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Impact of Dredging on the Sediment Quality of Igbedi Creek, Upper Nun River in Central Niger Delta, Nigeria

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Abstract: *The impact of dredging on the sediment quality of Igbedi Creek, upper Nun River in central Niger Delta was investigated from June 2009 to May 2011. Two locations – Ogobiri (Dredged Location) and Agoro-Gbene (Un-dredged Location) were studied. For the purpose of this study, the selected dredged and non-dredged sites were divided into stations: Ogobiri –* OGO_1DA*=Dredged Area,* $OGO_{1\&2}DS$*=Downstream,* $OGO_{1\&2}US$*=Upstream; Agoro-gbene –* AGO_1DS*=Downstream,* AGO_1MD*=Midstream,* AGO_1US*=Upstream. Physico-chemical characteristics of the sediment in both locations investigated includes:- particle size analysis (%silt, %sand & %clay), pH, available phosphate, nitrate, nitrite, total hydrocarbon (THC), %organic carbon, carbon/nitrogen (CN) ratio, total nitrogen (TN), sulphate, sodium, potassium, calcium and magnesium. The data revealed significant spatial differences (*$P<0.05$*) between the locations in all the sediment parameters measured except for Silt%, THC and CN Ratio. There were significant temporal variations between the locations for the following parameters: pH, TN, %Org.C, C/N Ratio, Mg,* $P0_4^{2-}$ *and Na. The results also showed high increase in values recorded for THC,* $S0_4^{2-}$ *and Ca in the station immediately downstream of the dredged area which steadily declined further downstream. The results obtained are indicative of impact of dredging on sediment quality of Iggedi creek, upper Nun River.*

I. Introduction

River modification dates back to the earliest days of human settlement on the floodplains of the Nile, Indus, and Mesopotamia and has increased steadily throughout history with the occupation of the valleys of most rivers. The initial impacts of such interventions were in all probability relatively slight (Welcome 1989). In its simplest form dredging consists of the excavation of material from a sea, river or lake bed, and the disposal of the dredged material.

Dredging brings about environmental problems (Balchand and Rasheed, 2000). The physical disturbances from dredging alone are often sufficient cause for concern; the impacts to ecological health might be even more extensive if the disturbed sediment contains elevated chemical concentrations. Specifically, suspension and dispersal of contaminated sediments could have ecological impacts that extend well beyond the time the physical effects caused by mechanical disturbances have returned to baseline conditions, particularly if persistent and bio-accumulative chemicals are involved (Su *et al.*, 2002).

Sediment quality assessments are useful in determining sediment quality in receiving streams of whole effluents, previously impacted sites, and other contaminated areas. The purpose of the sediment characterization task in the study area is to describe the nature and extent of contamination in the sediment of the system, to evaluate the effects of contamination on ecological and human health, and to identify and evaluate remedial action alternatives.

This research is intended to access the level of impact of dredging operations on the sediment quality of Igbedi Creek, upper Nun River. The objectives of the research are:

- To assess the physico-chemical characteristics of the sediment samples of the various stations in the Dredged and Un-dredged sites.
- Compare the data obtained in the Dredged and Un-dredged site and determine the possible impact of dredging on water quality of Igbedi Creek, upper Nun River.

II. Methodology

[1]Study Area

The study was carried out in Igbedi Creek, a tributary of the Upper Nun River in the Niger Delta located between latitude 5^0N01^1 and 6^017^1E. The stretch of the river is a long and wide meander whose outer concave bank is relatively shallow with sandy point bars (Abowei, 2000). The depth and width of the river vary slightly at different points (Sikoki *et. al.*, 1998). The minimum and maximum widths are 200 and 250 meters respectively. The river is subjected to tidal influence in the dry season. Water flows rapidly in one direction during the flood (May – October). At the peak of the dry season, the direction of flow is slightly reversed by the rising tide. At full tide the flow is almost stagnant.

[2]Field Study & Collection of Samples

Two communities were chosen as sample communities for this study. These are: Ogobiri (Dredged Location), in the Sagbama Local Government Area (SALGA) i.e. the community where the dredging is taking place, and Agoro-Gbene (Un-dredged Location), also in Sagbama Local Government Area (SALGA) which is a community that is relatively undisturbed. Both communities are located along the Nun River and are both predominantly fishing communities.

