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In The Name of God

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Investigation the mechanism of changes in the coastal landscapes of southeastern Iran based on geomorphological studies

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ABSTRACT

The southeast coasts of Iran as a part of the coasts of Makran are always changing. Since the southeastern coast of Iran is one of the most important strategic regions of the country and even the Middle East, it is obvious that the information related to geomorphology and other earth sciences can be an important factor both in organizing planning plans and policies and in evaluating private demands. The most important goal of the research is to introduce the factors affecting the change of landscape and coastal geomorphology phenomena and the state of erosion and sedimentation along these coasts. Library and documentary studies, field operations, laboratory studies, combining findings and conclusions have been the main methods of conducting research. In this research, the principles of catastrophism, uniform materialism, gradualism, and Davis's theory have been used, and the method of whole-to-part study (Australian method) has been used to study and investigate the mechanism of landscapes and geological effects. Based on the geomorphology evidence of the coasts, it was determined that from west to east on the southeast coasts of Iran (from Pozm Bay to Govatr Bay), the intensity of the advance and retreat of the sea water in destroying the coasts decreases, that is, with the change of the sea tide line and the advance of the water, the coastal development of the areas It happens much less in the west than in the eastern areas such as Ramin, Lipar and Govatr. The coastal area of Makran is under the influence of three tectonic, erosion and sedimentation activities and human activities (industrial, fishing and construction) are not effective. Two general models include the dominance of erosive and tectonic processes over sedimentation processes, causing the formation of landscapes such as erosion columns, sea stacks, sea arches, sea caves, headlands, Islands and raised beaches (Cliff) are found in the coastal areas of Pasabandar, Beris, Lipar, Tis, and Konarak, and the other is the dominance of sedimentation processes over other activities, which are landscapes such as Spit, Bar, Tombolo, Lagoon, Delta, Tidal Flat, Bay Barrier, Islands and Mud Flat in the coastal areas of Ramin, Chabahar Bay and Govatr.

1. Introduction

Geology of coastal areas is considered as one of the basic information, the basis of some planning and implementation of coastal areas management policies. Since the southeastern coast of Iran is one of the most important strategic areas of the country and even the Middle East, it is obvious that the information related to geology and other earth sciences can be an important factor both in the regulation of plans and planning policies and in the evaluation of private demands. The cycle of erosion of land and carrying sediments to the sea and the sedimentation process are among the important geological phenomena in sedimentary

environments that take place continuously. Weathering, erosion, deposition and finally diagenesis or hardening of sediments lead to the formation of sedimentary rocks on the coasts of seas and oceans. These rocks are again removed from the water according to the erosion cycle of William Morris Davis [1] with tectonic processes such as folding and forming new geological landscapes, and these changes always continue dynamically. This dynamic is more effective in the continental margins due to the interaction between sea water and currents.

In coastal areas, the history of sedimentation is used to document various changes [2]. When freshwater rivers enter the sea, they interact with the marine environment due to specific chemical differences such as total ion resistance, acidity, total hardness, salinity, and other characteristics, and the result of this is the occurrence of sedimentation or beach dissolution processes. Also, coastal environments are affected by interactions and human intervention [3]. Therefore, such environments are under severe tension. In coastal areas that have lower hydrodynamic energy, fine particles tend to settle and accumulate, while in areas with high hydrodynamic energy, fine particles are washed away and move away from the coast [4,5].

The structural-sedimentary zone of Makran extends from 30 degrees and 57 minutes in the southeast of Iran to 30 degrees and 66 minutes in the south of Pakistan. This zone is 1000 kilometers long and 340 kilometers wide. In other words, it extends from the Strait of Hormuz in the southeast of Iran to the Middle Gulf of Son (Deccan) in Pakistan. The difference in topographic height in Makran is from 3000 meters below the open water level and in the Oman sea bed to 1500 meters above the open water level in the heights of Makran [6]. Makran has four different sedimentary provinces, which include northern Makran, inner Makran, outer Makran and coastal Makran. Makran Sahil is located in the south of Outer Makran and represents the sedimentary basin above the accretionary wedge with a shallow sedimentary sequence from the marls of the continental slope to the bottom of the continental and coastal plateaus [7, 8].

From the point of view of geology, Makran is an ancient rift that is in the form of an accretionary prism, from the late Cretaceous to the early Tertiary and until the Holocene, in the outer wall of a shallow and low-slope subduction zone [9]. It divides Makran into three physiographic units, including marine barracks parallel to the coast, alluvial deposits north of the barracks, and the hills and heights of Makran [10]. In the Makran area, the folding of late Oligocene-Middle Miocene rock units, which are mainly sand flysch, was formed in the Mio-Pliocene [11]. The background of geological studies corresponds to the generalities and conditions of the formation of coastal areas, among which we can refer to the basic books of land preparation [12], the basics of geology [13], the application of geology in the preparation of land and environment [14], the application of geology in planning. National-regional and economic [15], Geology of Iran [16], Geology of Iran [17], Coasts of Iran [18], Application of geology in planning [19], Coastal geology [20, 21, 22]. Several reports have been made to investigate the landforms and characteristics of the coastal regions of the country, in which either the state of the coastal regions has been discussed from a geomorphological point of view, or geomorphological conditions such as coastal landform maps have been mentioned in addition to the main topics [23, 24, 25, 26, 27, 28, 29, 30] pointed out.

Therefore, in this research, it has been tried to describe the factors affecting the shape of coastlines, especially landscapes and geological phenomena, and predict the state of formation of these beaches. Therefore, by mentioning some of the most important geological structures and stating their mechanism of occurrence, the following questions should be answered regarding the coasts under erosion, in equilibrium and during sedimentation:

1- What are the main factors affecting the geological changes of the southeast coasts of Iran?

2- Does erosion and sedimentation with tectonic processes have an effect on the deformation of the southeast coasts of Iran?

Therefore, according to the previous research and since the development of the southeast coast of Iran (Makran) is on the agenda of the Islamic Republic of Iran and the southeast coast of Iran is considered as the most strategic region of the country, the necessity of this research doubles.

Geographical location and access roads to the area

The studied area is located between latitudes 25°14' to 25°26'N and longitudes 60°21' to 60°50'E in the north of Oman Sea and south of Sistan and Baluchistan province. From the geological point of view, this area is located in the geological zone of Makran; Makran zone is structurally divided into two outer (coastal) and inner parts [33]. The studied area is located in the outer part, although the area of Makran coastal structural land is wider than the selected area (Figures 1 and 2). One of the general features of this section is the presence of ophiolitic complexes, sedimentary deposits with felsic facies and the absence of rocks older than the Cretaceous in the region [35, 34]. The ophiolitic complexes of the region are mostly in the form of narrow and more or less continuous strips that often outcrop along the main longitudinal faults [36].

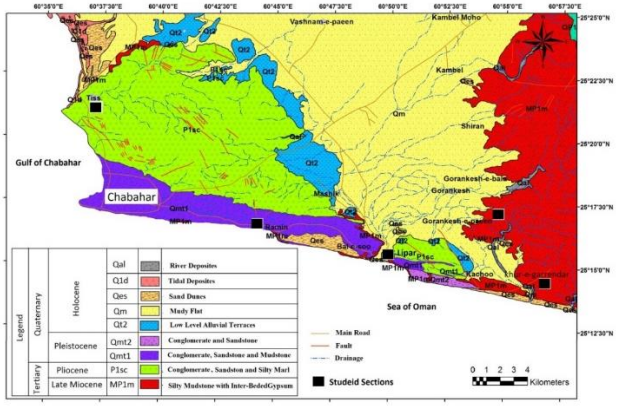

Figure 1. Geological map of Makran coasts (modified after 1: 100000 geological maps of Chabahar) [31, 32]

Different rock units in the coastal area and land overlooking the sea include marl units of Miocene age, Miocene-Pliocene marl and sandstone units, Pleistocene loamshells, sandy and silty sediments of alluvial cones, and sediments of the present age contain fossil shells. In general, the stratigraphic sequence of the studied area consists of four parts: Miocene rock units, Mio-Pliocene rock units, Pliocene rock units and Quaternary rock units, which are known as Neogene and Quaternary units [36]. Quaternary deposits in coastal Makran are post-Pliocene sediments placed on Pliocene conglomerate, but in the studied area they include coastal lowlands.

Holocene alluvial sediments are spread throughout the coastal area. Another important part of the sediments of this region is the sedimentary deposits of the estuaries in the region. The most sedimentary constructions in sedimentary deposits include gradual stratification, diagonal stratification on small and large scales, boudinage, imbrication, symmetrical and wave ripple marks, flute cast, toll mark, mud cracks, traces of biological disturbances and the activity of burrowing organisms.

Material and Methods

In this research, library and documentary studies, field operations, laboratory, data integration and conclusion were the main methods of doing the work. In library studies, it was first tried to collect and study books, articles, research reports, maps and what was related to the research topic.

Then, in field operations and field studies, numerous geological visits, taking pictures of geological landscapes and studying them took place. In this research, different principles of geology, namely the principle of catastrophism (sudden and large processes), the principle of uniformitarianism or the principle of similarity of processes (present key to the past) and the principle of gradualism or the principle of slow and gradual land changes (sudden events on a small scale) have been used. The method of studying geological structures has been using the Australian method, that is, studying the whole structure into parts after the formation and emergence of the structure.

For this purpose, the most important geological landscapes in the study area were identified and then the way of their occurrence was identified according to the geological characteristics. Also, with their structural reconstruction, the necessary be determined modeling and then destructive and constructive areas were introduced. Therefore, the coastal areas of Govatr, Bris, Pasabandar, Lipar, Ramin, Chabahar Bay, Tees, Kanarak and Pozm along the southern coastal strip of Sistan and Baluchistan province were selected and studied. Since erosion, tectonics, and sedimentation are probably the most effective and active processes in the Makran area, these areas were chosen because many geological landscapes are being formed, changed, or developed in this area.

Results and Discussion

The southeastern region of Iran is one of the regions in the country that has unique structures and landscapes. These natural potentials are due to special climatic and geological conditions,

including sea level fluctuations during different geological times, interactions related to external processes such as weathering and erosion conditions, as well as internal processes including tectonics caused by the subduction zone and its effects. Among these landscapes and natural structures, we can find head land, raised beaches, sea fans, barracks or coastal cliffs, Bad Land, Sea Caves, Sand Dune, Mud Volcano, Coastal Plain, Delta Plain, Estuary, Creek, Lagoon, Tidal Flat, Mud Flat, Spit, Bar, Tombolo, Bay, Cove, Erosion Column) and dozens of other examples, each of which in turn shows the geological activities of Makran over many years. Below, firstly, the introduction and mechanism of their occurrence and then their impact on Makran's coastal changes have been investigated.

Morphological landscapes with the influence of tectonic activities

As mentioned in the introduction of the research, the Makran area in the coastal part includes the east-west elevations that continue from the northern shores of the Oman Sea (south of Sistan and Baluchistan) to the Jazmurian depression. The western border of these mountains is separated from the collision zone of Zagros by the Minab fault, and in the east, after passing through Pakistan's Baluchistan, it continues to the axis of Las Bela. It should be mentioned that out of the 160,000 square kilometers of Makran, about 70,000 square kilometers are in Iran and the rest are in Pakistan [36]. The continental crust that separates North Makran from South Makran is the southern edge of Lut Block, which was placed in the Makran flysch basin after being separated [38]. According to the increasing age of the sedimentary formations from south to north, the existing shape change and the increase in height, Makran is considered to be a type of active arc system, in its formation, the subduction of the oceanic crust of Oman under Makran played a fundamental role [39, 40].

According to the researchers, the subsidence took place at a distance of 400 kilometers from the coast, and before the subsidence, the lithosphere was bent and the melting of the oceanic crust caused the formation of the magmatic rocks of the highlands. In this theory, Makran area is divided into two geological units [36]. One is the sunken part of Jazmurian, which is a type of subsiding basin, and the other is the southern uplifted part, which continues from the Beshagard Mountains to the depths of the Oman Sea, and is composed of two parts: the Slope Basin and the Trench Fill. is [36,40].

The Makran zone is actually an accretionary prism that is located on the outer wall of a shallow subduction zone. In this region, the subduction process has started since the Late Cretaceous and the final collision between the plates has not yet taken place, so the orogeny process in Makran is still continuing [42]. The subduction of the oceanic crust of Makran under the continental crust has led to the formation of complex structures and the Oman ophiolitic belt and accretionary prisms in Makran [43, 44]. Among the colliding plates, the subducted plate is the base of continental rocks. The magmatic arc resulting from subduction includes Mount Sultan volcanoes in Pakistan, Taftan and Bazman volcanoes in Iran [41]. It should be mentioned that the bending of the oceanic lithosphere before the subduction and especially the action of thrust faults is among the factors that make Makran rocks [36]. The oceanic lithosphere of the Arabian plate is moving towards the north and goes under the Lut plate and the Afghan-Helmand block. In geodetic measurements, the rate of movement of the two Arabian and Makran coasts between Muscat and Oman has been measured at 1.9 cm per year, while the current rate of subsidence between the Makran coast at Chabahar and Eurasia has been measured at about 8 mm per year [37, 45]. The accretionary prisms of Makran are a special example and one of the largest accretionary prisms in the world, which is a subduction of the oceanic lithosphere (Figure 2).

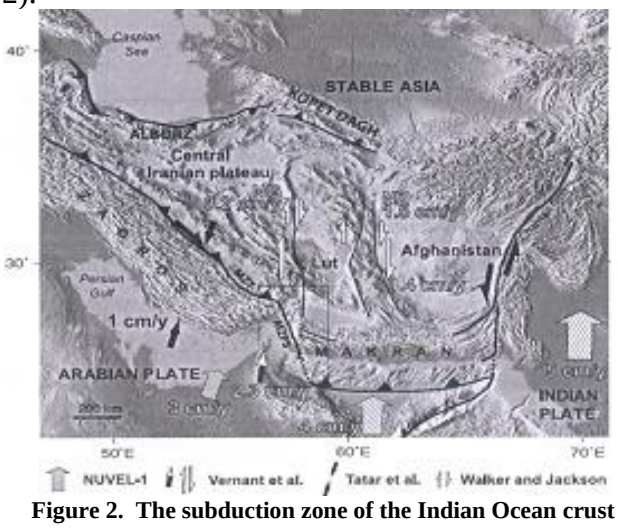

Figure 2. The subduction zone of the Indian Ocean crust under the Makran crust [48]

the angle of this subsidence is very low and less than 2 degrees. The width of the subduction system (deep subduction zone to the magmatic arc) is 400 kilometers on the Iranian side, which increases to 600 kilometers to the east of Pakistan [46, 47]. The rate of subsidence in the Oman Sea is estimated to be 4 cm per year [48]. The place of subsidence in the Cretaceous was at the place of the Jazmurian pit, which gradually receded towards the south and has now reached the deep area of the Oman sea bed [36].

According to the above, the tectonic face of the coasts, especially the uplift of the coasts, the existence of faults and cracks, proves that after the rock is affected by stress, it first undergoes elastic deformation and then breaks (in the state Normally, stones are brittle) but under confining pressures and high heat, many stones enter the plastic deformation stage after the elastic stage, and eventually the stones break under these conditions. This evidence is abundantly seen in the region, which is the reason for the tectonic impact.

In the following, we will describe the most important geological landscapes whose mechanism of formation is tectonic activities:

Coarsening in the sedimentary sequence upwards (Coarsening upward): The existence of a coarsening sequence on the coasts is a proof of tectonic influence in the Makran area, an example of which can be seen at the entrance of Tees village [49]. In this sequence, seven sedimentary layers can be seen, which show the coarsening of the sediments upwards (Figure 3).

