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Differences between Sediment Grain Size in Rip Channel and its Surrounding Area in Royan Marine Ecosystem, Iran

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ABSTRACT

Aim In this study, sediment size distribution and its statistical properties are studied in the rip channel, and its surroundings in the Royan marine ecosystem lied in the southern part of the Caspian Sea.

Materials & Methods Three rip current channels were selected every eight investigating months. Sediment samples were collected from inside each rip channel and its surrounding areas. The statistical indices, viz., D50, mean, skewness, and sorting, have been calculated for sediment grain size parameters. Finally, a general linear model and unpaired t-test were used to perform statistical comparisons of grain size characteristics between the rip channel and its surrounding area.

Findings In May, June, and July, the medians of sediment grain size were significantly higher in the rip channel (202.7, 168.9, and 174.5μm, respectively) compared with its surrounding areas. In general, the mean sediment grain size was significantly higher in the rip channel (193.1μm) than the control area (176.3μm). In May, June, and July, the highest values of the mean grain size of sediments were related to the rip channel (226.9, 178.5, and 183.2μm, respectively).

Conclusion The rip channel contains sediments with coarser grains than the surrounding area. The rip current leads the median and mean of sediment size distribution in the rip channel to move toward the larger sizes. Moreover, the skewness is a more sensitive factor to environmental changes of the channel and its surrounding area than the other sediment properties, emphasizing consideration in the studies.

Keywords The Caspian Sea, Grain Size Distribution, Rip Channel, Sediment

CITATION LINKS

[1] Rip currents, beach safety, physical oceanography ... [2] Rip current review ... [3] Rip current-related fatalities in India: A new ... [4] Rip currents: A process of geological ... [5] Morphodynamic variability of surf zones and ... [6] The coastal challenge ... [7] Mean Lagrangian flow behavior on an open coast ... [8] Mean currents and sediment transport ... [9] Sediment transport in low-energy ... [10] Rip-current type, spacing and persistence, Narrabeen ... [11] RIPEX: Observations of a rip current ... [12] Field observations on the morphodynamic ... [13] Rip currents, mega-cusps, and eroding ... [14] End member inversion of surface sediment ... [15] Rip current in the beach and its ... [16] Grain size analysis of marine sediments ... [17] GRADISTAT: A grain size distribution and statistics ... [18] Influence of different sieving methods ... [19] Grain size variability on a rip-channeled ... [20] Grain-size distribution of surface sediments in ... [21] Unexpected rip currents induced by a ... [22] Dynamic simulation of waves and sand transport ... [23] Application of neural networks and fuzzy logic ... [24] Sediment concentration and bed form structures ... [25] Principles of sediment transport in rivers ... [26] Sediment transport study along Gulf of ... [27] The modern sedimentary environment ... [28] An introduction to wind induced water ... [29] Grain-size characteristics of deposits ... [30] An interpretation of trends in grain size ...

Introduction

Rip current was described by Bowen as a strong and narrow current that flows seaward from the surf zone and was produced by the "continuous interchange of water between the surf zone and areas offshore" [1]. Rip currents can reach high velocities [2] and present a significant hazard to beach users worldwide [3]. This results in the drowning of many people and the imposition of significant rescue operations throughout the year.

Rips have been studied scientifically since measurements were made on the nearshore currents in the USA, and it was first termed 'rip currents' [4]. The earliest schematic illustration of an open beach rips current was developed and presented by Shepard *et al.* [4]. It indicated different parts of a current rip system, including feeder currents, rip neck and rip head. As the waves break on sandbars, the water flows into a feeder or longshore current, finding the deeper areas between the bars to flow offshore as a rip current [5]. The neck is the confinement of this flow between breaking waves and may receive further flows from the surf zone along the flanks of the rip [6]. Depending on the force and direction of the waves and the wind, the rip may recirculate back into the surf zone or exit beyond into the rip head, where the flow of the rip then dissipates and is taken over by other longshore currents [2, 7]. However, higher wave energy and velocity in rip current than its surrounding areas can transport the bed sands into the sea and create a channel named "rip channel" with different sand sizes and granulometry.

Although there is limited research on the quantification of sediment transport in rips [8, 9], there is a consensus among coastal scientists that rips are an important mechanism for the offshore transport of sediment [10, 11] and ultimately affect not only the beach morphology but also the particle size distribution of sediments in the nearshore zone [12, 13]. Generally, sediment grain-size data provide extensive information on sedimentation processes and are fundamental to understanding the hydrodynamic characteristics of the corresponding sedimentary regions [14]. Nevertheless, our literature review showed no study reported about sediment characteristics differences between rip channel and surrounding area in Iran and around the world.

