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The granulometry of the sediments of the sandy beaches of Santos (SP)

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Abstract – Beaches are transitions between terrestrial and marine environments and primordial ecosystems influenced by several natural and anthropic factors. The transport and deposition of sediments on beaches is due to the processes that the near bodies of water suffered in the recent past. This study aimed to analyze the hydrodynamics of the bodies of water in the region of Santos (SP) by determining calcium carbonate content and sediment granulometry. The sediments of eight points were sampled and analyzed. The sediments had the prevailing diameter Very Thin (0.063 mm) and Thin (0.125 mm). No Gravel (2.0 mm) were found. The hydrodynamics of water bodies in the region is low, as has been previously proven in other studies. With the exception of Ponta da praia with similar results, the sediments of the other points presented higher calcium carbonate levels when compared to previous studies. The beaches of Santos still represent predominantly salicylic environments; however, the increase in calcium carbonate content may have provided a better environment for formations and gradual adaptations of certain species of organisms, which accompany such sediment changes.
Keywords: Granulometry. Hydrodynamics. Sediment.

A granulometria dos sedimentos das praias arenosas de Santos (SP)

Resumo – As praias são transições entre ambientes terrestres e marinhos e representam ecossistemas primordiais que são influenciados por diversos fatores naturais e antrópicos. O transporte e a deposição de sedimentos em praias são decorrentes dos processos que os corpos d’água da região estiveram submetidos em um passado recente. Este estudo teve como objetivo analisar a hidrodinâmica dos corpos d’água da região de Santos (SP) ao determinar o teor de carbonato de cálcio e a granulometria dos sedimentos. Oito pontos foram amostrados e analisados em sete praias. Os sedimentos tiveram diâmetro prevalecente Muito Fino (0,063 mm) e Fino (0.125 mm). Não foram encontrados cascalhos (2,0 mm). A hidrodinâmica dos corpos d’água da região é baixa, como fora comprovado em estudos anteriores. Com exceção da Ponta da praia com resultados similares, os sedimentos dos outros pontos apresentaram teores de carbonato de cálcio mais altos quando comparados a estudos anteriores. As praias de Santos ainda representam ambientes predominantemente siliciclásticos, porém, o aumento do teor de carbonato de cálcio pode ter propiciado um melhor ambiente para formações e adaptações graduais de determinadas espécies de organismos, que acompanham tais mudanças do sedimento.
Palavras-chave: Granulometria. Hidrodinâmica. Sedimento.

Introduction

Coastal areas have suffered from the great urban occupation since the 20th century, resulting in the construction of avenues, sanitary works, landfills, gardens, submarine emissaries and other artificial constructions. The transition between continent, atmosphere

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and ocean in coastal areas involves anthropogenic interaction and the already delicate natural processes, which make them complex environments (FARINNACIO et al., 2009).

The major cities on the planet are located in coastal zones. In Brazil, approximately 25% of the population lives near those zones. Two-thirds of world beaches suffer from coastal erosion (IBGE, 2000; MUEHE, 2006; NEVES & MUEHE, 2008). Coastal currents, tides and winds are agents that modify the coastline, i.e. which cause sedimentary transport and deposition (KING,1972; KOMAR, 1976; GARRISON et al, 2010).

Sandy beaches are formed by sediments transported and deposited cover all or part of the world coastline (GARRISON et al., 2010). The beaches do not have static balance in the beach-ocean system and are qualified as open systems. The sediment that makes up the sandy beaches is constantly transported (MENDES & PINHO, 2008).

The urban occupation of the coastal zones in a disorderly manner, port activities and natural processes cause major disturbances in longitudinal sedimentary transit. The transversal sedimentary balance of the coastline suffers with those disturbances. To planning and using the coastal zone in a sustainable way, it is necessary to understand about the processes of transport and sedimentary deposition that operate on the coastal zone, and its implications for the dynamic and evolutionary behavior of the beach environment (CALLIARI et al., 2003).

Erosive processes and weathering of rocks from continental areas originate the terrestrial sediments. Most carbonic sediments have biotic and autochthonous origin, produced by organisms that develop in areas near the deposition site (PRESS et al., 2006).

This study aimed to analyze the hydrodynamics of water bodies in the region of Santos (SP) on one occasion in 2019 by determining the origin of sediments and analyzing their calcium carbonate contents. These procedures represent implications in marine and coastal biota, as well as possible ecological and economic damage.

