ISSN 1848-0071
627.222.1(262.3)+53.068.2=111
Recieved: 2014-05-08
Accepted: 2014-09-17
Original scientific paper

MARINE SEDIMENTS CHARACTERISTICS IN THE SPLIT AREA

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The distributions of granulometric composition, organic matter and carbonate content were determined in the sediment core at three stations and in the samples from surface sediment at eight stations in Split area (eastern Adriatic Sea). According to average values, clay and silt particles prevail in the sediment core and surface sediment. Average values of organic matter content for the three stations were 7.6 ± 0.9%, with range from 4.9 to 9.9%. In the surface sediment, average values were 6.2 ± 1.8%, with range from 3.9 to 8.9%. In the sediment core samples average values of carbonate were 45.1 ± 4.6%, with the range from 36.6 to 71.7%, while average values of carbonate in surface sediment were 52.5 ± 8.2%, with range from 41.1 to 66.5%. According to the Folk classification, the sediment type at Stations 1 and 2 is mud, and at Station 3 slightly gravelly sandy muds. In the surface sediment, at the four stations, prevailing sediment type is mud, following slightly gravelly sandy mud (at three stations), while sandy mud was determined only at one station According to the Shepard classification in sediment core prevailing sediment type is silty clay, while in surface sediment, sediment type vary from silty clay (clayey silt mixture to silt). Very poorly (2.08) to extremely poorly sorted (6.85) sediment indicated different origin of settled particles (terrigenous and biogenous). The relationship between determined parameters in the sediment was established using the regression analysis (Spearman correlation and Cluster analysis). Results of the Cluster Analysis, using all the investigated parameters (granulometric composition, organic matter and carbonate content) confirmed the granulometric composition as a leading differentiation parameter between investigated sediments.
Key words: granulometric composition, organic matter, carbonate, regression analysis.

Karakteristike sedimenata morskih okoliša Splita. Ispitivana je raspodjela granulometrijskog sastava i udjela organske tvari i karbonata u jezgrama sedimenta s tri postaje i površinskom sedimentu s osam postaja u priobalnom području Splita. Prema prosječnim vrijednostima u uzorcima jezgri i površinskih sedimenata prevladavaju čestice gline i silta. Prosječna vrijednost udjela organske tvari u jezgrama sedimenta bila je 7,6 ± 0,9%, sa rasponom od 4,9 do 9,9%, a u površinskim sedimentima 6,2 ± 1,8%, sa rasponom od 3,9 do 8,9%. Prosječna vrijednost udjela karbonata u površinskim sedimentima bila je 52,5 ± 8,2% s rasponom od 41,1 do 66,5%, a u jezgrama sedimenta 45,1 ± 4,6%, sa rasponom od 36,6 do 71,7%. Prema Folkovoj klasifikaciji u istraživanim površinskim sedimentima i jezgrama sedimenta najzastupljeniji je mulj. Po cijeloj dubini jezgre sedimenta mulj i neznatno šljunkovit pjeskoviti mulj su ustanovljeni na centralnim postajama Kaštelanskog zaljeva, dok mulj prevladava na istočnoj postaji Kaštelanskog zaljeva. U površinskim sedimentima osim mulja (na 4 postaje; dvije u Kaštelanskom zaljevu, a dvije izvan njega), zastupljen je i šljunkovito pjeskoviti mulj (tri postaje; dvije u Kaštelanskom zaljevu, jedna u Splitskim vratima), dok je pjeskoviti mulj nađen samo na jednoj postaji (ispred Omiša). Prema Shepard-ovoj klasifikaciji u jezgrama sedimenta najzastupljenija je siltozna glina, dok je u površinskim sedimentima ona ustanovljena na dvije postaje (u Kaštelanskom zaljevu). Osim tog tipa sedimenta u površinskim sedimentima nađeni su glinoviti silt (smjesa i silt). Na istraživanim postajama sortiranost sedimenta bila je u rasponu od vrlo loše do izuzetno loše (2,08-6,85), što ukazuje na različito porijeklo istaloženih čestica (terigeno i biogeno). Veza između određivanih parametara je određena pomoću regresijske analize (Spearman-ova korelacija i Cluster analiza). Rezultati Cluster analize potvrdili su kako je granulometrijski sastav sedimenta glavni parametar koji utječe na svojstva ispitivanih sedimenata.
Ključne riječi: nestandardno mjerenje, čestične tvari, zrak.