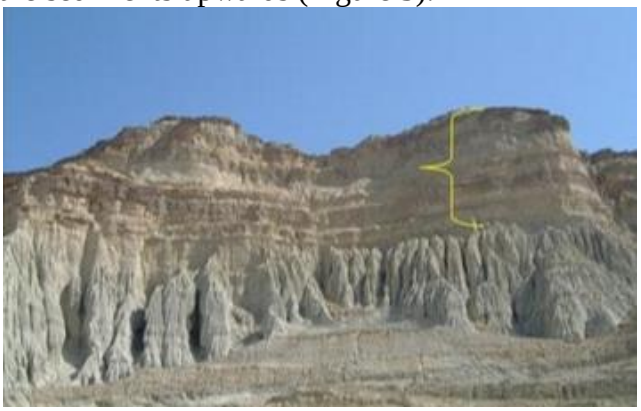

Figure 3. The Coarsening Upward of sediments in sequence at the entrance of Tis village

High and rising costs (Cliff): The sea defenses in the east of Chabahar become older with the increase in height and record the relative change of the sea level over time. Relatively severe changes in the sea level in the mentioned sediments are due to tectonic processes caused by the erosion rate of the subduction zone, global sea level changes and climate changes. The coastal strip area is considered one of the active areas due to its special tectonic situation. Of course, wherever the three factors of water, wind and land are in contact with each other, the process of erosion and weathering is more intense and causes the creation of special coastal forms. In the Makran area, the effect of the mentioned factors, especially the impact of the waves, has caused the destruction of the beaches, accompanied by tectonic activities, and has caused the formation of coastal heights and barracks (Cliff), which is one of the most important and spectacular geological landscapes of Makran (Figure 4). In some cases, these rocks are up to 50 meters thick, which are considered as one of the other sights of the tourist area.

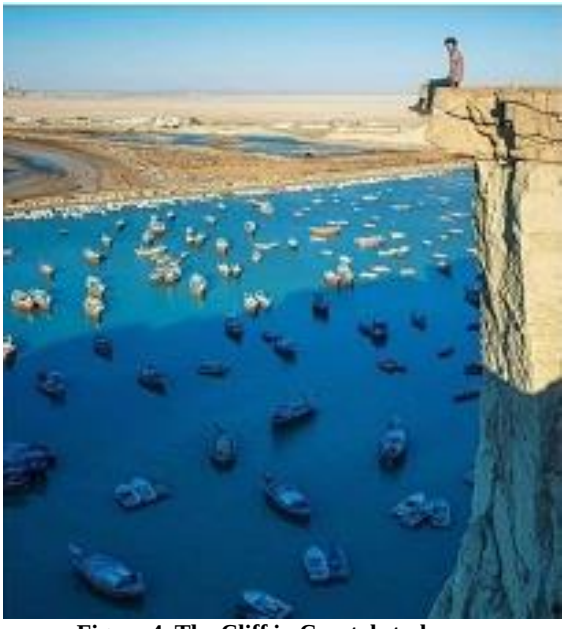

Figure 4. The Cliff in Coastal study area

In these coasts, the existence of faults and numerous other cracks is evidence of the tectonic influence in the studied area (Figure 5).

Figure 5. Faulted and jointed cliff coasts, Tis and Lipar coastal areas

Mud volcano: one of the very beautiful and spectacular geological forms and processes in the study area are the Mud volcano (Figure 5). This phenomenon is actually a natural phenomenon similar to a volcano, which is in the form of a

conical hill and instead of lava, gas and mud come out of its mouth. The mechanism of the formation of these glaciers is tectonic factors, including the movements caused by the subduction of the oceanic crust of the Indian Ocean and Oman Sea under the continental crust of Makran. The gulfs of the Makran coast are relatively young and their origin dates back to 30,000 to 40,000 years ago [50]. In addition to being one of the interesting and beautiful sights of geotourism, the flowers have therapeutic properties in traditional medicine, so that their flowers are used to treat diseases such as joint and spine pain, joint stiffness, neurological diseases, the early stages of vasoconstriction and muscle spasms, diseases femininity are very beneficial [51].

It is said that bathing in the flowers of Mud volcano is very beneficial for the skin due to the presence of special chemical elements in their compositions, and it rejuvenates human skin and improves skin ailments [52]. Glaciers cause ion exchanges due to the influence of underground water or sea water penetration. Therefore, it is possible to manage mudflows by building baths next to them, so that while visiting tourists, they can use the facilities installed there due to their therapeutic properties. It should be mentioned that with the previous researches and according to the chemical composition of the mud (organic and inorganic compounds), the therapeutic properties of Mud volcano in the treatment of diseases such as joint and spine pain, joint stiffness, neurological diseases, vasoconstriction, muscle spasms and Women's diseases etc. have been proven [52]. So far, 20 gulfs have been identified on the coast of Makran, and of these, 5 are located between Jask and Minab ports, 9 between Chabahar and Jask ports, and 6 between Chabahar and the Iran-Pakistan border, especially in the north of the Gulf of Govatr.

Figure 6. Mud volcano of Kahir in the northeast of Chabahar

Morphological landscapes with the dominant effect of erosion

he main formations of Makran region are mainly destructive and include shale, marl, sandstone and conglomerate, in the meantime, shale and marl have a high spread in the whole region. Most of the existing geological landscapes are formed in the sequence of shale, marl and sandstone units (Figure 6). Most of the geological landscapes of the Marni coast are hilly slopes, which are generally weak and resistant, and have deep valleys (known as a thousand valleys) formed due to the influence of surface water flow. In a wide area of the coastal strip, many fossil traces can be seen, which indicates that the area was covered by water in the past. The existence of whale fossils inside these sediments is a proof that the sedimentary environment of these formations is marine.

Figure 7. Clastic sediments in the northeast of Chabahar

The existence of various types of surface erosions, grooves and watersheds (Figure 7) as well as nesting erosion (Figure 8) is also a proof of the impact of weathering and erosion processes as well as the blowing of two-way winds in the coastal formations of Makran.

Figure 7. Grooving, surface and hydrostatic erosions in marl sediments (Ramin)

Figure 8. Honeycomb erosions in sandstone and marl sediments (Ramin)

In most of the coastal areas of Makran, due to the presence of strong, weak and non-resistant rocks, the topography of the beach's changes under the influence of the weight of the rocks. This means that the loose marl sediments are weathered and eroded and fall. This factor affects the resistant sandstone and loamy rocks, and over time, they begin to break and fall as the underlying rocks become empty. This causes the formation of a talus in the lower part of the heights (Figure 9).

Figure 9. Erosion in sandstone sequence, rock fall and talus formation, Lipar coastal area

Bad Land: between 25 and 20 kilometers from Chabahar on the northern shores of the Oman Sea (Chabahar-Govatr road), surface water and wind erosion on the green marl-sandstone formations of the region, beautiful views from the regular and numerous highlands. which is known as bad lands or Martian mountains or miniature mountains (Figure 10). These deposits were formed under the influence of water and wind erosions, which spread parallel to the sea coast line (east-west extension) from the Quechua area to the vicinity of the Gulf of Govatr.

Figure 11. Badlands in the southeast of Chabahar

Erosion Columns: Wind as the main factor of erosion in the region, like running water, causes erosion and transport of low-resistant sediments, and after hitting stone obstacles, it wears their surface. This process in the coastal areas has created beautiful constructions such as the elf chimney (Figure 4) and the devil's bed (Figure 5), which will attract the attention of every viewer. The height of these erosion columns sometimes reaches 46 meters. Also, in the northern part of Makran region, due to the placement of hard sediments on the soft sediments that have been exposed to weathering and erosion, very large masses of hard parts have been separated and placed on the road, which was created by the initiative of the highwaymen due to the size of the parts and the preservation of natural resources from They have used it as a field or field, which is very spectacular (Figures 11 and 12). Debt is that wherever the three factors of water, wind and land are in contact with each other, the process of erosion and weathering is more intense and causes the creation of special coastal forms. In the studied area, the effect of the aforementioned factors combined with tectonic activities has increased the intensity of the formation of these structures.

Figure 12. Erosion columns in the northeast of Chabahar

Figure 13. Placement of a large sandstone mass on the road with the initiative of road users

Fungal-shaped erosion forms known as oysters: Wind erosion combined with the action of running water, especially rain, has created beautiful mushroom-shaped and beehive-shaped buildings, which the natives of the region call oysters (Figure 13). These beautiful forms can be seen in the sandstone and carbonate part of Beaufort.

Figure 14. Mushroom-shaped structure in the southeast of Chabahar

Sea Arch: One of the geological landscapes resulting from water erosion caused by waves hitting the shore is the creation of coastal niches (Figures 14 and 15).

Figure 15. Sea arch in the coastal area of Beris

Sea Cave: Like the sea arch, one of the other geological landscapes resulting from the erosion of waves is the creation of sea or coastal caves (Figure 16).

Figure 16. Sea Cave in the coastal area of Pasbandar

Sea Stack: Like the sea arch, one of the other geological landscapes resulting from the erosion of waves is the creation of sea stacks (Figure 17).

Figure 17. Sea Stack in the coastal area of Pasabandar

Sea Island: One of the geologic landscapes resulting from water erosion caused by waves hitting the coast and transferring sediments to the parts of the sea island is the creation of Sea Island (Figure 18).

Figure 18. Sea Island in the coastal area of Pasbandar

Hollow beaches and dissolution holes: chemical and biological erosions in Makran region have caused geological landscapes. Coastal organisms such as worms, crabs, seabirds, etc., by digging in soft sediments (Barrowing), leave biological traces on the beaches, which indicate biological activity. Also, the effects of sea water, especially the effect of acidic water combined with the drilling of organisms in hard rocks (Boring), especially the beaches of Lomashelli, cause the creation of medium and large-scale holes on the rocks, which cause geological landscapes (Landforms) (Figure 19).

Figure. 19. Cavity beaches, soft (right) and hard (left) rocks

Jointed masses (Tor): The presence of three fault systems crosswise and widely and its impact on the coastal rock units form a wide network of joints and cracks and fault wedges. One of the geological landscapes resulting from the combined effect of tectonics, weathering, water erosion (caused by the hydrodynamics of waves) and wind erosion is the formation of jointed beaches or rocks full of fractures (Figure 20).

Figure 20. Joint stones (Tors) in the coastal area of Lipar

Morphological landscapes with the influence of sedimentation processes

According to the cycle of erosion, wherever weathering and erosion are active, there is a process of sediment transport and finally sedimentation. This issue has caused the formation of various geological landscapes in the studied area, the most important of which are mentioned below.

Sand Dunes: In the Makran area, especially in the parts where the permanent or temporary winds carry the existing debris (sand) sediments and by reducing the transport speed, the sediments settle and as a result of this process, sand dunes are formed. In the studied area, this process has caused sand dunes to expand along with wavy and symmetrical ripple marks. These effects are recorded and unrecorded on the beaches of Chabahar (Figures 21 and 22).

Figure 21. Sand dunes in the study area, Kachu Beach

Figure 22. Sand therapy in the sand dunes in the southeast of Chabahar

Tidal flat beaches: In the studied area, the increase in the erosion of the upstream beaches and the introduction of fine-grained sediments, the sedimentation process becomes more intense and causes the laying of new sediments and the expansion of sandy beaches. This process has formed coastal geological landscapes in the northwest and west of Chabahar (Figure 23).

Figure 23. Tidal beaches of the Tees coastal area

Lagoon: Many lagoons or lagoons can be seen on the coasts of the studied area, which are caused by the fluctuations of the sea level. Lipar Lagoon is located in the south of Lipar village and 15 km east of Chabahar on the Chabahar-Govatr coastal road with a wonderful view (Figure 24). The red lagoon of Lipar has a beautiful view with its red waters, some believe that its red color is due to the presence of bacteria that use the salt in the lagoon.

Figure 24. Lipar lagoon in the southeast of Chabahar

Estuary: Another geological landscape of Makran is the coastal estuaries. The mechanism of formation of estuaries is in such a way that with the advance of sea water, the upstream parts of the coast are flooded and with the deposition of sedimentary particles, its connection with the sea is cut off and they expand and cause the occupation of these sedimentary basins. Estuaries are intermediate environments between land and sea, which, due to their location, have special characteristics (high tolerance of salinity and being affected by land due to tides), which completely affect their environmental and living conditions and create a special ecosystem. provided (Figure 25).

Figure 25. A view of the coastal estuary of Hotan Parak

Small bays and omega-shaped bays: In the studied area, coastal sediments under the influence of sea level fluctuations, sedimentation and the combined effect of tectonics over time cause a drastic change in the coastline and the formation of a horseshoe-shaped bay. Omega) and give beauty (Figure 26). Among these sights are the bays of Chabahar, Pozm, Tis, and Govatr. On the coasts of the region, the effects of the prevailing sea currents on a large scale, along with the effects of the rivers entering the sea, have created beautiful bays in the region, which are known as omega bays due to their semicircular shape. Due to the expansion of stabilized sand dunes in the coastal strip and the effect of permanent winds, the movement of coastal sands along with degraded sand from sandstone formations on the one hand causes the expansion of plains full of quick sands and the release of fine sediment particles and remaining sediments. Coarse grain, on the other hand, has caused the formation of desert pavements in the coastal strip (Figure 27).

Figure 26. A view of the coastal bay in the northeast of Chabahar

Figure 27. Desert pavement on the coast of Makran

Mud Flat: On the coasts of Makran, due to the erosion of the upstream sediments, the thickness of the sediments is reduced and the sediments are added. These sediments are transported by surface water and finally the floodplain causes the expansion of mud flats. These sediments were formed at a distance from the coastline (Figure 28).

Figure 2. A mud flat on the northeast coast of Chabahar

Bar: In the studied area, coastal sediments under the influence of sea level fluctuations over time cause the sedimentation of sediments in the coastal area and the formation of Bar, in a way that in parts of Makran coasts, disconnects the sea from the land. (Figure 29).

Figure 29. Bar in the coastal area of Lipar

Sea spits: Coastal sediments under the influence of sea level fluctuations over time cause the sedimentation of sediments in the coastal area to form sea spits (Figure 30).

Figure 30. Sea Spit in the coastal area of Lipar

The general mechanism of change and development of Makran beaches

The coasts of the Oman Sea have been exposed to two groups of terrestrial and marine environmental factors due to the subduction zone. In this situation, the rock units have become increasingly porous under the influence of petrification processes such as dissolution, decomposition and alteration of the constituent components, and it makes the beaches very vulnerable to the impact of waves and local loads (Figure 31).

Figure 31. The effect of chemical and physical erosion factors in the coastal area

Geological evidence of the coasts revealed that from the west to the east of southeast Iran, the intensity of the advance and from the northern shores of the Oman Sea, from the Bay of Pozm to the Gulf of Govatr, the retreat of the sea water in the destruction of the beaches decreases, that is, with the change of the sea tide line and the advance of the water, coastal development It is much less than the eastern regions such as Ramin, Lipar and Govatr. Another important factor in the change of coasts is the presence of permanent and seasonal rivers in the region, such as the Sarkan River in the west of Pozm region and the Lipar River in the east of the region, which affect and sometimes destroy the coasts during flooding. This factor has changed the morphology of the coasts in such a way that it sometimes creates vast plains that will be covered with water in case of rains and floods. As mentioned in the first part, according to the subduction zone and the function of faults, such as conjugate faults and strike-slip faults, and the role of neotectonics and Makran subduction zone (coastal uplift), the resulting destructive changes are also significant. In such a way that the creation of cliff defenses in the coastal strip is quite evident and they are very effective in causing sedimentation and destruction of rock formations (Figure 32).

Figure 32. Neotectonics effect resulting from the Makran subduction zone and coastal uplift

In terms of engineering geology, the coastal area of Makran consists of resistant, less resistant and non-resistant rocks. The type of old sediments is soft sediments, and hard sediments are placed on top of these old sediments, which are washed away by the waves of soft sediments and become empty under the hard sediments, causing the fall of boulders and sometimes landslides occur. Like the previous two phenomena, the coastal regions of southeastern Iran are highly tectonized due to the existence of Makran subduction zone and have various type 1 and 2 fractures as well as numerous landslides and landslides. In general, there is more instability in the eastern part of the coastal areas of the province where there is an earthquake belt. In the highlands of the region,

the probability of instability will double. Therefore, the important factors that are effective in changing coastlines are wind erosion, which over time and the influence of air and sea water on the rocks of the sea intensify the destructive changes and cause the destruction of old stones and rock formations. Sea waves and currents, both deep and surface, play an important role in changing and creating the geological landforms of the coasts, and tidal currents play an important role. This process has caused the most destruction in marine structures and coastal components in the region (Figure 33).

Figure 33. The effect of erosion by waves on weak points and fractures and changing the coastal

Civil and human activities such as the development of coastal roads, the construction of fishing or commercial ports, urban development of both residential and commercial areas, and the construction of water catchment dams also cause major changes, especially in the location of the docks, and are affected by the creation of more sediments, which sometimes It is combined with the activities caused by the retreat of the sea water and causes the destruction or retreat of the sea and ultimately the destruction of these types of structures. These changes can be seen both in the west and in the east of the coasts. The fishing ports of Pasbandar, Breis, Ramin, Pozm and the commercial and military ports that were built especially in Chabahar Bay to Konarak have played a significant role in the changes of the coastlines (Figure 34).

