Major oxides study of the Euphrates River bed sediments from north Hilla to the Shatt Al-Arab at Basrah cities

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Abstract

The major oxides of the terrigenous bed sediments in the Euphrates River described in the present paper, was carried out through the field work during 2018; thus about 25 core samples from eight river bed sediment sites (from S1 to S12) along the course of the river to the Shatt Al-Arab River from Hilla to Basrah cities. The coordinate number of these sites are between 38°41′32.48″N–38°14′24.10″N latitude and 39°56′4.59″E–39°8′13.41″E longitude. Ten of major oxides were determined by XRF technique, these are SiO₂, CaO, Al₂O₃, Fe₂O₃, MgO, Na₂O, K₂O, TiO₂, SO₃ and P₂O₅ in addition to LOI. SiO₂ is the highest abundance, while P₂O₅ is the lowest; however SiO₂ and TiO₂ decrease from Hilla to Basrah cities, whereas CaO, and MgO increase in the same direction. The mean abundance of the major oxides of the Euphrates River bed sediments may order as following; SiO₂ >CaO>Al₂O₃>Fe₂O₃>MgO>K₂O >Na₂O>TiO₂> SO₃> P₂O₅. The source rocks of these sediments is mafic, and its geochemical classification is Fe-sand extends to Fe-shale. The geochemical weathering restricted between moderate to low degree. According to the elemental ratio, CaO, SiO₂, Fe₂O₃, MgO, and TiO₂ are enrichment, whereas Al₂O₃, K₂O, P₂O₅, and SO₃ are depletion. The paleoclimatic condition of the clastic bed sediments is arid coincide with low to moderate chemical maturity. The tectonic setting of clasts sediment fall in the island arc field.

Keywords: Euphrates, Shatt Al-Arab, weathering, Basrah, Hilla

1- Introduction

In term of hydrography, the Euphrates River is the longest river in western Asia with total length of 2940 km, where 1213 km of 40% of its distance in Iraq (Al-Bassam and Hassan, 2006). The Euphrates River flows from Anatolian plateau passing through Syrian lands, then enters Iraq at a few kilometers north of Huseiba on the Iraqi-Syrian territories. In its upper reaches in Iraq, the Euphrates cuts through carbonate bed rocks, having a very narrow strip of flood plain. The lithology of Euphrates River channel then changing to gypsum, limestone, green marl from north Hit to Ramadi (Al-Obeidi, 1983). In the middle and lower reaches the Euphrates River meander over the Mesopotamian alluvial plain. The drainage basin here is underlined by the Injana Formation (formerly Upper Fars of Upper Miocene) which consists of marl and sandstone at south Ramadi (Banat and Al-Rawi, 1986) . At lower reaches, the river flows over fluviatile recent sediments (Ramadi-Diwania), and Dibdibba Formation (Pliocene-Pleistocene) which is consist of clastic sediments basically arkosicarenite, as well as some recent sand dune at Nasiriya (Al-Rawi and Sadik, 1981). The Euphrates River joins the Tigris River near of Qurna area to form Shatt Al-Arab at Basra city.
(Southern Iraq), then drains in the Arabian Gulf. The Euphrates and Tigris Rivers are provided much of water that supported the development of ancient Mesopotamian culture.

The Mesopotamia Plain located in the central part of the Mesopotamia Foreland Basin. It has been an area of subsidence since the Late Cretaceous. The sediments are strongly influenced by the input of the Euphrates and the Tigris Rivers and their major tributaries which have their outlet into the Mesopotamia Plain. During the uplift of the Zagros Mountains, the rivers of Mesopotamia migrated west and southwest during the Pleistocene and Holocene. The Euphrates River drains through a number of geological formations of sedimentary origin from entering Iraqi territory until meeting with Tigris River in Qurna (Al-Bassam, 2000). The outcropping formations age range from the Eocene (Dammam Formation) till modern times (Quaternary deposits) as shown in figure1. The Holocene sediments of the Euphrates River consist mainly of unconsolidated to fairly well-indurated deposits of sands, silts and mud. Minor deposits of pebbles are present in some upstream areas. Many authors had been studied the major oxides of the Euphrates River, such as Ahmed (2011), and Qanbar (2016). The current study focuses on the major oxides of the Euphrates and Shatt Al-Arab Rivers including the chemical weathering, source, and paleoclimatic condition through a studsing the core bed sediments.