In Iran, it has been reported that rip current was the most important reason for the drowning of people in the sea [15]. According to Iranian National Oceanography and Atmospheric Sciences (INIOAS) studies, there was a significant direct relationship between drowned people and rip currents. Therefore it can be stated that any study on rip currents, including the recognition of the influence of various factors on the rips, the examination of the relationship between environmental factors and the rips, and the identification of the bed and sediments of the rip channel can be useful for reducing the mortality of swimmers and beach users.

The presence of a strong current inside a permanent channel with appropriate dimensions may increase the diameter of sediment grains inside the channel compared to its surroundings. However, due to the uncertainty of the formation and status of rip channels and their specifications in a coastal area, without doing research, it is not possible to provide facts and details such as the presence or absence of rip channels in the region, their permanence or seasonality, their dimensions and specifications, the amount of flow velocity in the channel and, most importantly, the actual impact of these factors on the distribution and granulation of sediments inside and outside the rip channel. Breaking waves are the main cause of rip currents and, thus, rip channels in a coastal area.

In this paper, after discovering the rip channels in the study area, the final effect of breaking waves and thus rip currents on the grain size distribution and its statistical specifications has been studied in the Royan marine region lied in the southern part of the Caspian Sea by sampling and comparison of sediment characteristics within the rip channel and its surroundings.

Materials and Methods

Selection of the study area

The study area was located on the southern coast of the Caspian Sea in Mazandaran Province, the Royan marine ecosystem area. At first, a field survey was carried out from the coasts of Royan City toward the coasts of Rustamrud in Noor city to identify the study area. In addition, some interviews were conducted with relevant and familiar local people, including lifeguards, to collect information about the rip currents in the region and identify the places where the possibility of occurrence of the rip currents are high. After that, the study area was limited to a ca. 1000m along the coast in Royan City (Figure 1). Various factors were considered in selecting the study area. Factors like the lack of private ownership, easy access, lack of human manipulation, and locations identified by lifeguards as the possible places of people drowned were considered for the final selection of the study location. Visual surveys were then conducted to identify the rips at the study area. Although some rip currents are visibly obvious and easily discerned, they are often not easily identifiable to most people. Some of the clues to rip current identification was included: A channel of churning, choppy water, a line of sea foam, seaweed, or debris moving steadily seaward, different watercolor beyond the surf zone, a break in the incoming wave pattern as waves roll into shore.

The main factors influencing the transport and distribution of sediments in a marine region, such as waves and coastal currents, have monthly and seasonal changes. Therefore, measurements were planned over one year. According to rip current signs and local information, we selected at least three rip current channels in each investigating month, including November and December in 2018 and January, March, April, May, June, and July in 2019. In the other months, our efforts for sediment sampling was failed due to the lack of rip currents in the study area or stormy sea conditions (Figure 1).

Figure 1) The location of the study area, green and red balloons show the location of sediment samples in the rip channel and surrounding area (control), respectively, in April, 2019.

Sediment sampling and analyses

At least three samples for the channels in each month were collected using Van Veen grab sediment sampler (Figure 2) to provide samples from inside each rip channel and outside of it (as control points). Since the depth of water varied between 0.5m to more than 3m, boat and grab sediment sampler was inevitable, particularly in the deep points. The samples were transported to the laboratory for sieve analyses. A sieve analysis (or gradation test) was used as a practice or procedure used to assess the particle size distribution (also called gradation) of granular material like sea bed sediments by allowing the material to pass through a series of sieves of progressively smaller mesh size and weighing the amount of material that is stopped by each sieve as a fraction of the whole mass [16]. Multiple meshes of sieves, including 30, 50, 60, 100, 140, 200, and 230, were used [16] for this study. GRADISTAT program has been written for the rapid analysis of grain size statistics from any of the standard measuring techniques, such as laser granulometry. In addition, previous results indicated that Folk and Ward measures, expressed in metric units, appeared to provide the most robust basis for routine comparisons of compositionally variable sediments [17]. Therefore, the Folk and Ward graphical method in GRADISTAT software was used to calculate median, mean, sorting, skewness, and kurtosis of sediment grain size [16, 17]. The sediment parameters were selected according to the previous studies. They stated that sand-size parameters are essential to study the coastal dynamics and other geomorphological behaviors of beaches and suggested that main parameters must include a measure of average grain size (D50), spread of the size around the average (e.g., sorting), degree of asymmetry (Skewness) and degree of peakedness (Kurtosis) [18].

Finally, a general linear model (GLM) and unpaired t-test were used to statistically compare grain size characteristics between the rip channel and its surrounding area (as control area). These statistical analyses were done using SPSS 21 (Figure 2).

Figure 2) Using Van Veen grab sediment sampler to provide samples from inside each rip channel and control area. Note that during the measurement at sea, it was not possible to provide a suitable photograph for underwater sampling. The provided photo only shows how to work with the Van Veen grab on the beach.