Figure 34. The significant role of construction activities in the drastic changes of Pozm and Konarak coastal areas

Table 1. Geomorphological and spatial characteristics of coastal study areas

Coasts	Description of geomorphology
Govatr	In this region, sedimentation processes prevail over erosive and tectonic processes. Major geological landscapes include Omega and small bays, raised beaches (Cliff), coastal tongue (Head Land), Sea Arch, Bar, Tidal Flat, coastal estuaries. Creek & Estuary).
Pasabandar	In this region, erosion and tectonic processes prevail over sedimentation processes. The main geological landscapes include the raised coast (Cliff), coastal tongue (Head Land), sea arch (Sea Arch), islands (Island), joints and faults (Joint & Fault), sea cave (Sea Cave), mountains of a thousand valleys (Bad). Land) and mushroom-shaped forms.
Beris	In this region, erosion and tectonic processes prevail over sedimentation processes. The main geological landscapes include the raised coast (Cliff), coastal tongue (Head Land), sea arch (Sea Arch), islands (Island), joints and faults (Joint & Fault), sea cave (Sea Cave), mountains of a thousand valleys (Bad). Land) and mushroom-shaped forms.
Lipr	In this region, erosion and tectonic processes prevail over sedimentation processes. The main geological landscapes include the raised coast (Cliff), coastal tongue (Head Land), sea arch (Sea Arch), islands (Island), joints and faults (Joint & Fault), sea cave (Sea Cave), mountains of a thousand valleys (Bad). Land), Lagoon, Bar, Creek & Estuary, Boring and mushroom-shaped forms.
Ramin	In this region, sedimentation processes prevail over erosive and tectonic processes. The main geological landscapes include cliffs, barrowing beaches, honeycomb erosion, mud flats, tidal flats, and sand dunes.
Chabahar	In this region, sedimentation processes prevail over erosive and tectonic processes. The main geological landscapes include cliffs, barrowing beaches, honeycomb erosion, mud flats, bar, tidal flats, and sand dunes
Tees	In this region, erosion and tectonic processes prevail over sedimentation processes. The main geological landscapes include cliff, coarsening up ward, head land, sea arch, islands, joints and faults, erosion columns. (Erosion Column), sea cave (Creek & Estuary), dissolution holes (Boring) and mushroom shapes.

Konarak	In this region, erosion and tectonic processes prevail over sedimentation processes. Major geological landscapes include cliff, head land, sea arch, island, joint & fault, sea cave, and mushroom-shaped formations.
Pozm	In this region, erosion and tectonic processes prevail over sedimentation processes. Of course, human activities such as fishing and shipbuilding industries also affect the region. The main geological landscapes include cliffs, coastal tongues, sea arches, joints and faults, erosion columns, sea caves, mudflats. Mud Flat, Tidal Flat, Creek & Estuary, Barrowing and Bay.

Reconstruction of geological models of the studied area

According to the previously mentioned materials, the southeastern coasts of Iran are affected by the subduction of the Indian Ocean plate under the Iranian plate. Therefore, all coastal processes including erosion, sedimentation and human activities are affected by tectonic activities. On the other hand, from the point of view of sedimentology, it seems that a dual regime of sedimentation has prevailed in the studied coastal area, meaning that when the sea level rises, carbonates are deposited and destructive sedimentation stops, and when the sea level drops. sea water level and debris particles entering the sedimentary basin, carbonate sedimentation is stopped and destructive sedimentation takes place. In the northern regions, permanent and seasonal rivers such as Sarkan (Shor), Lipar rivers, as well as estuaries and estuaries such as Khor Shor and Park (due to the closure of the mouth of these estuaries by sediments that are associated with the limitation of the invasion area of tidal currents), The facies of the area above intertidl has grown and by leaving sediments, coastal expansion occurs. On the other hand, there are coastal currents, longshore currents, and rip currents in Makran region. In the meantime, the water that came to the coast returns to the sea due to the difference in height on the slope of the coast, but the return of water to the sea is not uniform and it may intensify from the paths that are more similar to the river channel and cause the rip currents to break the coast. and these currents occur frequently (Figure 35).

Figure 35. Splitting currents in the southern region of Chabahar

Therefore, it can be said that the coastal area of Makran is under the influence of three tectonic, erosion, and sedimentation activities, and human activities (industrial, fishing, and construction) are not effective. Therefore, two general models for the formation of landscapes and geologic features of the southeastern coast of Iran are reconstructed and proposed:

The first model: the predominance of erosion and tectonic processes over sedimentation processes causes the formation of landscapes such as erosion columns, sea stacks, sea arches, sea caves, headlands, and islands. (Island) and raised beaches (Cliff) in the coastal areas of Pasbandar, Breis, Lipar, Tis, Konarak and Pozm (Figure 36).

The second model: the predominance of sedimentation processes over other activities, which are landscapes such as Spit, Bar, Tombolo, Lagoon, Delta, Tidal Flat, Barrier Islands. Bay Barrier) and mud flats in the coastal areas of Chabahar Bay cause rheumatism and goiter (Figure 37). Of course, it should be mentioned that tectonic and human activities are also effective on the processes of both models.

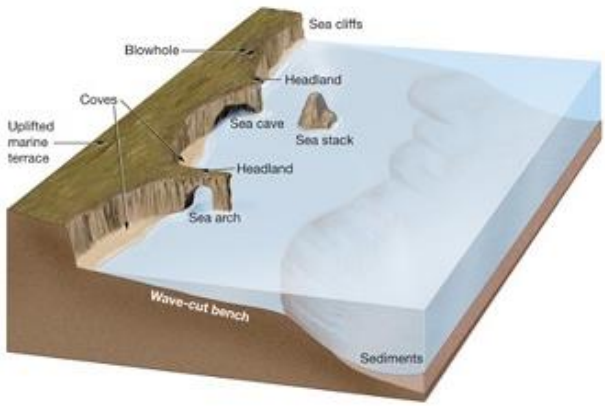

Figure 36. Erosion-tectonic model and formation of geological landscapes

Figure 37. Sedimentation-tectonic model and formation of geological landscapes

Conclusions

The southeast coasts of Iran are affected by the subduction of the Indian Ocean plate under the Iranian plate. Therefore, all coastal processes including erosion, sedimentation and human activities are affected by tectonic activities. On the other hand, from the point of view of sedimentology, it seems that a dual regime of sedimentation prevailed in the studied coastal area, meaning that when the sea level rises, carbonates are deposited and the destructive sedimentation stops, and when the sea level drops. sea water level and debris particles entering the sedimentary basin, carbonate sedimentation is stopped and destructive sedimentation takes place. In the northern regions, permanent and seasonal rivers such as Sarkan (Shoor), Lipar rivers, as well as estuaries and estuaries such as Khor Shor and Park (due to the closure of the mouth of these estuaries by sediments that are associated with the limitation of the invasion area of tidal currents), The facies of the area above intertidal has grown and by leaving sediments, coastal expansion occurs. On the other hand, in the Makran region, there are coastal currents, longshore currents, and rip currents that come to the coast and affect them.

Therefore, it can be said that the coastal area of Makran is under the influence of three tectonic, erosion, and sedimentation activities, and human activities (industrial, fishing, and construction) are not effective.

In terms of engineering geology, the southeastern coastal region of Iran in the south of Sistan and Baluchistan province is composed of resistant, less resistant and non-resistant rocks, which causes geological changes. Also, the high sediment carrying capacity of the coastal currents in the region compared to the import of sediment from the land on rocky shores causes the sediments accumulated in the rocky slopes to be washed away and ultimately the process of coastal erosion and retreat continues.

Two general models include the dominance of erosive and tectonic processes over sedimentation processes, resulting in the formation of landscapes such as erosion columns, sea stacks, sea arches, sea caves, headlands, Islands and raised beaches (Cliff) are found in the coastal areas of Pasbandar, Bris, Lipar, Tis and Konarak, and the other is the dominance of sedimentation processes over other activities, which are landscapes such as Spit, Bar, Tombolo, Wetland. (Lagoon), Delta, Tidal Flat, Bay Barrier Islands and Mud Flat in the coastal areas of Ramin, Chabahar Bay and Govatr.

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The effects of constructing Groynes to protect the coasts of the Dehnehsar Sefidroud area

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ABSTRACT

With the increase in construction in the sea, the use of protective structures to prevent their instability in the marine environment is of environmental concern. Coastal protection structures are used in marine structural engineering to reduce flow turbulence around marine structures to prevent scouring. In this research, the flow simulation around breakwaters constructed in the Dehnehsar Sefidroud area located in Guilan province was investigated using computational fluid dynamics and Fluent software. By constructing the breakwater structure, the speed between the breakwaters is reduced and conditions for sediment accumulation are provided. Also, the negative pressure on the west side of the western breakwater is reduced and reaches a positive value, changing from erosion potential to sedimentation potential. There is negative pressure in a part of the western tip of the breakwater, which will cause local scouring and needs protection. The results of the 2D and 3D models of isovelocity vectors with the installation of breakwaters of 90, 94 and 55 meters in length on the shore of the mouth of the Sefidrud River show that the velocity in the space between the 90, 94 and 55 meter breakwaters

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decreases, reducing the risk of scouring and allowing sediments that move west to east on the shore to accumulate. Also, the results of is velocity vectors and contours show that with the installation of breakwaters implemented on the shore of the mouth of the Sefidrud River, the pressure in the space between the 94 and 55 meter breakwaters decreases, reducing the risk of scouring.

1. Introduction

The village of Dehnesar Sefidrud is located on the Caspian Sea, north of Astaneh Ashrafieh County and east of Bandar Kiashahr. The distance from the village to Lahijan County and Astaneh Ashrafieh is about 38 kilometers. This village is bordered by the sea to the north, Hasan Ali Deh Village to the south, Jirbagh Village to the east, and Dastak and Lokh Village to the west. Dehnesar Sefidrud is part of Bandar Kiashahr. Identifying the condition of the southern coast of the Caspian Sea in terms of erosion and sedimentation characteristics to determine sensitive and unstable areas versus active and stable sedimentary areas is the main issue of this research. For this purpose, the erosion and sedimentation conditions in this area are investigated using numerical modeling.

Figure 1 - Geographical location of the Dehnehsar Sefidroud region in Gilan, adjacent to the Caspian Sea

Breakwaters are usually constructed to protect shores or to provide sufficient depth for navigation purposes. Known by names such as epis, groynes, and cross arms, these structures can be grouped by their shape, such as T-shaped or L-shaped.

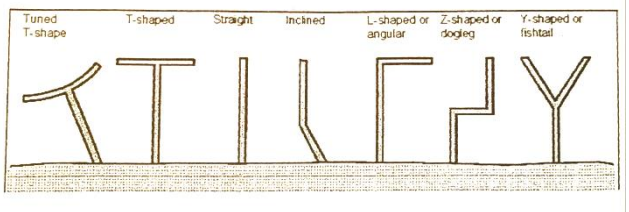

Figure 2 - Types of breakwaters that so far have been built

The most important parameters that should be considered in the design of breakwaters are: breakwater design plan, breakwater length, distance between breakwaters, orientation with the flow path, crest height, slope of the bank, materials used in the breakwater section.

In 2015, Vaghefi et al. investigated the effect of supporting structures on the flow pattern around T-shaped spur dikes in a 90-degree bend. Numerical methods can be useful for evaluating hydraulic parameters for spur dikes because of the reduced simulation time, while experimental experiments are time-consuming and require a large number of tools to simulate each model. In this paper, the flow patterns around a T-shaped spur dike and a supporting structure, which is located above the T-shaped spur dike, in a 90-degree bend channel are analyzed with the Flow-3D model. Numerical and experimental data are compared in the longitudinal section to validate the numerical model. The results show that there is a good agreement between the numerical and experimental data. After the numerical model was validated, the supporting structure was installed above the T-shaped spur dike with 3, 5, 7 and 9 times the distance of the T-shaped spur dike length. Support structure changes flow patterns and hydraulic parameters such as secondary flow strength and separation zone in all sections. By increasing the support structure from 3L to 9L, the secondary flow around the main circle decreases by approximately 40-120% and the length of the separation zone becomes 0.8 to 2.5 times larger than the length of the T-shaped dike[1].

Vaghefi et al. (2015) conducted a laboratory study of turbulent flow in a 180-degree bend. The high flow velocity near the free surface of rivers is due to the presence of shear stress near the bed and its absence at the free surface. This phenomenon leads to instability of the vertical velocity profile. In addition, secondary flows in river bends cause velocity changes, thus leading to changes in shear stress near the bed. In this study, the effect of velocity changes, maximum velocity distribution and secondary flow strength on the distribution of bed shear stress in a 180-degree bend constructed in the hydraulic laboratory of

Persian Gulf University has been investigated and analyzed. The results show that the maximum secondary flow strength is in the second half of the bend. Evaluation of the bed shear stress distribution using TKE, modified TCE and Reynolds methods in the turbulent boundary layer showed that the maximum shear stress occurs from the bend entry into the bend shear zone near the inner wall. In addition, a comparison of the Reynolds shear stress method at a distance of 5 and 15% of the flow depth from the bed showed that the maximum shear stress moves from the 40° section in the lower layer to the 60° section in the upper layer[2]. Van-den Heuer (2013) conducted a laboratory study to investigate erosion, sedimentation and flow hydraulics in a laboratory model constructed to resemble a meandering river. The length, spacing and angle of the weirs were the variables studied. From the results of his research, it can be noted that a low-velocity zone is created between the weirs, where sedimentation takes place. As the distance between the sluice gates increases, the velocity between the sluice gates increases, which causes a change in the sedimentation pattern between the sluice gates[3].

In 2012, Mehrnohad and Fedesian conducted an experimental study of the effect of the parameters of the sluice gate length and the diameter of the materials on the scour around a T-shaped sluice gate located at a 90-degree bend.

In this paper, laboratory studies were conducted to investigate the combined effect of the sluice gate length and the diameter of the bed materials on the scour around a T-shaped sluice gate located at a 95-degree bend. The experimental results indicate that the dimensions of the scour hole (including the maximum scour depth, the length of the scour hole upstream of the sluice gate, and the maximum width of the scour hole) are directly proportional to the length of the sluice gate, while the maximum scour depth and the length of the scour hole upstream of the sluice gate are inversely proportional to the average diameter of the materials[4].

Shaker and Shafai Bajestan conducted a laboratory study in 2013 of the effect of the length and angle of rectangular breakwaters on the distribution of velocity and shear stress in a 90-degree bend.

The results of the study showed that the presence of a series of breakwaters causes the upstream velocity to be uniform and the high-velocity zone to be transferred from the vicinity of the outer wall to the middle of the channel to the inner wall. The bed shear stress increases due to the presence of breakwaters, and increasing the length of the breakwaters increases it by about six times the shear stress upstream of the bend, but it does not have much effect on the location of the shear stress occurrence, so that in all cases, the maximum shear stress occurs at an angle of 70 to 80 degrees of the bend [5].

In 2009, Vaghefi et al. studied the temporal changes in scour around a T-shaped breakwater in a 90-degree bend. This paper investigates the temporal changes in scour hole dimensions and bed topography around T-shaped culverts fixed in a 90-degree bend. For this purpose, experiments were designed and conducted in a laboratory channel with a 90-degree bend and a gentle bed of sediment with an average grain size of 1.28 mm and clear water conditions. In these experiments, the effects of the parameters of culvert length, culvert crest length, culvert position in the bend, and the Froude number of the flow on temporal changes in scour hole dimensions around the T-shaped culvert and changes in bed topography were investigated. The results indicate that increasing the length of the spillway, decreasing the length of the spillway top, increasing the number of landings, and changing the position of the spillway downstream of the bend increase the dimensions of the scour hole. The experiments were conducted in a channel with a 90-degree bend at the Hydraulic Laboratory of Tarbiat Modares University, Tehran [6].