![Figure 1: Location of the study area in modified geologic map of Mesopotamian plain according to Sissakian and Fouad (2012)](image)

**2- Location of the Study area**

In the present study, eight core samples of river bed sediments were collected along the stream cross profile in the Euphrates River from north Hilla city in the central Iraq to Shatt Al-Arab River in Basrah city (southern Iraq). The distance of the study area is more than 480Km. It lies between latitude 32° 40' 01.147" - 30° 48' 8.423" and longitude 44° 19' 21.214" – 47° 35' 19.32" as illustrated in table 1 and figure 2.

**Table 1- Coordinate number of the studied sampling cores**
| Area name          | Core No. | Longitude (N) | Latitude (E) |
|-------------------|----------|---------------|--------------|
| Hilla/1           | S 1      | 44 19 21.214  | 32 40 1.147  |
| Diwania/2         | S 4      | 44 56 10.006  | 31 52 0.133  |
| Simawa/1          | S 5      | 45 17 46.751  | 31 18 51.425 |
| Nasiria/2         | S 8      | 46 18 0.841   | 31 1 48.645  |
| Basrah-Qurna/Furat| S 9      | 47 21 13.082  | 30 58 24.692 |
| Qurna//Tigris     | S 10     | 47 25 40.759  | 31 5 27.987  |
| Qurna//meeting    | S 11     | 47 27 48.024  | 30 59 56.798 |
| Basrah-Deer/Shatt Al–Arab | S 12   | 47 35 19.32   | 30 48 8.423  |

Figure 2: Spatial location map of the study area explains investigated sites.

### 3- Material and Method

Eight river core bed sediments at depths between 20-58 cm were collected by using Stream Sediments Core Sampler Device for this purpose. Table 2 presented the depths and the width of the river in the studied sites. The core sample of any site is preserved and folded by aluminum foil sheets. Thereafter, dried under sun light, then it divided into several parts depending on the core depth of each part (10cm ±4cm) as shown in table 3. The selected core samples were prepared to examine by XRF instrument. This technique deals with the
chemical composition of powdered studied core samples to identify the trace elements by choosing twenty five core samples from different localities covering the eight sites of the study area. This technique X-ray fluorescence (XRF) had been achieved, where the sampling core sediments were powdered and pressed to disc shape to examine XRF by a SPECTRO XEPOS tool (manufactured in Germany) in the XRF laboratory of the geology department /Collage of Science/ University of Baghdad.

Table 2: Depth and width of the Euphrates River in the study area.

| Area name      | Core No. | Depth of water(approximately) | Width of the river(approximately) |
|---------------|----------|-------------------------------|----------------------------------|
| Hilla/1       | S 1      | 3m                            | 144m                             |
| Diwania/2     | S 4      | 2.5m                          | 25 m                             |
| Simawa/1      | S 5      | 3m                            | 95 m                             |
| Nasiria/2     | S 8      | 7m                            | 150 m                            |
| Qurna/Furat   | S 9      | 4.5 m                         | 250 m                            |
| = /Tigris     | S 10     | 7m                            | 74 m                             |
| = /meeting    | S 11     | 5 m                           | 280 m                            |
| Deer/Shatt Al –Arab | S 12    | 10m                          | 200 m                            |

Table 3: Core parts and their depths in the investigated sites of the river course

| Name of site         | Core NO. | Core parts and their depth | Sum of partes | Total depth |
|----------------------|----------|----------------------------|---------------|-------------|
| Hilla/1              | S 1      | 1A=10cm 1B=10cm 1C=10cm 1D=10cm 1E=12cm | 5             | 52cm        |
| Diwania/2            | S 4      | 4A=10cm 4B=10cm 4C=10cm 4D=8cm | 4             | 38cm        |
| Simawa/1             | S 5      | 5A=10cm 5B=10cm 5C=10cm | 3             | 30cm        |
| Nasiria/2            | S 8      | 8A=10cm 8B=14cm          | 2             | 24cm        |
| Basrah/Qurna/Furat  | S 9      | 9A=10cm 9B=10cm 9C=11cm | 3             | 31cm        |
| Basrah/Qurna/Tigris | S 10     | 10A=10cm 10B=10cm 10C=10cm 10D=12cm | 4             | 42cm        |
| Qurna/meeting       | S 11     | 11A=10cm 11B=10cm 11C=12cm | 3             | 32cm        |
| Dear/Shatt Al-Arab   | S 12     | 12A=10cm 12B=10cm 12C=10cm 12D=10cm 12E=10cm 12F=8cm | 6             | 58cm        |