For the purpose of this study, the selected dredged and non-dredged sites were divided into stations: Ogobiri – OGO_1DA=Dredged Area, $OGO_{I\&2}DS$=Downstream, $OGO_{1\&2}US$=Upstream; Agoro-gbene – AGO_1DS=Downstream, AGO_1MD=Midstream, AGO_1US=Upstream.

Collection of sediment samples

Sediment samples were collected from three (3) points on each of the stations in each study location. The sediment samples were collected onshore; midstream and over side. The sediment samples at each sampling point were collected as separate samples. The sediment samples were collected by scooping bottom sediments using a grab into labelled containers and subsequently taken to the laboratory for analysis

[3]Analysis of Experimental Data

The following statistical tools were used to analyzed the data obtained – Analysis of Variance (ANOVA) for sediment data analysis; Microsoft Excel (2010) for computation of means and standard deviation.

III. Results And Discussion

The results of the sediment samples physico-chemical characteristics for both Ogobiri (Dredged) and Agoro-Gbene (Un-Dredged) Locations are shown in Tables 1, 2, and 3 respectively.

The monthly %Sand values ranged between 9% and 94% across the locations and stations. The highest %Sand was recorded in June (OGO_1US1); lowest %Sand was recorded in March (AGO_1DS3). The highest %Sand was recorded in the wet season, while the lowest %Sand was recorded in the dry season. The mean %Sand values were significantly different ($P<0.05$) across the stations. There was significant difference ($P<0.05$) in mean %Sand in Ogobiri (47%±2.56) and Agoro-Gbene (52%±3.30) locations. There was also significant ($P<0.05$) variation in %Sand between the locations for dry (50%±3.62, 51%±4.67) and wet (44%±3.62, 53%±4.67) seasons.

The monthly %Silt values ranged between 2% and 30% across the locations and stations. The highest %Silt was recorded in June (OGO_2DS2); lowest %Silt was recorded in June (OGO_2US2), July (OGO_2US2). The highest %Silt was recorded in the wet season, while the lowest %Silt was also recorded in the wet season. The mean %Sand values were significantly different ($P<0.05$) across the stations. There was no significant difference ($P>0.05$) in mean %Silt in Ogobiri (15%±0.42) and Agoro-Gbene (14%±0.54) locations. There was also no significant ($P>0.05$) variations in %Silt between the locations for dry (14%±0.59, 15%±0.77) and wet (17%±0.59, 14%±0.77) seasons.

The monthly %Clay values ranged between 5% and 78% across the locations and stations. The highest %Clay was recorded in January (OGO_1DS3) and March (AGO_1DS3); lowest %Clay was recorded in June (OGO_1DS3, (OGO_2US2), July (OGO_1DA2, OGO_2DS3, OGO_1US3), August (OGO_1DA2, OGO_1US3) and September (OGO_1DS3, OGO_1US3, OGO_2US3). The highest %Clay was recorded in the dry season, while the lowest %Clay was also recorded in the wet season. The mean %Clay values were significantly different ($P<0.05$) across the stations. There was significant difference ($P<0.05$) in mean %Clay in Ogobiri (38%±2.33) and Agoro-Gbene (34%±3.01) locations. There was also significant ($P<0.05$) variation in %Clay between the locations for dry (36%±3.29, 35%±4.25) and wet (40%±3.29, 34%±4.25) seasons.

The texture of sediments obtained from both locations were generally Sandy Loam with %(Sand, Silt & Clay) as follows: Ogobiri - 47,15 & 38 and Agoro-Gbene – 52, 14 & 34 respectively.

The results show that the texture of sediments obtained from both locations were generally Sandy Loam with % (Sand, Silt & Clay) as follows: Ogobiri – (47,15 & 38) and Agoro-Gbene – (52, 14 & 34) respectively. Low sand percentage was however, recorded in the Dredged area (38, 17 & 46) which identifies the texture of the Dredged area as Clay Loa. This can be attributed to dredging in the area. The stations immediately downstream of the Dredged area had high sand percentages with % (Sand, Silt & Clay) as follows :- (57, 14 & 29) and (44, 18 & 38) respectively. The result of the particle size analysis obtained in this study is in agreement with the results (57, 18 & 25) obtained by Davies and Abowei (2010) in Okpoka creek. However, the observed sediment particle size distribution in this study contradicts those of Ekweozor (1999) of the Bonny Estuary, Chindah (1998) of New Calabar Estuary and Nweke (2000) of Elechi Creek.