2. Methods

In this paper, Gambit software version 16.3.2 is used to generate the geometry and mesh. The mesh pattern is Quad element and map type is used for the surfaces. The existing boundary conditions are velocity input from the left and north and the pressure output boundary condition is at the outlet from the right. Fluent software uses continuity and Navier-Stokes equations in flow analysis. If the flow is turbulent, then the governing equations are transformed into Reynolds equations and one-equation, two-equation, five- or six-equation models are used to determine the eddy viscosity, with the user specifying the type of model. The flow field is solved based on the separation of equations by the finite volume method and different methods of separation of the transfer terms of the equations such as upstream, second-order upstream, power and Quick can be selected by the user. In order to couple the velocity field and the pressure field, the Simple, Simple C and Piezo methods are available in the program. In this article, Fluent software version 6.3.26 has been used to simulate the flow field.

To solve the flow using computational fluid dynamics, the following steps must be performed (Shojaifard and Noorpour Hashtroodi, 1995):

- Selecting the Gambit model to create the geometry
- Selecting the computational model
- Selecting the calculation solution method in the model
- Selecting the basic equations to solve
- Determining the physical characteristics of the materials

- Determining the boundary conditions
- Specifying the problem solving parameters
- Making an initial guess in the entire solution field
- Performing the solution and outputting the calculations.

Figure 3- Coastal deformation in the presence of a non-submersible breakwater in the Dehne Sar Sefidroud area (Summer 2019)

Figure 4- Location of the breakwater near the coastal road in the village of Dehne Sar Sefidroud (Dastak Astaneh Ashrafieh)

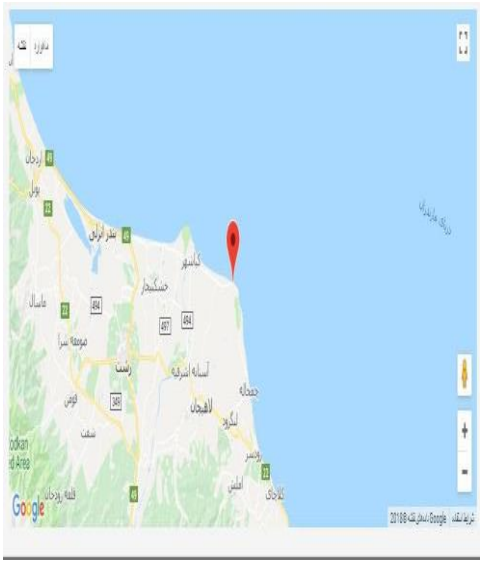

Figure 5- Location of the breakwater near the coastal road in the village of Dehne Sar Sefidroud in Gilan Province

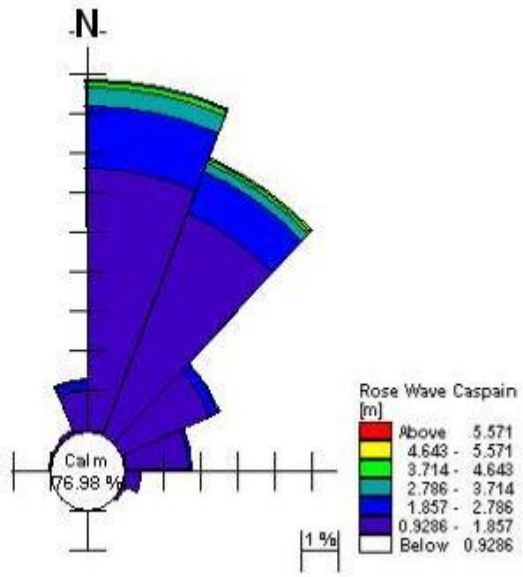

Figure 6- Wave mud based on ISWM results (Iranian Ports and Shipping Organization, 2003)

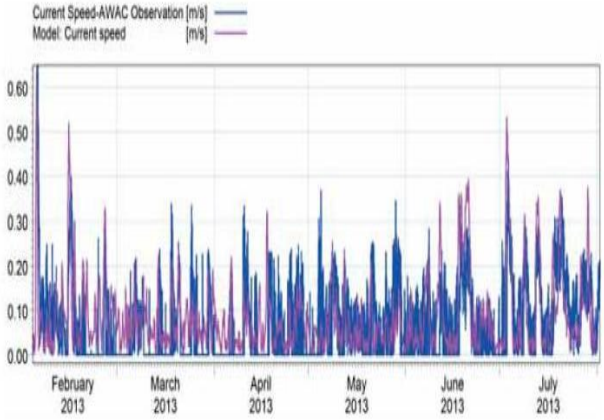

Figure 7- Results of field velocity observations in the village of Dehne Sar Sefidroud in Gilan Province

3. Results and Discussions

In this study, Gambit software version 3.3.2 was used to generate the geometry and mesh it. The mesh pattern was Quad element and map type was used for the surfaces. The existing boundary conditions are velocity input from the left side from the top of the arc and pressure output boundary condition at the bottom of the arc outlet. The simulation results from Fluent software are seen in Figures 8 to 11.

The first and second stages of the solution process require a geometry and mesh generator. The GAMBIT preprocessor or one of the CAD/CAE software can be used to generate the geometry and mesh. The Tgrid preprocessor can also be used to generate a mesh with volume elements from an existing surface mesh. In the third stage, the two-dimensional FLUENT software must be run. The velocity input boundary conditions from the north and west of the area are based on previous studies and the pressure output boundary condition is applied from the right side of the area. The entire southern part is considered as the wall boundary for the beach.

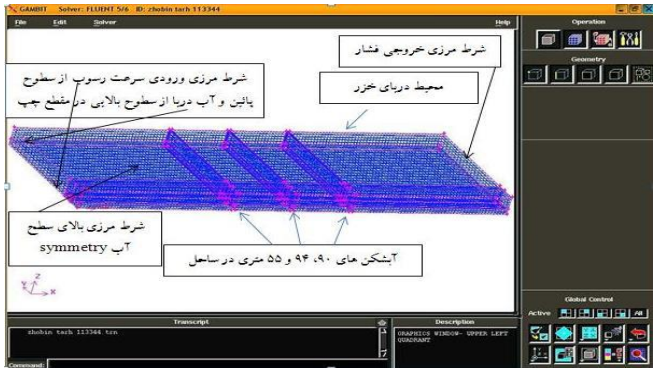

Figure 8 - Meshing in Gambit software of the 3D seawater space in the Dehnehsar Sefidroud area with the implemented breakwaters with lengths of 90, 94 and 55 meters respectively from right to left. The boundary condition of water and sediment velocities input from the left cross-section surfaces and the boundary condition of pressure output from the right cross-section and the boundary condition of symmetry for the water surface and the boundary condition of the wall for the surfaces of the breakwaters.

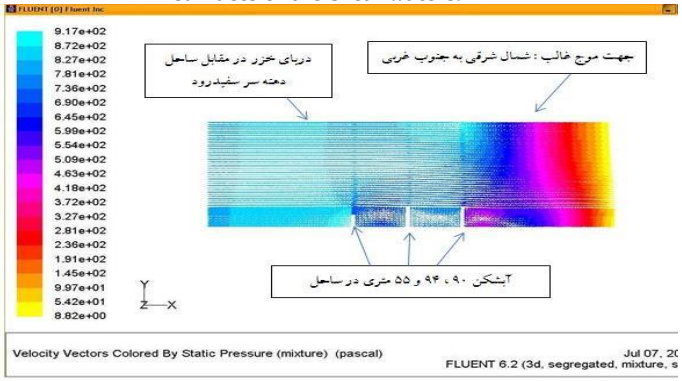

Figure 9- Equal pressure vectors are created by installing breakwaters on the shore of the mouth of the Sefidrud River, which reduces the pressure in the space between the 94- and 55-meter breakwaters, reducing the risk of scouring.

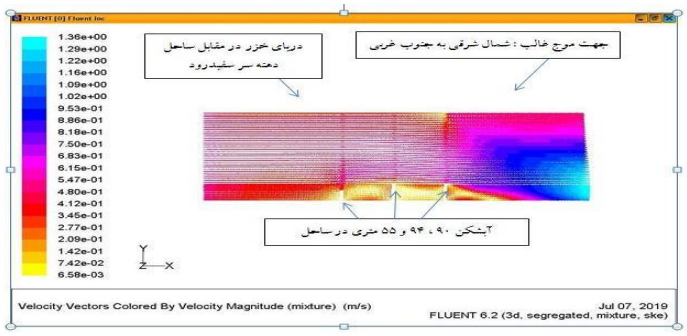

Figure 10 - The same velocity vectors are created by installing breakwaters on the shore of the mouth of the Sefidrud River, which reduce the velocity in the space between the 94- and 55-meter breakwaters, reducing the risk of scouring and allowing sediments that move west to east to accumulate on the shore.

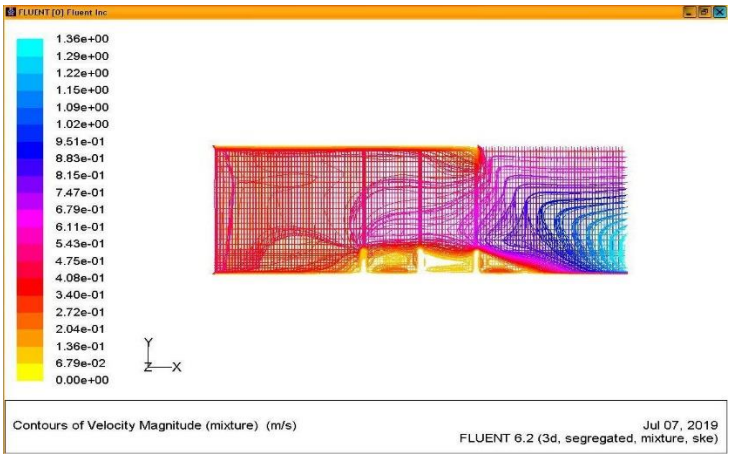

Figure 11 - The same-velocity contours are constructed by installing breakwaters on the shore of the mouth of the Sefidrud River, which reduce the velocity in the space between the 94- and 55-meter breakwaters, reducing the risk of scouring and allowing sediments that move west to east along the shore to accumulate.

The results of the 2D and 3D models of isovelocity vectors with the installation of breakwaters of 90, 94 and 55 meters in length on the shore of the mouth of the Sefidrud River show that the velocity in the space between the 90, 94 and 55 meter breakwaters decreases, reducing the risk of scouring and allowing sediments that move west to east on the shore to accumulate. Also, the results of isovelocity vectors and contours show that with the installation of breakwaters implemented on the shore of the mouth of the Sefidrud River, the pressure in the space between the 94 and 55 meter breakwaters decreases, reducing the risk of scouring.

4. Conclusion

The solutions to reduce the flow turbulence cause the flow lines formed around the coast of the mouth of the Sefidroud River to lengthen, as a result of which the pressure gradient across the base of the breakwater decreases. The reduction of the pressure gradient is one of the main and most fundamental factors in the formation and

development of scour around the base of the coastal protection wall and the formation of the ragab phenomenon around it.
In this research, the flow around the breakwaters of the mouth of the Sefidroud River area was investigated using the computational fluid dynamics method and the Fluent software.
As we approach the breakwaters on the eastern shore of the breakwater, the flow velocity between the breakwaters decreases and the potential for beach sedimentation between the breakwaters on the shore increases, and the probability of erosion decreases.

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Analysis of the effectiveness of indigenous knowledge in the coastal villages of Chabahar County in reducing flood risk

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ABSTRACT

Recent studies show that the views towards flood risk reduction have undergone a turn of approach. Indigenous knowledge Coastal villages (IKCV) have used several indigenous flood control and management knowledge systems to minimize the risk of flood disasters. Therefore, there is a growing demand to empirically identify the effectiveness of indigenous knowledge in flood risk reduction. As a result, this article has experimentally investigated the effectiveness of local knowledge of coastal villages in Chabahar County in reducing the risk of flood disasters. A mixed research methodology has been designed along with a (qualitative-to-quantitative conversion strategy. Qualitative data collection was realized through interviews with focus groups (FGDs), categories and categories were extracted through the thematic analysis method, and a questionnaire was used to collect quantitative research data. To measure the effectiveness, a confirmatory factor analysis method with SmartPLS 4 software was used. The samples were selected non-probably, including 32 people who were knowledgeable about the research subject. The thematic analysis of the interviews of the participants in the coastal villages of Chabahar indicates five categories of native knowledge of the coastal villages, which are mainly based on the experiential knowledge and local creativity of the natives. Therefore, the five main structures of indigenous knowledge of the coastal villages of the Chabahar region were confirmed. Respectively, Meteorological with a factor load of 0.851, Human with 0.626, Riverine with 0.477, Ecological with 0.468, and Celestial with 0.431 had the greatest role in reducing flood effects. This means that knowledge of local flood control and management in coastal villages of Chabahar effectively reduces flood risk. This study proposes a sustainable approach to flood disaster risk reduction based on the integration of indigenous knowledge systems and modern flood management strategies.

1. Introduction

Flood is one of the main challenges facing humanity [1]. Heavy rain causes runoff to exceed the capacity of existing drainage facilities and floods occur on the land. The nature of flooding and the consequences of human activities have caused flooding to become an inherent environmental problem [2]; So that today, instead of eradicating it, they think about controlling and reducing its effects [3]. Studies of the last two decades of coastal villages show that the views towards flood risk reduction have experienced a turn of approach [4]. IKCV have used several indigenous flood control and management knowledge systems to minimize the risk of flood disasters. For example, Bariweni, et al. [5] showed that rural communities in Nigeria used indigenous initiatives such as diversions, dams, and spillways to prevent rivers from overflowing their banks; a subject that has its roots in the experiences of their ancestors [6]. In general, the strategies employed by coastal communities include a

wide range of human and natural actions, including planting early crops, harvesting crops before the flood approaches, moving to higher areas and building water channels, building local bridges, concrete embankments [7]. And stone embankments and continuous investigation of climatic, plant and animal behavior were used to protect coastlines and villages. A report by the UN/ISDR [8], shows that the efforts made so far to integrate indigenous knowledge in flood risk reduction efforts have been very inadequate, even though there is convincing evidence that indigenous knowledge can provide practical solutions to minimize disasters at the levels offer different The role of indigenous knowledge in providing an effective strategy for mitigating flood disasters, which has apparently been neglected for decades, can be recognized [9]. The knowledge system of coastal communities is very suitable for the resilience of settlements against flood disasters [10, 11]. There is a growing demand to empirically identify the effectiveness of indigenous knowledge in flood risk reduction [12].

The province of Sistan and Baluchistan, located in the southeast of Iran, has such geographical and climatic diversity that it has turned it into a four-season province and at the same time has given it a dangerous face [13]. In the south of the province, in the Chabahar and Makar region, which is Iran's gateway to the world's oceans, floods have become one of the main dangers in the past periods, and the main disasters of these floods are damage to traffic routes and destruction of villages located on the banks of rivers. Is. The simultaneity of coastal storms with floods multiplies the depth of vulnerability of the conflict villages, which is considered one of the maritime hazards in that area, one of its examples is the Ashuba storm that hit the Chabahar coast not long ago [14]. With the arrival of the heavy rain system from the southwest of the country, on the 28th to the 30th of Farudin month, 1403 villages of Chabahar county have been involved in flooding. It has been unprecedented in the last half century. In the report announced by the Chabahar Marine Meteorological Station, for the first time in the last half century, 164 mm of rain fell within 24 hours and the recent system rains have caused at least 10 new rainfall records to be recorded in the climate of the southern regions of the country [15]. Despite the aforementioned conditions and features, due to environmental conditions and features such as unevenness, soil type and texture, and other factors such as the characteristics of the materials used in the construction of most residential houses, etc., it has created a complex situation in the coastal villages of Chabahar. According to the reports of Iran Red Crescent Organization, until April 29, 2024, the roads of a number of villages in the county were blocked and 2 villages faced a complete power outage. Also, with the continuation of torrential rains, the evacuation of some villages was put on the agenda [16].

Thus, it should be said that in Chabahar county, flood has become a dangerous event with destructive physical and socio-economic effects for coastal villages. To overcome the challenges caused by floods, the coastal communities of this region have potential capacities of indigenous knowledge that can be used in flood control and management. Indigenous knowledge systems, which are the understandings, talents, and philosophies developed in societies with a long history of interaction with their natural environment, inform decision-making about the essentials of everyday life. The long-term establishment of knowledge systems enables coastal communities to develop indigenous flood control and management practices that help minimize the risk of flood disasters. For coastal communities, perhaps due to the frequency and long history of flooding, patterns of collective action and cognitive patterns can be found that are adapted to the conditions of risk [17].

