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Microbial mats covering recent sediments in the tidal flats of Khor Al-Zubair South of Iraq, NW Arabian Gulf

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Abstract - This present study was deal with the microbial sedimentary structures which are mainly induced by the cyanobacteria in the tidal flats of Khor Al-Zubair, North west of the Arabian Gulf. There are three types of sedimentary structures in the area; (i) physical genetics, (ii) biological genetics and (iii) bio-physical genetics. The last one represents the microbial induced sedimentary structure appeared in ten forms, which led to increasing of tidal flats resistance to erosion process and concentrating the coarse grain sizes that accompanied with these structures. The identification of cyanobacteria shows five genera, four of them are filamentous; *Microcoleus* sp., *Lyngbya* spp., *Oscillatoria* spp., *and Schizothrix* sp., while the other is coccoid *Aphanothece* sp.

Key words: Cyanobacteria, Khor Al-Zubair, Tidal Flats, and Iraq.

Introduction

The microbial mats represent a film cover the surface sediments and appear in many forms and color (Gerdes *et al*., 2000), which give a fascinating panorama. They form a cohesive surface to attract the dust fallouts. The studied area is covered with cyanobacteria, which are prokaryotic and self-nutrition (Mundt *et al*., 2001). It was discovered from 3.5 million years as fossils in rocks (Collerson and Kamber, 1999). Before they were called stromatolites, now they have many names such as; cyanophyta, myxophyceae, cyanophycophyta and cyanochloronta (Bold and Wynne, 1978) and blue-green algae. The use of electron microscope, detected a strong relationship between the bacteria and the blue-green algae with the similarity in the physiological properties, for that, they give a general term as cyanobacteria (Pandey and Trivedi, 1996). Many scientists suggested that the above are responsible for the generation of oxygen of the atmosphere (Bold and Wynne, 1978; Collerson and Kamber, 1999). Cyanobacteria could be also involved in some reactions which lead to formation and precipitation, one of them is cyanobacteria calcification (Kamennaya *et al*., 2012). Cyanobacteria grow to high densities in tropical marine environments, allowing direct isolation of many secondary metabolites (Leao *et al*., 2013). Cyanobacteria are widely distributed and live in different environments from fresh to marine waters, on the rocks, soil and plant stems of low alkalinity, but some species prefer to live in acidic environment of pH is between 4 and 5, or in hot springs, by photosynthesis (Bold and Wynne, 1978). In the tidal flats of hot and dry such as the sabkha (Taher, 2014), the microbial mats become flourishing and attract a notable quantity of dust fallouts.

Thomas *et al.* (2013) studied the rippling in cyanobacteria and suggested that, the storm events provide strong hydrodynamic flows, deforming the mats in an undulative manner. The cyanobacteria called now the Microbial Induced Sedimentary Structures (MISS), which formed in shallow, wide and gentle slope marine environments and recorded from Archaean age to Recent (Noffke *et al*., 2006). Cyanobacteria are adapted to live in high temperature and salinity, distributed in tidal flats from supratidal to intertidal zones (Gerdes *et al*., 2000)

The aim of the present study was to classify the sedimentary structures, obtain the relationship between these structures and the cyanobacteria genera which are responsible for the development of the structures and the local factors affecting the growth of cyanobacteria.

Geologic Settings:

(a) Location of the study Area:

The study area is a part of tidal flats of Iraqi coast, starting from Khor Al-Zubair and continue surrounded the Faw Peninsula to the mouth of the Shatt Al-Arab River, south of Iraq. Khor Al-Zubair is a marine tongue extended from the North West part of Arabian Gulf, its Length is about 40 km. and the width is between 1 km in low tide and 2 km in high tide, whereas, the depth is between 15-20 m. In 1983, the north end of Khor Al-Zubair was connected with a canal of Shatt Al-Basrah, which also the last canal connected with the canal of Al-Massab Al-Aam. The later one is an artificial canal to flush the soils from Baghdad to the south of Iraq. From that time Khor Al-Zubair has been considered as a new estuary, represents the interaction between the brackish water of Al-Massab Al-Aam and marine water of the Gulf. The study area includes the creeks of the Khor (Fig. 1).