4- Major Oxides. Chemical elements in river sediments may be found as constituents of primary forming minerals, minerals formed during weathering, ions adsorbed onto colloidal
particles and clays, and in combination with organic matter (Rose, et al., 1979). Weathering of parent rock materials are the common source for the different types of oxides in the river sediments (Yong et al., 2012). The major oxides of river bed sediments in the work area are listed in Table 4, those are SiO$_2$, CaO, Al$_2$O$_3$, Fe$_2$O$_3$, MgO, Na$_2$O, K$_2$O, TiO$_2$, SO$_3$ and P$_2$O$_5$ in addition to LOI and the texture of their core samples, whereas the average ratios of major oxides for investigated sites can be shown in Figure 3. The analyzed core samples display the heterogeneous results according to the heterogeneity in the various sedimentation conditions and the nature of source rocks environment. The mean abundance of the major oxides of Euphrates River bed sediments follow the decreasing order of SiO$_2$ > CaO > Al$_2$O$_3$ > Fe$_2$O$_3$ > MgO > K$_2$O > Na$_2$O > TiO$_2$ > SO$_3$ > P$_2$O$_5$. Table 4-7 shows the comparison between the current major oxides of bed sediments of Euphrates River with other selected studies (mean value of % units).

-SiO$_2$ Silicon dioxide is a major element in primary silicate minerals, represent the largest proportion among other oxides which restricted from 35.21% to 51.29% and the mean is 40.89%, in our study area. Silica enrichment is a measure of sandstone maturity and is a reflection of the duration and intensity of weathering and destruction of other minerals during transportation (Obiefuna and Orazulike, 2011). The concentration values decreases from first site at Hilla city to the south trend until last site at Deer city due to the declining of grain size from sand to silt texture.

-CaO The calcium oxide content in the study arises from Hilla to Basrah cities in a wide range from 14.83% to 24.89% with a mean of 19.76% mainly due to the increase of calcite (CaCO$_3$) and dolomite [(Ca, Mg) (CO$_3$)] minerals, as well the participation of anorthite, pyroxene, amphiboles and palygorskite minerals, where the hot and arid climate is predominated, in addition to skeletal fragments of funna. The high percentage of calcium indicated to the fluctuation of the sedimentation environment.
Table 4: Major oxides and their mean of sampling sites of the study area with upper continental crust (UCC) after (Taylor and McLennan, 1985).