As a result, this article aims to empirically investigate the effectiveness of the indigenous knowledge system of coastal villages in reducing the risk of flooding, focusing on the coastal rural communities of Chabahar. This study will answer the following two research questions: First, to discover the implications and components of the indigenous knowledge system used by the coastal villagers of Chabahar to reduce floods? Second, how effective is the effectiveness of each of these indications of the local knowledge system in reducing the risk of flood disaster? The answers to the research questions provide the empirical basis for formulating appropriate strategies to increase flood risk reduction in the coastal villages of Chabahar.

2. Background

The term "native knowledge" has been mentioned under several topics such as traditional knowledge, local technical knowledge, rural knowledge, local knowledge, as well as ethnology or people's science in several existing researches. In defining indigenous knowledge, Mapara [18] says, *"Indigenous knowledge systems are the body of knowledge of the indigenous people of specific geographical areas that have survived there for a long time."* It is the experience gained over thousands of years due to human contact with the environment, which transcends all aspects of human endeavor including agriculture, medicine, security, botany, zoology, food technology, arts and crafts skills, linguistics, education, resource management. it is normal [19]. Risk management or crisis management and a host of other activities were passed down from generation to generation through proverbs, riddles, folk tales, songs, legends and myths, culture, religion, stories, informal teachings, communication, beliefs, traditions, apprenticeship. With the emergence of modernism currents and the dominance of common

academic science, the local people think that indigenous knowledge lacks the necessary qualifications and does not have the opportunity to develop [20]. So that exactly this knowledge is designed to respond to people's needs and local conditions. Similarly, UN/ISDR [8] believes that knowledge is indigenous, creative and experimental, constantly combining external influences and internal innovations to meet new conditions. The study found that it is often a mistake to consider indigenous knowledge as 'old', 'backward', 'static' or 'unchanged' as it is necessary to reduce the effects of disasters and this gap can be bridged. Between the required disaster response and what is available.

In the literature of the last two decades, the importance of including indigenous knowledge in reducing the effects of floods has been especially emphasized [21]. As in the academic literature in general and specifically in the field of reducing the effects of floods, there is talk of integrating indigenous knowledge with academic knowledge. Several studies have investigated the effectiveness of indigenous knowledge on flood risk reduction. For example, Jha and Jha [22] examined the effectiveness of indigenous knowledge in providing adequate understanding of flood risks and vulnerabilities. They found that it enabled the Lepcha people of India to develop an adequate understanding of the nature and causes of disaster, as well as to increase their capacity to accurately predict natural disasters and ways and means to mitigate their effects. They suggested that indigenous knowledge deserves global recognition, conservation, documentation and integration into modern disaster management strategies. Similarly, Chen and Cheng [23] found that adequate understanding of flood risks and vulnerabilities through indigenous knowledge is effective in building resilient communities. They proposed the integration of indigenous flood forecasting and management techniques with scientific methods of flood control with the aim of achieving sustainable flood management and control systems. Obi, et al. [24] examined the effectiveness of indigenous knowledge from a gender perspective. He found that most rural women who are exposed to floods due to geographical location, gender role, poverty, gender inequality, lack of education and information, have used their knowledge about local coping strategies and mechanisms for flood management in Kailali region [25]. Nepal This study suggested strengthening indigenous flood control and management practices to minimize the vulnerability of rural women to floods. explored the potential of indigenous knowledge. He found that it had the potential to contribute much more than expected to disaster risk reduction. Choudhury, et al. [26] in aligned with Parsons, et al. [27] found that indigenous knowledge enables Char people in Bangladesh to reduce flood-related vulnerabilities. Hadlos, et al. [28] correlate with other studies on the ability to reduce flood risk with indigenous knowledge. This study showed that indigenous knowledge plays an important role in reducing flood disasters in different regions of the world. Also, this study found that the amount of indigenous knowledge increases communities' resilience to floods, which is derived from geophysical locations, flood exposure and socio-economic capabilities. Furthermore, the work of Membele, et al. [19] on the effectiveness of indigenous knowledge in flood forecasting was consistent withLeal Filho, et al. [29]. They found that indigenous knowledge is effective in predicting the nature of climate change, which enables Odisha's coastal fishing communities to manage and mitigate flood disasters [30]. This study opined that despite its findings, indigenous knowledge continues to be undervalued in global environmental change studies.

The study of Leal Filho, et al. [29] confirmed the previous studies in the field of indigenous knowledge and disaster risk reduction. This study showed that indigenous knowledge reduces the vulnerability of Zuzan rural communities in Khaf province to natural disasters. They proposed the integration of indigenous and modern knowledge to improve the efficiency of the risk reduction system. Similarly, Paulraj and Andharia [31] found that indigenous knowledge based on cultural beliefs, practices and environmental understanding enables Konyak communities in India to be resilient to floods and other natural disasters. They suggested that policy makers should recognize the importance of indigenous knowledge system and integrate it into the disaster management system. Kaya and Koitsiwe [32] agreed with the results of existing studies on the predictive capacity of indigenous knowledge. This study showed that the use of this knowledge base can effectively predict the occurrence of natural disasters in Botswana. They suggested the formulation of appropriate laws to protect the intellectual property rights of indigenous knowledge holders. In this regard, Sohail and Chen [33] found that indigenous knowledge was effective in predicting and interpreting weather patterns, increasing food security, facilitating flood coping mechanisms and healing flood victims in Bayira of the Rwenzori region. They suggested the integration of indigenous knowledge with scientific knowledge that is suitable for the local environment of the people.

In line with previous studies, Neeta [34] found that indigenous knowledge practices are an effective mechanism for flood management and disaster risk reduction among the Lozi people of Zambia. He proposed the integration of indigenous knowledge into development planning strategies to enable local communities to resist the phenomena of floods and climate change. Because they are very important for sustainable planning and future development [35, 36]. The work of Theodory [37] differed from previous studies in that he examined the factors that hinder the

effectiveness of indigenous knowledge. He found that weak recognition of indigenous knowledge, lack of knowledge sharing culture, reduction of indigenous knowledge custodians and loss of culture and traditional practices are some of the obstacles to this. Successful application of indigenous knowledge in climate adaptation at the local level Inconsistent with previous studies, Macnight Ngwese, et al. [38] argued that indigenous knowledge has been effective in flood forecasting and management. They suggested integrating indigenous disaster mitigation techniques with modern scientific knowledge to minimize the vulnerability of coastal communities to floods. Therefore, the indigenous knowledge of the civil society about the nature of the risk and the mechanism to deal with it also shows inherent flexibility. In the face of a wide range of potential environmental stresses, including risks from climate change, the inherent flexibility of civil society and its capacity to adapt form the first line of defense [39]. In other words, when civil society and its organizations become sufficiently sensitive about their vulnerability to hazards and minimize their exposure and strengthen their capacity to cope with hazards, that means they are more resilient to environmental stressors. are [40]. From the review of the literature, it is clear that the existing studies lacked empirical evidence about the effectiveness level of indigenous knowledge of coastal villages in reducing the risk of flood disasters, especially in Chabahar region [41, 42]. As a result, this study fills the gap in the literature by empirically investigating the knowledge of local flood control and management and its effectiveness in reducing the risk of flood disasters in coastal communities of Chabahar. The result of this study provides a basis for strengthening the local approach to flood disaster risk reduction.

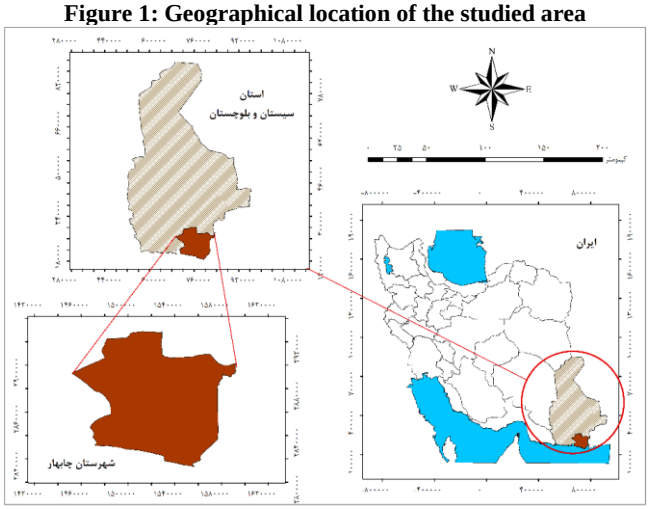
3. Methodology

This section explains the details of the study area and the reason for its selection. Chabahar was chosen as the study area. It also explains the sampling plan and data collection method. Finally, the indicators selected for the study and the technique adopted for data analysis are discussed in detail.

1.3. Case study

Chabahar county is one of the cities of Sistan and Baluchistan province, which is located seven meters above sea level. Chabahar is located in the southeast of Iran at 60 degrees and 37 minutes east longitude and 25 degrees and 17 minutes north latitude. This county is bordered by Iranshahr and Nikshahr cities from the north, Oman Sea from the south, Pakistan from the east, and Kerman and Hormozgan provinces from the west. The latest census indicates that Chabahar county includes three districts, six rural districts and 135 villages. The rural population of Chabahar has 40,918 households and 170,778 people. Chabahar has a temperate tropical climate with relatively humid humidity, the hottest part of the country in winter and the coldest southern port of Iran in summer. The weather of this county and its surroundings is always mild and springy. That is why it is called Chabahar (four seasons of spring).

Figure 1: Geographical location of the studied area



Source: Authors, 1403

The recent rains caused a lot of damage to the coastal villages of Chabahar. Flood damage has caused human casualties and waste, destruction of all kinds of buildings, damage to agricultural fields and gardens, destruction of infrastructure such as roads and communication arteries, energy transmission networks and lines, etc. According to the statement of the representative of the people of Chabahar in the parliament, more than 10 people have lost their lives and the transit and rural roads in some cities have been destroyed up to 70%. 400 villages have faced the issue of blocked roads and flooded houses. Many bridges have been destroyed and agricultural gardens have been destroyed, especially in Zarabad. The conditions of the recent flood show that since the flood of March 1402 in this region, there are still infrastructural and management weaknesses. The conditions of the people of those areas are also becoming more difficult day by day in terms of lack of access to roads, telecommunication and electricity. Damage to the communication ways, agricultural sector, out-of-season cultivation fields and tropical fruit gardens, electricity and water supply network are among the most extensive damages caused by the recent floods in Chabahar county. Disconnection of telecommunications in more than 30 villages of Chabahar due to problems with optical fiber, damage to three thousand hectares of dry land cultivated with sorghum and mung beans, five poultry units with 80 thousand chickens and chickens, more than 600 dams and 10 dams, more than It has caused 5 thousand billion rials in damage.

According to the statements made, the heavy rain has blocked the roads of 154 villages and 470 cases of low pressure blackouts, and important routes have also

been blocked in the road area. Also, due to the intensification of the rains, the Khairabad Nikshahr dam overflowed for the second time in the last 2 months, and despite issuing warnings and recommending the transfer of pregnant mothers to the nearest medical centers, unfortunately, 6 pregnant mothers were caught in the flood, and with the efforts of the public and relief forces, they were taken to the centers. They were transferred for treatment.

The deputy of the crisis management headquarters of the governorate stated that the initial damage to the covered roads is 18 thousand billion rials, which is still increasing due to the volume of rains. It is worth mentioning that the loss of two billion cubic meters of water to the sea during the recent rains in southern Sistan and Baluchistan, including Chabahar, is the most pathetic part of repeating the story of the lack of proper flood management in a region that is facing a shortage of drinking water and agriculture.

2.3. Materials and Methods

This research is a hybrid study. The strategy used in the present research is of the type of conversion from qualitative to quantitative. Thus, in order to discover and document the components of early warning by the knowledge of natives of coastal villages to reduce the effects of floods and understand their early actions, this study has adopted a qualitative approach. Qualitative research method has been used due to its high flexibility to collect, lack of information and the ability to deeply interpret the topic of indigenous knowledge of coastal villages. In the second step, quantitative methodology has been used to measure the influence of the components and implications of local knowledge of coastal villages on reducing flood damage.

3.3. Data collection

For the qualitative data collection, focus group interviews (FGDs) and key informant interviews (KII) were used, allowing researchers to collect a large amount of high-quality primary data in a relatively short time frame, representing a significant number of participants. provides For this purpose, first the focus group discussion of local flood control and management knowledge used by coastal communities were identified. This group, consisting of 12 elders from each of the selected coastal communities, was determined based on age criteria. The criterion of age was used to create a focus group discussion because the elders are the custodians of indigenous knowledge of the coastal communities in the villages. Societies defined the elderly as any person over 70 years of age. The focus group discussion was held three times in the village square of each respective community and different types of local flood control and management knowledge used by their communities were discussed. The guide of the questions used for the focus groups is designed based on the review of the literature texts and the comprehensive coverage of the research topic: 1) an overview of the flood situation in coastal villages, 2) the main components of local early warning for flooding in coastal villages and 3) the reliability of each of the local knowledge. How much was it?

A questionnaire was used to collect quantitative research data. Empirical data was obtained from the participants in the interviews along with the introduction of other people. Respondents were asked to evaluate the effectiveness of indigenous knowledge of coastal villages in reducing flood effects based on a 5-point Likert scale, i.e. very effective (5), effective (4), moderate (3), low (2) and very low (1). . The responses led to principal component analysis.

4.3. Selection of sample units

Sample villages were introduced as flood-prone areas. In this research, five old coastal villages in Chabahar county named Kachu, Sham, Komb, Ramin, Osman Abad were selected. The reasons for choosing these villages are historical, coastal, and flood experience. The samples were selected in such a way that they have a low development status, are geographically connected and are located in the coastal area of Chabahar county. Research participants were selected using purposive sampling (i.e., study participants were selected based on a set of criteria), after consulting with village community leaders (e.g., village elders) who helped connect with individuals. FGD participants were selected based on the following criteria:

- living in the village for most of his life;
- Over 55 years old (for most participants), and no upper age limit;
- Maximum two participants from a different age group;
- Extensive experience with flooding (ie preferably living in flood prone areas);
- Be known in the community for having native knowledge related to disasters.

Overall, 32 interviews were obtained from the focus groups, of which 24 were male and 9 were female participants. Focused groups are conducted in social spaces (for example, in front of a mosque, in front of a shop, etc.). Due to travel restrictions, according to the initial planning, it was not possible to hold centralized centers of male and female villagers in each village at the same time. However, since the conducted focal point sample represents a relatively large sample for a qualitative study, the above-mentioned exclusion does not seriously affect the validity of the study and allows the achievement of data saturation. The duration of the focus groups was approximately two hours. Most of the participants in the sessions were subsistence farmers, fishermen and small business owners and were in the age group of 56 years or older.

5.3. Analysis method

According to the mixed research design, the analysis has been done in two consecutive stages. In the first

stage, thematic analysis, which is one of the most common data analysis approaches in qualitative research, was used to implement the interviews taken from the participants. Thematic analysis is a process in which the collected data is thoroughly examined to identify recurring themes in the text. First, the data were coded by the authors of the report (i.e., assigning a code to a specific section of the text), followed by a process in which the codes were merged into themes of interest. After the iterative process of coding and subject identification, the final report and findings were written. In this process, general themes were developed based on themes covered in the interview guides, and a coding scheme was developed and applied to the data transcripts. Since the set of qualitative data sampled in this study was relatively large and there was no significant difference in the ecological, meteorological, river and cultural context of the participants, it was pointed out that data saturation (i.e. after a certain number of data) was achieved. During the writing phase of the report, quotes from the participants have been used in order to fully capture the in-depth information collected and provide textual results. Even though it would contribute to the overall validity of the results produced, due to logistical constraints, there was no opportunity for participants to provide feedback on the findings.

In the second step, confirmatory factor analysis using SmartPLS version 4 software was used for the quantitative part to measure the components and implications (resulting from the qualitative method) [43]. Researchers used this model for several reasons. First, this model assesses the quality of the measurement model; second, the reflexive nature of the model allows the consideration of multiple criteria that were needed by the researchers; covers [44]. Secondly, finally, the model leads to the consistency test between the theoretical structure and the experimental structure of the research, which provides the possibility of interpreting the results [45].

