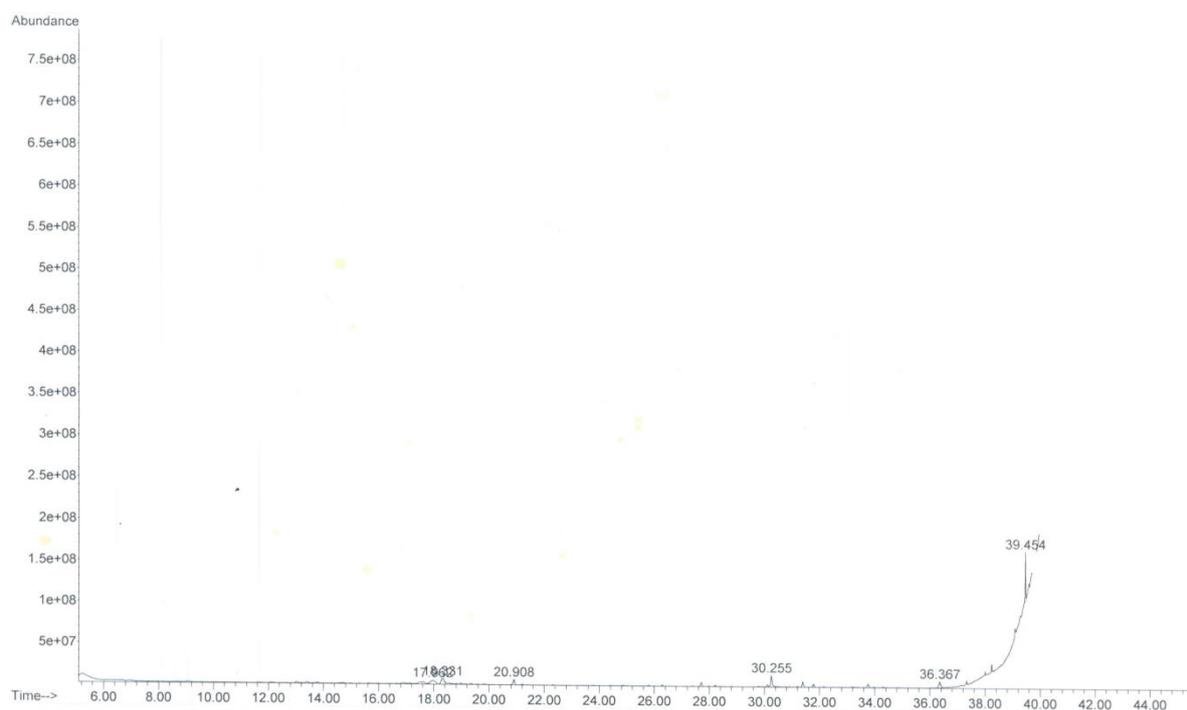
**Table 10.** Identified compounds in Matara-Uku wetlands during the dry season

S/N	t <sub>R</sub> (min)	Name of Compound	Molecular weight
1.	13.304	Methyl-9-Octadecen-12-ynoate	292
2.	14.278	1-methyl-4-propan-2-ylbenzene	134
3.	14.686	2-Ethyl hexan-1-ol	112
4.	17.883	2-Methyl decane	141
5.	18.276	2,6-Dimethyldecane	170
6.	18.425	2-Hydroxy-2-octylsebacic acid	312
7.	20.845	7-Tetradecene	196
8.	28.975	?-ylangene	204
9.	31.347	2,4-Bis(1,1-dimethylethyl)phenol	206
10.	33.696	2-Methyl hexadecane-1-ol	238
11.	36.288	5-Octadecenal	252
12.	37.042	3-Ethyl-5-(2-ethylbutyl) octadecane	364
13.	38.205	17-Pentatriacontene	490
14.	39.43	Methylhexadecanoate	270
15.	40.577	Rhodopin	536