| Site                   | S.N. | SiO₂ | CaO  | Al₂O₃ | Fe₂O₃ | MgO  | Na₂O | K₂O  | TiO₂ | P₂O₅ | SO₃ | LOI  | total | texture      |
|------------------------|------|------|------|-------|-------|------|------|------|------|------|-----|------|-------|--------------|
| Hilla/S1               | 1a   | 49.37| 15.93| 8.948 | 5.923 | 3.943| 1.59 | 1.351| 1.059| 0.125| 0.189| 11.441| 99.875| sand         |
|                        | 1b   | 51.29| 15.15| 9.146 | 5.792 | 3.92 | 1.74 | 1.471| 1.006| 0.145| 0.243| 9.953 | 99.855| sand         |
|                        | 1c   | 50.35| 16.23| 8.865 | 6.235 | 3.799| 1.66 | 1.404| 1.094| 0.13  | 0.189| 9.908 | 99.87  | sand         |
|                        | 1d   | 50.93| 15.74| 9.206 | 6.359 | 3.886| 1.67 | 1.468| 1.181| 0.148| 0.218| 9.046 | 99.852| sand        |
|                        | 1e   | 42.22| 14.83| 8.418 | 5.44  | 4.105| 1.69 | 1.361| 0.912| 0.153| 0.554| 20.161| 99.847| sand        |
| Diwaniya/S4            | 4a   | 49.76| 15.71| 9.645 | 5.761 | 4.191| 1.64 | 1.389| 0.918| 0.165| 0.181| 10.475| 99.835| silty sand   |
|                        | 4b   | 47.38| 16.12| 9.765 | 5.995 | 4.509| 1.72 | 1.471| 1.039| 0.166| 0.267| 11.398| 99.834| silty sand   |
|                        | 4c   | 44.91| 15.68| 8.855 | 5.662 | 3.895| 1.59 | 1.406| 0.958| 0.152| 0.316| 16.42  | 99.848| silty sand   |
|                        | 4d   | 47.87| 16.12| 9.495 | 5.99  | 4.249| 1.70 | 1.468| 1.034| 0.152| 0.235| 11.529| 99.848| silty sand   |
| Simawa/S5              | 5a   | 40.67| 19.15| 9.465 | 6.434 | 4.625| 1.07 | 1.312| 1.03  | 0.187| 0.368| 15.504| 99.813| silty sand   |
|                        | 5c   | 41.41| 17.96| 9.34  | 6.048 | 4.431| 1.11 | 1.272| 1.053| 0.183| 0.54  | 16.106| 99.817| silty sand   |
|                        | Nasiriya/S8   | 8a   | 37.22| 17.9  | 9.352 | 7.146| 4.791| 0.92 | 1.323| 0.808| 0.179| 0.458| 19.715| 99.821| Sandy silt   |
|                        | 8b   | 37.11| 19.11| 9.141 | 6.86  | 4.85 | 0.90 | 1.327| 0.794| 0.185| 0.71  | 18.824| 99.815| Sandy silt   |
| Basra/Qurna/S9         | 9a   | 31.72| 22.74| 7.446 | 5.181 | 4.164| 0.78 | 1.217| 0.666| 0.178| 0.807| 24.918| 99.822| silt        |
|                        | 9c   | 33.98| 23.98| 7.617 | 4.895 | 4.456| 0.93 | 1.193| 0.71  | 0.159| 1.061| 20.882| 99.841| silt        |
| Basra/Qurna/S10        | 10a  | 38.84| 22.73| 9.29  | 5.6   | 4.24 | 0.67 | 1.5  | 0.76  | 0.16  | 0.25  | 15.8  | 99.84  | silt         |
|                        | 10d  | 37.53| 21.47| 8.916 | 5.768 | 4.307| 0.63 | 1.438| 0.758| 0.156| 0.428| 18.438| 99.844| silt         |
| Basra/Qurna/S11        | 11a  | 34.82| 24.26| 8.51  | 5.5   | 4.12 | 0.65 | 1.44 | 0.71  | 0.18  | 0.33  | 19.3  | 99.82  | silt         |
|                        | 11c  | 35.22| 22.78| 8.54  | 5.71  | 4.22 | 0.69 | 1.47 | 0.634| 0.172| 0.402| 19.992| 99.828| silt         |
| Basra/Deer/S12         | 12a  | 35.35| 21.99| 8.365 | 5.678 | 4.452| 0.74 | 1.241| 0.752| 0.165| 0.665| 20.438| 99.835| silt         |
|                        | 12b  | 38.24| 24.23| 9.145 | 5.884 | 4.853| 0.72 | 1.163| 0.816| 0.174| 0.697| 13.458| 99.826| silt         |
|                        | 12c  | 37.98| 21.06| 9.068 | 5.779 | 4.69 | 0.80 | 1.055| 0.81  | 0.177| 0.61  | 17.786| 99.823| silt         |
|                        | 12d  | 36.94| 24.03| 8.791 | 5.928 | 4.739| 0.67 | 1.221| 0.763| 0.175| 0.56  | 16.003| 99.825| silt         |
|                        | 12e  | 34.35| 23.95| 8.168 | 5.428 | 4.447| 0.73 | 1.088| 0.7   | 0.176| 0.752| 20.033| 99.824| silt         |
|                        | 12f  | 35.21| 24.89| 8.336 | 5.563 | 4.567| 0.79 | 1.009| 0.725| 0.201| 0.788| 17.715| 99.799| silt         |
| Mean                   |      | 40.89| 19.75| 8.85  | 5.887 | 4.334| 1.10 | 1.31 | 0.87  | 0.16  | 0.48  | 16.26 | 99.83 |            |
| UCC                    | 60   | 4.2  | 15.2 | 4.5   | 2.48  | 3.9  | 3.4  | 0.5  | 0.15  | 0.1   | ----  | ----  |       |            |
Figure 3: Bar chart shows the average ratios of major oxides for investigated sites.

- $\text{Al}_2\text{O}_3$: Alumina is, mainly sourced from clay minerals (McLennan et al., 1983), and it is a common element in primary silicate minerals, from which it may be released by weathering (Huang et al. 2014). Alumina concentration is restricted between 7.45% and 9.76% with an average of 8.85%. Therefore, the alumina distribution exhibits low variation between the studied sites. Ruxton ratio ($\text{SiO}_2/\text{Al}_2\text{O}_3$) proposed by Ruxton (1968) reflects the weathering action and multiple sedimentary cycles; furthermore, it is considered as an indication of sediments maturity, accordingly the low ratios represent chemically immature rock samples (Roser et al., 1996).