The maximum likelihood method was used to validate the model. In fitting the model, the closer the GFI, CFI, and AGFI indices are to one (0.10 to 1.00), the better the model fits and the better the data confirm the assumed relationship pattern. Also, the closer the RMSEA is to zero (0.10 to 0.00), the better the model fits. The fit index X2/df is also the lower the better and should not be more than 2. If the chi-square is not statistically significant, it is very appropriate to indicate it, but since this index is often obtained in samples larger than 100, it is not considered a suitable index to measure the fit of the model. In general, all the fit indices of the model presented in the present study had a good fit and confirmed the assumed model [46].

6.3. Screening and classification of categories

During data collection, FGD participants and interviewees provided a number of indicators that are seen in a community as indicators of local flood prediction of a future event. Following the findings of the literature review, it was revealed that the indicators are locally limited and case specific. However, it was observed that most of the indicators, even if they differ between the communities in question, are similar in the sense that they derive from the close relationship of the community with the surrounding environment and similar agricultural practices. Flood prediction signs are available through the specific behavior of local flora and fauna, changes in river behavior, monitoring of weather and temperature changes, and through the nature of the behavior of celestial bodies. Importantly, a large number of observed symptoms are related to villagers' anticipation of rainfall events (ie, not floods explicitly, but periods of rainfall leading to floods). Indigenous knowledge is embedded in people's daily life and livelihood and emerges from a close relationship with surrounding behaviors and environments. Considering that the majority of the population in the studied areas are subsistence farmers, in the absence of widespread access to irrigation agriculture, the amount and distribution of rainfall determines the performance of farms and, as a result, the availability of food for people.

With a set of existing indigenous flood forecasting indicators, it was necessary to create a meaningful classification, in order to present the results in a coherent manner and create a simple, yet comprehensive overview of the indigenous warning practices in the studied communities. As shown in the literature review section, previous studies have proposed different classifications of indigenous knowledge for EWS. In this study, the taxonomy developed by Acharya [47] was used, with documented indigenous flood prediction indicators grouped into four main categories:

Indigenous ecological knowledge: behaviors, phenomena and patterns that are not related to human behavior.

Indigenous Riverine knowledge: behavior of river waters;

Indigenous Meteorological knowledge: Wind movement, rain pattern, temperature and clouds and... .

Indigenous Celestial knowledge: This knowledge deals with celestial elements such as the moon and its role in tides, rainbows.

Indigenous human knowledge: canalization, building architecture, construction of decks for food storage, planting of early crops, road access.

۴. Result

The findings of the research are reported in the first stage of a report of the content analysis of round-trip interviews. Qualitative findings including 4 classes of

native flood forecasting of native villages along with 23 indications were identified. The second part of the findings is presented to the output of the confirmatory factor analysis, which describes the implementation of the measurement model and its output. Then, in order to measure the validity of the obtained model, all the indicators and components of the model will be tested by the Fornell-Larker divergence validity matrix. Finally, the T-test was used to determine the significance of the path of the factor loading of the model.

Summary of focus group discussions on indigenous flood control and management knowledge used by coastal communities Table 1 shows a summary of focus group discussions of 35 types of indigenous flood control and management knowledge used by coastal communities in flood risk reduction.

1.4. Themes of indigenous knowledge of coastal villages

The main themes and classification were prepared during the interviews. In Table 3, the core class, the flood prediction class and the implications of the local knowledge of the coastal villages along with the explanations in the studied area are presented. An attempt has been made to document a general picture of what was available. A detailed explanation of the specific categories is provided later in this section (Table-3).

Axial categori	Selective category	The implications of indigenous knowledge	Explanation
Indigenous knowledge of coastal villages in	Indigenous ecological knowledge	Fisherman observe increased number of fish in the rivers (E1)	Observing the increase in the number of fish in rivers by fishermen during floods is a phenomenon that they use in the field of flood forecasting. This phenomenon is often referred to as the "tributary sanctuary hypothesis". This suggests that fish take refuge in tributaries during floods, which can be a safer and more favorable environment for them compared to the main river stem.

Table 3: Summary of focus group discussions on indigenous knowledge of coastal villages used by participants

		Migration of shorebirds (E2)	Coastal communities also use the migration patterns of some birds, especially seagulls and swallows, to predict floods. Their disappearance in the sky indicates that the flood is approaching, while their appearance indicates that the flood is receding. The focus group discussion revealed that when birds migrate from the islands, flooding is just around the corner. On the other hand, the migration of birds to coastal communities is a sign that the flood has stopped. Additionally, flooding is indicated when birds begin to perch only on tall trees. The focus group discussion also revealed that immediately after observing the pattern of bird migration, residents of coastal communities move their pets and other valuables to safety because floodwaters often come at night.
		Increase fruit trees (E3)	Flooding is an abiotic stress that can affect plant growth, yield and fruit quality of many fruit tree species. In full of rain years, indigenous communities use the increase in the amount of fruiting trees to predict floods. When this phenomenon occurs clearly, it acts as a long-term warning mechanism for the residents of coastal areas.
		animal behavior (E4)	This is another flood forecasting measure used by coastal communities. They study animal behavior and use it to predict floods. The focus group discussion revealed that the croaking of frogs and toads indicates that a flood is around.
		The presence of beach flies and the increase of mosquitoes (E5)	This is an early warning sign that is accepted by coastal communities. They revealed that a high presence of greenish beach flies and an increase in mosquito infestations are signs to the community that flooding is around the corner. As soon as this happens, farmers quickly harvest their crops.
	Indigenous Meteorological knowledge	Extremely hot temperatures (M1)	Understanding temperature patterns, especially warm temperatures, is critical to flood forecasting. Extreme heat can lead to increased evaporation rates, which can contribute to the accumulation of moisture in the atmosphere and subsequently affect precipitation patterns, potentially leading to heavy rainfall and flooding events. By incorporating temperature data into flood forecasting models, researchers and decision makers can increase the accuracy and effectiveness of flood forecasting systems and ultimately improve preparedness and response strategies for flood events.
		Rainfall intensity (M2)	People also use the amount, distribution, and duration of rainfall to predict the onset, magnitude, and type of flooding. They revealed that when there is rainfall in December and then stops and starts again from January to March, and also when it starts raining continuously every 3 days, it indicates severe flooding.
		Occurrence of dark clouds (M3)	The occurrence of dark clouds can be a significant indicator for flood forecasting, especially when flood modeling and forecasting using Earth observation data is considered. In different communities, including in coastal areas, the presence of dark clouds is considered as a key indicator of heavy rains and the possibility of floods. Indigenous knowledge practices, as highlighted in the resources provided, include observing weather patterns, studying cloud formation, and interpreting natural signs such as animal behavior and tree changes to predict flood events.
		Heavy winds (M4)	Nature and direction of winds: People in the past have successfully used the nature and direction of winds to predict floods. The focus group discussion revealed that when the

			wind from the river is strong and blows south, there will be flooding that year. Similarly, when strong winds start approaching in May, major flooding occurs in that season. This situation was very evident in the recent flood.
	Indigenous Riverine knowledge	Increased sounds from the waters moving in the river (R1)	It is a predictive measure used by societies. They revealed that a river overflow or increased eddies in the river is a sign of an approaching flood.
		Colours of water (darker, muddier, increased debris) (R2)	The presence of large amounts of debris such as dead leaves, grass, polythene bags, and sand and silt particles indicates an impending flood. Also, the watercolor changes from yellowish brown to dark brown.
		Creation of foam in the waters (R3)	This technique is used by communities to predict floods. They revealed that the high foam and howling sound from the river was a sign of a fast approaching flood.
		Flood cycle (R4)	Coastal communities study the flood cycle to predict high magnitude floods. They revealed that high-magnitude floods occur on a two- to three-year cycle. In other words, when a big flood occurs this year, the previous year's flood will not be as big.
	Indigenous Celestial knowledge	Full moon (C1)	Coastal communities study the moon and use it to predict flood years. They revealed that the approach of a full moon at the time of peak rainfall indicates that a flood is imminent.
		Nature of water currents and tides (C2)	When the water currents move faster, especially in May, it signals to people that a flood is near. Also, the focus group discussion revealed that to recognize that a flood is imminent, it is when the water becomes very turbulent and the tide rises to a height of about 1 meter.
		Use the rainbow (C3)	Coastal communities have stated that they use rainbows to predict the magnitude of floods, even though this rarely happens. They revealed that the repeated appearance of rainbows infers that the flood of that year will be very large. They also revealed that three conditions are necessary for a rainbow to be accepted as a prediction. First, it must be raining. Second, there must be sunshine, and finally, the forecaster must come outside between the sun and the rain to see the rainbow.
	Indigenous human knowledge	Channelization (H1)	Canalization: These are local drains built by residents to divert floodwater from their communities to the river. The purpose of canalization is to drain floods in communities. The discussion of the focus group showed that in times of big floods, there are mudslides and drainage blockages.
		Parallel architecture of buildings (H2)	Buildings are tilted towards the direction of water flow to ensure that water does not get trapped in the building but flows downwards. The focus group discussion showed that the foundations of the buildings are high in such a way that one part of the foundation is higher than the other part, and as a result, the building leans to a level. They also noted that the buildings were stretched and lined up with the flow of the waterways (rather than across) to create a natural passageway for the water to flow through instead of standing still.
		Using the flooded surface of trees and docks (H3)	Local people have used the inundation level of trees and docks to predict the severity of flooding in their communities. The focus group discussion showed that when the water level only covers the pier in a year, it means that the flood intensity will not be high. On the other hand, if the water level reaches about three feet (90 cm) of a tree or building on higher ground near the pier, it indicates that there will be a flood that year.
		Building a deck to store food in times of crisis (H4)	It is a flood coping strategy used by local communities to store boat products and fish catches. This deck is high enough to prevent flood water from reaching the farm crops.
		Construction of temporary and low-cost houses (H5)	Most of the coastal communities' houses are made of mud, wood, and bamboo, and some live in tents. The focus group discussion revealed that this is a strategy adopted by people to minimize flood damage if their communities are completely submerged.
		Planting early crops (H6)	This is another emergency preparedness measure adopted by coastal communities to deal with flooding. They plant early crops that can be harvested within 3 to 6 months of planting before the flood approaches. Examples of these products include potatoes, vegetables, watermelons, etc.
		Bringing boats closer to home (H7)	It is a preliminary flood emergency measure adopted by coastal communities. The focus group discussion revealed that almost every family has a canoe that they keep very close to home to evacuate family members and property in case of flash floods.
		Road access (H8)	This is an early warning sign of impending flooding. They revealed that the inundation of access roads to communities indicated that flooding was imminent. On the other hand, the retreat of water from the access roads shows the reduction of floods.

1.4.1. Indigenous Ecological knowledge

In the studied communities, many ecological indicators were documented. In this category, it seeks to predict the occurrence of floods based on the specific behavior of animals. For the ecology class, 5 main categories were identified. The most common category was observing the increase in the number of fish in rivers by fishermen during floods. Among rural communities, observing the increase in the number of fish in the tributaries of rivers is used by fishermen as a phenomenon to predict floods. Mainly, this behavior of the fish shows that they take refuge in the tributaries to protect themselves, which can provide them with a safer and more favorable environment compared to the main river. By monitoring fish movements during floods, fishermen and researchers can gain valuable insights into fish behavior in response to changing environmental conditions. This behavior can be critical to the survival of fish populations during flood events, as it allows them to

escape strong currents, debris, and other flood-related hazards. By studying fish movement patterns during floods, scientists can improve their understanding of fish behavior and use this information to improve flood prediction models and conservation efforts aimed at protecting fish populations and their habitats. Also, among rural communities, the migration of coastal birds such as seagulls is considered one of the other signs of flooding, and their disappearance is a sign of an accident. In addition to birds, the excessive sound of frogs and toads can be observed.

"When there's a flood, the birds move away from the area. They go several kilometers further. These animals give us a good understanding of how to deal with the flood. Wherever the birds migrate from, that's exactly where the flood wants to go. "

Most of the above categories occur in the short time period before the rainfall event. In the focus groups, it was noted that most of the floods occurred from December to May. Examples of animal behavior that indicate heavy rainfall or flooding in the future were discussed. For example, ducks raise their wings and want to be in the water, fishermen see and catch more "trout" than usual, and cows show signs of excitement.

Different species of trees were recorded as another important ecological indicator found in the communities visited and serve as an indication of the heavy rainfall expected in the coming season. Communities see trees as long-term information, as changes in trees can be seen from July to the flood season. Two main patterns were shown, i.e. the increase in the number of fruits and their abundant flowering are signs of the rainy season and warning. The abundance of weed growth in the area is effectively used to predict the occurrence of floods in coastal communities. The focus group discussion showed that when weeds started to grow in large quantities in the river and its course indicated an approaching flood. Finally, the focus group discussion also showed that immediately after observing the bird migration pattern, residents of coastal communities domesticated animals. And other valuables they take to a safe place because the floodwaters often come at night.

2.4.1. Indigenous Meteorological knowledge

Understanding the meteorological indicators that cause floods plays a vital role in predicting this destructive event. Weather indicators are considered as a main class in flood forecasting, which were extracted from the focus groups of four main categories. These indicators include "very hot temperature", "precipitation intensity", "occurrence of dark clouds" and "heavy winds", which provide valuable insight into weather conditions and help predict flooding. Indigenous communities try to make accurate predictions about possible flood events by analyzing various and complex criteria that are the result of the experience of their ancestors.

The participants stated in their interviews that the rain intensity pattern is the most important indicator of meteorological flood forecasting. Monitoring local rainfall patterns and intensity emerged as a major indicator of meteorological flood forecasting. As interviewee 5 quoted*: "We focus more on the intensity of the rain than on the clouds or the wind to understand that a flood is coming."* Study participants noted that the intensity of rainfall is indicative of future flooding, as it rains for several days in a row before a flood. It should be mentioned that the villagers pointed out that floods in their localities sometimes occur when there is no local rainfall, and the reason for that is the rainfall in the upper parts. Rainfall changes are closely monitored by communities to increase overall preparedness and secure early action. For example, they pointed out that in the olden days, when there was heavy rain, there were people responsible for monitoring the changes, who had the duty to warn other members of the community. If they notice heavy rain that starts in the morning and continues throughout the day in the evening, they stay awake and monitor the situation.

Meteorological indicators show both seasonality (i.e. forecast of heavy rainfall in the season) and more immediate feature (i.e. future flooding). Extremely hot temperatures starting in October and leading to the flood season are cited as one of the dominant indicators. Some of the villagers pointed out that during this period, the movements of the villagers are much less than before. Research participants directly associated higher temperatures in the coastal region with higher amounts of rainfall. Strong monsoon winds causing damage to houses (eg damage to roofs) during the flood season have also been documented. In addition, wind direction (both southerly and northwesterly winds) was also an indicator of impending heavy rains and floods. In addition, the meteorological indicators of the appearance of dark clouds and the increase of tornadoes have been reported. From the interviews obtained in this section, it can be concluded that meteorological indicators are defined in relation to ecological indicators in the short-term time domain for flood detection.

3.4.1. Indigenous Riverine knowledge

The study of Acharya [47] showed that river-based flood forecasting indicators are the most reliable indicators. Similar results can be obtained for the present study. Taking advantage of the availability of residual moisture, a large percentage of people farm along the river banks. Since flooding affects crops and perpetuates the cycle of disaster-poverty downstream, people have developed several strategies to monitor water and predict future flooding during their close relationship with flowing water. For example, one of the participants explained in this regard:

"The river water immediately before the flood is very dirty and they (the waters) come with garbage and wooden

planks and the moment they appear we know it's only a few hours before the river floods."

Villagers said that as the flood rises, the sound of the water in the river bed becomes louder and they realize that the water level is rising rapidly and the banks of the rivers are filled to their maximum capacity. The speed of the water has increased and challenges people to cross the rivers. The presence of rubbish and debris, muddy colours, the bottom of the waters and the foul smell emanating from the river have all been recorded as signs of the coming flood.

The nature of the water in the river is a predictive measure used by coastal communities to predict approaching floods through the smell of their rivers. Participant 12 stated that *"the closer it gets to the time of the flood, the river starts to smell like rotten eggs and is unfit to drink."*
Also, the contributors went on to state *that "a sudden change in water color from clear to deep brown indicates that a flood is about to occur."* Similarly, when the water starts to clear, it indicates that the floods have started to recede. This action was very useful for the beaches. The communities' response to the flood event has been useful.