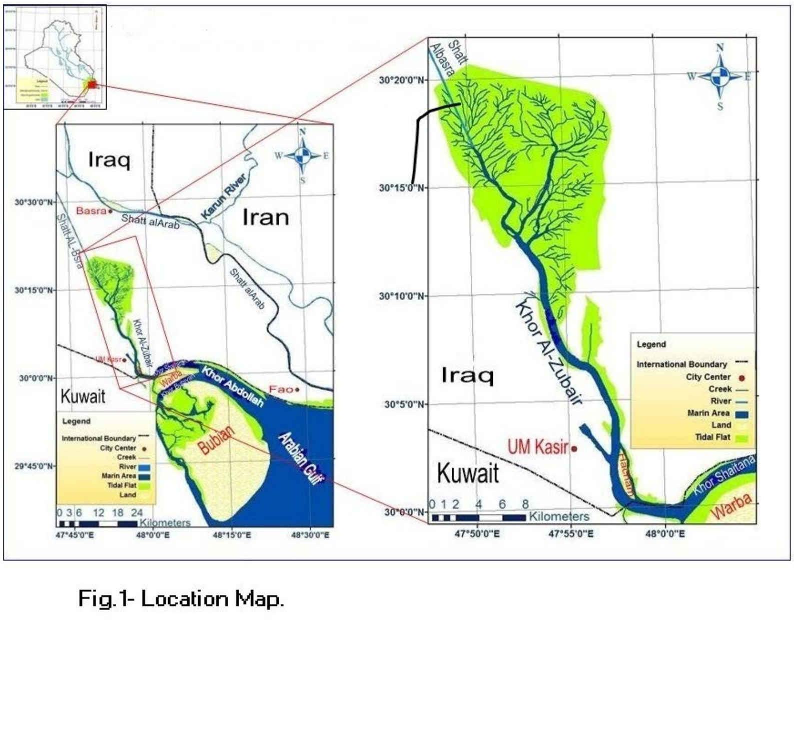

Fig.1- Location Map.

The area was covered by Quaternary sediments of Dibdibba and Hammar Formations, followed by fluvial sediments of Tigris, Euphrates and Karun Rivers; Dibdibba Formation is alluvial composed of gravel and sand sediments of Upper Miocene-Pleistocene (Aqrawi *et al.*, 2010). The Hammar Formation considered as a transgressive phase of marine clay sediments in Recent period (Buday, 1980). The tectonic setting of the studied area situated in Mesopotamian Zone of unstable shelf (Buday and Jassim, 1987), due to the influence of Alpine orogeny movement, tectonic of salt domes and upleft of basement rocks (Al-Mutury and Al-Maiahi, 2010). Khor Al-Zubair could be formed during Wurm glaciations by a subsidence due to fault with trend from current Al-Hammar Lake to the southern end of Khor Al-Sabiya (Al-Mussawy, 1993). The northwestern part of the Arabian Gulf manifests many variations during its history as, erosion, sedimentation, recent tectonism and climate changes. These factors provided a great influence on its sediments and structure (Al-Azawi, 1996).

(b) Physical Conditions of the Area:

The tides in the Khor Al-Zubair area are semi-diurnal influenced by mixed of diurnal and semi-diurnal tides (Al-Ramadhan, 1986), for that the tidal flats of Khor Al-Zubair covered twice a daily by water. The northern end of Khor Al-Zubair formed from many tidal channels (creeks). These tidal flats are divided into, subtidal, intertidal and supratidal zones. The subtidal zone starts from the lower limit of intertidal during the ebb tide to a depth of 2-3 m. below the lowest water level (Kadhim, 1999). Its width is 5-10 m, characterized by high side slope of the bank (approximately 35 degree). This zone represents unstable zone due to the continuous erosion and deposition (Al-Mulla, 1999).

The intertidal zone has a width of 5-20 m of gentle slope (Kadhim, 1999) and represents a special character in the area (Al-Mulla, 1999). The supratidal zone represents a horizontal flat with few undulations covered by water (Kadhim, 1999) and its elevation is no more than 2 m above sea-level (Al-Mulla, 1999). The sediments of the tidal flats vary in texture, dominant by silt and little amount of sand (Darmoian and Lindqvist, 1988), it is believed these detrital sediments transported from the surrounding area (Aqrawi and Darmoian, 1986 and Aqrawi and Evans, 1994). Albadran and Albadran (1994) concluded that, the recent sediments of Khor Al-Zubair and Khor Abdullah are products of different transport agents. The eastern side of Khor Al-Zubair composed of fine and soft sediments, and these sediments are washed sediments of the tidal flats, whereas, the sediments of Khor Al-Zubair channel are mixture of mud and marly silts with mollusks, foraminifera and ostracoda (Albadran *et al.*, 1991).

The water temperature and salinity vary with the seasons, time and place. They are low in winter and during the increase of discharge of Shatt Al-Basrah. The outer limits of tidal flats are more saline than the rest of the tidal area, where the evaporation and air temperature are high. The mean, maximum and minimum air temperature are 49.63, 51.7 and 30.40 °C in summer season, and in winter was between 19.32 to 23.40 °C for the mean of high temperature to 8.37 to 11.19 °C for the mean of low temperature (OIAA, 2010).

Materials and Methods

The study area is located on the eastern side of Khor Al-Zubair (Fig. 1). The field work started from October 2009 to February 2010. Thirty surface sediment samples were collected in 12/10/2009 and 10/2/2010 from different places, the GPS was used to fix their locations (Fig. 2). The samples are distributed around the outer limits of tidal flats due to the access difficulties of the wet and soft area. The samples were gathered manually and the sediments were isolated from the cyanobacteria. The sediments kept in plastic bags, and the algae kept with fresh water in plastic bags and stored in refrigerator. Seasonal field measurements were carried out using; portable pH meter (Lovibons/pH 200), and EC meter (Lovibond/con 200), in addition to the water and air temperatures using thermometer in three stations (Fig. 3).