The monthly pH values ranged between 6.19 and 8.75 across the locations and stations. The highest pH was recorded in October (AGO_1DS2); lowest pH was recorded in February (OGO_1US1). The highest pH was recorded in the wet season, while the lowest pH was also recorded in the dry season. The mean pH values were significantly different (P<0.05) across the stations. There was significant difference (P<0.05) between mean pH in Ogobiri (6.84±0.01) and Agoro-Gbene (7.62±0.02) locations. There was also significant (P<0.05) variation in pH between the locations for dry (6.74±0.02, 7.58±0.03) and wet (6.94±0.02, 7.66±0.03) seasons. The pH ranging from 6.19 – 8.75 obtained in this study show acidic to alkaline for the study locations. These values were relatively higher than 4.00 – 5.61 recorded by Seiyaboh *et. al.,* (2007) in the Nun River and 5.22 recorded by Davies and Abowei (2010).

The monthly THC values ranged between 0.22mg/g and 1.27mg/g across the locations and stations. The highest THC was recorded in August (OGO_1DS2); lowest THC was recorded in January (OGO_1DA1). The highest THC was recorded in the wet season, while the lowest THC was also recorded in the dry season. The mean THC values were significantly different (P<0.05) across the stations. There was no significant difference (P>0.05) in mean THC in Ogobiri (0.63mg/g±0.01) and Agoro-Gbene (0.53mg/g±0.02) locations. There was also no significant (P>0.05) variation in THC between the locations for dry (0.61mg/g±0.01, 0.51mg/g±0.01) and wet (0.66mg/g±0.01, 0.56mg/g±0.01) seasons. The THC values reported for this study are higher than 0.24µg/g reported by Davies and Abowei, (2010). Low THC values recorded in the Dredged location might not be unconnected with a lower boat traffic in the area.

The monthly TN values ranged between 1.230mg/g and 4.619mg/g across the locations and stations. The highest TN was recorded in August (AGO_1US3); lowest TN was recorded in February (OGO_1DA3). The highest TN was recorded in the wet season, while the lowest TN was also recorded in the dry season. The mean TN values were significantly different (P<0.05) across the stations. There was significant difference (P<0.05) in mean TN in Ogobiri (2.185mg/g±0.02) band Agoro-Gbene (3.357mg/g±0.03) locations. There was also significant (P<0.05) variation in TN between the locations for dry (2.094mg/g±0.03, 3.121mg/g±0.04) and wet (2.275mg/g±0.03, 3.592mg/g±0.04) seasons. The presence of Nitrogen in an aquatic system indicates the addition of domestic and agricultural effluents and if in excess can lead to eutrophication.

The monthly %ORG.C values ranged between 0.14% and 0.87% across the locations and stations. The highest %ORG.C was recorded in July (OGO_1DA2); lowest %ORG.C was recorded in October (AGO_1DS3) and February (OGO_2US2). The highest %ORG.C was recorded in the wet season, while the lowest %ORG.C was also recorded in the wet and dry seasons. The mean %ORG.C values were significantly different (P<0.05) across the stations. There was significant differences (P<0.05) in mean %ORG.C in Ogobiri (0.50%±0.003) and Agoro-Gbene (0.31%±0.004) locations. There was also significant (P<0.05) variation in %ORG.C between the locations for dry (0.44%±0.01, 0.28%±0.01) and wet (0.56%±0.01, 0.34±0.01) seasons. The values obtained in this study fall within the acceptable limits and therefore would sustain higher benthic abundance and biomass.

The monthly CN RATIO values ranged between 0.034 and 0.675 across the locations and stations. The highest CN RATIO was recorded in July (OGO_1DS2); lowest %ORG.C was recorded in November (AGO_1US2). The highest CN RATIO was recorded in the wet season, while the lowest CN RATIO was recorded in the dry seasons. The mean CN RATIO values were significantly different (P<0.05) across the stations. There was no significant difference (P>0.05) in mean CN RATIO in Ogobiri (0.240±0.05) and Agoro-Gbene (0.264±0.06) locations. There was significant (P<0.05) variation in CN RATIO between the locations for dry (0.221±0.07, 0.099±0.08) and wet (0.258±0.07, 0.429±0.01) seasons. Previous studies conducted by Elva *et. al.,* (2009) reported that sediments dominated with algae, leaves and other materials from the surrounding environment can influence the CN Ratio. The low CN Ratio recorded in this study may be attributed to low amounts of these materials in the sediment.

