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The effects of sediment used in beach nourishment: Study case El Portet de Moraira beach

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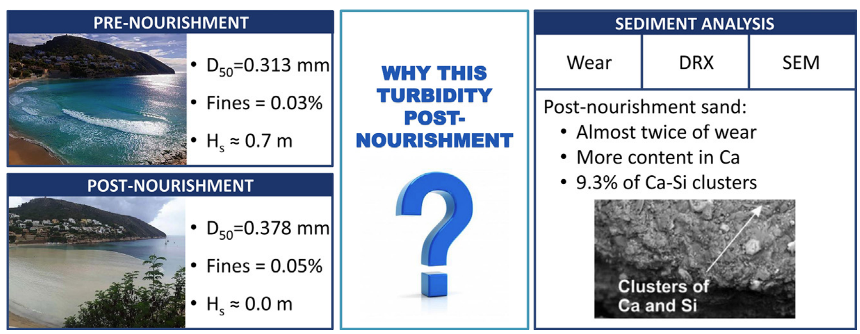
HIGHLIGHTS

- Beach nourishment sand generates great turbidity even with calm wave.
- Pre and post-nourishment sands are similar but post-nourishment wears faster.
- Post-nourishment sands have more calcium and a 9.3% of Ca-Si cluster particles.
- Turbidity after nourishment is due to the rapid decomposition of sand particles.

GRAPHICAL ABSTRACT



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ABSTRACT

Actions taken to prevent or reduce coastal erosion often do not have the desired effect, leading to major problems instead of solving the original one. This research focuses on why a nourished beach— with borrowed sand and 0.05% of particles <0.063 mm— causes the presence of suspended particles that are observed by beach users as turbidity. This means that the colour of the water was not its characteristic blue, even with calm wave conditions. This research involved a shoreline evolution analysis and a sedimentological study of the sand from 1977 to 2017. The results show that the turbidity episodes that occurred after the beach fill of May 2017 do not coincide with major storms that affected the beach. Furthermore, prior to this beach nourishment, even after the most important storms turbidity was not so pronounced. However, when the pre-nourishment and post-nourishment sediment are compared and analysed in detail, by studying the microstructure and morphology of the sand particles, their composition and morphology were observed to be completely different. These differences are also reflected in the accelerated particle weathering test, with the post-nourishment particles showing greater dissolution of carbonates. From its mineralogy, the post-nourishment material presents a smaller proportion of quartz in its composition and a significant amount of particles (9.6%) formed by clusters of Calcium and Silicon. The separation of this mineralogical composition produced by waves explains the formation of particles measuring <0.063 mm, a fact that has also been confirmed by the accelerated particle weathering test. This is, therefore, the cause of turbidity in the swash zone of the beach.

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1. Introduction

Coastal erosion is a natural phenomenon that is becoming a growing problem. This issue is the result of multiple factors (rising sea levels, the frequency of major storms, lack of sand input from rivers and ravines

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etc.), many of them a result of global climate change (Mee, 2012). Furthermore, given the importance of coastal regions for humans, anthropogenic activities increase and, as a result, coastal erosion rises (Steffen et al., 2007). Some of these actions have even led to the disappearance of important coastal habitats such as seagrass meadows (Aragonés et al., 2015; Orth et al., 2006; Pagán et al., 2016; Waycott et al., 2009).

Over the last few decades, there has been a gradual shift in coastal defence techniques, tending in recent years to soft actions such as the nourishment of sandy beaches as an erosion mitigation mechanism (Dean, 2003; Trembanis and Pilkey, 1999). The placement of sand on the beach is considered by many authors to be the most acceptable form of coastal stabilization (Aragonés et al., 2016; Hobbs, 1988; Leonard et al., 1990; Magoon et al., 2001; Walker and Brodeur, 1993). Therefore, periodic artificial beach filling is widely regarded as an acceptable method of beach protection and dune restoration (Hanson et al., 2002). Additionally, increasing pressure from tourists has involved, for example, requests from coastal residents to protect their properties from coastal hazards, such as flooding, sea level rise, etc. (Obiol Menero, 2003). Therefore, governments should provide solutions, such as beach nourishment for protection against erosion (Kriebel, 1988).

Some researchers have found that taking the shoreline location as a reference point indicates a regression from the initial position and therefore, significant volumes of sediment have been lost (Aragonés et al., 2015; Roeland and Piet, 1995; van Koningsveld and Mulder, 2004). Different procedures of beach nourishment have been tested on a world-wide basis. Thus, van Duin et al. (2004) observed how the studied beaches had disappeared in just two years after their nourishment, a fact that can also be analysed in the study carried out by van Koningsveld et al. (2009). However, the conclusions of both studies do not specify where the exact destination of the nourished sand on the coast. Grunnet and Ruessink (2005) demonstrated that after the nourishment the autonomous migration of sandbars was halted during the period of 6 to 7 years. Therefore, an important issue related to assessing the success of this type of beach action is that there is no regular protocol to monitor the changes that occur after the sand placement (Leonard et al., 1990; Stauble, 1988).