INTRODUCTION

Aquatic sediments represent an, dynamic and heterogeneous biogeochemical system, act as sink for particulate matter introduced to the aquatic environment from a variety of sources, such as continental run-off, coastal erosion or atmospheric fall-out, which is then deposited on the bottom of the sea. Typically, sediments are a structured accumulation of particulate mineral matter, inorganic matter of biogenic origin, organic matter in various stages of decomposition or synthesis, and water [1]. Inorganic and organic particles are complex physical, chemical and biological structure and characteristics. They can scavenge some elements, acting as an adsorptive sink with metal concentrations more important than in the water column. Sediments are therefore an appropriate matrix for monitoring of various contaminations. However, sediments are not only a sink but also a possible delayed source of different organic and inorganic contaminants into the water column due to desorption, remobilization processes, redox reactions and degradation of sorptive substances [2]. The resuspension is consequence of natural activities: natural events, such as tidal currents, wind waves, storm events, and wave current interaction, and anthropogenic activities, such as dredging, trawling and fisheries activity [3]. Marine sediments with high content of organic matter have a high affinity to accumulate organic and inorganic contaminants. The content of organic matter is usually related to the granulometric composition of the sediment [4]. The organic matter as well as different micro and macro components in the aquatic environment will be closely associated with suspended mineral particles, e.g. adsorbed on single particles, forming complexes with metal (usually iron) oxides on the surface of particles, become aggregates and are deposited or transported in this form within the lake [5].

During the twentieth century, Kaštela Bay became one of the most industrialized and contaminated areas in the eastern Adriatic, Croatia. The situation has improved from 1991 onwards due to the fact that most chemical industries were closed down during the war in Croatia. Transport of sediment and suspended particles in Kaštela Bay is controlled by the prevailing circulation in the bay which is mostly induced by wind. Possible sources of the suspended matter in the bay are river input (Jadro river), coastal erosion, marine organisms production and particles of anthropogenic origin [6].

The objectives of this work were to determine the granulometric parameters, granulometric composition, organic matter and carbonate content in the sediment core and surface sediment samples at stations in the Split area and to investigate a possible correlation between these parameters in order to determine the characteristics of the marine sediment at investigation stations.

MATERIALS AND METHODS

Study area

City of Split, second largest city in Croatia is economic, administrative, educational, sports and tourist centre of Central Dalmatia, with an approximately 180 000 inhabitants (as per 2011 census). Split is located at peninsula enclosed Kaštela Bay from south east side, in the central part of the eastern Adriatic coast. Kaštela Bay is small, semi-enclosed bay, 14.8 km long and 6.6 km wide with average depth of 23 m and surface area of 61 km^2 [7]. The narrow coastal strip of the Bay is a highly developed area where the urban and rural population amounts is about 350 000. As intensive industrialisation and urbanisation of this area (the population has increased six fold over the last 45 years) have not been accompanied by an adequate development of necessary urban infrastructure, large quantities of urban and industrial waste waters are released untreated into the Bay [8]. In the maximum of pollution, the Kaštela Bay was received are a structured accumulation of yearly 32 million m^3 of untreated municipal waste water, and 20 million m^3 of partially treated industrial wastewater. The Bay also receives water from agricultural and urban runoff. Such discharges usually contain heavy metals and organic matter. In November 2004, the sewage system was completed, comprising a network of pipelines, pumping stations, a tunnel, treatment plants and offshore submarine outfalls. Consequently, sewage discharge into Vranjic Basin suddenly stopped [9]. The monitoring program of sanitary quality of sea in Kastela Bay (October 2008 - May 2009) indicates a significant improvement in the sanitary quality of sea Vranjic after years of extremely high concentrations of faecal pollution indicators in this area (The Integral Project of kaštela Bay Protection (ECO Project).

The predominant rocks surrounding the area are carbonates and flysch [10]. Transport of sediment and suspended particles in the bay is controlled by the prevailing circulation which is mostly induced by local winds [11]. SE wind (scirocco) induces typical estuarine circulation with incoming flow in the surface layer and the outgoing flow in the deeper layers with turbulent vertical exchanges.

Split, with its surrounding area, is an important industrial centre with cement, brewery, plastic, food, textile and ship building industries. It is also an important traffic centre (vehicular, ship, yacht harbours and air traffic) [12].

Sediment core samples were collected on stations located in Kaštela Bay (Figure 1), station 1 (S1) located in the middle part of the Bay, with least influenced by coast, station 2 (S2) located in the eastern, formerly heavily polluted, part of the Bay, under the river Jadro influence, near the peninsula of Vranjic. Station 3 (S3) is located in the vicinity of the former chlor-alkaline factory. Factory is closed, but there is still some activity left in production of plastics and chemicals. These stations are significantly different by distances from the coast, depth and anthropogenic inputs.

Surface sediment samples were collected in the Brač and Split Channel (Figure 1). In this area is the most important Split harbour, which is one of the largest Mediterranean ports with approximately 3.5 million passengers and 700000 vehicles per year. Apart from that, there are agricultural and tourist areas on the southeast from Split (Stations S7 and S8). Station S8 is located near the estuary of the river Cetina. Carbonate rocks constitute about 74% of the total basin area of the Cetina. As a result of the surrounding flysch deposit weathering clay particles prevail in the sediment.