The monthly $N0_3^-$ values ranged between 0.120mg/g and 0.650mg/g across the locations and stations. The highest $N0_3^-$ was recorded in July (AGO_1US1) and August (AGO_1DS3); lowest $N0_3^-$ was recorded in September (OGO_1US1), November (OGO_1US1) and January (OGO_1DA3). The highest $N0_3^-$ was recorded in the wet season, while the lowest $N0_3^-$ was recorded in the wet and dry seasons. The mean $N0_3^-$ values were significantly different (P<0.05) across the stations. There was significant difference (P<0.05) in mean $N0_3^-$ in Ogobiri (0.286mg/g±0.004) and Agoro-Gbene (0.428mg/g±0.01) locations. There was no significant (P>0.05) variation in $N0_3^-$ between the locations for dry (0.269mg/g±0.01, 0.385mg/g±0.01) and wet (0.302mg/g±0.01, 0.471mg/g±0.01) seasons. These values were relatively lower than the 1 – 3.3mg/g (Ikomah, 1999), 3.07 – 6.47mg/g (Umesi, 1999) and 3.11 – 14.40 (Seiyaboh *et. al.,* (2007) previously recorded in various areas of the Niger Delta.

The monthly NO_2^- values ranged between 0.028mg/g and 0.169mg/g across the locations and stations. The highest NO_2^- was recorded in August (AGO_1US1); lowest NO_2^- was recorded in September (OGO_2DS3), November (OG_2DS3). The highest NO_2^- was recorded in the wet season, while the lowest NO_2^- was recorded in the wet and dry seasons. The mean NO_2^- values were significantly different ($P<0.05$) across the stations. There was significant difference ($P<0.05$) in mean NO_2^- in Ogobiri (0.068mg/g±0.0001) and Agoro-Gbene (0.113mg/g±0.001) locations. There was no significant ($P>0.05$) variation in NO_2^- between the locations for dry (0.064mg/g±0.001, 0.110mg/g±0.001) and wet (0.072mg/g±0.001, 0.117mg/g±0.001) seasons.

The monthly SO_4^{2-} values ranged between 2.40mg/g and 20.28mg/g across the locations and stations. The highest SO_4^{2-} was recorded in October (AGO_1US3) and January (AGO_1US3); lowest SO_4^{2-} was recorded in February (OGO_2DS1). The highest NO_2^- was recorded in the wet and dry seasons, while the lowest SO_4^{2-} was recorded in the dry season. The mean SO_4^{2-} values were significantly different ($P<0.05$) across the stations. There was significant difference ($P<0.05$) in mean SO_4^{2-} in Ogobiri (6.66mg/g±0.10) and Agoro-Gbene (14.25mg/g±0.13) locations. There was significant ($P<0.05$) variation in SO_4^{2-} between the locations for dry (5.95mg/g±0.14, 13.14mg/g±0.18) and wet (7.36mg/g±0.14, 15.36mg/g±0.18) seasons. The results showed higher values for SO_4^{2-} in the station immediately downstream of the dredged area which steadily declined further downstream. This is indicative of impact of dredging on SO_4^{2-} levels

The monthly Ca values ranged between 5.40mg/g and 30.90mg/g across the locations and stations. The highest Ca was recorded in August (OGO_1DS3); lowest Ca was recorded in February (OGO_2DS1). The highest Ca was recorded in the wet season, while the lowest Ca was recorded in the dry season. The mean Ca values were significantly different ($P<0.05$) across the stations. There was significant difference ($P<0.05$) in mean Ca in Ogobiri (12.14mg/g±0.21) and Agoro-Gbene (14.06mg/g±0.28) locations. There was no significant ($P>0.05$) variation in Ca between the locations for dry (10.29mg/g±0.30, 11.25mg/g±0.39) and wet (14.00mg/g±0.30, 16.86mg/g±0.18) seasons. The results showed higher values for Ca in the station immediately downstream of the dredged area which steadily declined further downstream. This is indicative of impact of dredging on Ca levels.