4.4.1. Indigenous Celestial knowledge

Celestial indicators class compared to other indicator groups, celestial indicators were a smaller group. This class includes three main categories. In a number of societies, the full moon is considered a sign of heavy rain. A full moon between October and December indicates rain, and participants explained that the full moon is surrounded by stars that "fall over each other" in an east-west direction. In parallel, the tidal cycles created by the moon are important in interpretations. Strong tides create the possibility of waves of sea water and its entry into the land. The formation of rainbows along with the appearance of other signs can help predict floods. Despite the fact that this atmospheric phenomenon rarely occurs, its participants have expressed a high correlation between the presence of rainbows and the occurrence of floods in villages.

5.4.1. Indigenous Human knowledge

The class of human indicators with eight indications was identified as one of the most important classes to reduce the effects of floods in the villages of Chabahar city. Predicting the impact of flooding on livestock and smaller animals (such as goats, pigs and chickens) poses an additional challenge to communities, as animal replacement is often beyond the financial means of individuals. Hence, the participants explained the various mechanisms they developed to minimize the loss. For example, villagers built their poultry on high platforms and kept it from local materials to ensure safety during floods. As heavy rainfall and rising water levels are observed, larger animals, such as cattle, may move to higher elevations for grazing, and community members advise each other not to feed cattle near beaches or rivers. The results show that livestock management measures are mainly based on river flood forecasting indicators and meteorological conditions closer to the flood event.
By default, the existence of customary construction rules compatible with nature determines the unwritten rules of construction in the areas by prohibiting the construction of houses in accident-prone areas. However, observations show that in cases where such construction is unavoidable, before starting the structure, the area should be filled with sand and the foundation raised up to six blocks (1.2 m), which is less considered. The focus group discussion showed that the communities People are not allowed to build on low-lying land that is not part of the land designated for residential purposes. Another important and noteworthy point regarding the effects of flood risk in Chabahar county is that due to the smoothness of the land surface and the fineness of the soil texture and low permeability, it is faced with the spread and persistence of water on the surface of the land and the flooding of residential units in the settlements, especially the settlements, and many times in The reports of ABFA organization of Sistan and Baluchistan province and the published news have mentioned the extent and intensity of flooding in this province. For example, it is mentioned in the ABFA report of Sistan and Baluchistan province that:

"It should be noted that the type of soil is effective on the stability of the structures and preventing possible risks due to the loosening of the building, and the size and shape of the soil grains creates unique and special characteristics, which in this region, high absorption of moisture in fine-grained soils, the possibility It increases the settlement of the building... On the other hand, according to the report of the head of the earthquake and hazard department of the Road, Housing and Urban Development Research Center and based on the statistics of the Statistics Center in 2015, of all the residential units located in the settlements affected by the recent floods in Sistan and Baluchistan province, such as In Dashtiari area, around Chabahar and Konarak port, 18% of them are rural skeleton buildings and more than 80% of the rest are made of clay, stone, mud, and even mud Therefore, when they are exposed to water, they will absorb moisture and completely lose their previous strength, and under the influence of factors such as the occurrence of an earthquake, even if it is weak, the possibility of complete destruction increases Housing and Urban Development has recommended that in addition to the renovation of destroyed and flood-damaged units, standing buildings with the above conditions also need renovation and cannot be trusted to rebuild."

Other construction measures such as canalization, drainage by local farmers to direct water to fields around villages have been one of the common activities. Also, the comparison of the water level to the pier (water structures) helps to better understand the high probability of flooding. On the other hand, these docks are used for multipurpose activities. In addition to the measuring criteria, aspects of life and food security were used to store food in times of crisis. People revealed that they harvest their crops ahead of time and sell them as soon as they see any sign of approaching flood. This enables them to recoup part of the investment in planting crops.

Looking at the above components, it can be said that the local human knowledge that prevailed in the coastal villages of Chabahar has mainly provided solutions based on compatibility with nature. Hotak is one of the most comprehensive structures for collecting floods caused by seasonal rains in Chabahar villages. As the participants acknowledged; Hotak is a pit-shaped device that is built with the purpose of collecting floods caused by seasonal rainfall for various purposes, including providing drinking water for cattle and helping to irrigate seasonal crops. Contributors 1, 2, 3, 4, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 29 and 30, 31 and 32 jointly mentioned this. For example, participant 23 stated that:

“Hotak or hotag in Balochi language means a big pit where water collects. Many times these hotags are formed naturally; whenever it rains, they are filled with water; now, due to the drought, many hotags are dry. .. Yes, these hotags help to control the flood, but the amount of water that is taken from the flood also depends on the size of the pit even use it for agriculture."

According to the report published by the water management of Sistan and Baluchistan province (2023), it shows that the construction of hotak is considered a conventional method of water extraction in the region. The report states that:

"Around Chabahar and Dashtiari region, the people of 548 villages use hotak for irrigation and cattle drinking purposes. Sometimes hotak are the unique water resources of Chabahar and Dashtiari region. Therefore, in most cases, next to Degar, Godtri area is called hotak. They create water for the village's consumption. After successive droughts, water extraction from Hotak is given a higher priority than Degar."

Coastal villages of Chabahar are among the areas that have the most prominent local methods in relation to flood exploitation. Hotek and Degar systems have been thriving in these areas in the villages of Kachu, Sham, Komb, Ramin, and Osman Abad since the distant past. Therefore, in this region, despite the development of modern irrigation, local methods are still the most efficient in these regions. Participant 3 says:

"In our village, the flood caused damage every time it came; this has been experienced for us; our ancestors came and made these "degars" to be able to store drinking water. From that time until now [this knowledge] has reached us and we also taught our children."

Relocation and evacuation have been identified as one of the oldest human strategies to reduce the effects of floods. Although it was challenging to determine the level of adherence to the warning message delivered through local channels, study participants explained that when advice is given to move from flood hotspots (eg, lowlands), some people will move to the area. Highlands In the highlands, there are several options where people will stay. Or with relatives, in evacuation centers (eg schools), tents or temporary shelters, or rented houses. In addition, some people may have houses in both low and high areas. Villagers explained that in most cases, women and children move to the highlands with livestock, while men may stay in the lowlands and monitor the situation. Near an impending flood event, based on weather and river indicators, some people look for a safe place in the mountains or on top of ant hills. It is evident that despite a large number of long-term local indicators (eg ecological), and a recommendation to move to higher ground, people in the studied communities prefer to wait closer to the flood event or even when the flood waters are approaching.

The interviews showed that the preparation of houses and temporary shelters have been recognized as an adaptation strategy. By showing an understanding and self-awareness of living in flood-prone areas, the studied communities emphasized several ways in which they strengthen houses before heavy rains, strong winds, and floods. Foundations are improved by adding an extra layer of mud around the houses. In addition, the roofs are reinforced by a process of thatching (i.e. adding extra layers of palm fronds) and covering the roof with plastic sheeting, thus preventing water leakage while making the roofs more resistant to strong winds. Those who live in mud houses may also add additional layers of mud. In addition to the retrofitting of houses, the construction of temporary shelters was also recorded. Traditional pavilions are built in flood-prone areas and families will stay in these temporary shelters during the rainy season.

The waters are rising. Based on these observations, a decision will be made regarding possible evacuation. In other cases, the participants mentioned that the water level was only observed without the use of sticks. We note that these are primary measures that do not directly reduce risk, but are more quantifiable and actionable indirectly through observing the river index (i.e. water level). In addition, there are several primary actions related to religion that lead to e.g. Increasing social cohesion or mental resilience was mentioned as an initial measure to reduce the effects of floods, which can have a long-term effect.

2.4. Measuring the effectiveness of local knowledge components of coastal villages in reducing the effects of floods

Examining the measurement model

Figure 1 shows the measurement model in the form of an output with path coefficients, R2 values and factor loadings. Because the values of factor loadings of items (observable variables) should not be less than 0.4. Therefore, as can be seen, the values of factor loadings are acceptable for all routes and R2 values greater than 0.4 have been obtained.

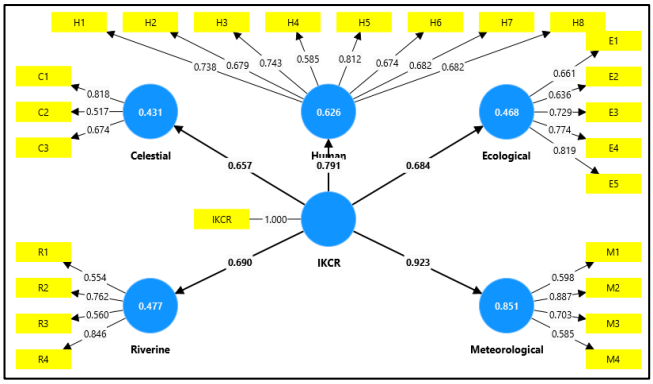


Figure 1- Implementation of the measurement model and its output

Therefore, the five main indigenous knowledge structures of the coastal villages of Chabahar region were confirmed. Respectively, Meteorological with a factor load of 0.851, Human with 0.626, Riverine with 0.477, and Ecological with 0.468 and Celestial with 0.431 had the greatest role in reducing flood effects. In Meteorological structure, Rainfall intensity (M2) with 0.887 and Occurrence of dark clouds (M3) with 0.703 have the highest factor loading and Heavy winds (M4) with 0.585 show the lowest factor loading. In the Human structure, two items Using the flooded Construction of temporary and low-cost houses (H5) with 0.812 and surface of trees and docks (H3) with 0.743 have the highest factor loadings and the item Building a deck to store food in times of crisis (H4) With 0.585, it shows the lowest factor loading. In the Riverine structure, two items Flood cycle (R4) with 0.846 and Colors of water (darker, muddier, increased debris (H2) with 0.762 have the highest factor loading and the item Increased sounds from the waters moving in the river (R1) with 0.556 have the lowest factor loading The two items The presence of beach flies and the increase of mosquitoes (E5) with 0.819 and animal behavior (E4) with 0.774 had the highest factor load and the item Migration of shorebirds (E2) had the lowest factor load with 0.636. In the Celestial structure, the two items Full moon (C1) with a score of 0.818 and Use the rainbow (C3) with 0.674 have the highest factor loading and the item Nature of water currents and tide (C2) has the lowest factor load (Figure-1)

Table 2: Fornell-Larcker criterion

	Celes	Ecolo	Hu	IK	Meteorol	Rive
	tial	gical	man	CR	ogical	rine
Celestial	0.68					
Ecological	0.45	0.72				
Human	0.63	0.60	0.70			
IKCR	0.65	0.68	0.79	1		
Meteorological	0.62	0.56	0.71	0.92	0.70	
Riverine	0.61	0.45	0.70	0.69	0.60	0.69

In Table 2, the output of divergent validity (diagnostic validity) of the measurement model is presented. According to common views, the root is taken from the AVE values of hidden variables. If the root value of each latent variable is greater than the correlation of that variable with other reflective latent variables, the model has divergent validity. Based on this, the divergent or diagnostic validity of the measurement model is also acceptable.

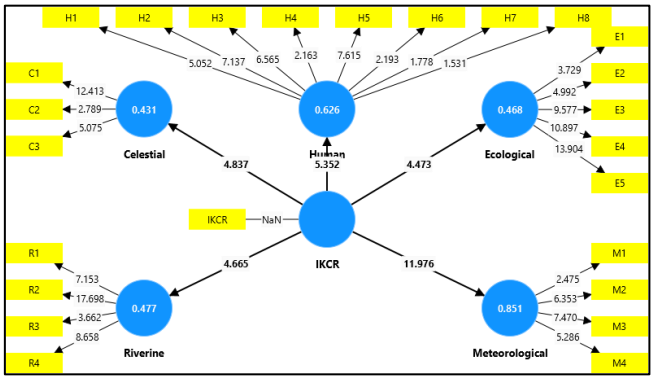


Figure 2: T values of the measurement model

Table 3: Test of research hypotheses (path and significance coefficients)

	Original sample (O)	R-square	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
IKCR -> Celestial	0.657	0.431	0.617	0.136	4.837	0
IKCR -> Ecological	0.684	0.468	0.64	0.153	4.473	0
IKCR -> Human	0.791	0.626	0.743	0.148	5.352	0
IKCR -> Meteorological	0.923	0.851	0.898	0.077	11.976	0
IKCR -> Riverine	0.69	0.477	0.647	0.148	4.665	0

Table 3 shows the significance of the model and its related indicators. Figure 2 also shows the T values of the measurement model. According to the measurement model, five routes have been examined and tested, the results of which are as follows:

Path of IKCR structure to Celestial: path coefficient value and T value are obtained as 0.657 and 4.837 respectively. This path is significant at the alpha level of one percent (P≤0.01) and the value of R2 is 0.431, which shows; 43.1% of the Celestial element is explained by the IKCR structure.

Path from IKCR structure to Ecological structure: path coefficient and T values in this path are 0.684

and 4.473, respectively. The mentioned path, which is significant at the alpha level of one percent (P≤0.01), shows the R2 value of 0.468; therefore, 46.8% of the changes in the Ecological element are explained by the IKCR structure.

Path of IKCR structure to Human structure: In this case, the path coefficient and T value were obtained as 0.791 and 5.352, respectively, which is significant at the alpha level of one percent (P≤0.01). Also, the value of R2 is equal to 0.626. In this way, 62.6% of the changes in the Human element can be explained by the IKCR structure.

The path of the IKCR structure to the Meteorological structure: the path coefficient and T value of this path are 0.923 and 11.976, respectively. The above path is significant at the alpha level of one hundredth (P≤0.01). The R2 value of 0.851 shows that 85.1% of the changes in the control element are explained by the structure of the organization, which is a significant amount.

IKCR structure path to Riverine structure: the path coefficient and T value of this path are obtained as 0.69 and 4.665, respectively. The above path is significant at the alpha level of one hundredth (P≤0.01). The R2 value of 0.477 shows that 47.7% of the changes in the Riverine element are explained by the IKCR structure.

5. Discuss

Considering a mixed approach, the present study tried to investigate the effectiveness of local knowledge components of coastal villages in reducing the effects of floods, focusing on the villages of Chabahar county. The researchers tried to bring out the hidden components of indigenous knowledge of coastal villages from the heart of the local community. The findings reveal a number of components of indigenous knowledge of coastal villages that are used by local people to predict future flood risks. The indicators that emerged through discussions with the study participants can be categorized into five different categories of ecological, meteorological, river, celestial and human indicators. It is obvious that the vast majority of indicators are directly related to people's observation and observation of changes in the natural environment around them and are highly context and case specific. The indigenous knowledge indicators of coastal villagers for floods are generally placed in one category. Indigenous early warning indicators that were obtained to deal with and predict floods, in many cases, have been derived from adaptation to the behaviors of their living environment. This suggests that communities have a high level of experience with flood risks in their area and have developed integrated warning systems. Also, the indicators that go from one society to another show a high similarity, which is most likely due to the geographical, social, cultural and economic conditions of the studied societies. This serves as a valuable lesson for governmental and non-governmental organizations living in the coastal villages of Chabahar county to deal with floods. However, there is a need to fully understand that efforts should be extended to understand this community-specific knowledge system and its context. However, there is no doubt that in case of establishing a Community-based Early Warning System, as one of the priority areas of the disaster risk management policy in the villages of Chabahar county, considering the local views about this system should be the starting point.

From the interpretation of the findings, it is inferred that the studied villages in Chabahar county have devised a wide range of coping and reduction strategies to minimize the effects of flood risks on their lives and livelihoods. This research provided a detailed description of these actions. However, the assessment of the effectiveness of the components showed that despite a large number of measures, a limited number of them are known to be efficient and some are only proposed as auxiliary and complementary components for predicting the flood of impact reduction. However, local communities state that these methods of flood detection and warning have been neglected, which is rooted in an overemphasis on academic knowledge. The combination of this situation with the ineffectiveness of institutions in charge of crisis management in the studied area makes local communities vulnerable to natural hazards such as floods. Possible explanations include insufficient dissemination and communication, lack of understanding, lack of timely action, and weak trust in the indigenous knowledge components of coastal villages by the custodian institutions.