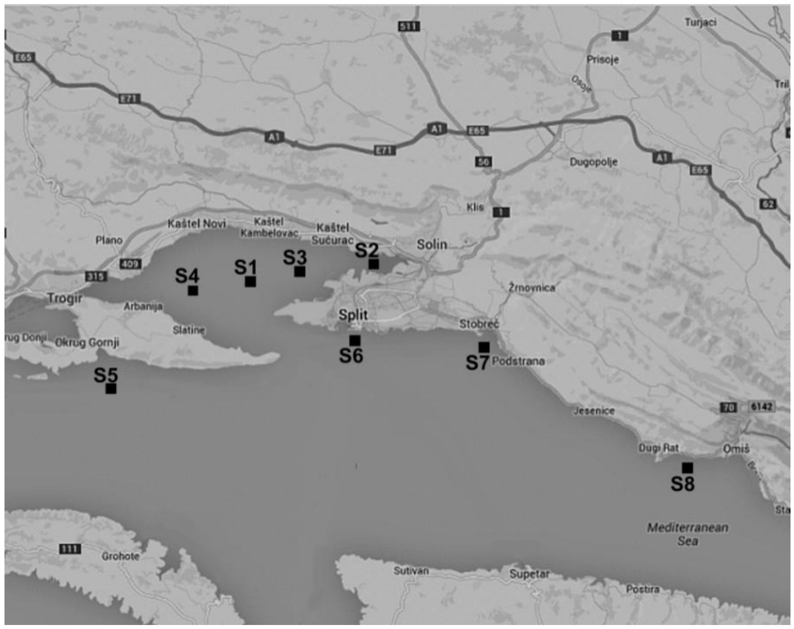

Figure 1. Investigated area with sampling stations
Slika 1. Istraživano područje sa označenim postajama uzorkovanja

Sampling methods

The sediment core samples were collected during the cruise of the R/V "Bios" on 13th July 2008 at three stations (Figure 1), using plastic gravity corer. At each station four sediment cores were taken and each core (up to 10 cm long) was sliced into 1 cm long sub-samples. Three cores were selected for organic matter and carbonate determination and analyzed in triplicate. The residual, fourth core was used for determination of granulometric composition. Surface sediment samples (0-2 cm) were collected using Van Veen gravity corer at eight sampling sites (Table 1).

The sub-samples were packed in hermetically closed plastic bags, frozen at -18°C and kept at this temperature until analyzed. In laboratory the sub-samples were freeze-dried and used for analysis.

Table 1. Depths and geographical cordinates for sampling stations
Tablica 1. Dubina i geografski položaj postaja

Station	Depth (m)	Geographical cordinates	
		φ (N)	λ (E)
S1	38	43° 31′ 11"	16° 22′ 53"
S2	18	43° 31′ 57"	16° 27′ 15"
S3	30	43° 32′ 11"	16° 24′ 24"
S4	24	43° 31′ 04"	16° 20′ 47"
S5	56	43° 28′ 04"	16° 16′ 26"
S6	38	43° 29′ 53"	16° 26′ 31"
S7	15	43° 29′ 37"	16° 31′ 40"
S8	43	43° 25′ 38"	16° 40′ 26"

Analyses

A preparation of lyophilized samples prior to analytical procedures was performed by breaking up aggregates in an agate mortar and by separating the fine sediment fraction (< 63 μm) with dry sieving with an acid pre-cleaned nylon mesh. Granulometric composition of the sediment samples (gravel-particles >2 mm, sand (0.063-2 mm), silt (0.004- 0.063 mm) and clay-particles <0.004 mm) was determined both by sieving (>0.063 mm) and the hydrometric method (<0.0063 mm) according to Cassagrande [13]. The method is based on the density measurements of suspension in sediment samples depending on particles settling velocity during 48 hours.

Granulometric parameters were calculated according to Folk and Ward [14]. Particles size distribution was determined according to Wenthworth [15], while sediment type according to Folk classification [16]. The organic matter content was determined as a weight loss by weighing the sample before and after H_2O_2 treatment and heating at 450°C for 6 h [17]. The carbonate content pronounced as $CaCO_3$, was determined as weight loss after treatment with 4 M HCl [18].

Results were analyzed using STATISTICA software modules for Windows (www.stat-soft.com). The regression analysis (Spearman's Product-Moment Correlation) was used to examine relationships between organic matter content, carbonate content, granulometric composition of sediments and granulometric parameter sorting. In all cases, the level of significance was set at $P<0.01$ and $P<0.05$.

Cluster analysis was applied to identify granulometric similarities between sediment samples. Hierarchical cluster analysis is complementary tool to molecular diagnostic ratios for the classification of the specific atmospheric conditions in respect of their sources [19]. The aim of hierarchical clustering is to identify subsets of objects, i.e. clusters, having similar characteristics from within the whole sample. The hierarchical approach starts with all objects being independent cluster. The two most similar clusters will then be combined into one new cluster. This combination step reduces the number of cluster by one, and it is repeated until an arbitrarily selected cluster is reached [20].

RESULTS AND DISCUSSION

Granulometric composition

The results of granulometric analysis of the sediment core samples are presented in Figure 2 abc. The sediment type according to the Shepard classification showed that all sediment cores are fine-grained. Clay particles predominated in sediment core at all three investigated stations. Station S3 is characterized with higher percentage of sand (13.5 - 19.4%) and gravel (0.7 - 5.1%). At station S2 percentage of sand was in the range from 3.9 to 6.4% and gravel 0.0 – 3.7%, while at S1 highest coarse-grained particles content were less then 3%. The sediment type varies with stations. In the shallower part of the Bay the sediment was coarse-grained, while fine-grained sediment predominated at the deeper stations.