- $\text{Fe}_2\text{O}_3$: The concentration of $\text{Fe}_2\text{O}_3$ is limited between 4.89% to 7.15% with a mean of 5.89%. It exhibits a slight heterogeneous distribution among the studied sites, but the highest values are clear at S5 and S8 at Simawa and Nasiria cities, respectively. It refers to the presence of ferromagnesian minerals, heavy minerals as opaque constituents or may back to absorbed on clay minerals surface or combined with S to form (FeS$_2$) pyrite mineral (Veld and Meunier, 2008).

- MgO: Magnesia constituents are closely related to the presence of ferromagnesian minerals. Dolomite occurs as fragments also added very little quantity of MgO due to its scarcity, where the presence of montmorillonite in the sediment samples consider a source for magnesium. The concentration values ranged from 3.78% to 4.85% with an average of 4.34%, showed the relatively increasing to the south trend that compatible with CaO variation in the same direction.

- TiO$_2$: Titanium dioxide occurs either as independent mineral (rutile) or as illmenite in case of association with iron oxide. Another probable source of TiO$_2$ is clay minerals, due to the availability of Ti to substitute Al and easily absorbed on clays (Dai et al. 2015). Titania is considered the most resistant during weathering and Ti is the least mobile element (Al-Bassam, and Yousif, 2014). Its distribution has been appeared heterogeneous and its concentration restricted between 0.63% to 1.18% with a mean of 0.87% reflected the low abundance, moreover the values of TiO$_2$ at the Basrah sites are less than those at the other sites. This result may attributed to reduce in grain size. Many types of ratios can be utilized to detect the synthesis of orogenic rocks; one of them which is the $\text{Al}_2\text{O}_3$/TiO$_2$ against SiO$_2$ to be plotted as a diagram (Nagarajan et al., 2007). The plot diagram refers to mafic source...
rocks as in figure 4.

![Diagram](image)

Figure 4 : Source rocks of Euphrates River bed sedimentsafter (Nagarajan et al., 2007)

- Na$_2$O and K$_2$O Sodium dioxide content in the sediment is due to its association with clay minerals, especially montmorillonite and halite (Weaver and Pollard, 1975). The contents of Na$_2$O seem in a narrow range of distribution and is restricted between 0.63 and 1.74 % with an average of 1.10%.

Potash dioxide limited from 1.01% to 1.5% and the mean is 1.32%. Potassium feldspars (orthoclase and microcline), mica minerals (muscovite) and clay minerals like illite may produce potassium oxide.

Alkalis (Na$_2$O and K$_2$O) reflected sub mature to mature sandstones (Obiefuna and Orazulike, 2011). The concentrations of Na$_2$O and K$_2$O were very low as a result of their high mobility and intense weathering. The depletion of Na$_2$O and K$_2$O can be attributed to the modification of feldspars in the source region or during transportation (Tobia and Aswad, 2015), and to the rise of evaporation due to the hot and arid climate at the south sites of the study area. The very low percent of K$_2$O/Al$_2$O$_3$ (0.15) is denoting that the dominated content is montmorillonite, kaolinite and low minor of illite because this ratio in clay minerals is generally lower than 0.2 (Cox et al., 1995).

The geochemical classification of core samples sediments in the studied sites depends on diagram proposed by Herron (1988) to classify these sediments using scatter plots of log (Fe$_2$O$_3$/ K$_2$O) versus log (SiO$_2$/Al$_2$O$_3$), accordingly the studied bed sediments are classified as Fe- sand to Fe- shale reflecting the Fe enrichment in the river bed sediments as observed in figure 5.
Figure 5: Classification of river bed sediments proposed by Herron (1988).

- P₂O₅ Phosphorus pentoxide (P₂O₅) in bed river sediment samples rangeed from 0.125% to 0.201% with a mean value of 0.165% and this concentration represents the lowest values among other oxides. Although the values of P₂O₅ is low minor oxides, but it increases relatively to southern trend whilst its amounts fluctuates between rise to decline due to the increasing the depth interval. This trend may be associated with organic matter present and anthropogenic influence of using phosphate fertilizers in agricultural, especially from Simawa to Basra cities.

- SO₃ Sulfur trioxide or Sulfate in in the core samples of studied sediments extends from 0.18% to 1.06% with a mean of 0.48% in concentration values representing the relative minor amount. The obvious increasing of values is clear from Hilla/S1 site to Basrah/S12 site, as well as with the increasing of the depth interval of the core samples, synchronous with the authigenic salinization by poor drainage, hot and arid climate, where the evaporation rate is too more than the rainfall rate in these terrains. Soluble gypsum and anhydrite in the Euphrates River has obvious contribution in form of SO₃.