Findings

According to the GRADISTAT outputs, sediment characteristics were provided in the excel sheet to be statistically analyzed in SPSS. Appendix 1 showed the output of GRADISTAT for two sediment samples in the channel and the control area.

The results of GLM showed that the time (month) and location of sampling (inside the channel or in the control area selected outside of the channel) and their interactions had significant effects on sediment characteristics in some cases (Table 1).

In the table, df indicates degrees of freedom. In statistics, the number of degrees of freedom is the number of values in the final calculation of a statistic free to vary without breaking any constraints. The *P*-value or probability value is the probability of obtaining test results at least as extreme as the results observed, assuming that the null hypothesis is correct. The F-statistic is simply a ratio of two variances, variation between sample means to variation within the samples. SPSS prints something called the R-square change, which is just the improvement in R-square when the second predictor is added. The R-square change is tested with an F-test, which is referred to as the F-change. A significant F-change means that the variables added in that step significantly improved the prediction.

Table 1) The effect of time (month), sampling location and their interactions on sediment characteristics.

Indices		df	F	P-value
D50 (Median)	Month	7	1.92	0.081
	Location	1	2.19	0.145
	Month*Location	7	0.74	0.640
Mean	Month	7	2.80*	**0.014**
	Location	1	5.60*	**0.029**
	Month*Location	7	0.79	0.591
Sorting	Month	7	0.98	0.462
	Location	1	3.93*	**0.049**
	Month*Location	7	0.88	0.534
Skewness	Month	7	1.67	0.143
	Location	1	6.57*	**0.013**
	Month*Location	7	3.67**	**0.003**

*significant at p<0.05; **significant at p<0.01

The main effect of time (month) was significant on the mean value of sediment grain sizes, while the main effect of sampling location was significant not only on the mean value of sediment grain sizes but also on their sorting and skewness. Independent t-test results showed that in May, June, and July, the median of sediment grain sizes was significantly higher in the rip channel (202.7, 168.9, and 174.5μm, respectively) compared with its surrounding areas (173.2, 159.8, and 160.7μm, respectively) (Figure 3).

The results showed that, in general, the mean of sediment grain sizes was significantly higher in the rip channel (193.1μm) than control (176.3μm). In May, June, and July, the higher values of the mean grain size of sediments were related to the rip channel with values of 226.9, 178.5, and 183.2μm, respectively (Figure 4).

The results showed no significant differences in the sorting of sediment grain size between the rip channel and its surrounding area in each studied month (Figure 5).

In addition, the results showed that for the whole data, skewness of sediment grain size, generally, in the rip channel (0.24μm) was different from its surrounding area (0.11μm) (marginal significant: p=0.06). These differences were also significantly pronounced in June and July, higher in the rip channel, 0.62 and 0.24μm, respectively (Figure 6).

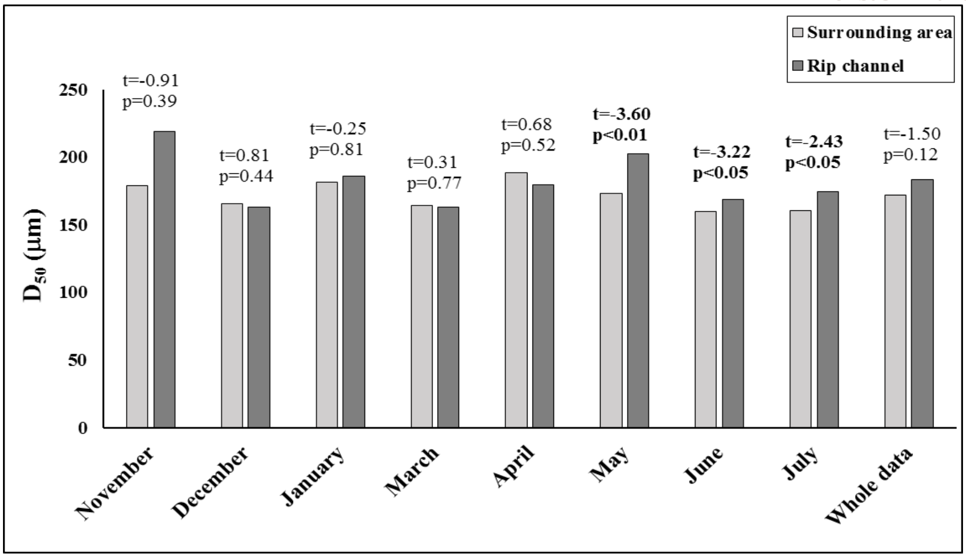

Figure 3) Differences of grain size median of sediments between rip channel and its surrounding area (control area) in each month using (t and p show unpaired t-test results).

