A Review of Biogeochemical Composition in Accordance with Bacterial Diversity in Eastern Mediterranean Sea

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Abstract—The Mediterranean Sea having eastern and western basins with different hydrological and nutrient regimes is characterized by high salinity, temperature, density and low nutrient concentrations. Eastern Mediterranean Sea has higher oxygen and oligotrophy with N or N and P co-limitations. On the other hand, the Gulf of Lions, the Algerian coasts, the North Adriatic, the Nile Delta, the Levantine basin of the Eastern Mediterranean Sea and the North Aegean Sea are identified as the most productive regions. In addition to the geographical separation, geochemical composition of sediments illustrates the differentiation of North Aegean Sea influenced by both Aegean Sea and nutrient-rich Black Sea from Central Aegean Sea and also from South Aegean Sea influenced by both Aegean Sea and oxygen-depleted and oligotrophic Levantine Sea. According to 16S rRNA gene libraries, Acidobacteria are dominant but Firmicutes and Actinobacteria account minor part in deep sediments of Eastern Mediterranean Sea. In contrast, together with Gammaproteobacteria they become dominant according to culture-dependent studies in sediments of Eastern Mediterranean Sea. Moreover, it has shown that environment effects bacterial characteristics such as higher antibiotic resistance and higher phylogenetic diversity in higher taxa in coastal sediments compared to lower antibiotic resistance and higher phylogenetic diversity in lower taxa in deep-basins of Eastern Mediterranean Sea.

Keywords—Bacterial diversity, biogeochemical parameters, 16S rRNA genes, Mediterranean Sea.

I. PHYSICOCHEMICAL CHARACTERISTICS

The Mediterranean is a semi-enclosed sea exchanging water with the North Atlantic Ocean through the Strait of Gibraltar and with the Black Sea through the Turkish Strait System as the Dardanelles, the Marmara Sea and the Bosphorus Strait. It is characterized by high salinities, temperatures, densities and low nutrient concentrations [1]. It has the western and eastern basins separated with the Strait of Sicily and they have different hydrological features and nutrient regimes.

The Eastern Mediterranean Sea is connected to the Aegean Sea and the Black Sea which has small but significant inflow due to its low salinity. While the Adriatic Sea was previously the deep water formation area in the Eastern Mediterranean Sea, in the early 1990’s the Aegean Sea became the main deep water formation area generating an event known as the Eastern Mediterranean Transient [1]. It is suggested that the Eastern Mediterranean Transient is caused by very strong winters transporting high-salinity waters into the Aegean Sea [2]. The new deep water of Aegean Sea (below 1200 m depth) is characterized by higher temperature and salinity than previous deep water of Adriatic Sea [2].

The Mediterranean Sea is well oxygenated and oxygen utilization rate values are similar to other oceans in the upper water column but higher in the deep water layers [3]. The recently formed deep waters during the Eastern Mediterranean Transient containing labile dissolved organic carbon brought from the surface layer to the deep layer increased the oxygen consumption rate [4]. The oxygen concentrations are higher in the Eastern Mediterranean Sea than in the Western Mediterranean Sea [1]. In contrast, the horizontal distribution of oxygen is more uniform in the western compared to the eastern basin since Eastern Mediterranean Sea has more complex morphology restricting the spread of new, dense and more oxygenated waters [1].

Due to the anti-estuarine circulation of the Mediterranean Sea as exporting deep water with higher nutrient values and importing low nutrient Atlantic Water, it has low nutrient concentrations [5]. The studies of the nutrient regime in Mediterranean Sea show no significant seasonality [6]. However, the influence of river discharge and coastal runoff is significant throughout spring due to snow melt [7]. The Eastern Mediterranean Sea has thicker nutrient depleted surface layer and deeper nutrient maximum layer than the Western Mediterranean [1].

In spite of N:P ratio in the world ocean is around 16 [8], it is 24–27 in the deep eastern basin, and 20–22 in the deep western basin. The reason of this anomaly is still questioning and possible suggestions are the Adriatic rivers [9], the atmospheric inputs and the lack of denitrification in the generally well oxygenated Mediterranean waters and sediments [10, 11].

The Mediterranean, particularly the Eastern Mediterranean Sea, has been considered as phosphorus limited for biological growth [10], although recent work has suggested N or N and P co-limitations [12]. The phosphate and nitrate concentrations in deep waters increased in Western Mediterranean Sea from 1960 to 1994 [13, 14] in association with agricultural, industrial and urban activities since the 1960s [14] although the river outflows are generally the most significant source of phosphate supply and the atmosphere is for inorganic nitrogen [7, 13, 15]. In contrast to this increase, the phosphate, silicate and nitrate concentrations have not dramatically changed in the Eastern Mediterranean Sea due to the differences in the residence times of deep waters in those western and eastern basins [6]. One explanation for the lower nutrient
concentrations in the eastern basin is the nutrient supply of the Eastern Mediterranean to the Western Mediterranean [16].