**Table 11.** Identified compounds in Baturiya wetlands during the wet season

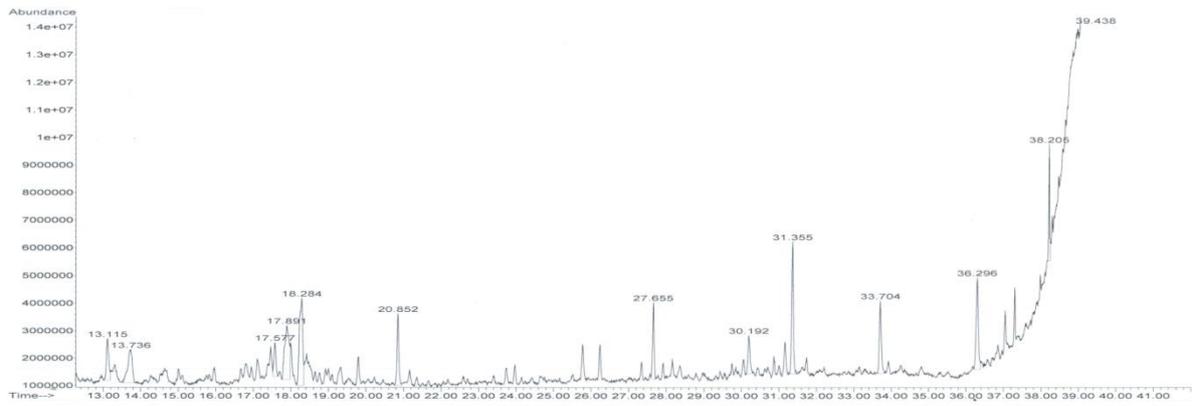
S/N	t <sub>R</sub> (min)	Name of Compound	Molecular weight
1.	10.201	3,6,6-Trimethyl bicyclo[3.1.1]hept-2-ene	121
2.	12.039	Z,Z-4,6,9-Nonadecatriene	262
3.	14.348	cis-5,8,11-Eicosapentaenoic acid	292
4.	15.668	1-Methyl-4-(1-methylethylidene)-Cyclohexene	136
5.	27.027	alfa. Copaene	204
6.	28.386	Caryophyllene	204
7.	29.446	Humulene	204
8.	31.355	2,4-Bis(1,1-dimethylethyl)phenol	206
9.	35.338	2-[4-methyl-6-(2,6,6-trimethylcyclohex-1-enyl)hexa-1,3,5-trienyl]cyclohex-1-en-1-carboxaldehyde	324
10.	36.131	? bisabolol	222
11.	31.630	<u>1,2,4a,5,8,8a-Hexahydro-4,7-dimethyl-1-(1-methylethyl) naphthalene</u>	204
12.	39.438	Methyl hexadecanoate	270

Chromatograms of the DOM samples are shown in Figs. 6–15. Some lignin-derived phenolic compounds are observed. These compounds mostly originate from the cleavage of the  $\beta$ -O-4 bonds from lignin-derived moieties. The major components identified in all DOM samples were phenol, 2,4-Bis(1,1-dimethylethyl)phenol, 1-Methyl-4-propan-2-ylbenzene (p-Cymene), methyl esters, 2-Myristynoyl pantetheine, 2,2,4-Trimethyl-3-carboxyisopropyl, isobutyl ester, 1,1-Bis(dodecyloxy) hexadecane, Stearic acid hydrazide, 3-Trifluoroacetoxytetradecane, aldehydes, Rhodopin, 2-hydroxy-2-octylsebacic acid, 3-acetoxy-7,8-epoxylanostan-11-ol, alkenes, alcohols and cyclocompounds. The presence of methyl esters in the studied DOM samples suggests that these samples may contain lignin-derived moieties, which have been oxidized at the  $\alpha$ -carbon of the side chain of the lignin subunit. Lignin polymers may be attacked by microbial enzymes which selectively oxidize the  $\alpha$ -carbon in the side-chain (Crawford, 1981).