Percentages of gravel in the surface sediment (Figure 2d) were in the range from 0 to 4.1%, with average values of 1.3 ± 1.5%. The largest percentage of gravel is determined at station S4 (4.1%), while at station S1 gravel was not found. On most stations percentage of gravel is less than 1%. Percentages of sand in the surface sediment were in the range from 1.8 to 47.1%, with average values of 14.1 ± 15.9%. The highest percentage was determined at station S4 (47.1%), while the lowest is determined at S1 (1.8%).

At the deepest Station S1 (38 m water depth) silt and clay content vary along the core (15.4 – 43.8% and 54.5 – 82.0%) as result of sediment resuspension in shallowest part of the Kaštela Bay and their transport to deeper part and sedimentation at this station. Station 2 is located in the shallowest part of the Kaštela Bay and under the river Jadro influence. However, despite the vicinity of river, the higher silt content (45.9 ± 3.9%) at Station 2 is result of the persistence of biogenic component, low depth (merely 17 m water depth) and coast location in nearby area. At Station 3 (30 m water depth), in comparison with the other two stations, clay content predominated (49.1 ± 4.1%), while silt and clay content were similarly distributed along the core. At Station 2 clay content were lowest (47.7 ± 4.9%), while at S3 were highest (61.7 ± 8.0%).

Percentages of silt in the surface sediment were in the range from 18.8 to 75.5%, with average values of 47.9 ± 16.4% (Figure 2d). At station S7 was determined the highest average value of silt (75.5%), while the lowest at station S4 (18.8%). Silt content higher than 50% determined at near shore stations is a result of the weathering of flysch deposits. The elevated silt content in the sediments at most near-shore stations presented here is in accordance with data obtained for 11 near-shore stations along the Croatian coast [21], which also indicated terrigenous sedimentation.

Percentages of clay were in the range from 21.5 to 52.5%, with average values of 36.7 ± 11.1%. The highest percentage was determined at station S1 (52.5%), while the lowest is determined at S7 (21.5%).

In the sediment core most prevalent particles were clay while in the surface sediment most prevalent particle was silt.

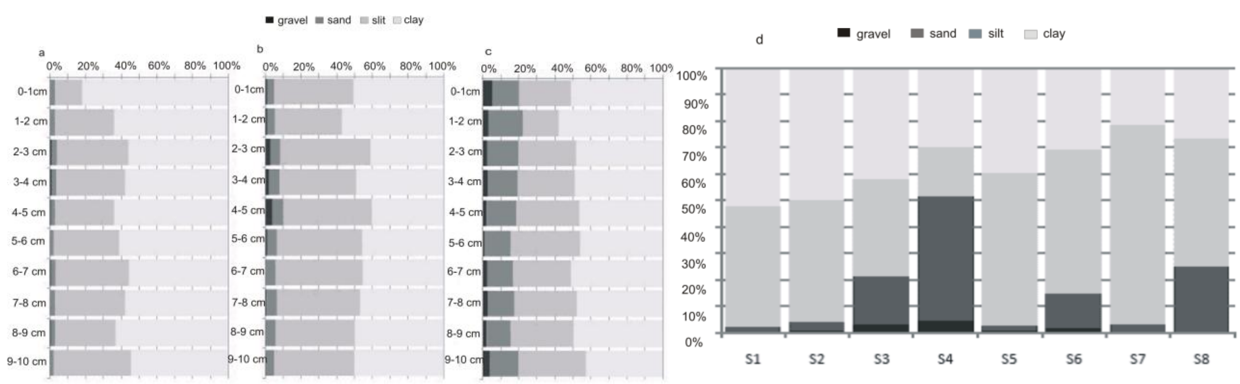

Figure 2. Granulometric composition along the first 10 cm in sediment core at a) S1; b) S2; c) S3; and for d) surface sediment

Slika 2. Granulometrijski sastav kroz prvih 10 cm u jezgrama sedimenta a) S1; b) S2; c) S3; i za d) površinski sediment

According to the Folk classification, (Table 2) the sediment type at Stations 1 and 2 is mud, and at Station 3 slightly gravelly sandy mud. In the surface sediment (Table 3) prevailing sediment type is mud (at S1, S2, S5 and S7), following slightly gravelly sandy mud (at S3, S4 and S6), while sandy mud was determined only at station S8.

According to the Shepard classification in sediment core prevailing sediment type is silty clay, while in surface sediment prevailing silty clay (at S1 and S2), clayey silt (S5 and S6), mixture (S3 and S8) and silt (S7).