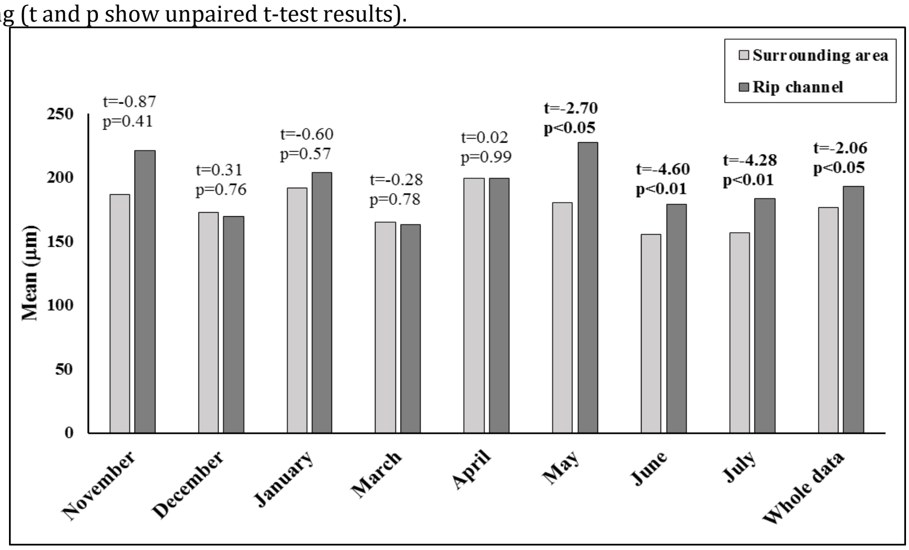

Figure 4) Differences of grain size mean of sediments between rip channel and its surrounding area (control area) in each month (t and p show unpaired t-test results).

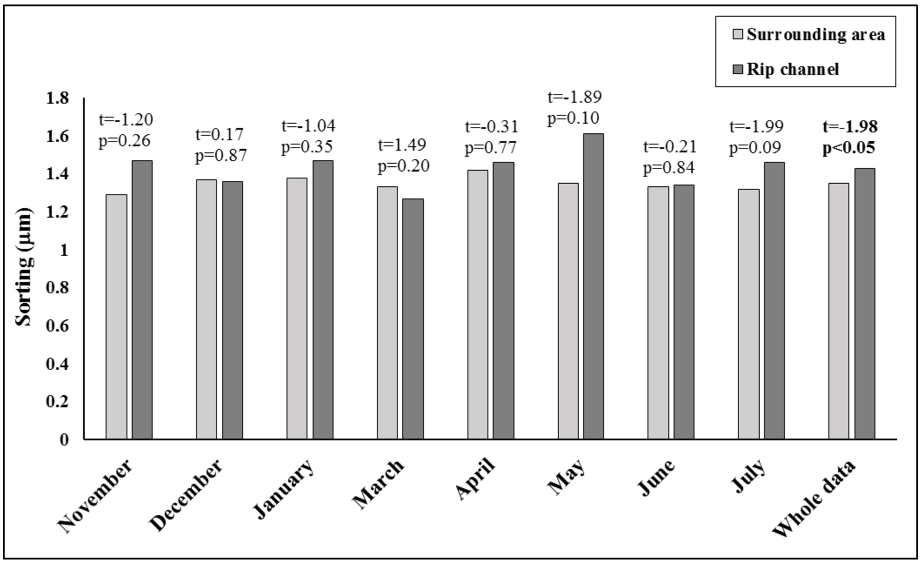

Figure 5) Differences of grain size sorting of sediments between rip channel and its surrounding area (control) in each month (t and p show unpaired t-test results).

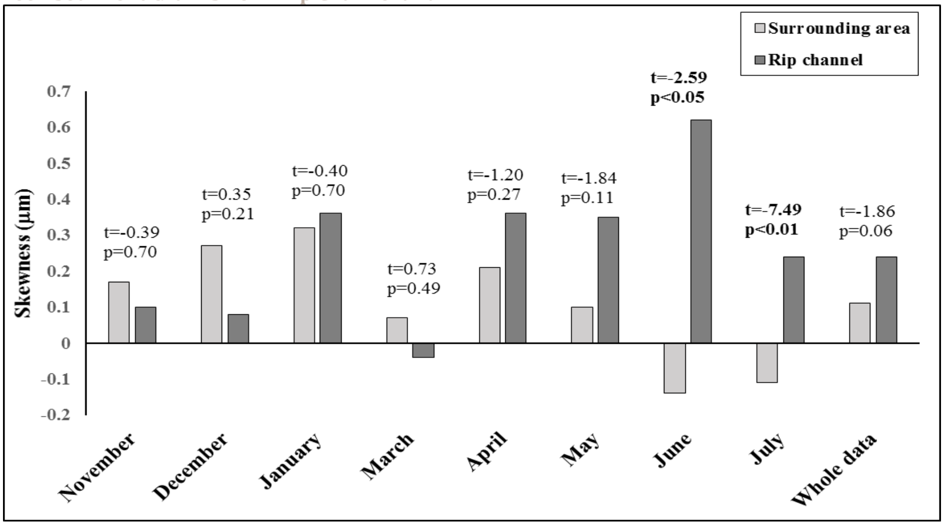

Figure 6) Differences of grain size skewness of sediments between rip channel and its surrounding area (control area) in each month (t and p show unpaired t-test results).