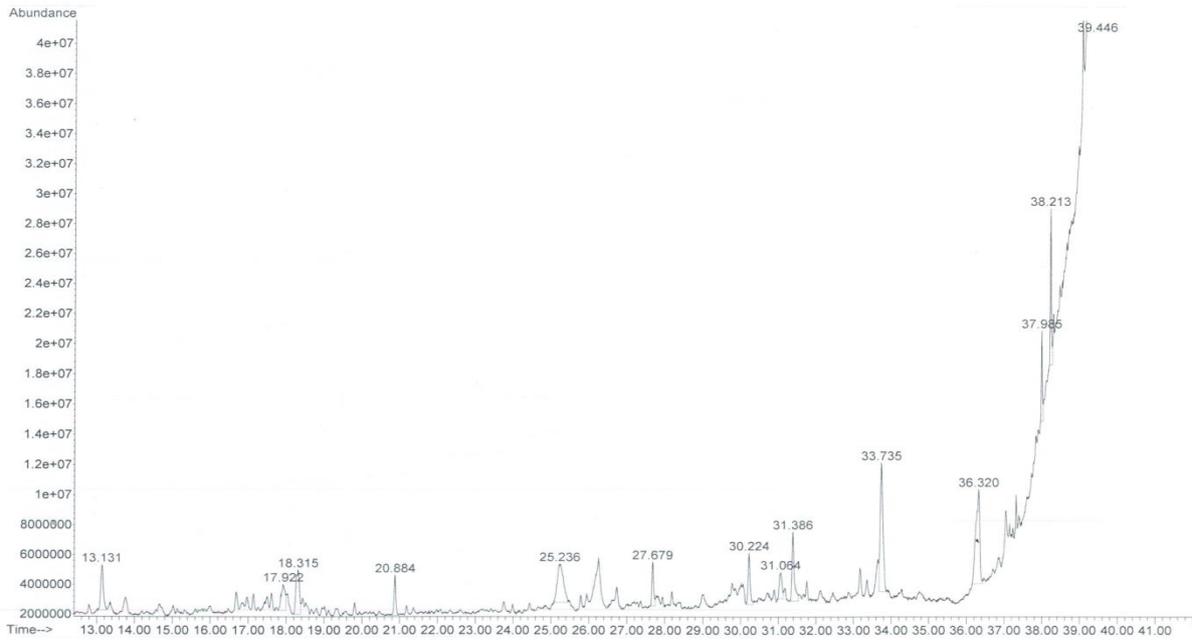


**Fig. 6:** Chromatogram of DOM from Jebba wetlands during the wet season

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**Fig. 7:** Chromatogram of DOM from Lokoja wetlands during the wet season