Table 2. Granulometric characteristics of sediment core samples according to the Folk and Shepard classification
Tablica 2. Granulometrijske karakteristike uzoraka jezgri sedimenata prema Folku i Shepardu

Station Sediment depth (cm)	S1 Folk	S1 Shepard	S2 Folk	S2 Shepard	S3 Folk	S3 Shepard
0-1	M	clay	M	silty clay	gM	silty clay
1-2	M	silty clay	M	silty clay	(g)sM	sandy clay
2-3	M	silty clay	(g)M	clayey silt	(g)sM	silty clay
3-4	M	silty clay	(g)M	silty clay	(g)sM	silty clay
4-5	M	silty clay	(g)M	clayey silt	(g)sM	silty clay
5-6	M	silty clay	M	clayey silt	sM	silty clay
6-7	M	silty clay	M	clayey silt	(g)sM	silty clay
7-8	M	silty clay	M	silty clay	(g)sM	silty clay
8-9	M	silty clay	M	silty clay	(g)sM	silty clay
9-10	M	silty clay	M	silty clay	(g)sM	silty clay

M – mud, (g)M - gravelly mud, (g)sM - gravelly sandy mud

Table 3. Granulometric characteristics of surface sediment samples according to the Folk and Shepard classification
Tablica 3. Granulometrijske karakteristike uzoraka površinskih sedimenata prema Folku i Shepardu

Station	Folk	Shepard
S1	M	silty clay
S2	M	silty clay
S3	(g)sM	mixture
S4	(g)sM	clayey sand
S5	M	clayey silt
S6	(g)sM	clayey silt
S7	M	silt
S8	sM	mixture

Sediment is very poorly (2.08) to extremely poorly sorted (6.85), indicated different origin of settled particles (terrigenous and biogenous) (Figure 3). At S1 and S2 sediment is very poorly sorted (2.53 – 2.82) with prevailing terrigenous particles in sediment. However, at S3 sediment is very poorly to extremely poorly sorted (4.36) as result of comparatively higher gravel and sand content of biogenous origin. In the surface sediment prevailing very poorly sorted sediment (3.16). At S3 and S4 sediment is extremely poorly sorted (4.25 – 4.37).

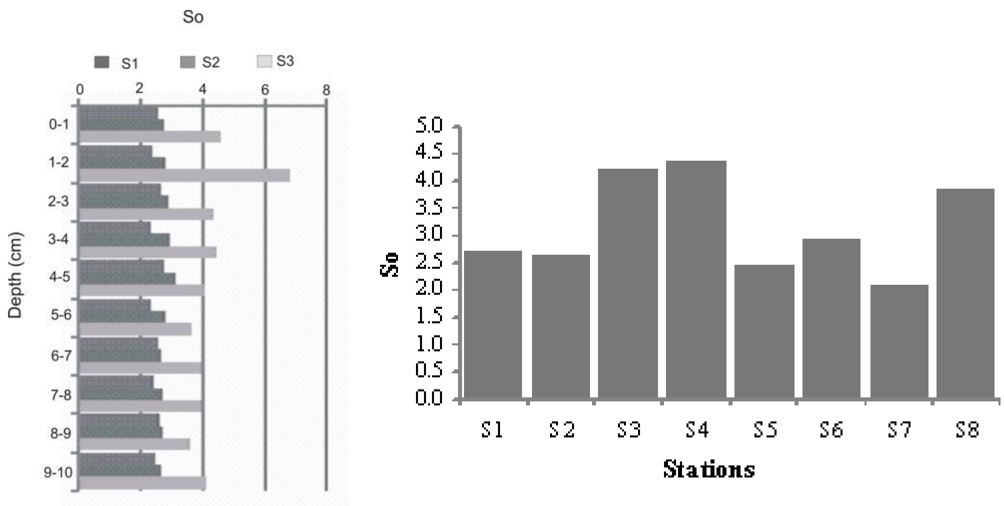

Figure 3. Sorted (So) of sediment core and surface sediment samples
Slika 3. Vertikalna raspodjela sortiranosti sedimenta (So) u jezgrama i površinskim sedimentima na istraživanim postajama

Organic matter

Organic matter content in sediment core varied in the range from 3.9 to 9.9%, while the average values calculated from the three cores for each station were in the range from 7.8 to 9.9% (Figure 4). Differences in organic matter content generally follow the difference in sediment grain-size composition for all stations. In our case, the highest organic matter content recorded in sediment at S3 (8.1 ± 0.2%) is a result of nearby discharge of urban and industrial wastewaters containing suspended organic matter, while the lowest values were found at S1 (7.3 ± 0.5), where the coast influence is comparatively smaller. Station S3 is located nearby outlets discharging urban and industrial waste water containing high organic matter concentrations.

The vertical distribution of organic matter along the sediment cores indicates that at the station S1 organic matter content decreased towards deeper sediment layers, while at S2 and S3 organic matter content generally remains the same with increasing depth.