Discussion

Grain size has been studied for different reasons during recent years. For instance, it is an important variable when predicting beach morpho-dynamics. However, to the eye, beaches seem relatively uniform in grain size and, morpho-dynamic modeling efforts usually assume a single mean grain size for an entire beach environment [19]. In this study, we proved that grain size and some of its statistical characteristics are different in the vicinity of the rip channels in the alongshore direction, which should be considered in coastal studies. Among studied sediment parameters, sorting showed a negligible difference between the rip channel and control area. The sorting coefficient is a good indicator of sediment sorting, indicating the uniformity of grain sizes. It is often used as an environmental indicator to represent the relative sedimentary environment [20]. The sorting coefficients in our study area are in the 1.3–1.6 range. The average values are 1.4 in the rip channel and 1.3 in the control area. Therefore the sorting is poor in both locations. This result agrees with the previous studies [20], which also reported a poor sorting, generally less than 2, in the sediments. They showed that the sorting coefficient gradually increases with distance offshore, indicating that sorting gradually becomes poorer. The sorting coefficients near the Welu Estuary in Thailand were generally between 1 and 2, indicating poor sorting [20].

This study showed that the rip channel generally contained sediments with coarser grains than the surrounding area. Since the flow velocity is higher in the rip channel [21], it can be discussed that increasing the flow velocity inside the rip channel probably resulted in the transport of some fine-grained sediments toward the sea but was not capable of transporting coarser-grained sediments. Transport of fine-grained sediments changed the texture of the residual sediment into coarser grains in the bottom of the channel [22], and thus, these changes significantly alter the granulometry between the rip channel and the surrounding environment. However, sediment transport and the study of the relationship of sediment characteristics with environmental features such as water flow rate are still an evolving science because it depends on complex processes. It is important to note that some of these processes are not measured or fully understood; therefore, it is essential for engineers and scientists to note that even the best predictions in the field of sediment transport have a wider margin of error than those expected in other disciplines and fields of science and engineering [23]. Sediment transport is a three-step mechanism involving sediment removal or erosion, transport, and sedimentation. Indeed, some environmental characteristics, including sea water level changes, tides, waves, rivers, and sea currents, are major factors affecting sedimentation processes [24].

One of the most important characteristics of sea currents affecting sediment transport is current velocity [25]. As the current velocity increases, the rate of sediment transport increases [26]. As a result, higher current speed in the rip channel than surrounding areas might increase the removal of sediments, creating the channel and finally changing the sediment grain size into coarser particles [21]. Indeed, coarser sediment grains indicate that the hydrodynamic conditions are stronger in the channels. A similar phenomenon has been investigated in rivers and inland channels [20]). At the same time, the sea is fundamentally different from the land. On land, water flows only into rivers or canals. Nevertheless, at sea, water flows not only in and on the rip channel but also around it. Compared with samples collected in the control area, the results of this study show that the sediment grain size in the rip channel shows a coarsening tendency and might be formed under the erosion of strong hydrodynamic conditions. This indicates that sediments inside the rip channel are subject to more severe erosion due to stronger hydrodynamic conditions than the environment around the rip channel. This result is consistent with some of the results reported in the literature [28]. Furthermore, it can be concluded that despite the continuity of water in the vicinity of the rip channel and its surroundings, the velocity of the water mass located inside and on the rip channel is higher than the velocity of water mass movement in the area adjacent to the rip channel. Moreover, changes in sediment characteristics such as mean particle size in some months (i.e., November, December, January, March, and April) were less influenced by sampling location (channel or surrounding area of rips). It can be concluded that the winter climate was likely to be associated with more wind speed, higher waves, and water turbulence in the sea than the stable climate in the calm months, i.e., May, June, and July. This water turbulence distributed sediments more uniformly across the rip channel. Therefore, sediment transport was more affected by waves than by rip currents during the winter and the months with unstable climate. Rudeh *et al.* [22] stated that coastal sands were distributed along the coastline and the sea bed under waves and currents. The direction of the dominant waves and the mode of production of these waves and the shore influence the distribution of sand particles along the coastline and the shallow water environments near the coastline. Some researchers have also stated that breaking waves and nearshore currents are two of the major known factors responsible for coastal sediment transport. Wave breaking causes turbulence in the seawater and sediment movement [28]. This study showed that the skewness of the grain size distribution curve is also significantly different between the rip channel and its surrounding area, with a higher rate in the channel. While this difference is less pronounced in the sorting of grain sizes. Therefore, it can be deduced that skewness is a more sensitive factor to environmental changes of channel and its surrounding area than the other sediment properties. It is recommended that this factor be prioritized in future studies on sea sediments' characteristics. The skewness results of sediment size distribution curves in the present study refer to the particle size distribution in the μm scale) and agree with those of Srivastava *et al.* [29]. Thus, positive skewness indicates coarse grain abundance with one tail towards the coarse particles, and negative skewness indicates the abundance of fine particles with one tail towards the fine particles [30]. The results showed that the skewness of sediment grain size varies spatially and temporally. Its value is low and around zero in March, indicating asymmetry of the particle size distribution for both the rip channel and the control area sediments. In other months, grain size skewness differs significantly from in the rip channel to its surrounding area. The differences were also significantly pronounced in June and July. Moreover, in June and July, the negative rate of the skewness of the surrounding areas' samples indicates the abundance of fine particles in the control area compared with the rip channel samples.