**Fig. 8:** Chromatogram of DOM from Nguru wetlands during the wet season

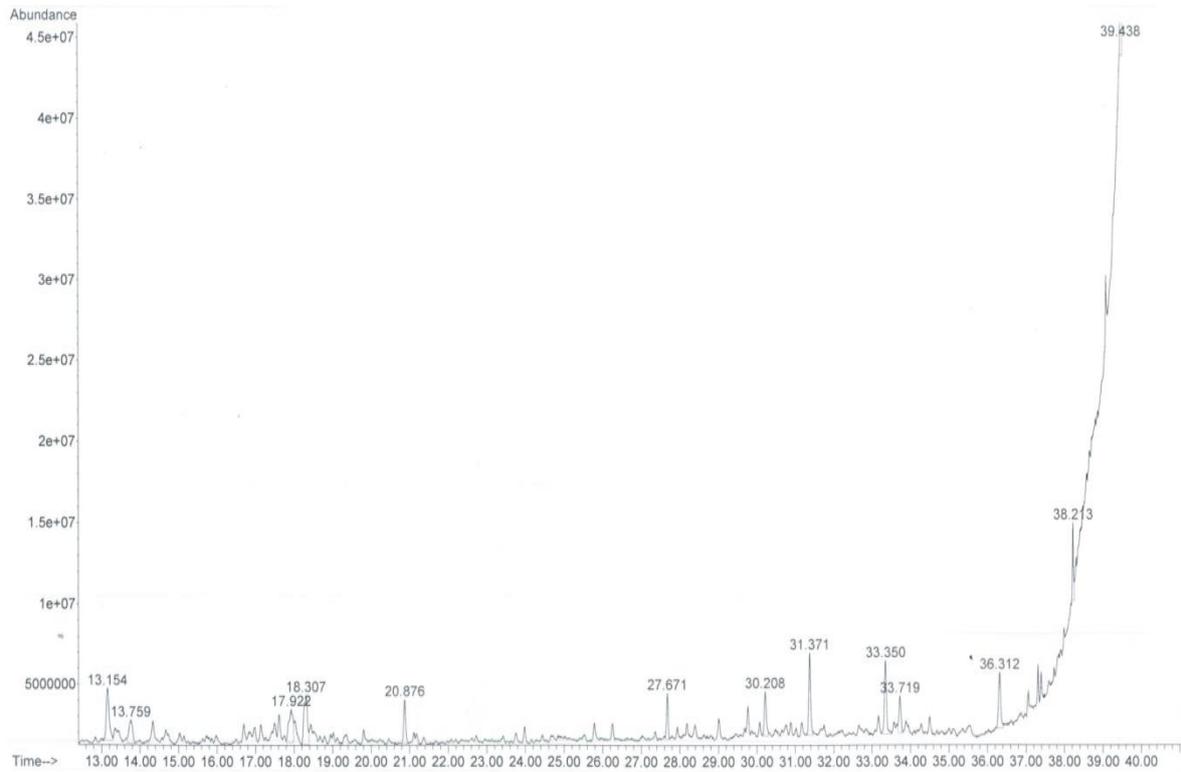