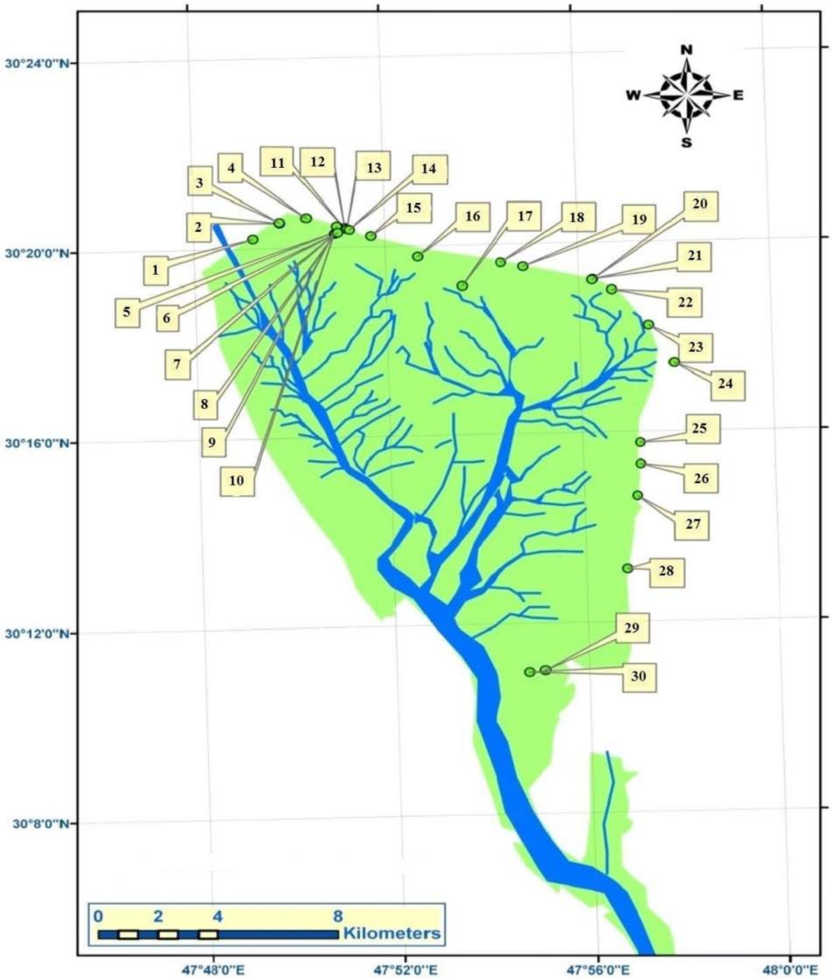

Fig.2- Locations of Surface Sediments.