Study area

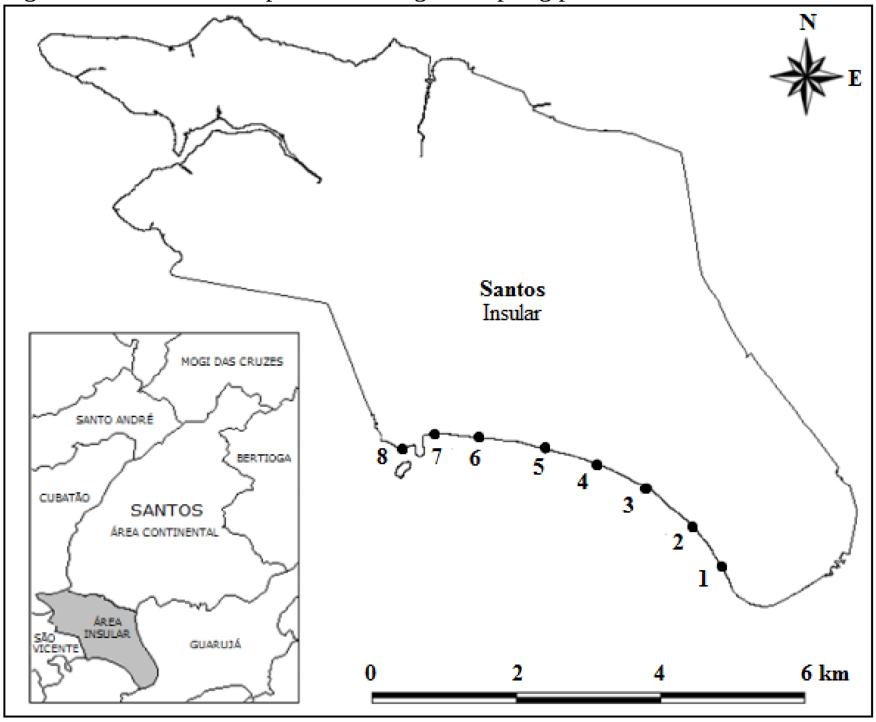
Located in the central portion of the coast of the state of São Paulo, Brazil, Santos Bay suffer the action of waves originated by the frontal systems, coming from the southern quadrant (FARINNACIO et al., 2009). In the region, swells, cold fronts and consequent high-energy waves and over-elevation of sea levels are associated with the development of extra tropical cyclones (SIGAM, 2014), in addition to urban occupation and natural processes (MAGINI et al., 2007).

The main force factors that influence circulation of water in Santos Bay are the baroclinical pressure gradients caused by river discharges, tides, synoptic winds and background geomorphology (HARARAI & CAMARGO, 1998). The Santos Bay beaches receive estuarine waters from two main channels: on the west side of the São Vicente Canal and on the east side of the Port Channel (MAGINI et al., 2007; FARINNACIO et al., 2009; GREGORIO, 2009).

The only obstacles in Santos Bay are the island of Urubuqueçaba, on the border of Santos and São Vicente, where wave diffraction occurs (FARINNACIO et al., 2009; CAMPOLIN et al., 2017) and a deposition area near the submarine emissary of the region. All the Santos Bay beaches are dissipative (MAGINI et al., 2007). During storm events, effects such as sand taking are occasioned and, in some episodes, the invasion of seawater on the avenues and seaside buildings (MAGINI et al., 2007; SILVA & QUIÑONES, 2012; SIGAM, 2014; SOUZA, 2015; VENANCIO, 2018).

In Santos, the main city in the region, the territory divides itself between island and continental portions. The coastal areas in Santos are occupied and vulnerable. The seven sandy beaches of Santos are Ponta da Praia (1), Appeared (2), Embaré (3), Boqueirão (4), Gonzaga (5), Pompeia (6) and José Menino (7 and 8) (Figure 1).

Figure 1 – Santos island portion and eight sampling points on seven beaches



Source: Adapted by Silva & Quiñones (2012)

Ponta da Praia (1) is narrow, decreases towards the drainage channel at the entrance of the Port Channel, and presents fine sand, as it is subject to direct wave action in cold front events. On this beach, there are parallel post-beach walls and cross-sectional piers to the shoreline (FARINNACIO et al., 2009; ITALIANI, 2014).

The Aparecida (2), Embaré (3), Boqueirão (4) and Gonzaga (5) beaches form the central portion of BS. These beaches are rectilinear, with fine sand, average width of 100 meters, low slope and dissipative characteristics. In Gonzaga (5), there is a direct incidence of cold front waves, which at this point arrive without any diffraction process at the base (FARINNACIO et al., 2009; ELLIF et al., 2013).

The José Menino beach subdivides between two sections: the one on the right (7) and the one to the left of the submarine emissary (8). The left section (7) suffers constant sediment removal and consequent retreat from the coast (FARINNACIO et al., 2008). In the left section (8), the presence of the island of Urubuqueçaba and of the emissary creates a shadow of natural deposition of sediment accumulation (FARINNACIO et al., 2009).