Fig. 9: Chromatogram of DOM from Matara-Uku wetlands during the wet season

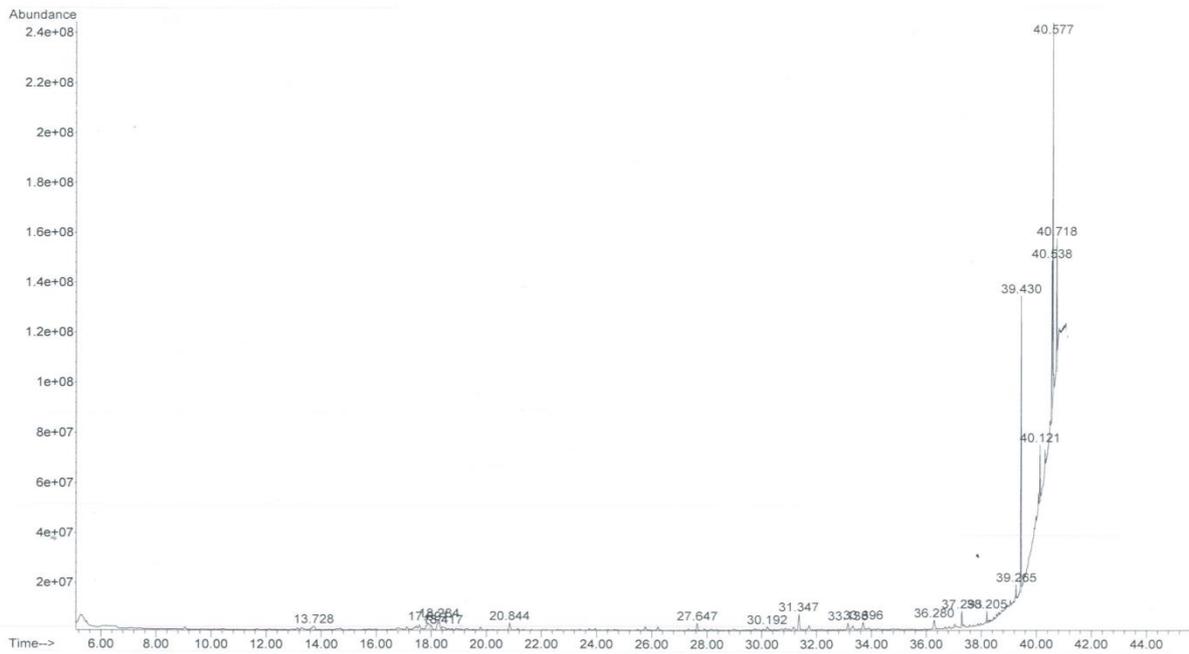
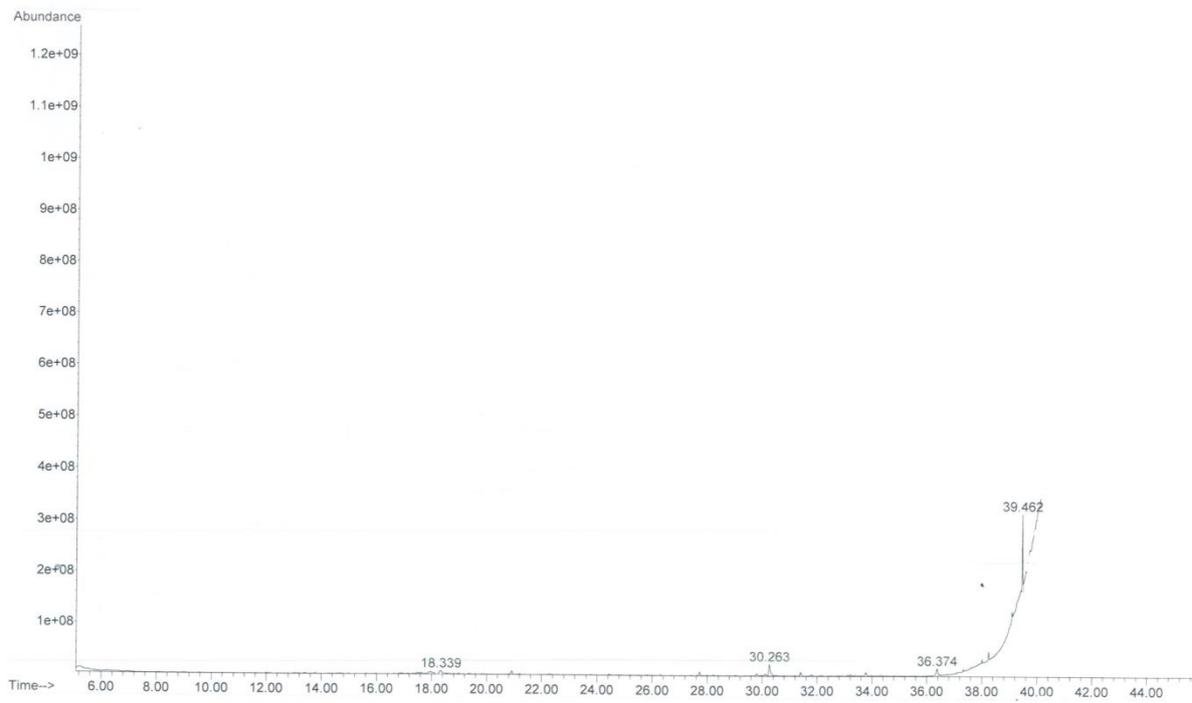
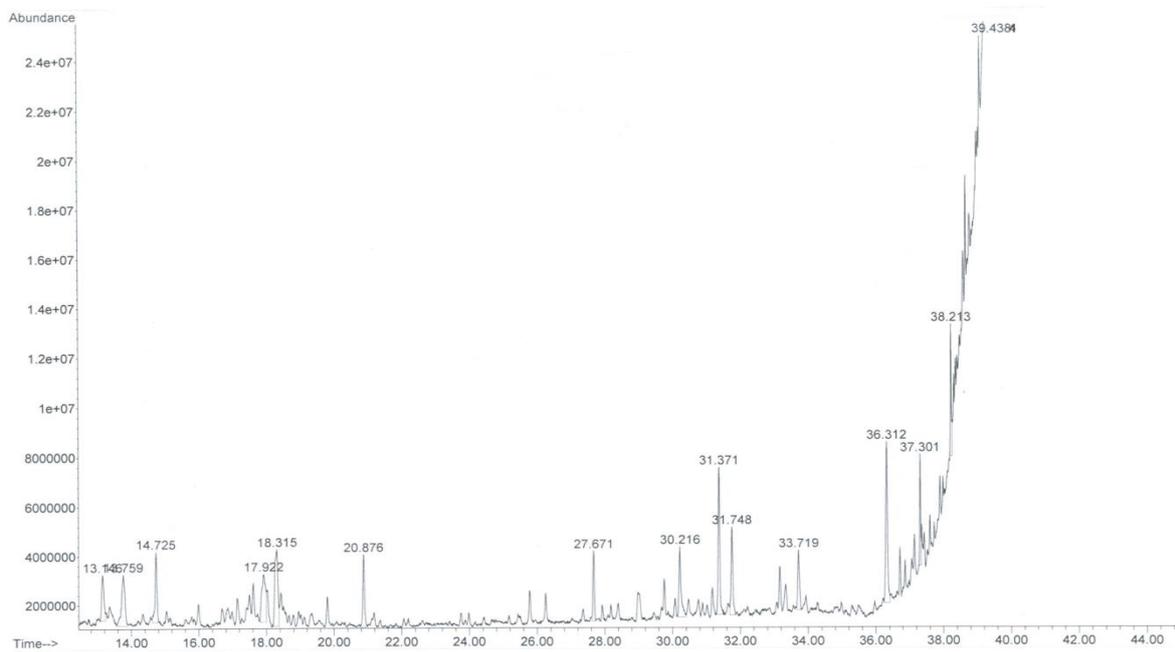