To contain coastal erosion, it is necessary to understand the factors that generate it, such as wave energy or the properties and origin of sediment. Waves and ocean currents mobilize the sediment. The thickness of the activation layer depends on the slope of the beach, as well as the significant breaking wave height(Anfuso et al., 2000; Jackson and Malvarez, 2002; King, 1951. Others authors include sediment porosity and period (Ciavola et al., 1997 #122) and others add the incidence angle of swell (Bertin et al., 2008).

The erosive process begins with the movement of the particle. This happens when the instantaneous force of the fluid is greater than the grain's resistance force, which is a function of particle weight, particle angle at rest, lifting force and drag force (Allen, 1970; Komar, 1987; van Rijn, 2007). Once the sediment is set in motion, its mineralogical composition is another aspect that can influence the erosive process (Roberts et al., 1998). For example, the high proportion of carbonates in the sediment composition influences its dissolution (Milliman, 1993; Milliman and Syvitski, 1992; Syvitski and Kettner, 2008 by the action of CO_2 which causes acidification of seawater (Harrould-Kolieb and Herr, 2012 #114). Another element that influences the sediment erosion process is the breakage and separation of the particles that form the sample (López et al., 2016a).

In addition, it is essential to assess the influence of changes in sand fill (from quarries, marine dredges, rivers, etc.) on water quality and therefore, the integrity of coastal ecosystem (Pagán et al., 2016 #76). In this sense, the *Posidonia oceanica* meadows, which are found in the Mediterranean Sea, are an indicator of water quality and can be affected by turbidity, reduction of light and/or silting (Medina et al., 2001).

Therefore, it is clear that many factors may influence coastal erosion, but their exact influence is not well known. For this reason, this article aims to analyse the reasons why El Portet de Moraira beach (Teulada, Spain), suffered a major change after its nourishment. This beach had turquoise blue waters (Fig. 1a and c) prior to the beach fill in March 2017 with 8000 t of borrowed sand. With 0.05% of grain size finer than 0.063 mm, a suspended plume of sediments was formed after being in contact with the incoming waves (Fig. 1b and d). For this purpose, the historical evolution of the beaches will be studied, and the evolution of particle wear, its mineralogy and morphology will be analysed in detail to identify the differences between the material existing on the beach and the material contributed during a beach nourishment.

2. Study area

The province of Alicante is located in the southeast of the Iberian Peninsula and it has 244 km of shoreline (Fig. 2a). Two different morphological zones can be delimited in Alicante province: i) the northern part (in which the beach under study is located) comprises two thirds of Alicante province. It is a mountainous land with river valleys and gravel beaches are the most common found. ii) The southern third of Alicante consists of a large alluvial plain and it is entirely comprised of sandy beaches.

The study focuses on El Portet de Moraira beach (Fig. 2c), which is located in the municipality of Teulada (38°41′14.43″N and 0°8′46.66″E). The beach is placed between Cape d'Or on the east and, on the west, by a low-rise cliff that reaches the Moraira Port. Its total length is about 330 m (Fig. 2d).

The basin of the studied area is composed of hillside and limestone debris, with some traces of loams, sandy limestones and clays. This basin flows mainly into the Moraira ravine, with some contributions to the coastal area (Fig. 2). However, as can be seen, >90% of the basin's surface area is urbanized (Fig. 2e and f). According to the National Soil Erosion Inventory (INES) 2002–2012 in Alicante (M.M.A, 2012), the soil erosion on slopes where it has not yet been eroded ranges between 10 and 50 t/(ha-years). However, given the high degree of urbanization, roads are virtually non-existent today, which means that the basin no longer contributes material to the coastal zone, as shown in later sections by the historical evolution of the coastline.

As far as climatology is concerned (Fig. 2e), the maximum precipitations take place between September and December with average precipitations of 78 mm/month. The summer period is the hottest and with less precipitation, which indicates that these precipitations are not the main cause of turbidity observed in the area during the period studied.

Because of the lack of contributions due to the urbanization of the basin, the beach has suffered a continuous process of erosion over the time. The beach has been nourished twice with sand to control the problems due to the erosion of the shoreline in two different periods. The first one, in 1985, with 40,000 t of sand from dredging. The second, in March of 2017, with 8000 t of sand from the screening of natural aggregates were used to nourish the beach. After the last nourishment, a great turbidity is observed. The water colour of the beach, before turquoise and crystalline (Fig. 1a), has changed to brown and turbid (Fig. 1b).

3. Methodology

For determining the causes of the water turbidity caused by the last beach nourishment, the procedure was as follows (Fig. 3): i) analysis of the shoreline historical evolution and the equilibrium profile; ii) maritime climate and iii) sediment analysis.

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