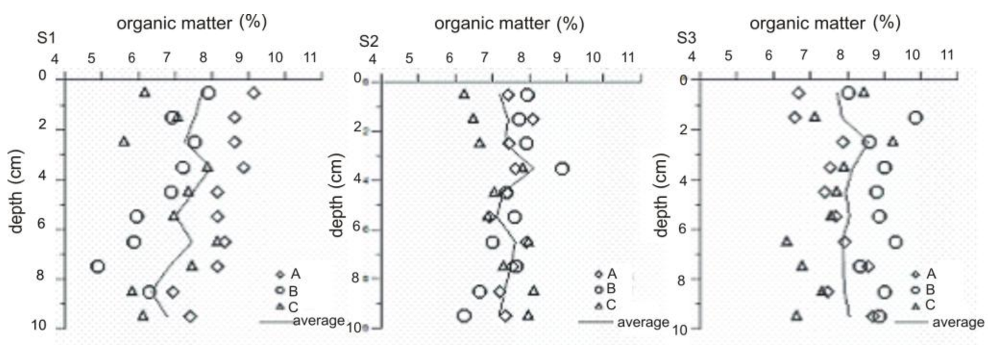

Figure 4. Organic matter content (%) in three cores (A, B and C) and their average values (average) at investigated stations (S1, S2 and S3)
Slika 4. Vertikalna raspodjela udjela organske tvari u tri jezgre sedimenta (A, B, C) i njihova prosječna vrijednost na istraživanim postajama (S1, S2 i S3)

In surface sediment organic matter content were in the range from 3.9 (S7) to 8.9 (S2), with average value of 6.2 ± 1.8% (Figure 5). The highest average organic matter content was recorded at stations S2, S3 and S1 in the Kaštela Bay, which is most likely due to their position in the semi-enclosed basin. In this part, organic matter could be autochthonous, as result of primary production in the sea and allochtonous, i.e. from the land.

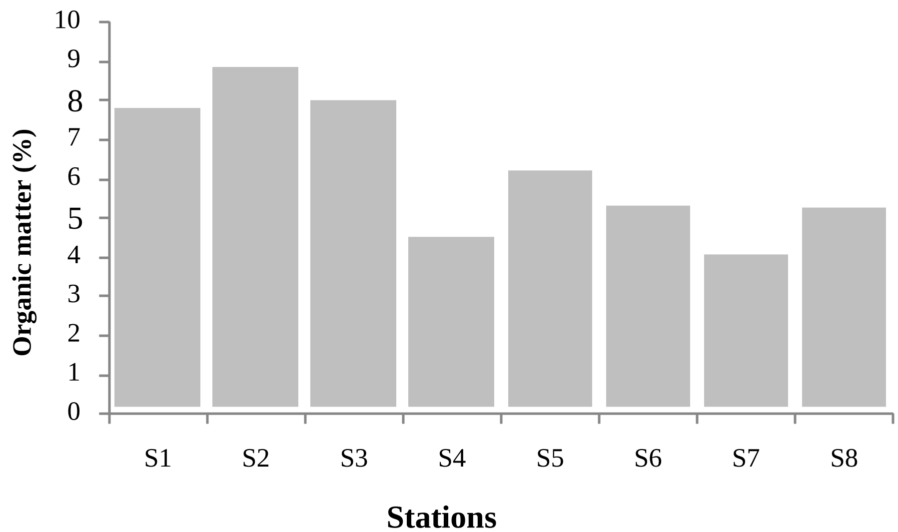

Figure 5. Organic matter content (%) in surface sediment at investigated stations
Slika 5. Udio organske tvari u površinskim sedimentima istraživanih postaja

Carbonate contect

Carbonate content varied in the range from 36.6 (S1, 6-7 cm) to 71.7% (S1, 4-5 cm) (Figure 6). Highest average carbonate content for sediment core samples is recorded at the S2 (48.8 ± 1.9%), while similar carbonate contents were determined at other two stations (43.2 ± 3.4% for S1 and 43.6 ± 0.7% for S3). The percentages of carbonates indicate non-carbonate sedimentation in this part of the Bay, i.e. carbonate content is less then 50%. The data for sediment cores are partially different from the previously investigation (Decembre, 2007) [10], when the highest content established at station S1, while the other two stations (S2 and S3) have similar carbonate contents. Higher carbonate content determined in sediments core of those near-shore stations originated from coarse-grained biogenic remains and particles resulted from carbonate rocks weathering.

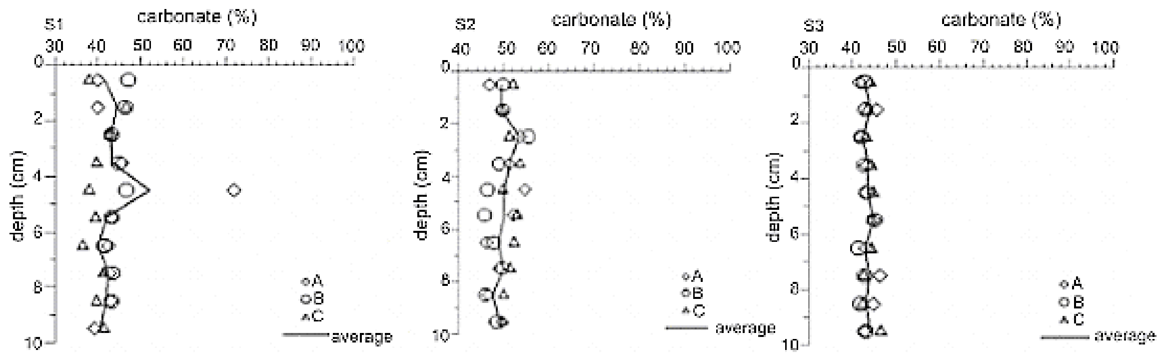

Figure 6. Carbonate content (%) in three cores (A, B and C) and their average values at investigated stations
Slika 6. Vertikalna raspodjela udjela karbonata u tri jezgre sedimenta (A, B, C) i njihova prosječna vrijednost na istraživanim postajama

In the surface sediment carbonate contents were from 41.1 (S1) to 66.5% (S4), with average value of 52.5 ± 8.2% (Figure 7). At investigation stations prevailing carbonate sedimentation.