- LOI After heating the sediment sample at selected temperature, its weight has been partially lacked resulting from decomposition of carbonate, hydrocarbon constituents and organic matter, moreover the interstitial water liberating. This is represented the loss on ignition (LOI) which is limited from 9.05 to 24.92% with a mean of 16.27% in the core samples of study area. Loss on ignition values reflected a heterogeneity in its distribution ether with the southern direction or with the depth interval. Table 5 displayed the comparison of the current study to other studies carried out by several authors on the Euphrates River sediments related to major oxides.

Table 5: Comparison between the current major chemical oxides of river bed sediments with other selected studies (mean value of % units).

| Studied oxides   | Fe₂O₃ | Al₂O₃ | CaO   | MgO  | K₂O  | Na₂O  | SO₃  | TiO₂ |
|------------------|-------|-------|-------|------|------|-------|------|------|
| Present study    | 5.89  | 8.85  | 19.79 | 4.34 | 1.32 | 1.10  | 0.48 | 0.87 |
| Qanbar, 2016     | 4.41  | 3.60  | 11.7  | 3.80 | 0.23 | 0.15  | 0.41 | 0.17 |
| Benni, 2015      | 2.96  | 5.80  | ----  | ---- | ---- | ----  | ---- | ---- |
| Al-Bassam, 2014  | 3.14  | 6.03  | ----  | ---- | 1.01 | ----  | 10.13| 0.46 |
5- Chemical Weathering. The mineral and geochemical characteristics of sediments have been influenced, strongly by intensity of chemical weathering (Mongelli et al., 2006). Nesbitt and Young (1982) proposed the chemical index of alteration (CIA), which was the common weathering and alteration reflector that happened in the source area, calculated by the following formula suggested by Obasi and Madukwe (2016):

$$\text{CIA} = \frac{\text{Al}_2\text{O}_3}{(\text{Al}_2\text{O}_3 + \text{CaO}^* + \text{Na}_2\text{O} + \text{K}_2\text{O})} \times 100$$

Where the oxides are expressed as molar proportions and CaO* merely refers to the Ca incorporated only in silicate fraction (Baiyegunhi et al., 2017). Honda and Shimizu (1998) provided the following formula to correct CaO*.

$$\text{CaO}^* = 0.35 \times 2(\text{Na}_2\text{O})/62$$

To remove the impact of post-carboniferous leaching, an assumption was adopted accordingly. The CaO represents the mole fraction of remnant CaO after removing CaO from apatite. In the case of CaO equal or less than Na_2O, then the value of CaO is acceptable; whereas, if CaO more than Na_2O, then CaO* is Na_2O. Consequently, all CaO* was considered as silica fraction due to the low content of carbonate in Euphrates River bed sediments.

The quantity of mobile cations such as K\textsuperscript{+}, Na\textsuperscript{+} and Ca\textsuperscript{2+} in addition to the less mobile cations such as Al\textsuperscript{3+} which remain steady in the weathering residue that are present in the core samples may be determined by using this index (CIA). The significant rising elimination of K, Ca, and Na cations compare to the more stable Al\textsuperscript{3+} back to high CIA values, and these consequently, refer to the weathering intensity (Concepcion et al., 2011). Therefore the consumption of alkalis and alkaline earth elements and preferential enrichment of Al\textsubscript{2}O\textsubscript{3} may be produced by the alteration of rocks during weathering (Baruah et al., 2017). CIA is also much affected by grain size. It increases as grain size decreases (Oni and Olatunji, 2017).

The CIA values ranged between 45 and 100 in the case of fresh rocks and completely weathered rocks respectively. Wherefore CIA value between 45-55 denote absent chemical weathering and indicate to cool and/or arid climatic conditions (Fedo et al., 1995). CIA ≥ 60 infer low chemical weathering, between 60-80 imply very little moderate chemical alteration, whereas those that are more than 80 refer to high intensity of chemical weathering (Sang et al., 2018). The CIA values of core samples in the studied sites are ranging from 54.43% to 71.47% with an average of 63.74% indicating that the river bed sediments at Hilla/S1 and Diwania/S4 suffered low grade, whilst the other sites from Simawa to Basrah/Deer had moderate chemical weathering grade, as in figure 6.