Field procedures

On November 25, 2019, approximately two hundred grams of sediment were manually sample at the eight points, near the new tide line, and dumped into properly labeled plastic bags (DIAS, 2004).

Laboratory procedures

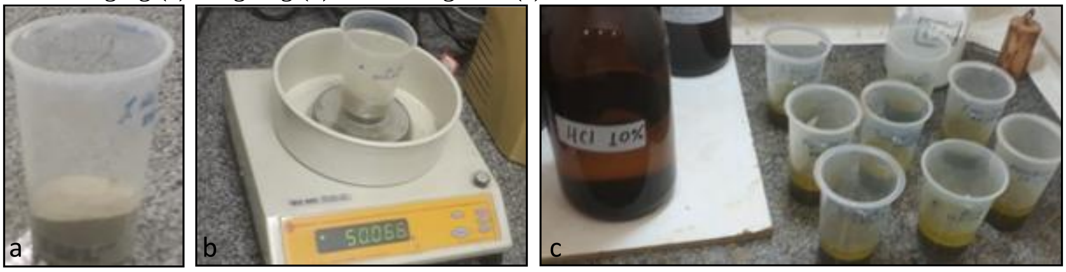
Those two hundred grams of sediment were washed with 0.5 liters of distilled water to remove salt excess (Figure 2a). To eliminate moisture, samples were placed on Petri dishes (Figure 2b) and in a greenhouse at 40ºC per 28 hours (Figure 3c).

Figure 2 - Washing (a) packaging (b) and drying (c) of the sediment

Source: Personal archive (2019)

To determine the calcium carbonate ($CaCO_3$) contents, about 50 grams of sediment (post greenhouse) of each sample was weighed in plastic cups (Figure 3a), using precision scale (Figure 3b). Hydrochloric acid (10% HCl) were added to the plastic cups (Figure 3c). The cups were placed in the greenhouse for six days.

Figure 3 - Packaging (a) weighing (b) and adding HCl (c) into the sediment



Source: Personal archive (2019)

The $CaCO_3$ content were eliminated due to the reaction with HCl. After sediment stabilization, the samples were washed in distilled water until neutralized (Figure 4a), reconditioned in Petri dishes (Figure 4b) and in the greenhouse for another six days (Figure 4c). The difference between the initial weight (50 grams) and the final samples weight resulted in the $CaCO_3$ content.

Figure 4: washing (a), packaging (b) and drying (c) of sediment

Source: Personal archive (2019)

The particle size of the sediments represented the percentage by weight that each specified particle size range represents in the total mass covered, determined through the sieving techniques in the Geology Laboratory of the São Judas University Center - Unimonte Campus.

The samples were placed on a particle agitator for a 20 minutes period (SUGUIO, 1973). The sieves used were: Gravel (2,000 mm), Very Thick Sand (1,000 mm), Thick Sand (0.500 mm), Mean Sand (0.250 mm), Fine Sand (0.125 mm), Very Fine Sand (0.063 mm) and Silte and Clay (<0.063 mm, which were retained in the last layer of the agitator).

Results and Discussions

In half of the beaches analyzed in the present study, the predominant diameter range was Fine Sand, while the other half was Very Fine Sand (Table 1).

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Table 1 - Sediment diameter ranges

Beach	Gravel	Very Thick Sand	Thick Sand	Mean Sand	Fine Sand	Very Fine Sand	Silte and Clay
Pta da praia (1)	0,000	0,006	0,004	0,770	57,874	41,346	0,000
Aparecida (2)	0,000	0,002	0,062	0,464	56,845	42,628	0,000
Embaré (3)	0,000	0,006	0,072	0,206	56,522	43,192	0,002
Boqueirão (4)	0,000	0,008	0,058	0,195	48,763	50,976	0,000
Gonzaga (5)	0,000	0,014	0,086	0,286	43,799	55,807	0,008
Pompéia (6)	0,000	0,006	0,010	0,202	45,873	53,905	0,004
José Menino (7)	0,000	0,002	0,006	0,468	40,457	59,067	0,000
José Menino (8)	0,000	0,004	0,004	0,245	55,694	44,029	0,024