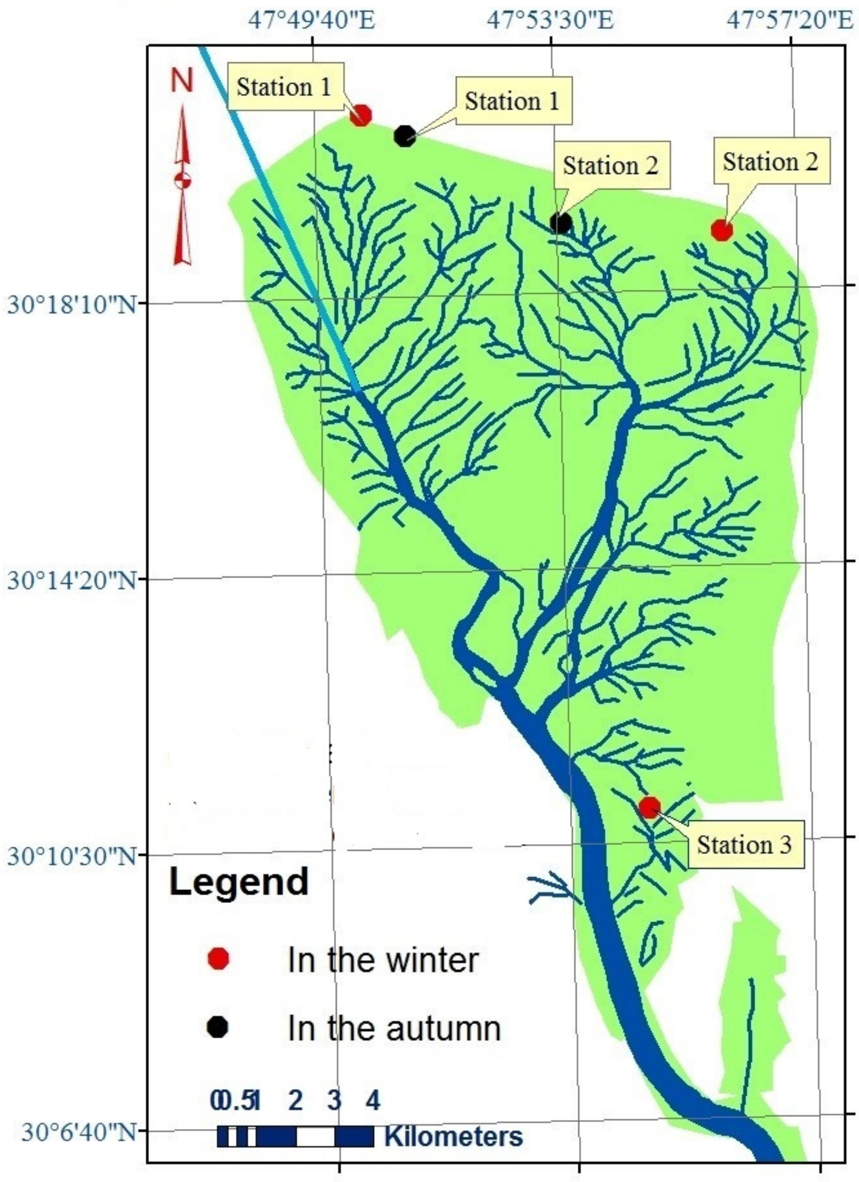

Fig.3- Locations of Environmental Measurement Stations.

XRD analysis for powder of 6 samples were carried out using instrument type X' Pert. The cyanobacteria were classified according to their external shape and dimensions as the length and width by using compound microscope (HM-Lux 3), and refers to the literatures of classification as Desikachary (1959), Prescott (1975) and Bold and Wynne (1978).

Results

The grain sizes analysis show that, the 22 samples of sandy silt, 5 samples of silt, 2 samples of silty sand and one sample of mud (Fig. 4). Mineral composition by XRD of bulk samples seem the dominant of quartz followed by calcite (Table 1 and Fig. 5).

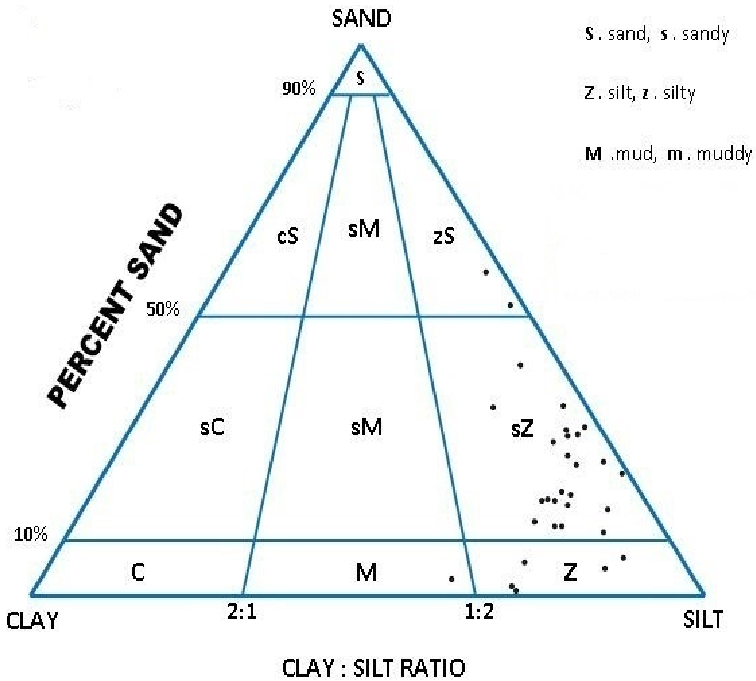

Fig.4- Surface Sediments Texture.

Table 1. Mineral composition of sediments.

Sample No.	Depth cm	Calcite %	Quartz %	Feldspar %	Gypsum %	Halite %	Dolomite %	Clay Minerals %
1	Surface	22.24	33.18	7.26	22.16	11.35	---	3.81
3	Surface	23.08	35.65	10.19	26.55	4.53	---	---
3	25cm	38.96	21.47	9.85	5.87	3.47	---	20.38
7	Surface	28.86	24.45	12.27	16.49	5.50	---	12.38
20	Surface	43.52	10.71	10.65	6.62	---	13.08	15.42
22	Surface	64.61	14.40	11.09	---	---	4.76	5.71
Average		36.83	23.30	10.35	12.90	4.04	2.97	9.61