The chemical index of weathering (CIW) is another index, in addition to the CIA, provides information on the intensity of chemical weathering that sediments have undergone (Baiyegunhi et al., 2017). In comparison to other weathering indices, the CIW is a superior method involving a restricted number of components that are well-known with consistent geochemical behavior during weathering. This index is identical to the CIA, except that it eliminates K\textsubscript{2}O from the equation. CIW index avoids the problems related to the remobilization of K during diagenesis or metamorphism (Condie, 1993, Oyebanjoa, et al., 2018).
Figure 6: CIA (%) vs Al₂O₃ % diagram for the chemical weathering of bed river sediments of Euphrates River in the study area after (Obasi and Madukwe, 2016).

The CIW formula as expressed by (Harnois, 1988) is shown below:

\[
CIW = \left( \frac{Al_2O_3}{Al_2O_3 + CaO* + Na_2O} \right) \times 100
\]

Where the unit of oxide Al₂O₃, CaO, and Na₂O in the aforementioned equation is mol. This index does not incorporate potassium because it may be leached or it may accumulate in the residue during weathering. According to Harnois (1988) and Oni and Olatunji, (2017), a CIW between 0-40 implies low weathered, 40-65 moderately weathered and greater than 70 intense weathered sediments. The CIW values of core sample sediments are restricted between 60.2% to 81.1% with a mean of 71% recording the dominance of moderate chemical weathering at Hilla and Diwnia cities, whereas intense grade at other sites.

Source area weathering and elemental redistribution during diagenesis also can be assessed using the plagioclase index of alteration (PIA) (Fedo et al., 1995; Baiyegunhi et al., 2017). PIA monitors and quantifies progressive weathering of feldspars to clay minerals because plagioclase is abundant in silicate rocks and dissolves relatively rapidly (Armstrong-Altrin et al., 2004). It can be calculated by the following equation (molecular proportions) as:

\[
PIA = \left( \frac{(Al_2O_3 - K_2O)}{(Al_2O_3 + CaO* + Na_2O - K_2O)} \right) \times 100
\]
The maximum value of PIA is 100 for completely altered materials (i.e. kaolinite and gibbsite) and unweather plagioclase has PIA value of 50.

PIA values range from 55.5% to 79.2% with a mean of 68.25 referring to moderate destruction of feldspars during source weathering, transport, sedimentation, and diagenesis and may reflect arid climate conditions (Etemad-Saeed, 2011).

Elemental ratios calculated with respect to the least mobile element Al can be used to identify and evaluate the major element mobility. The ratio of the content of element X and Al$_2$O$_3$ in the river bed samples divided by the same element content of world sediment, which is here (UCC) upper continental crust (Taylor and McLennan, 1985). The ratios can be obtained by the following elemental ratio (Singh et al., 2005; Sang et al., 2018):

\[
\text{Elemental ratio } X = \frac{X/Al_2O_3 \text{ sample}}{X/Al_2O_3 \text{ UCC}}
\]

The elemental ratio refers to the relative enrichment or depletion of the element, i.e., >1 indicates enrichment, <1 indicates depletion, and =1 indicates no change in the relative abundance of the element (Singh et al., 2005). From the table 6 of the elemental ratio and their means of sampling sites, the SiO$_2$ content in bed sediments is enrichment, suggesting that strong chemical weathering processes occur in the parent rocks. The immobile Fe$_2$ and Ti, which represented resistance heavy minerals like rutile and iron oxide, are enriched in all bed river sediments, suggesting their common source from ferromagnesian minerals (Zhifei L., 2009). The high enrichments of Ca and Mg are due to the abundant of carbonate rocks in the source rocks and the study area. While highly mobile elements of Na and K are depleted and reflect weak weathering of source rock, and/or strong leaching during weathering processes (Cullers, 1988). Na are tightly held in feldspar in anorthite and albite, also K in orthoclase and micasous minerals (Liu Z., et al., 2005).

| sites  | SiO$_2$ E.R. | CaO E.R. | Al$_2$O$_3$ E.R. | Fe$_2$O$_3$ E.R. | MgO E.R. | Na$_2$O E.R. | K$_2$O E.R. | TiO$_2$ E.R. | P$_2$O$_5$ E.R. |
|--------|--------------|----------|------------------|-----------------|----------|-------------|-------------|-------------|----------------|
| S1     | 1.43         | 3.05     | 0.37             | 2.93            | 5.86     | 0.16        | 0.57        | 3.15        | 0.51           |
| S4     | 1.31         | 3.17     | 0.37             | 2.90            | 6.18     | 0.17        | 0.51        | 2.80        | 0.59           |
| S5     | 0.02         | 0.27     | 0.19             | 0.58            | 0.94     | 1.20        | 15.58       | 2.96        | 0.98           |
| S8     | 0.65         | 3.08     | 0.31             | 6.30            | 7.65     | 0.11        | 0.41        | 2.32        | 0.56           |
| S9, S10, S11 | 0.02     | 0.40     | 0.18             | 0.74            | 0.821    | 1.18        | 18.34       | 2.25        | 0.67           |
| S12    | 1.01         | 5.22     | 0.30             | 6.32            | 8.61     | 0.10        | 0.36        | 2.35        | 0.68           |
| mean E.R. | 1.20     | 3.91     | 0.33             | 4.41            | 6.93     | 0.13        | 0.45        | 2.63        | 0.61           |