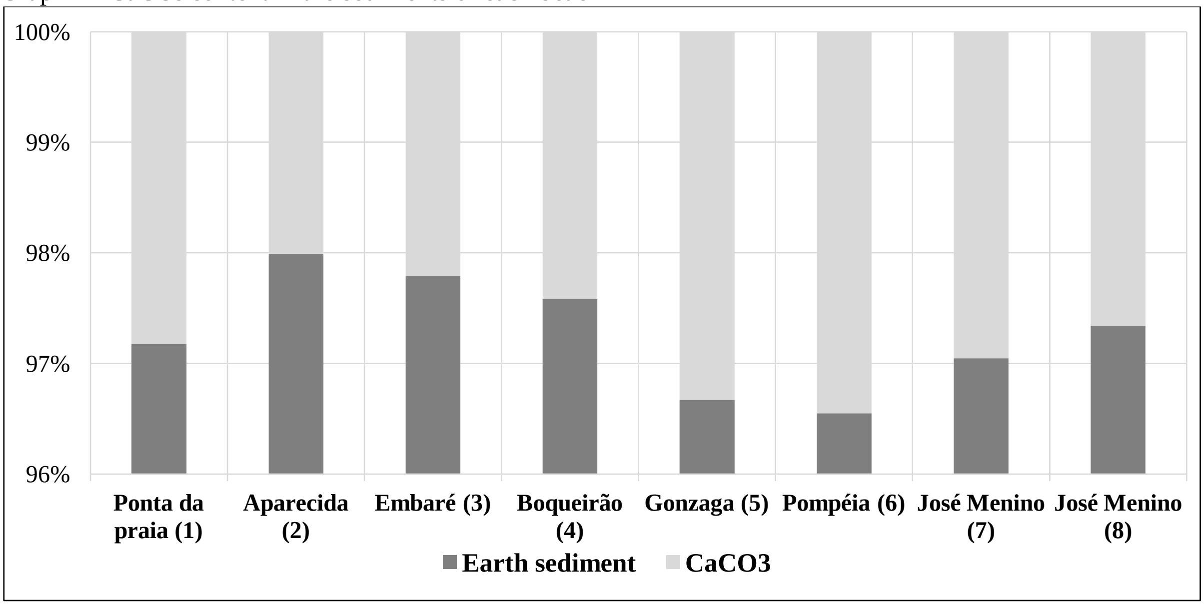
Source: Personal archive (2019)

According to Fariannacio et al. (2009), the seven beaches of Santos have sediments classified as predominantly Fine Sand. However, as Elliff et al. (2013) and the present study found that, some beaches in Santos the predominant range of sediments is Very Fine Sand and the fractions of gravel, very thick sand, coarse sand, medium sand and silt and clay had low representativeness, composing less than 1% of the samples.

The granulometric study may support information for the knowledge of physical processes working during sediment deposition (SUGUIO, 2003), the source area and the base level of sedimentation (SUGUIO, 1973). The sediments that arrive in Santos beaches are smaller, which indicates low hydrodynamics of Santos Bay bodies of water. The larger sediments may be deposited at the bottom of the estuary. This hydrodynamics type can provide a good environment for some species near sediments, such as polychaetas and isopods (COUTINHO, 2013).

The calcium carbonate content represented a maximum of 3.452% of the samples on Pompéia beach and a minimum of 2.007% on Aparecida beach (Graph 1). These $CaCO_3$ percentages on all beaches are considered low.

Graph 1 - $CaCO_3$ content in the sediments of each beach



Source: Personal archive (2019)

In Ponta do praia (1), in September and October 2012, Italiani (2014) found approximate values of $CaCO_3$ of the ones verified in the present study. In Gonzaga (2), Elliff et al. (2013) found 1.04%, and the present study found 3.44% of $CaCO_3$.

The increase in calcium carbonate content may have provided a better environment for formations and gradual adaptations of certain species of organisms, which accompany such sediment changes (COUTINHO, 2013). Those organisms can be the skeletons and shells of biolytic organisms (PRESS et al., 2006), corals, foraminifera, mollusks, echinoderms or limestone algae (LEÃO, 1982; LEÃO & GINSBURG, 1997; SILVA, 2011).

Besides proved higher concentrations of deposition of those organisms on the sediments of some beaches, this study also provided a database from all seven beaches of Santos (SP). Those results can and should be replicated as a viable and simplistic alternative to provide greater information about the benthic abundance of those organisms inhabiting in Santos.

Conclusion

The sediments founded on the seven beaches of Santos had smaller dimensions. The larger sediments may be deposited at the bottom of the estuary. In that region the hydrodynamics of the near bodies of water is low. This type of hydrodynamics can provide good environments for some species, such as polychaetas and isopods. The calcium carbonate content was low on all seven beaches. Although in some beaches, this $CaCO_3$ content was higher than the years before, which indicated an increase in a number of species and organisms such as skeletons and shells of biolytic organisms, corals, foraminifera, mollusks, echinoderms or limestone algae.

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