Fig. 10: Chromatogram of DOM from Baturiya wetlands during the wet season

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**Fig. 11:** Chromatogram of DOM from Jebba wetlands during the dry season



**Fig. 12:** Chromatogram of DOM from Lokoja wetlands during the dry season

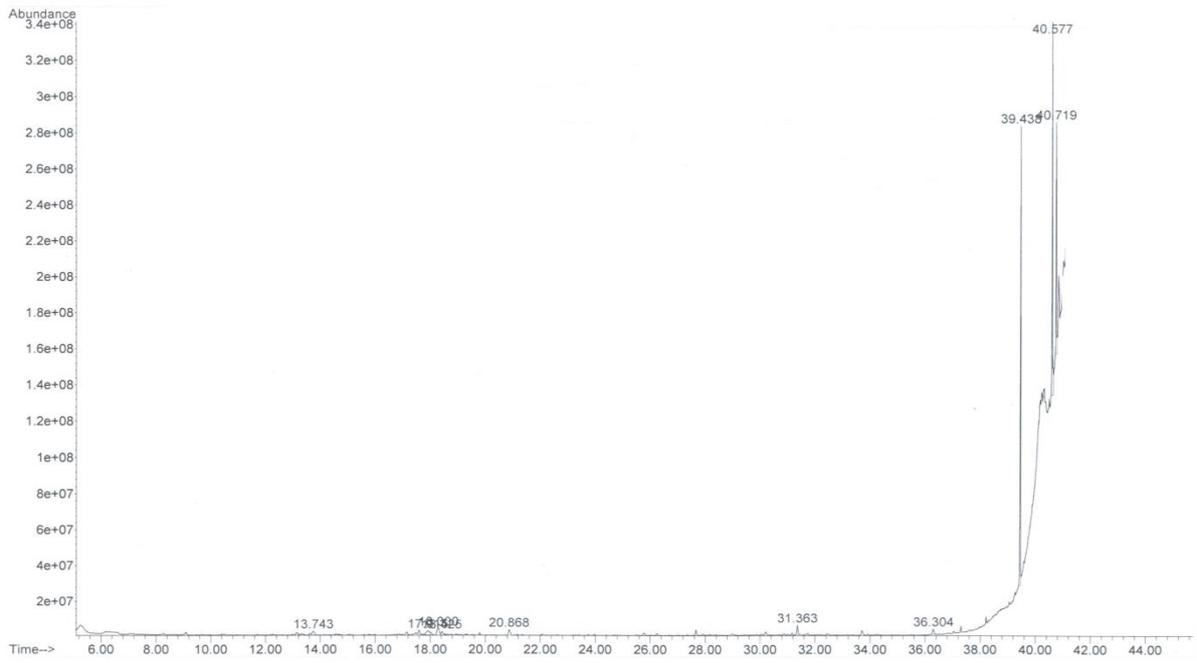


Fig. 13: Chromatogram of DOM from Nguru wetlands during the dry season

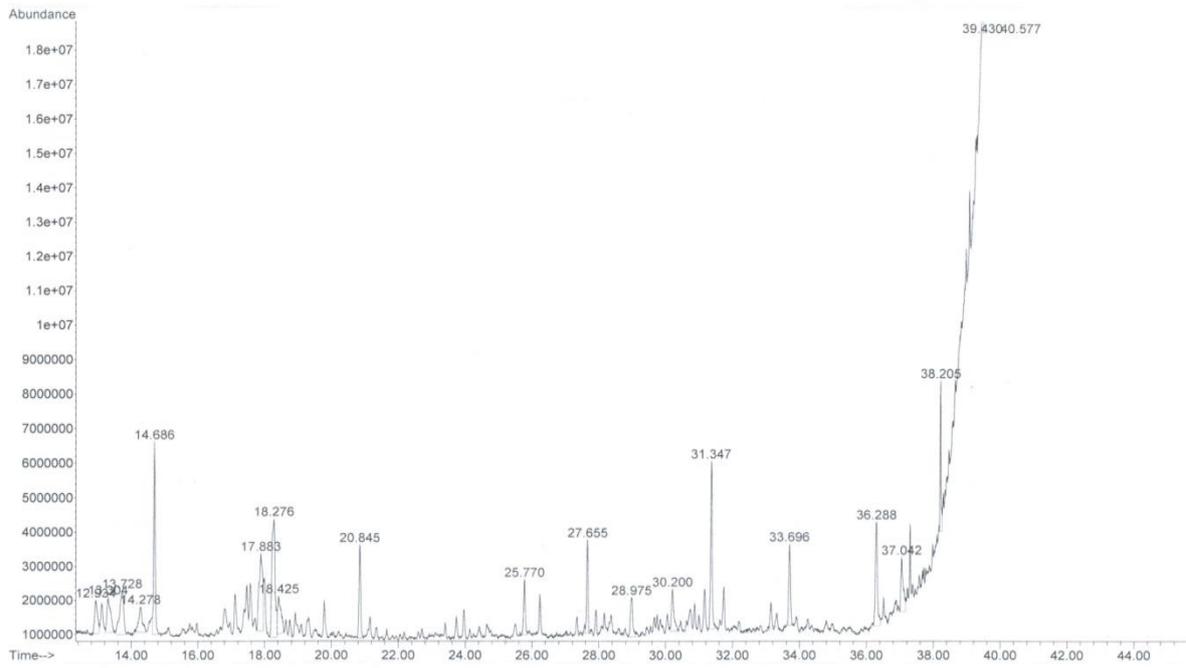


Fig. 14: Chromatogram of DOM from Matara-Uku wetlands during the dry season

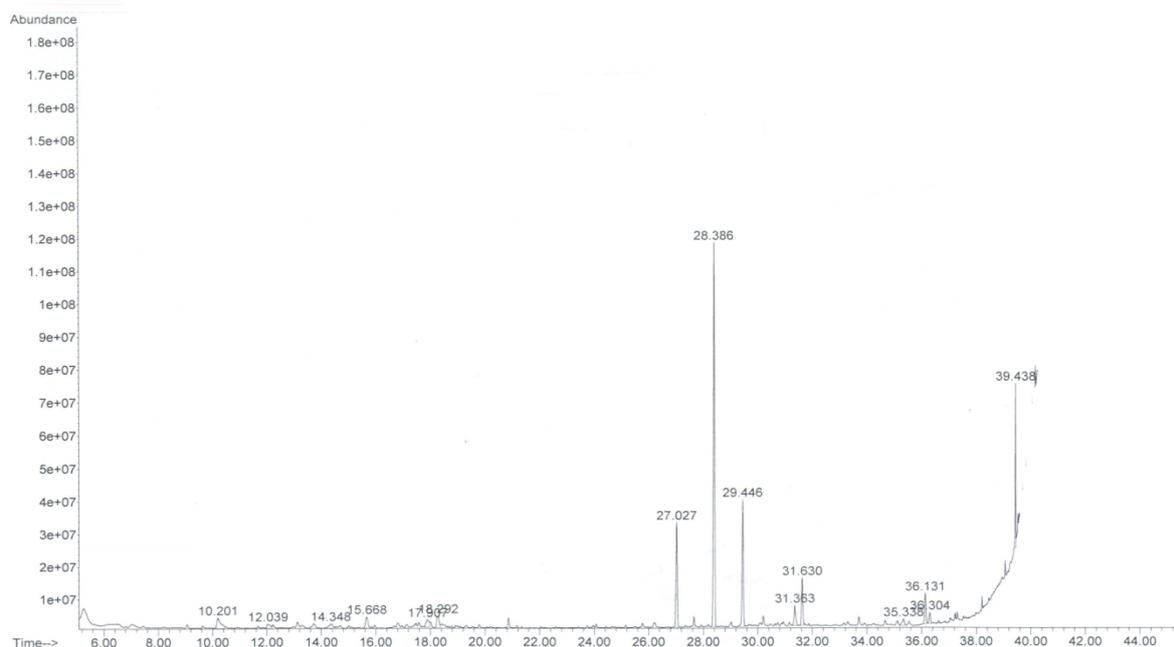


Fig. 15: Chromatogram of DOM from Baturiya wetlands during the dry season

2,4-Bis(1,1-dimethylethyl)phenol, which have been related to some extent to the presence of algal polyphenolic macromolecules (Van Heemst *et al.*, 1996) and proteinaceous organic matter (Van Heemst *et al.*, 1999), were recorded in the spectra of these DOM samples. Therefore, the contribution of polyphenolic macromolecules from non-lignin moieties to DOM in the Northern Nigeria Wetlands is significant.

Dissolved organic-matter (DOM) molecules contain functional groups capable of complexing inorganic and organic pollutants. This is a potential risk as these pollutants are taken up by plants and consumed by man.

### Conclusion

The infrared spectrum showed the structural composition of the DOM present in the wetlands. These results indicate that the DOM of these wetlands contain the phenolic hydroxyl groups, hydroxyl group, conjugated double bond of aromatic family (C=C), amino, amide and free carboxyl groups. The major components identified in all DOM samples analyzed using GC-MS were phenol, 2,4-Bis(1,1-dimethylethyl)phenol, 1-Methyl-4-propan-2-ylbenzene (p-Cymene), methyl esters, 2-Myristinoyl pantetheine, 2,2,4-Trimethyl-3-carboxyisopropyl, isobutyl ester, 1,1-Bis(dodecyloxy) hexadecane, Stearic acid hydrazide, 3-Trifluoroacetoxytetradecane aldehydes, Rhodopin, 2-hydroxy-2-octylsebacic acid, alkenes, alcohols, amines and cyclocompounds. It was observed that these wetlands contain carbonyl, phenyl hydroxyl and amino functional groups which indicate that dissolved organic matter (DOM) from these wetlands have a strong reactive potential with inorganic and organic pollutants. These functional groups have been implicated for the formation of disinfectant by-products like trihalomethane and trihaloacetic acids which are carcinogenic.

### Competing Interests

Authors have declared that no competing interests exist.

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