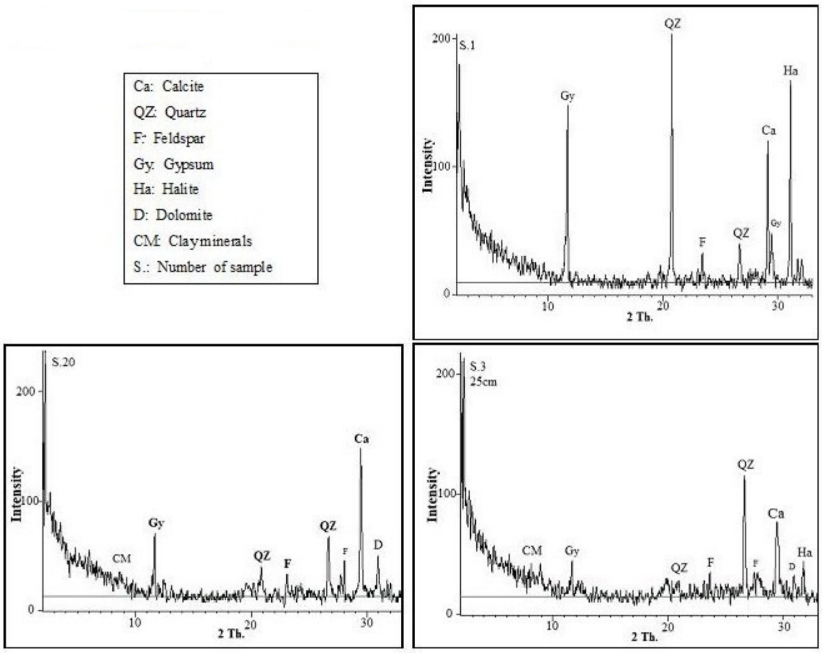

Fig. 5- XRD Analysis.

Environmental measurements including temperature, salinity and pH of water were taken during the fieldwork (Table 2) in three stations (Fig. 3) covered the study area. Salinity and electrical conductivity were also measured in laboratory from the extracted water of sediments (Table 3).

This study based on the classification of Bold and Wynne (1978) to classify the cyanobacteria, and five genera were identified (Table 4), which appeared in ten forms of MISS (Plates 1, 2 and 3) in the study area as: Wrinkles structures, ridges, domes, polygonal mat, tepee, mat crakes, chips mat, finger structure, irregular mounds, and pinnacles.

Table 2. Chemical and physical properties of water in study area.

Measurements	12/10/2009			10/2/2010		
	First Station	Second Station	Third Station	First Station	Second Station	Third Station
Temperature (°C)	26.00	26.00	Ebb tide	16.70	15.00	17.00
Salinity (‰)	42.36	62.20	Ebb tide	31.00	36.80	44.80
pH	---	---	Ebb tide	8.05	8.12	8.04

Table 3. Analysis of extracted water from sediment samples.

12/10/2009			10/2/2010		
Sample No.	EC (mmohs)	Salinity (‰)	Sample No.	EC (mmohs)	Salinity (‰)
11	52.30	33.40	1	45.80	29.31
12	271.60	173.82	3 surface	38.00	24.32
13	72.60	46.46	3 depth 25cm	45.20	28.92
14	46.60	28.60	5	80.40	51.45
15	56.60	36.22	6	92.20	59.00
16	73.80	47.23	7	105.00	67.20
17	62.20	39.80	8	97.00	62.08
19	108.20	69.24	9	52.00	33.28
25	181.60	116.22	18	94.00	60.16
29	167.00	106.88	20	40.40	25.72
			21	41.00	26.24
			22 bed	16.80	10.75
			22 bank	24.80	15.87
			23	18.78	12.02
			24	45.20	29.00
			26	80.20	51.32
			27	87.80	56.20
			30	32.40	20.73

Table 4. Identified genera of cyanobacteria in study area.

Sample No.	*Aphanothece microscopic*	*Oscillatoria* spp.	*Lyngbya* spp.	*Schizothrix* sp.	*Microcoleus* sp.
1	---	+3	+	---	+3
5	---	+	+	---	+
6	---	+	+2	+	+
7	---	+	+3	---	+
7	---	+3	+3	---	+
8	---	+3	+	---	+3
9	---	+	---	---	+
10	---	+	+2	---	+3
11	---	+	---	---	+
13	---	+	+	---	+
15	---	+	+	---	+2
17	---	+	+	---	---
18	---	+	+3	---	+3
19	---	+	---	---	---
20	---	---	+3	---	+3
21	---	+	+3	+	+
25	---	+	---	---	---
26	+3	+	---	---	+
29	---	+	+2	---	+

- Absent, + Rare, +2 Few, +3 Abundant.

Plate 1. A. Tidal dendritic creeks at the northern end of Khor Al-Zubair, B. Salt crest, pencil in the upper left to scale, C. Salt Ridges, pencil in the mid of photo to scale, D. Burrows of crabs, E. Rounded opening of burrows, red scraper to scale, and F. Small Ridges.

Plate 2. A. Color of cyanobacteria layers reversed on hand to scale and shows the layers in bellow, B. Submerged MISS, arrows to show it and the shovel to scale, C. Wrinkle Structure, red scraper in the mid of photo to scale, D. Ridge structure, the pencil in the mid of the photo to scale, E. Dome Structure, pencil to scale, and upper left, inversed piece in hand, and F. Polygonal Mat in green color, shovel to scale.