6- Maturity and Paleoclimate. Alternatively, SiO$_2$/Al$_2$O$_3$ ratios of siliciclastic rocks are sensitive to sediment recycling and weathering process and commonly used index of sedimentary maturation. With increasing sediment maturity, quartz survives preferentially to feldspars, mafic minerals and lithics (Roser et al., 1996). The average SiO$_2$/Al$_2$O$_3$ ratios in unaltered igneous rocks ranged from 3.0 (basic rocks) to 5.0 (acidic rocks). Values of SiO$_2$/Al$_2$O$_3$ ratio > 5.0 in sandstones and shales pointed to progressive maturity. Values of
SiO$_2$/Al$_2$O$_3$ in the studied sites range from 3.9 to 5.6 which confirm basic to intermediate source rocks. The chemical weathering intensity of bedrock generally associated with the warm and humid climates, whilst a more arid climate is generally associated with relatively weak chemical weathering (Nesbitt and Young, 1982).

The chemical maturity identification as a function of paleoclimate has been expressed by utilizing bivariant diagram of SiO$_2$ against (Al$_2$O$_3$ + K$_2$O+Na$_2$O) proposed by Suttner and Dutta (1986). SiO$_2$ reflects the quartz content, whilst Al$_2$O$_3$ + K$_2$O+Na$_2$O refers to the feldspar (Malick and Ishiga, 2016). The investigated core samples of Euphrates River bed clasts in this plot represent arid climatic condition coincide with low to moderate chemical maturity, as shown in figure 7 that generally, is linked with relatively low to moderate chemical weathering (Nesbitt and Young, 1982).

![Bivariant plot SiO$_2$ versus Al$_2$O$_3$+ K$_2$O + Na$_2$O showed paleoclimatic conditions and chemical maturity of Euphrates River bed sediments after Suttner &Dutta (1986).](image)

7- Provenance and Tectonic Setting. Source rock composition is commonly thought to be the dominant factor that controls the composition of sediments (Verma and Armstrong-Altrin, 2013, 2016). Plate tectonic settings of depositional basin had controlled, considerably the chemical compositions of siliciclastic sedimentary rocks (Bhatia and Crook, 1986); consequently, geochemical discrimination parameters have certain interest in determine provenance and tectonic settings of terrigenous sedimentary rocks. Concepcion et al (2011) established the tectonic setting of clasts sediment suites by using major oxides such as K$_2$O, Na$_2$O as log versus SiO$_2$ and adopted by Roser and Korsch (1986). Producing from this diagram clarifies that Euphrates bed river clasts fall in the island arc field as in figure 8.
Figure 8: Scatter plot of SiO$_2$ vs. log (K$_2$O/Na$_2$O) explained tectonic setting clastic bed sediments of Euphrates River

8- Conclusions

1-The main studied major oxide of the Euphrates River bed sediments are; SiO$_2$, CaO, Al$_2$O$_3$, Fe$_2$O$_3$, MgO, Na$_2$O, K$_2$O, TiO$_2$, SO$_3$ and P$_2$O$_5$ in addition to LOI.

2- These major oxides may order as following; SiO$_2$ >CaO>Al$_2$O$_3$>Fe$_2$O$_3$>MgO>K$_2$O >Na$_2$O >TiO$_2$> SO$_3$> P$_2$O$_5$.

3- The source rocks of these sediments is mafic, and its geochemical classification is Fe-sand extends to Fe-shale

4-The geochemical weathering restricted between moderate to low degree.

5-CaO, SiO$_2$, Fe$_2$O$_3$, MgO, and TiO$_2$ are enrichment, whereas Al$_2$O$_3$, K$_2$O, P$_2$O$_5$, and SO$_3$ are depletion.

6-The paleoclimatic condition of the bed sediments is arid coincide with low to moderate chemical maturity.

7-The tectonic setting of the sediment fall in the island arc field.

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