Conclusion

The rip channel of our study area contains sediments with coarser grains than the surrounding area. It can be concluded that the rip current leads the median and mean of sediment size distribution in the rip channel to move toward the larger sizes. Moreover, the skewness is a more sensitive factor to environmental changes of the channel and its surrounding area than the other sediment properties, emphasizing more consideration in the sediment studies. Using the results of this research and by sampling the sediments of a marine area and comparing them, it is possible to identify areas that have been affected by a rip current in the past. Also, depending on the difference in the size of sediment grains in different areas of the study area, it is possible to understand the intensity and strength of the dominant and effective hydrodynamic conditions in the area. In addition, it is suggested that in future research, flow velocities in and around the rip channel be measured.

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References

1- Leatherman S, Fletemeyer J, editors. Rip currents, beach safety, physical oceanography and wave modeling. Boca Raton, Florida: CRC Press; 2011. pp. 1-29.
2- MacMahan JH, Thornton EB, Reniers AJ. Rip current review. Coast Eng. 2006;53(2-3):191-208.
3- Kumar SA, Prasad KVSR. Rip current-related fatalities in India: A new predictive risk scale for forecasting rip currents. Nat Hazard. 2014;70(1):313-35.
4- Shepard FP, Emery KO, La Fond EC. Rip currents: A process of geological importance. J Geol. 1941;49(4):337-69.
5- Wright LD, Short AD. Morphodynamic variability of surf zones and beaches: A synthesis. Mar Geol. 1984;56(1-4):93-118.
6- Inman DL, Brush BM. The coastal challenge. Science. 1973;181(4094):20-32.
7- MacMahan J, Brown J, Brown J, Thornton E, Reniers A, Stanton T, et al. Mean Lagrangian flow behavior on an open coast rip-channeled beach: A new perspective. Mar Geol. 2010;268(1-4):1-15.
8- Aagaard T, Greenwood B, Nielsen J. Mean currents and sediment transport in a rip channel. Mar Geol. 1997;140(1-2):25-45.
9- Brander RW. Sediment transport in low-energy rip current systems. J Coast Res. 1999;15(3):839-49.
10- Short AD. Rip-current type, spacing and persistence, Narrabeen Beach, Australia. Marine Geol. 1985;65(1-2):47-71.
11- MacMahan JH, Thornton EB, Stanton TP, Reniers AJ. RIPEX: Observations of a rip current system. Mar Geol. 2005;218(1-4):113-34.
12- Brander RW. Field observations on the morphodynamic evolution of a low-energy rip current system. Mar Geol. 1999;157(3-4):199-217.
13- Thornton EB, MacMahan J, Sallenger Jr AH. Rip currents, mega-cusps, and eroding dunes. Mar Geol. 2007;240(1-4):151-67.
14- Zhang X, Ji Y, Yang Z, Wang Z, Liu D, Jia P. End member inversion of surface sediment grain size in the South Yellow Sea and its implications for dynamic sedimentary environments. Sci China Earth Sci. 2016;59(2):258-67.
15- Siuf Jahromi M, Ghaderi D. Rip current in the beach and its hazards. First National Conference in Marine Sciences. Bandarabbas: Unknown Publisher; 2014. pp.1-13. [Persian]
16- Poppe LJ, Eliason AH, Fredericks JJ, Rendigs RR, Blackwood D, Polloni CF. Grain size analysis of marine sediments: Methodology and data processing. US: Geological Survey East Coast sediment analysis, procedures, database, and georeferenced displays; 2000 May. Report No.: 00-358. Sponsored by the Department of Geological Survey.
17- Blott SJ, Pye K. GRADISTAT: A grain size distribution and statistics package for the analysis of unconsolidated sediments. Earth Surf Process Landf. 2001;26(11);1237-48.
18- Poullet P, Muñoz-Perez JJ, Poortvliet G, Mera J, Contreras A, Lopez P. Influence of different sieving methods on estimation of sand size parameters. Water. 2019;11(5):879.
19- Gallagher EL, MacMahan J, Reniers AJHM, Brown J, Thornton EB. Grain size variability on a rip-channeled beach. Mar Geol. 2011;287(1-4):43-53.
20- Wang C, Chen M, Qi H, Intasen W, Kanchanapant A. Grain-size distribution of surface sediments in the chanthaburi coast, Thailand and implications for the sedimentary dynamic environment. J Mar Sci Eng. 2020;8(4):242.
21- Linares Á, Wu CH, Bechle AJ, Anderson EJ, Kristovich DA. Unexpected rip currents induced by a meteotsunami. Sci Rep. 2019;9(1):1-9.
22- Rudeh H, Lorestani G, Etemadi F, Valikhani S. Dynamic simulation of waves and sand transport on the coast of the caspian sea. Quant Geomorphol Res. 2014;2:1-18.
23- Kabiri-Samani AR, Aghaee-Tarazjani J, Borghei SM, Jeng DS. Application of neural networks and fuzzy logic models to longshore sediment transport. Appl Soft Comput. 2011;11(2):2880-7.
24- Kunte PD. Sediment concentration and bed form structures of Gulf of Cambay from remote sensing. Int J Remote Sens. 2008;29(8):2169-82.
25- Van Rijn LC. Principles of sediment transport in rivers, estuaries and coastal seas. Amsterdam: Aqua publications; 1993. pp. 11-3.
26- Muralidharan J, Ganesh Kumar B, Kunte PD. Sediment transport study along Gulf of Kachchh – a numerical and geospatial approach. Int J Appl Eng Res. 2015;10(55):4291-6.
27- Fang J, Chen J, Wang A, Li D, Huang C. The modern sedimentary environment and transport trends in Jiulongjiang estuary. Mar Geol Quat Geol. 2010;30(2):35-41.
28- Azarmsa SA. An introduction to wind induced water waves. Tehran: Tarbiat Modares University Press; 2019. P. 348. [Persian]
29- Srivastava AK, Ingle PS, Lunge HS, Khare N. Grain-size characteristics of deposits derived from different glacigenic environments of the Schirmacher Oasis, East Antarctica. Geologos. 2012;18(4):251-66.
30- McLaren P. An interpretation of trends in grain size measures. J Sediment Res. 1981;51(2):611-24.

Appendix 1) The GRADISTAT output for analysing the sediment samples collecting from the channel (A) and control (B) in July