The monthly Mg values ranged between 2.48mg/g and 15.70mg/g across the locations and stations. The highest Mg was recorded in August (AGO_1DS1); lowest Mg was recorded in February (OGO_1US1). The highest Mg was recorded in the wet season, while the lowest Mg was recorded in the dry season. The mean Mg values were significantly different ($P<0.05$) across the stations. There was significant difference ($P<0.05$) in mean Mg in Ogobiri (6.90mg/g±0.11) and Agoro-Gbene (8.62mg/g±0.14) locations. There was significant ($P<0.05$) variation in Mg between the locations for dry (5.81mg/g±0.15, 7.20mg/g±0.20) and wet (7.99mg/g±0.15, 10.04mg/g±0.20) seasons.

The monthly P values ranged between 0.26mg/g and 0.96mg/g across the locations and stations. The highest P was recorded in August (OGO_1DA3); lowest P was recorded in September (AGO_1DS1). The highest and lowest P were recorded in the wet season. The mean P values were significantly different ($P<0.05$) across the stations. There was significant difference ($P<0.05$) in mean P in Ogobiri (0.65mg/g±0.003) and Agoro-Gbene (0.45mg/g±0.004) locations. There was significant ($P<0.05$) variation in P between the locations for dry (0.57mg/g±0.01, 0.42mg/g±0.01) and wet (0.72mg/g±0.01, 0.48mg/g±0.01) seasons. The values recorded in this study of 0.26 – 0.96mg/g were lower than those of 2.2 – 2.9mg/g recorded in a previous study in Amadi and Nwaja creeks (Ekeh, 2005) and 2.71 – 20.74mg/g in the Nun River around Tombia and Opokuma (Seiyaboh, *et. al.*, 2008).

The monthly Na values ranged between 0.06mg/g and 0.42mg/g across the locations and stations. The highest Na was recorded in June (OGO_1DS1) and August (OGO_1DS1); lowest Na was recorded in November (AGO_1US3). The highest Na was recorded in the wet season, while the lowest Na was recorded in the dry season. The mean Na values were significantly different ($P<0.05$) across the stations. There was significant difference ($P<0.05$) in mean Na in Ogobiri (0.18mg/g±0.20) and Agoro-Gbene (0.12mg/g±0.25) locations. There was significant ($P<0.05$) variation in Na between the locations for dry (0.14mg/g±0.28, 0.11mg/g±0.36) and wet (0.21mg/g±0.0.28, 0.13mg/g±0.36) seasons

The monthly K values ranged between 4.48mg/g and 26.90mg/g across the locations and stations. The highest K was recorded in July (AGO_1DS2) and August (AGO_1DS1); lowest K was recorded in February (OGO_2DS2). The highest K was recorded in the wet season, while the lowest K was recorded in the dry season. The mean K values were significantly different ($P<0.05$) across the stations. There was significant difference ($P<0.05$) in mean K in Ogobiri (10.34mg/g±0.12) and Agoro-Gbene (13.89mg/g±0.16) locations. There was significant ($P<0.05$) variation in K between the locations for dry (8.72mg/g±0.17, 10.98mg/g±0.22) and wet (11.96mg/g±0.0.17, 16.79mg/g±0.22) seasons.

IV. Conclusion

The results indicate that the sediment quality in the Un-dredged location were generally better than in the Dredged location. From the above information, it is concluded that there has been an impact of dredging on the sediment quality of Igbedi Creek, Upper Nun River.

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Table 1: Physico-Chemical Characteristics of Sediment Samples in Ogobiri Location

Parameters	OGO_1DA	OGO_1DS	OGO_2DS	OGO_1US	OGO_2CO
Particle Size Analysis Sand %	38±5.72	57±5.72	44±5.72	38±5.72	56±5.72
Silt %	17±0.94	14±0.94	18±0.94	16±0.94	14±0.94
Clay %	46±5.21	29±5.21	38±5.21	47±5.21	30±5.21
Texture	Clay Loam	Sandy Loam	Sandy Loam	Clay Loam	Sandy Loam
pH	6.87±0.04	6.86±0.04	6.93±0.04	6.69±0.04	6.86±0.04
THC mg/g	0.43±0.01	0.89±0.01	0.39±0.01	0.64±0.01	0.79±0.01
TN mg/g	1.974±0.05	2.179±0.05	1.693±0.05	2.179±0.05	2.288±0.05
% ORG C	0.55±0.01	0.57±0.01	0.49±0.01	0.40±0.01	0.50±0.01
C/N RATIO	0.266±0.10	0.283±0.10	0.283±0.10	0.166±0.10	0.202±0.10
NO_3^- mg/g	0.266±0.01	0.293±0.01	0.241±0.01	0.346±0.01	0.283±0.01
NO_2^- mg/g	0.045±0.001	0.060±0.001	0.037±0.001	0.084±0.001	0.116±0.001
SO_4^{2-} mg/g	5.12±0.22	7.99±0.22	6.41±0.22	5.52±0.22	8.25±0.22
Ca mg/g	11.00±0.48	18.16±0.48	9.95±0.48	10.31±0.48	11.30±0.48
Mg mg/g	9.16±0.24	6.47±0.24	6.04±0.24	5.24±0.24	7.60±0.24
Av. P mg/g	0.76±0.01	0.68±0.01	0.58±0.01	0.52±0.01	0.68±0.01
Na mg/g	0.18±0.44	0.26±0.44	0.21±0.44	0.15±0.44	0.07±0.27
K mg/g	8.51±0.27	12.07±0.27	14.79±0.27	7.23±0.27	9.11±0.27