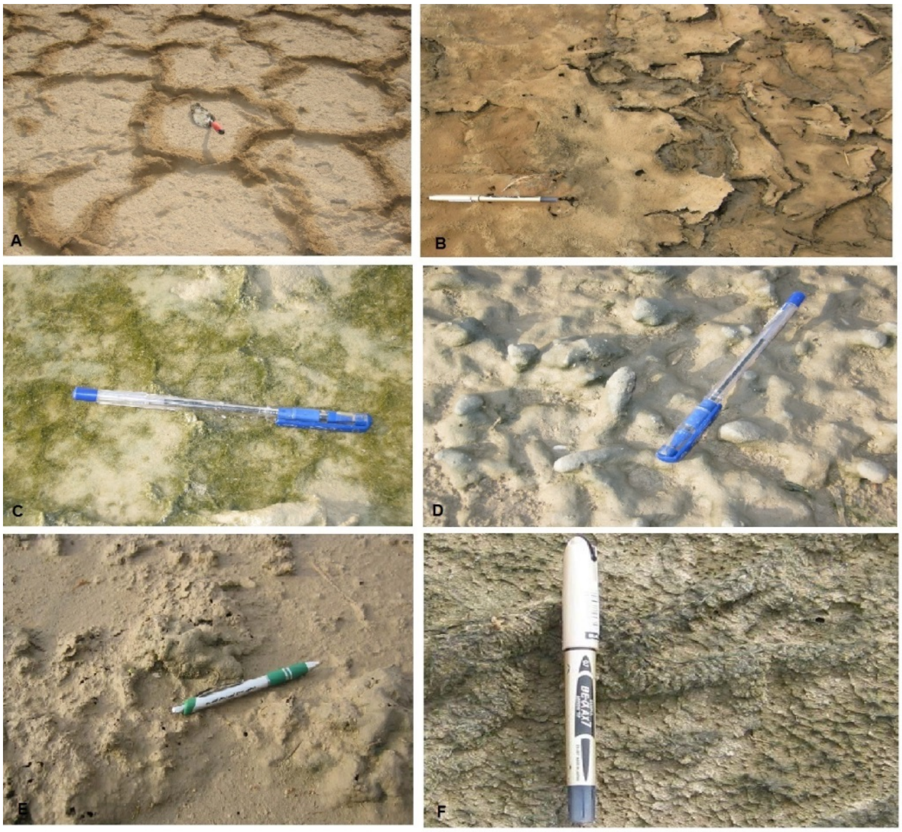

Plate 3. A. Tepee Structure, scraper to scale, B. Crack in the Mat, C. Chips Mat, D. Finger Structure, covered the root or stems of dead plants, E. Irregular Mounds, and F. Pinnacle Shape.

Discussion

The grain size distribution indicated that the abundance of sandy silt texture from the other types. It is considered that the presence of sand in samples could related to the road bank erosion as, the samples are on the periphery of the tidal flats near the main road of the area. It is difficult to get access to the middle of the tidal flats, due to the nature of sediment; soft and fine sediments. Cyanobacteria have the ability to attract the coarse sediments of windblown. Also, other consideration about the coarse grained sediments are related to the nearest of study area to the Dibdibba Formation (Basi *et al.*, 1989). The other source of sand material is the aeolian deposits and dust fallout arrived to the northern part of the study area (Al-Ali, 2007). Whereas, Al-Jabbry (2005) stated that the derived sediments from Khor Al-Zubair to Khor Abdullah are fine grained materials.

The mineralogical composition of sediments shows the high ratio of quartz (Table 1) due to the contribution of the bed erosion (Darmoian and Lindqvist, 1988) and aeolian sand (Al-Ali, 2000 and 2007). The aeolian sand is more abundant in calcite than dolomite (ROPME, 1987), for that the ratio of dolomite is less than calcite (Table 1).

The relative abundance of gypsum mineral could relate to the diagenetic gypsum which is accompanied with the algal mat like the coast of Santa Pola in France (Busson and Schreiber, 1997) and Union of Arab Emirates (Kendall *et al*., 1998). The high temperature and evaporation of the ground water raised to the surface (Al-Bassam, 1986) add also gypsum to the sediment budget. The study of Issa (2006) does' not mention the gypsum, which could attributed to the sampling place of this study near the high limits of tidal flats. Clay minerals appeared in the bulk sediments and the major part of clay minerals derived by fluvial, tidal currents and dust fallouts (Al-Dhabagh and Albadran, 1995).

The temperature is considered as the main influencing factor on the physical, chemical and biological nature of any area. Water temperature is a controlling factor on the density and distribution of marine biota (Power *et al*., 2000). The temperature of air and water in the area was 34 and 26 °C respectively. It was 20 °C for air in February. Water temperature varies from 15 to 26 °C in the creeks (Table 2). Maximum water temperature was 33.5 °C in August and minimum in January 10°C near the north station of current study.