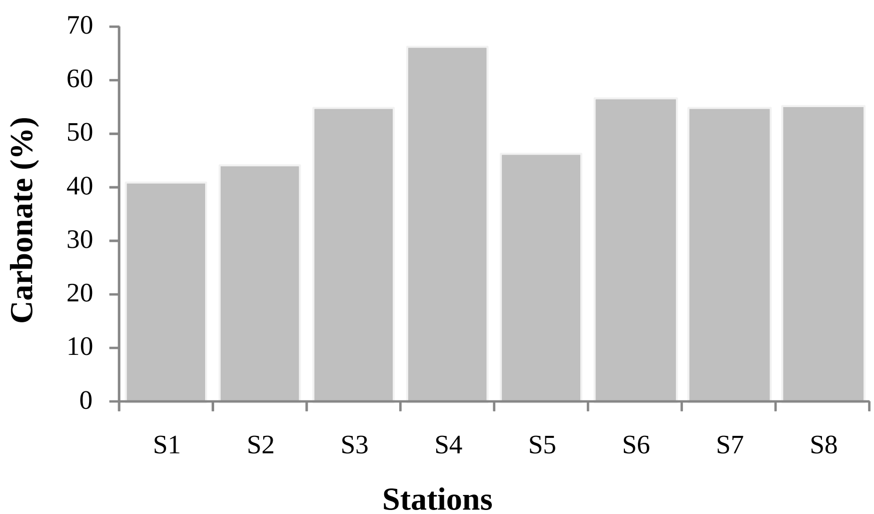

Figure 7. Carbonate content (%) in surface sediment from investigated stations
Slika 7. Udio karbonata u površinskim sedimentima istraživanih postaja

Statistical analysis

Statistically important correlations between organic matter content and coarse-grained fractions (gravel and sand) in the sediment cores were determined (Table 4).

Table 4. Spearman correlation between parameters in sediment core (statistically important correlations P<0.01 are marked bold and P<0.05 are italic), n =30
Tablica 4. Spearman koeficijenti korelacija između ispitivanih parametara dobivenih za poduzorke jezgara istraživanog područja (statistički značajne korelacije sa značajnošću: p<0,01 označene su podebljano; p<0,05 označene su kurzivom), n=30

	Gravel	Sand	Silt	Clay	Organic matter
Gravel					
Sand	**0,80**				
Silt	-0,21	-0,21			
Clay	**-0,50**	**-0,64**	**-0,53**		
Organic matter	**0,58**	**0,65**	*-0,43*	-0,24	
Carbonate	0,07	0,19	**0,51**	*-0,46*	*-0.23*

The comparison of the results obtained in this study to those reported previously [22], reveals similar positive correlations. These coarse-grained particles could be covered with organic film; maybe they are biogenous and was alive in sampling period influencing higher organic content or could be result of coast influence and greater input of biological detritus mostly plant debris from near coast area in fine-grained particles [10]. The negative statistically important correlations (P<0.05) between organic matter and fine-grained particles differ from the earlier research results for the east Adriatic coast [21]. A positive statistically significant correlation between carbonate and silt indicates depletions of marl from the surrounding area and its deposition in the Kaštela Bay. Marl has varying content of carbonate and siliciclastic particles. Negative statistically significant correlations between carbonate and organic matter, is in accordance with other research results along east Adriatic coast [23, 24]. Statistically positive correlations in surface sediment (Table 5) indicated that carbonate is accumulated in sediment with higher coarse-grained (gravel and sand) particle content, while organic matter is accumulated in sediment with higher fine-grained (clay) particle content. Similar results were determined in the previously study for eastern part of the Adriatic coast [22].