Key: OGO_1DA=Dredged Area, $OGO_{1\&2}DS$=Downstream, $OGO_{1\&2}US$=Upstream

Table 2 Physico-Chemical Characteristics of Sediment Samples in Agoro-Gbene Location

Parameters	AGO_1DS	AGO_1MD	AGO_1US
Particle Size Analysis			
Sand %	51±5.72	55±5.72	49±5.72
Silt %	15±0.94	12±0.94	15±0.94
Clay %	34±5.21	33±5.21	36±5.21
Texture	Sandy Loam	Sandy Loam	Sandy Loam
pH	7.73±0.04	7.50±0.04	7.63±0.04
THC mg/g	0.60±0.01	0.53±0.01	0.47±0.01
TN mg/g	3.329±0.05	2.831±0.05	3.910±0.05
% ORG C	0.25±0.01	0.44±0.01	0.24±0.01
C/N RATIO	0.572±0.10	0.157±0.10	0.063±0.10
NO_3^- mg/g	0.444±0.01	0.361±0.01	0.478±0.01
NO_2^- mg/g	0.101±0.001	0.090±0.001	0.149±0.001
SO_4^{2-} mg/g	13.68±0.22	12.97±0.22	15.10±0.22
Ca mg/g	19.81±0.48	12.69±0.48	9.66±0.48
Mg mg/g	11.15±0.24	8.28±0.24	6.43±0.24
Av. P mg/g	0.38±0.01	0.45±0.01	0.52±0.01
Na mg/g	0.16±0.44	0.11±0.44	0.99±-0.44
K mg/g	16.21±0.27	14.32±0.27	11.12±0.27

Key: AGO_1DS=Downstream, AGO_1MD=Midstream, AGO_1US=Upstream

Table 3: Seasonal Means for Ogobiri & Agoro-Gbene Locations (Sediment)

Parameters	AGO DRY	AGO WET	OGO DRY	OGO WET
Particle Size Analysis				
Sand %	51±4.67	53±4.67	50±3.62	44±3.62
Silt %	15±0.77	14±0.77	15±0.60	17±0.60
Clay %	35±4.30	34±4.30	36±3.30	40±3.30
Texture	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
pH	7.58±0.03	7.66±0.03	6.74±0.02	6.94±0.02
THC mg/g	0.51±0.01	0.56±0.01	0.60±0.01	0.66±0.01
TN mg/g	3.121±0.04	3.592±0.04	2.094±0.03	2.275±0.03
% ORG C	0.28±0.01	0.34±0.01	0.44±0.01	0.56±0.01
C/N RATIO	0.099±0.08	0.429±0.08	0.221±0.07	0.258±0.07
NO_3^- mg/g	0.385±0.01	0.471±0.01	0.269±0.01	0.302±0.01
NO_2^- mg/g	0.110±0.001	0.117±0.001	0.064±0.001	0.072±0.001
SO_4^{2-} mg/g	13.14±0.18	15.36±0.18	5.95±0.14	7..36±0.14
WCa mg/g	11.25±0.39	16.86±0.39	10.29±0.30	13.99±0.30
Mg mg/g	7.20±0.20	10.04±0.20	5.81±0.15	7.99±0.15
Av. P mg/g	0.42±0.01	0.48±0.01	0.57±0.01	0.72±0.01
Na mg/g	0.11±0.36	0.13±0.36	0.14±0.28	0.21±0.28
K mg/g	10.98±0.22	16.79±0.22	8.72±0.17	11.96±0.17