The water salinity of the studied area is high and considered as euhaline and hypersaline, according to the classification of Nelson-Smith (1977). Whereas, it was mesohaline (it was 6.7 to 10.5 ‰) for Al-Mulla (1999) and Kadhim and Al-Mulla (2002). This variation in salinity is related to the high temperature, shallow water in tidal flats, salinity of influx water from Khor Abdullah and the discharge of brackish washing water from Shatt Al-Basrah. The last factor could be more effective than the others, where during the studies of Al-Mulla (1999) and Kadhim and Al-Mullah (2002), the discharge of Al-Massab Al-Aam through Shatt Al-Basrah canal was higher than in present time. The discharge was 325 m^3/s during the flood tide and 1050 m^3/s in ebb tide (Albadran *et al*., 1996). The high value of salinity in the present study was 62.2 ‰, in summer in shallow creeks where the water depth was few centimeters. The salinity of sediments was also high (Table 3). The seasonal variation in sediment salinity could be related to the effect of rainfall in the region, and the evaporation process. According to these variable physical parameters, the density of cyanobacteria in the present study varies among the stations according to the value of salinity, no records for cyanobacteria in places of low salinity and near the Khor. The ideal limit of salinity for algal mat formed by cyanobacteria is between 80 and 150 ‰ (Busson and Schreiber, 1997). In this study, where cyanobacteria was present in the salinity of sediments was from 25.72 to 116.22 ‰. This could be attributed to living some genera in hypersaline sediments as; *Lyngbya*, *Microcoleus*, and *Oscillatoria* (Al-Delamii, 2000). The cyanobacteria in the northern part of the creeks indicate that they are abundant in winter than in Autumn, three genera were recorded in autumn and five in winter. The reason of that could be related to the increase of nutrients in winter (Shamshom and Yacob, 1986) when the primary productivity in the area is high (Al-Abayachi and Gani, 1986) or cyanobacteria prefer to live in temperature between 18 and 25 °C (Al-Mussawy, 2007).

In the present study, three structures were classified based on the origin and motive of formation; physical, biological and bio-physical structures.

a) Physical Structures:

The physical are; creeks, where the area is characterized by the multi bifurcation of these tidal channels (Plate 1A). These creeks give to the area a dendritic geomorphologic form (Fig. 1). These geomorphologic forms are the biggest and formed by aqueous and wind erosion in addition to the tectonic setting (Karim, 1991 and Al-Mulla, 1999), the eroded materials by these forms washed down to the southern end of the biggest creek.

Salt structures have a chance in the study area, formed after their deposition on the surface of sediments due to the development of gypsum and halite minerals. Salt structures occur in sabkha region rich in salts and high rate of evaporation. Two types of sedimentary structures recorded in the area; salt crust and salt ridges. Salt crusts are irregular and the thickness is 2-5 cm (Plate 1B), whereas, the salt ridges are irregular, pointed end and polygonal shape (Plate 1C). The height of these ridges was 2-5 cm and friable in nature. Salt structures exist in the other side of the road where this road blocks the tidal water from arrival to this area and the main source of water is from the capillary phenomenon, rainfall in winter, and little bit the humidity during the humid wind of southeast direction in the region.

b) Biological structures:

Biological sedimentary structures or disturbed sedimentary structures are due to the activity of the biota such as; burrows of crab and mudskipper. Burrows of crabs vary in their shape and size (Plate. 1D), the depth of the burrows is 10-30 cm and diameter was not more than 10 mm in the intertidal zone, whereas the diameter reaches 30 mm in the supratidal zone (Kadhim and Darmoian, 1999). This could relate to the age and size of the crabs (Kadhim, 2008). Some crabs make ridges a rounded the opening of burrows (Plate. 1E), to reinforcement the opening and keep the opening from windblown sand, and to prevent themselves from enemies (Kadhim and Al-Mulla, 2002). Mudskipper burrows have different shape and size of holes and, they buildup the clay around the hole in polygonal shape of small ridges (Plate. 1F) to keep water around the hole during the ebb tide period.

c) Bio-physical structures:

The bio-physical sedimentary structures are mainly cyanobacteria. Cyanobacteria form structures which are called microbial induced sedimentary structures (MISS). These structures are products of interaction between cyanobacteria and the environment, covering the tidal flats during the annual seasons. The MISS in the studied area appear in two forms; algal mat in different forms and algal mound also in different colors and forms. The first type formed through three stages and the second one formed by fourth stage, these two types of mechanisms was explained in detail by Noffke *et al.* (2001). The internal structure of these cyanobacteria are composed of fibers with different color as in Wrinkles structures (Plate. 2C), appear in wrinkle forms parallel to subparallel each other formed due to the action of tidal currents and weak marine waves. The fibers of cyanobacteria present in two colors, deep and pale green in location 7 and 8 (Fig. 1). Microscopic identification indicates that the genus *Oscillatoria* sp. was responsible for the deep green color. Sometimes the mat of cyanobacteria are rushed by tidal currents as in the Ridge structures (Plate. 2D), multi-faces and antiform in shape. These are formed from the rush of mats by tidal currents, mostly hollow and filled later by sediments to form zones in the antiform. The color of this structure varies with seasons, deep color in winter and pale in autumn. This structure found in locations 5, 6, 20 and 25 (Fig. 1). The sediments adhesive on the surface of fiber by a polymer material secreted from the fiber, extracellular polymeric substances (EPS). This is noted in Dome structures, formed by the rush action of gases in the mats after filling of mats by sediments and salt crystals (Plate. 2E). Porada *et al.* (2007) found that the coccoid cyanobacteria are responsible for the formation of this structure. Microscopic study in the current study reveals that the spherical genus *Aphanothece* sp. forms this structure and heavy secretion of EPS. This structure presents in locations 19 and 26 (Fig. 1). This material was a gelatin composed of protein, carbohydrates and starch led to cohesive the sediments (Guadrado and Pizani, 2007). The adhesive sediments with fiber make zones in the structure from 1 to 4 micrometer in thickness (Stephens *et al.*, 2008).