In contrast to oligotrophic system of the Mediterranean Sea, some coastal regions such as The Gulf of Lions (northwestern Mediterranean Sea), the Algerian coastal zone, the Northern Adriatic, the Nile Delta, and the northeastern part of the Levantine basin of the Eastern Mediterranean and the Northern Aegean Sea are identified as the most productive regions [17]. The nutrient concentration in the Aegean Sea is twelve times lower than in Atlantic Ocean and eight times lower than in Alboran Sea [6]. The oxygen and nutrient data collected in the Eastern Mediterranean Sea during the past decade showed a depletion of nutrients in the following order: Levantine > Ionian > Aegean [6, 18].

Geochemical composition of sediments in Aegean Sea also indicates the separation of North Aegean Sea having complex bottom topography and highly dynamic hydrographic conditions influenced by both Aegean Sea and nutrient-rich Black Sea from Central Aegean Sea and also from South Aegean Sea influenced by both Aegean Sea and oxygen-depleted and oligotrophic Levantine Sea and similarly, the separation of the inner bay highly influenced by industrial and domestic sewage discharge and river input from middle and outer bays of Izmir Bay [19, 20].

In the Aegean Sea, there are coastal areas with eutrophication problems related to anthropogenic activities, agricultural runoff, sewage outfalls and river outflows. For instance, in the Gulf of Heraklion in Crete, inorganic nitrogen flux from agricultural runoff is 40 – 60 % during the winter period and the oligotrophic water from the Aegean Sea enters into the gulf influencing the nutrient levels during the warm months of the year (April to October), in addition to the untreated domestic wastewater and effluents from the local industrial activities, especially olive oil processing by-products resulting to the development of eutrophication crises during the year [21]. In most of the polluted Helenic coastal areas, the limiting factor is nitrogen [6] as similar to Izmir Bay in Turkish coasts [22, 23] in which high terrestrial inputs result to the increase of nutrient values [24].

II. ENVIRONMENTAL EFFECTS ON BACTERIAL DIVERSITY

According to 16S rRNA clone libraries, the Acidobacteria are the dominant bacteria in deep sediments of Eastern Mediterranean Sea [25, 26]. Although the Firmicutes and Actinobacteria account minor part in 16S rRNA gene libraries of Mediterranean sediments [27], especially for sediments of Eastern Mediterranean Sea as 3 % Firmicutes and 4 – 28 % Actinobacteria of total sequence [28], they become dominant according to cultivation-based methods for the sediments of Cretan Sea together with Gammaproteobacteria which become dominant under hydrostatic pressure incubation of those sediments [29] and similarly, the Firmicutes are dominantly isolated in addition to the Actinobacteria and Gammaproteobacteria using culture-dependent methods from sediments of Eastern Mediterranean Sea [19, 20]. However, the Gammaproteobacteria are mostly obtained in shallow sediments of Aegean Sea [19, 20] supporting the frequent 16S rRNA gene clones of this class compared to the deeper sediments of Eastern Mediterranean Sea [25].

Environmental parameters together with geographical differences influence the bacterial characteristics and community composition in sediments of Eastern Mediterranean Sea [20, 25, 26, 28, 30-32]. In addition to antimicrobially active strains of actinomycetes isolated from the sediments in Turkish coasts of Black Sea, Aegean Sea and Mediterranean Sea [33], enzymatic activity results of actinomycetes strains and organic nitrogen depletions underlying N limitation in the sediments of Eastern Mediterranean Sea support protein utilization rather than carbohydrates [32]. Another indicator of environmental effects on bacterial characteristics as the relation between antibiotic resistance and geographical differences is given as higher resistance in coastal areas of Syria than Turkey and Lebanon [30] and similarly higher resistance in coastal sediments compared to deep-basins of Eastern Mediterranean Sea [20, 32, 34-36]. Moreover, in addition to the north–south latitudinal separation of bacterial diversity in sediments of Eastern Mediterranean Sea [25], higher phylogenetic diversity in higher taxa for shallow sediments due to the dynamic environmental factors as continuous terrestrial and anthropogenic effects i.e. river and sewage input increasing the eutrophication and higher diversity in lower taxa for deep-basins due to high hydrostatic pressure, depletion of oxygen and nutrients so that bacterial community composition shifts according to hard environmental conditions are obtained in Eastern Mediterranean Sea [19, 20, 34, 37].

REFERENCES