Table 5. Spearman correlation between parameters in surface sediment (statistically important correlations P<0.01 are marked bold and P<0.05 are marked italic), n =8
Tablica 5. Spearman koeficijenti korelacija između ispitivanih parametara dobivenih za poduzorke površinskih sedimenata istraživanog područja (statistički značajne korelacije sa značajnošću: p<0,01 označene su podebljano; p<0,05 označene su kurzivom), n=8

	Gravel	Sand	Silt	Clay	Organic matter
Gravel					
Sand	0,64				
Silt	-0,52	-0,38			
Clay	-0,02	-0,60	-0,43		
Organic matter	0,10	-0,45	-0,33	**0,90**	
Carbonate	0,67	**0,90**	-0,19	-0,64	-0,57

The hierarchical cluster analysis was used further to identify relatively homogeneous groups of variables. The objects which belong to the same cluster are similar with respect to the predetermined selection criterion. Ward`s cluster method [25] was applied, because this method produces stable and compact clusters. Ward`s method defines the distance between two clusters as the sum of squared distances, i. e. a measure of the compactness of a cluster, within the cluster which is the combination of two clusters. Figure 8 displays six main clusters for granulometric parameters, organic matter and carbonate in sediment core samples, which are divided into subgroups according to the stations. Sub samples at the stations are grouped together with the exception of sub samples S1 at depth 0-1 cm, 4-5 cm and S3 at depth 1-2 cm. Hierarchical cluster analysis for granulometric parameters, organic matter and carbonate in surface sediment samples (Figure 9) indicates that the stations S1 and S2 are the most similar, while the station S4 (where the prevailing particle size of sand) are most different from all other.

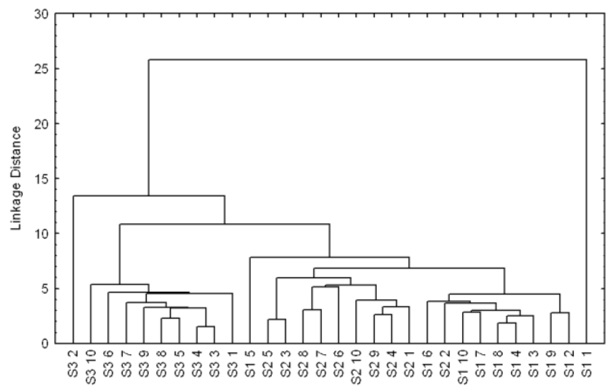

Figure 8. Hierarchical cluster analysis for granulometric parameters, organic matter and carbonate in sediment core samples at three samplings sites
Slika 8. Dendrogram klaster analize dobivene na temelju matrice sličnosti vrijednosti svih granulometrijskih parametara, te udjela organske tvari i karbonata na poduzorcima debljine 1 cm u jezgrama morskog sedimenta na postajama S1, S2 i S3.

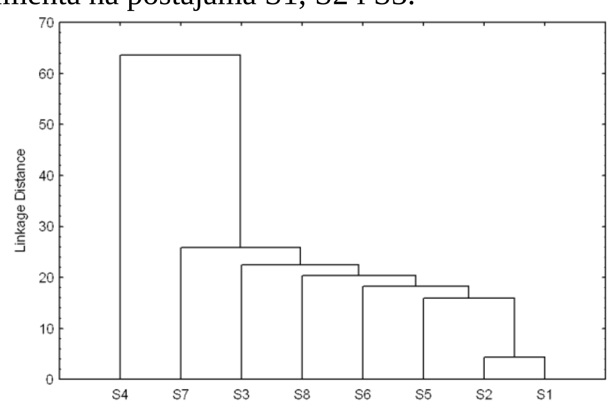

Figure 9. Hierarchical cluster analysis for granulometric parameters, organic matter and carbonate in surface sediment samples at eight samplings sites
Slika 9. Dendrogram klaster analize dobivene na temelju matrice sličnosti vrijednosti svih granulometrijskih parametara, te udjela organske tvari i karbonata u površinskom morskom sedimentu na osam istraživanih postaja

CONCLUSION

In the investigated area fine-grained particles settled as result of surrounding flysh deposit weathering and anthropogenic influence, while coarse-grained particles are mostly biogenous and autochthonic in origin. The studied sediments, despite the small size of the Bay have different grain size distributions. In the sediment cores clay particles predominate, while in surface sediment dominated silt particles. According to the Folk classification prevailing sediment type is mud, while according to the Shepard classification prevailing sediment type is silty clay in the sediment core and surface sediment samples.

The highest average organic matter content was recorded in sediment core samples, at stations S1, S2 and S3 in the Kaštela Bay, were organic matter could be autochthonous, as result of primary production in the sea and allochtonous, i.e. from the land. Organic matter is mainly associated with fine grained fractions. Carbonate content depends on biogenous particles content, and also on marl composition in flysh. In sediment cores prevailing non - carbonate sedimentation, while carbonate sedimentation prevailing in the surface sediment samples.

For sediment cores negative correlation between silt and clay particles and positive correlations between sand and gravel indicates their different origins. Statistically important correlations between organic matter and coarse-grained particles (gravel and sand) in the sediment core were determined, which is compliance with previous studies. Negative correlations between carbonate and organic matter, is in accordance with other research results along east Adriatic coast. For the surface sediment samples statistically positive correlations indicated that carbonate is accumulated in sediment with higher coarse-grained (gravel and sand) particle content, while organic matter is accumulated in sediment with higher fine-grained (clay) particle content. Results of the Cluster Analysis, using all the investigated parameters also confirmed the granulometric composition as a leading differentiation parameter between investigated sediments.

The differences between the investigation stations are the result of different geographical location of these stations and hydrodynamic condition at the stations, presence of organisms with calcareous skeleton and anthropogenic impact.

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