A

SAMPLE STATISTICS

SIEVING ERROR: -3.3%

SAMPLE IDENTITY: Channel no 4

ANALYST & DATE: Sampling in July

SAMPLE TYPE: Unimodal, Well Sorted

TEXTURAL GROUP: Sand

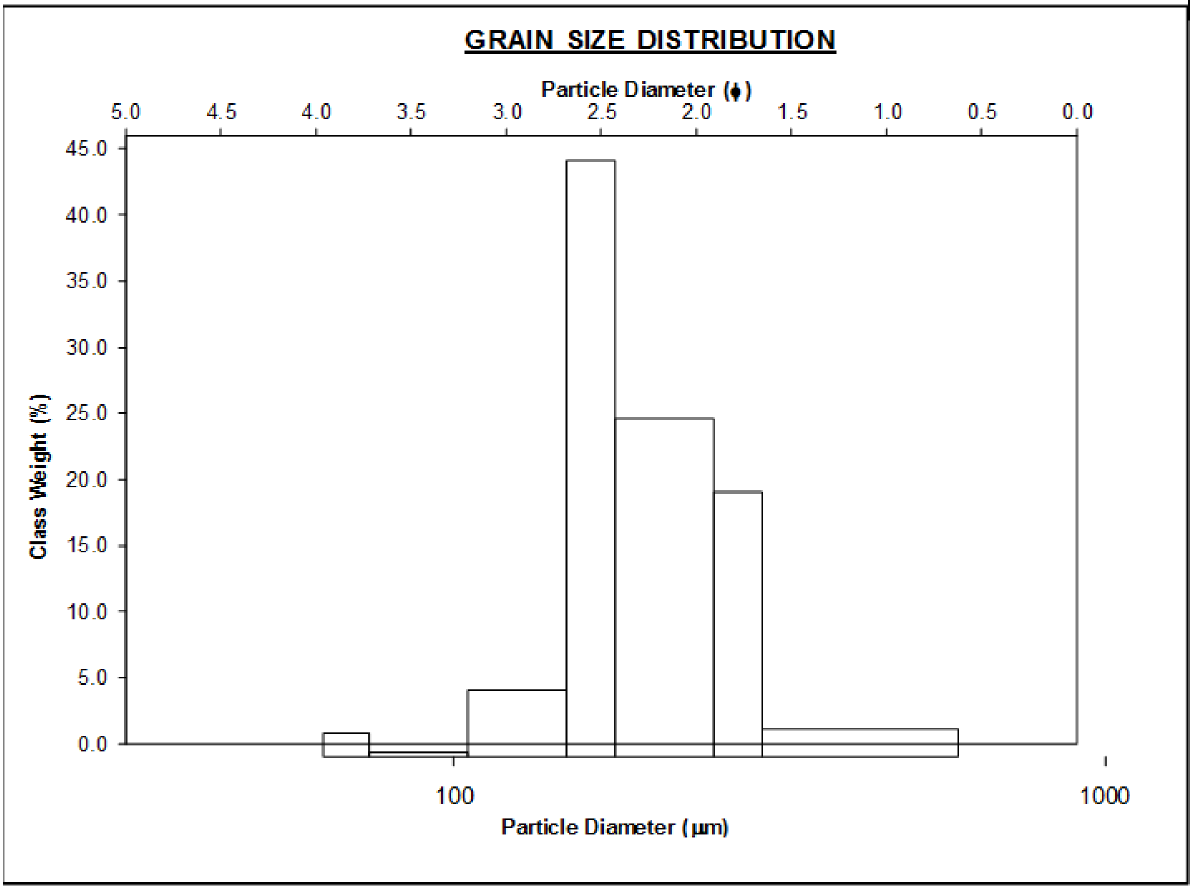
SEDIMENT NAME: Well Sorted Fine Sand

	μm	ϕ
MODE 1:	163.0	2.622
MODE 2:		
MODE 3:		
D_{10}:	149.8	1.778
MEDIAN or D_{50}:	192.9	2.374
D_{90}:	291.5	2.739
(D_{90} / D_{10}):	1.946	1.540
$(D_{90} - D_{10})$:	141.7	0.961
(D_{75} / D_{25}):	1.506	1.291
$(D_{75} - D_{25})$:	82.11	0.590

GRAIN SIZE DISTRIBUTION

GRAVEL:	0.0%	COARSE SAND:	3.8%
SAND:	100.0%	MEDIUM SAND:	18.9%
MUD:	0.0%	FINE SAND:	72.0%
		V FINE SAND:	5.3%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.0%	V FINE SILT:	0.0%
V COARSE SAND:	0.0%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	207.0	176.1	2.284	200.7	2.317	Fine Sand
SORTING (σ):	80.93	2.314	0.565	1.394	0.479	Well Sorted
SKEWNESS (Sk):	1.119	-5.136	-1.370	0.252	-0.252	Coarse Skewed
KURTOSIS (K):	5.992	32.18	7.793	1.270	1.270	Leptokurtic