In the study area the colors of these zones are; green, black, white and red (Plate 2A). Stephens *et al.* (2008) found that, the variation in color depending on variation in chemical composition, green color comes from the interaction of fibers of algae, black could related to reduction. While, white color belongs to the deposition of salts and red one is from the oxidation by dissolved oxygen in water. It could also possible to form authigenic minerals in the structures of cyanobacteria as; siderite and pyrite (Noffke, 2000).

The growth of EPS, nature of sediments, and erosion and sedimentation processes act on the development of MISS to submerge to the water surface (Plate 2B). In other places where the environment suffer from alternative wetness and dryness many MISS developed such as, Polygonal mat, which represents an extended mat with elevated edges in hexagonal forms (Plate 2F), found in location 13 (Fig. 1), Tepee structure is a polygonal mat exposed to desiccation (Plate 3A) formed in location 12 (Fig. 1) in the sabkha near tidal area, and Mat cracks are formed in thin mat from the alternative subsequent wetness and dryness during flood and ebb periods and recorded in location 18 (Fig.1). The cracks take place in the weak periphery area (plate 3B). Chips mat is a thin mat (Plate 3C) found in location 11 (Fig. 1), which could be the first step to form mat.

The remains of dead plants could play a role in the formation and development of MISS where the later growth on these remains in this tidal flats as the Finger Structures which formed due to the uplift of algal mat in a finger form in the area (Plate 3D). This structure was associated with plant roots and stems. It was recorded in location 10 and 13 (Fig. 1).

The area is a witness of notable windblown and raised sediments from the traffic on the road, these raised sediments could be attracted by cyanobacteria due to their adhesive surface and forming the Irregular Mounds are elevations (Plate 3E) found in location 1 and 9 (Fig. 1), the evidence is the nearest of this structure to the road, where the sediments arrived from movement in the area.

Pinnacles, is a pointed form like a pencil (Plate 3F), found in location 15 (Fig. 1). This structure is a small bridge originated from algal mats due to a difference in the behavior of cyanobacteria fibers network with sediments. Two genera are responsible for this structure; *Oscillatoria* and *Microcoleus*.

From field observations and laboratory analysis, there is no accordance between the presences of cyanobacteria and burrows of crabs. This could be related to the high cohesive mats formed by cyanobacteria, where the crabs could not able to burrow it, in addition to the cyanobacteria prefer the high salinity area to live.

The tidal currents are weak in the area for that the erosional MISS are absent, and the algal mat cohesion is strong and capable to resist the erosion (Noffke and Krumbien, 1999; Gerdes, 2007), and the EPS material increase the shear strength of structure and subsequent increase in consistency against erosion (Guadrado and Pizani, 2007).

Conclusion

Three types of sedimentary structures are present in the study area; physical, biological and bio-physical structures. Sediment textures, physical and chemical properties of the study area are convenient to cyanobacteria to live and growth. Cyanobacteria are the most frequent sedimentary structures in the area, formed in many types as; Wrinkles structures, Ridge structures, Dome structures, Polygonal mat, Polygonal mat, Tepee structure, Mat cracks, Chips mat, Finger Structures, and Irregular Mounds. They attract the windblown and eroded sediments by the EPS. These cyanobacteria differ in shape and structure in accordance with genus, cohesion of fibers, and density of EPS, physical and chemical parameters of environment. Algal mats increase the resistance of tidal flats against the erosion. The presence of cyanobacteria is not in accordance with the presence of crabs.

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غطاء الحصيرة المايكروبية للرواسب الحديثة لمسطحات المد في خور الزبير جنوب العراق، شمال غرب الخليج العربي

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المستخلص - تهتم هذه الدراسة بالتراكيب الرسوبية التي تكونها السيانوبكتريا في مسطحات المد لخور الزبير شمال غرب الخليج العربي. هناك ثلاث انواع من التراكيب الرسوبية في المنطقة؛ ذات الاصل الفيزيائي والاصل الاحيائي والاصل الفيزيواحيائي. النوع الاخير يمثل التراكيب الرسوبية التي تحدثها السيانوبكتريا، وظهر منها عشرة انواع والتي تؤدي الى زيادة مقاومة رواسب المسطحات المدية لعوامل التعرية مع تجميع للرواسب الخشنة في تركيبها. أظهر تشخيص السيانوبكتريا في المنطقة عن وجود خمسة اجناس اربعة منها خيطية؛ *Microcoleus* sp., *Lyngbya* spp., *Oscillatoria* spp., *Schizothrix* sp.، والجنس الأخير كروي coccoid *Aphanothece* sp.