B

SAMPLE STATISTICS

SIEVING ERROR: 19.4%

SAMPLE IDENTITY: Control no 3

ANALYST & DATE: Sampling in July

SAMPLE TYPE: Unimodal, Well Sorted

TEXTURAL GROUP: Sand

SEDIMENT NAME: Well Sorted Fine Sand

	μm	ϕ
MODE 1:	163.0	2.622
MODE 2:		
MODE 3:		
D_{10}:	109.5	2.218
MEDIAN or D_{50}:	159.8	2.645
D_{90}:	214.9	3.191
(D_{90} / D_{10}):	1.963	1.439
(D_{90} - D_{10}):	105.4	0.973
(D_{75} / D_{25}):	1.233	1.119
(D_{75} - D_{25}):	32.74	0.302

GRAIN SIZE DISTRIBUTION

GRAVEL:	0.0%	COARSE SAND:	1.0%
SAND:	100.0%	MEDIUM SAND:	2.2%
MUD:	0.0%	FINE SAND:	78.9%
		V FINE SAND:	17.9%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.0%	V FINE SILT:	0.0%
V COARSE SAND:	0.0%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	163.5	152.4	2.665	153.8	2.701	Fine Sand
SORTING (σ):	54.55	1.564	0.434	1.290	0.367	Well Sorted
SKEWNESS (Sk):	2.686	-6.922	-1.338	-0.203	0.203	Fine Skewed
KURTOSIS (K):	16.03	80.26	10.94	1.865	1.865	Very Leptokurtic