The researchers' findings regarding the reduced reliability of IK warning signs are consistent with previous research. For example, Cagonio et al. (2016), while investigating the use of indigenous weather forecasting methods by pastoralists in northern Kenya, found that the increased frequency and severity of droughts in the past decade had negatively affected the reliability of indigenous forecasting. The findings of this issue should also be examined through the lens of methodological choices. Sampling for this, as well as our study, was designed for older people in communities, assuming that these people are more knowledgeable about the subject and are accustomed to using these signs. As IK communities have established themselves over decades and typically across a full range of climate variability, the question now arises as to how climate change (and related globalization processes) has and will affect these IK systems. In general, climate change and globalization are considered a threat to IK [48], although there is much research that explains the value of IK in climate change adaptation design [25]. It is likely that the inclusion of younger subjects in our study would have led to different findings, as they are likely to adapt to

these changes differently than older subjects. At the same time, our findings show that - according to the elderly - young people rely less on IK. To confirm this point, a follow-up study with young people as the target group should be conducted. Despite the uncertainty surrounding the reliability of IK for EWS, the results of this study show that, in general, an indigenous EWS is considered more reliable than official warning information. This may be due to the previously discussed gaps in the existing formal system.

There are several limitations to the present study. First, the data collection process in each community was relatively short, with one half-day visit by one research team. However, due to a long-term relationship between MRCS and the communities under study, there was an existing connection and the research team members were able to extract as much information as possible. Second, even though the composition of FGD participants was communicated to community leaders in advance, FGDs sometimes included more than two individuals under the age of 55. The concept of IK for Disaster Risk Reduction from the perspective of not only the older community members (as is usually done in IK studies) but also of society as a whole, thus creating a more realistic picture. Third, it was challenging to attach a specific timeline to the observed indicators and to identify a trigger level for a specific indicator (eg, understanding the severity of future floods and heavy rains based on the number of ants occurring in the area). A possible solution for this could be the use of other tools from the rural participatory assessment spectrum (except for focus group discussions and semi-structured interviews) or innovative tools such as memory threads (Climate Center, 2013). In addition, in many cases, it was not possible to obtain photographic evidence of common predictive indicators due to the remote location of the interviews and FGDs and the timing of the study. Also, since communities provided examples of indicators in the local language (such as specific tree or animal species), it was not always possible to obtain an English or scientific name for the species. Finally, since the FGDs and KII were conducted in the local language, some information was lost in the translation to English. Every effort was made to minimize this effect on the validity of our findings.

Kamarudin, et al. [49] In order to more easily use IK to improve community-based and national EWS, our study suggests the integration of IK with scientific knowledge. categorize IK into a dimension of whether it can be scientifically explained (or not) and whether it is relevant for DRR or CCA, emphasizing that IKs that cannot be scientifically explained should continue to be used by communities. Apart from the scientific explanation, they also had communities that confirmed the IK that had been captured. Similarly, we propose to integrate the IK of this study with scientific knowledge, as a sequence of further identification and documentation as described in R1. This process should be carried out in a participatory and inclusive manner, including local communities, scientists and professionals, ensuring that documented IK is widely held and implemented in areas prone to floods and droughts (and not just in the study area). There is actually an IK connection for the initial action.

The analysis showed that Meteorological (with an influence coefficient of 0.923) was the most effective in reducing the risk of flood disasters among the five classes of indigenous flood control and management knowledge practices employed by coastal villages. Other classes such as Human, Riverine, Ecological and Celestial knowledge are followed in descending order. This empirical evidence supports the findings of the focus group discussion, which shows that indigenous knowledge systems have great potential in reducing flood risk in coastal communities. In general, five categories of indigenous flood control and management knowledge applied by coastal communities are included in the framework of global structural and non-structural flood risk management (FRM) measures. This indicates the presence of indigenous structural and non-structural practices of FRM in coastal communities. This suggests that coastal communities rely on indigenous structural and non-structural measures to reduce flood risk. Also, indigenous knowledge of coastal communities is compatible with modern flood risk management techniques in Chabahar county. It also shows that indigenous and modern flood control and management systems are in the same direction and related.

In addition, indigenous technical knowledge, which is an indigenous structural action, was the most effective indigenous flood control and management knowledge system employed by coastal communities. This means that indigenous technical knowledge is very effective in flood risk management. It also shows that the use of local technology in flood risk management can invent new ways to reduce flood risks. Such methods can be a link between local and specialized knowledge that minimizes the contribution of coastal villages' excessive dependence on imported expertise and technologies in the implementation of flood defense structures such as canals, embankments, and dikes. Understanding this issue can explain the reason for the failure of many measures to reduce flood risks in Chabahar and even other regions of the country, which are mostly foreign to local knowledge. The results of the research in line with the study of Trogrlić, et al. [50] indicate that the identification of the constituent components of indigenous knowledge, in addition to the greater efficiency of modern project macro-cost measures, moderates the elitism of projects towards the local community and leads to the

use of modern technologies compatible with local characteristics.

The indigenous Meteorological knowledge method consists of four components of high heat, rainfall intensity, occurrence of dark clouds and heavy winds, which acts as a local warning system for flood control and management. Because high heat causes evaporation and increases the humidity of the air, and after that the masses of black and watery clouds start to rain heavily. Such components mainly occur in combination and local people acknowledge that the identification of one of these components alone cannot be considered a serious warning; but the collection of evidence can be used effectively. These results are consistent with the study of Bucherie, et al. [51]. Their results show that the interviewed Lake Malawi communities have detailed knowledge of flood early warning signs (changing clouds, wind direction and rainfall patterns) and distinct meteorological processes that lead to flash floods. In general, indigenous meteorological knowledge has a stronger warning power for flash floods than other categories.

In the context of indigenous human knowledge, it can help create a shared sense of confrontation and ownership of the project, which includes structured actions. This result is consistent with the focus group discussion; In a way that shows that indigenous human knowledge has contributed to eight major methods in reducing flood damage in coastal communities. First, the construction of canalization enables the collection of floodwaters and directs them to the river. Second, building buildings lined up along the river helps create a natural passageway for the water to flow instead of stagnant. Fourth, the use of human structures such as piers have been used to predict the intensity of floods. Fifth, they consider the use of low-cost materials for construction in order to minimize the damage caused by floods. Sixth, using natural warning systems to harvest agricultural products, which is considered a deterrent. Seventh, the construction of light boats for emergency preparedness and eighth, access to the road is considered as a warning mechanism. These results are consistent with the study of Macnight Ngwese, et al. [38], which show that indigenous human knowledge is an effective strategy for flood management in rural Ghana.

Three categories of indigenous knowledge practices, i.e. Riverine, Ecological and Celestial knowledge, include non-structural indigenous flood risk management practices employed by coastal communities. This is an indication that indigenous non-structural practices constitute a major part of FRM in coastal communities. The implication is that indigenous non-structural FRM measures developed and implemented by coastal communities are effective in reducing the risk of flood disasters. Also, it shows that the adoption of indigenous non-structural measures tends to minimize the flood risk disaster in the coastal villages of Chabahar county. Consequently, indigenous non-structural measures are very important and reliable FRM practices in coastal communities. Studies by Kelman, et al. [52] and Echendu [53] support the argument that there is a need to localize non-structural FRM practices in coastal villages. It is essential that indigenous non-structural measures are relevant in modern FRM practices. This result is consistent with the findings of the focus group discussion, which show that indigenous non-structural measures enable coastal communities to receive early warnings of impending flooding using the local knowledge system. Communities respond to the warning by harvesting their crops and taking their pets and other valuables to a safe place. This has been very effective in predicting flood events for decades, most notably a recent one that was one of the worst in 40 years. Also, signs of early rainfall, inundation of the access road, and high water flow and tide, which indicate the occurrence of a large flood, enable coastal communities to prepare preventive, safety and response measures to reduce the risk of flood disasters. In addition, the focus group discussion revealed that communities use indigenous safety knowledge practices to keep children and property safe from flood water. Coastal communities also built local silos to store farm produce and also hid during early warning of impending flooding to ensure that floodwaters did not destroy their farm produce based on indigenous food security practices. This ensures the availability of food in coastal communities during floods. Focus group discussion also revealed that indigenous flood control practices (such as construction of defense and water channels, sand dumping and tilting of buildings along the direction of water flow) enable coastal communities to minimize the effects of flooding and increase local capacity to overcome create a flood

5. Conclusion

The results of this study showed that the indigenous knowledge of the coastal village was divided into five categories. These are local ecological knowledge, local meteorological knowledge, local riverine knowledge, local celestial knowledge and local human knowledge, each of which can be of particular importance in controlling and managing floods in coastal villages according to the characteristics and environmental and human conditions of rural areas. This is compelling evidence that indigenous knowledge can provide pragmatic solutions for disaster minimization at many levels of governance. This study proposes a sustainable approach to flood disaster risk reduction based on the integration of indigenous knowledge and flood management strategies in a more adaptive and modern way. In addition, there is a need to formulate a policy instrument that promotes and publicizes indigenous

knowledge and improves the capacity of indigenous technical knowledge of coastal communities to respond more to flood challenges.

The recurrence of floods in the country and in the province of Sistan and Baluchistan highlights the need to predict and prepare for risks, and especially emphasizes the need to improve infrastructure and apply effective flood control strategies that are compatible with the natural environment in the coastal villages of Chabahar county due to their high vulnerability. It is undeniable in different physical, social, economic and environmental aspects. Examining the situation of the studied areas shows that the coastal villages were more affected than other areas due to the intensity of sudden rainfall. In these areas, the weakness in infrastructure and communication network, structures, sewage network and surface water disposal is highly evident; in the situation that the experience of recent periods and even the review of past records show the pattern of recurring floods and flooding in the villages of Chabahar county.

Since ancient times, one of the most common ways to provide water in dry areas is to use rainwater, and in this province, people have co-existed with nature since the past, and in order to provide water for their consumption, based on local knowledge and knowledge of the region, rainwater is used. And they controlled the floods and directed them to certain places. Still, despite many advances in the field of science and technology, structures such as Hotak, Degar, Darband and Khoshab are used in different regions of Iran, especially in the studied area, to provide water and support people's lives. These methods and where should the structures be built? What is the type of soil used? Is it suitable for water extraction or not? The degree of permeability or impermeability of the soil, etc., is the result of the experience and years of coexistence of the natives with the region. It should be mentioned that in the past, people created these structures with the least facilities and using materials that are generally soil and stone, and they did not have powerful tools and machines for this work. But despite this, generations have been engaged in life and livelihood with these "nature-based solutions". Hotek is one of the most comprehensive structures for collecting floods caused by seasonal rains in Sistan and Baluchistan province. The creation of "Bandsar" in order to control floods, supply and adjust underground water and sustainable agricultural process has also been customary in different parts of Chabahar county. This method is also a "mechanism based on the knowledge and wisdom of Baloch natives and affected by the climatic conditions of the region" and can be considered a suitable strategic model for managing water resources and watershed management as well as sustainable agriculture. In particular, the natives of Chabahar and Konarak cities have been able to protect the sustainable resources of their climate for a long time by creating and constructing earthen dams (dams) to control floods, watersheds and increase and adjust the level of underground water (aquifers), create a bed of rich flood-prone soils, and stabilize the soil. Blocking the advance of the desert, especially the sand-blasted sediments, and in order to exploit sustainable agricultural products in a rainfed manner.

One of the most important points that is important in the floods of coastal rural areas of Chabahar county is the understanding of "taking advantage of the golden opportunity of flood storage" in order to use rainwater in the time periods when these areas are not only providing water in economic sectors but also in providing water. Drinking is also facing a dead end. Meanwhile, according to the statement of the chairman of the Agriculture, Water and Natural Resources Commission of the Islamic Council, nearly 2 cubic millimeters of water has flowed into the sea during the recent rains. In this way, it seems that despite the fact that the local knowledge of coastal villages can help watershed management and flood control in these areas; but it is still not taken into account and the coastal villages of Chabahar are highly vulnerable to these dangers.

These points are compelling evidence that indigenous knowledge can provide pragmatic solutions to minimize disasters at many levels of governance. In general, as the findings of this study show, any primary action at the local level is not solely informed by a single knowledge system, in this case, the indigenous knowledge system of coastal villages. Surveyed communities reported that some receive official warning information about imminent danger. Therefore, based on a complex process of triangulation between different sources of warning information, the decision to take initial actions is made. This shows that, like any other knowledge system, the indigenous knowledge system for the early warning system is constantly evolving and adapting to changing conditions. In any case, fully understanding local ways of coping and mitigation, auditing them, integrating them into planned interventions and strengthening them if possible can improve existing approaches by NGOs and government and provide more cost-effective interventions for DRR and actions. Provide humanitarian aid in the region.

7. Suggestions and applications of research results

Indigenous flood control and management knowledge is effective in reducing the risk of flood disasters in local coastal communities. Therefore, there is still a need to improve its level of effectiveness by inculcating modern flood control and management techniques in indigenous practices. This makes it

more responsive to the challenges caused by floods in coastal communities. As a result, a sustainable approach to reduce the risk of flood disasters should include the integration of indigenous and modern disaster management strategies such that, first, the necessity of comprehensive watershed management as a conscious process to integrate different aspects of natural resource exploitation (biophysical, socio-political and economic) in A local sustainable management system should be designed in order to achieve the goals of the users (food security, profitability, risk reduction) considering the goals of the society (poverty reduction, welfare of future generations and environmental protection). Secondly, meteorological stations should be built in strategic locations of coastal communities. This allows coastal residents to learn about a set of weather parameters, especially precipitation parameters and wind speed and location. This will help them to improve their skill in flood forecasting instead of relying on the inundation level of trees, buildings and docks in studying flood cycle and flood forecasting. Second, the services of construction industry professionals, including architects, engineers, and urban planners, should be engaged in educating local people on the construction of affordable, sustainable houses of good aesthetic value, whose building materials are locally sourced and processed. This allows people to build houses that are more flood resistant. Also, the government should employ the services of engineers to train coastal communities in the construction of local bridges, dykes, and earthen ponds. This not only improves the indigenous technology base but also serves as a source of livelihood for the local people. Fourth, in an effort to reduce the impact of flooding, coastal communities harvest their crops as soon as they receive signals of impending flooding and sell the leftovers cheaply. To prevent this, the government should provide high-yielding, early-ripening seedlings and modern crop storage facilities in coastal communities. Camps should be established in flood-prone rural areas so that people are safe from the danger of floods. Insurance companies should be encouraged to operate in coastal communities. It allows people to insure their products and property. Coping strategies and other ways to reduce the flood risk of coastal communities should be harnessed by relevant organizations and integrated into the flood control and management system of coastal villages of Chabahar. This strengthens the capacity base of managers and residents of coastal rural areas in managing the challenges caused by floods in the coastal villages of Chabahar. The government, in cooperation with the coastal communities, should establish a more effective communication system by installing observation centers in the village squares of the coastal communities. This ensures easy and quick dissemination of information about impending flooding and quick response of coastal communities. Policy makers should develop mechanisms that promote and popularize indigenous knowledge. It should focus on public awareness, educational activities, and inculcation of indigenous knowledge in policies and programs at macro and micro levels. In addition, identification, validation and adaptation of indigenous knowledge will be key to their preservation as well as increased flood risk reduction in Chabahar coastal communities.

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Ecological modeling of pollutant removal in urban wetlands

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ABSTRACT

Wetlands are unique, diverse, and productive habitats in the natural environment. They have significant ecologic values due to their potential to deposit, sediment, and filter out pollutants from the water that flows through them. Wetlands have been investigated from different aspects in the past years; however, the computer modeling of the complex processes that occur in wetlands has attracted less attention. In this study, the mechanism of pollutant removal has been studied by developing a new template for the ecological modeling of the wetlands. The kinetics of oxygen balances, biochemical oxygen demand, coliform, and nutrient removal are numerically simulated. To explore modeling capabilities, a wetland in northern Iran, was investigated as a case study. Field measurements were performed for parameter estimations and model calibration. The numerical results exhibited that concentrations of BOD, total coliform, phosphate, and nitrate decreased up to 45%, 44.96%, 44.8%, and 43.47%, in the outflow when model has run for spring and summer seasons and the results compared to the field sampling data.

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1. Introduction

Today, urbanization is increasing, all around the world. About four billion people, half of the world's population, now live in urban areas and this ratio will reach 66% by 2050 due to the migration of people to cities hoping to find jobs and a more active social life [1]. Cities make up 80% of the world's economic values and contribute fundamentally to world purposes for sustainable development goals [2]. Meanwhile, urban sprawl has raised concerns as a significant threat to natural resources by destroying the cities' marginal lands, i.e., forests, farms, and wetlands. The loss of wetlands, which are among the first casualties of such a blind and unsustainable development system, has been reported to constantly destroy wildlife habitats and biodiversity mostly around the urban areas [3]. In return, experts believe that if the wetlands were left untouched and protected, they would make cities more habitable and environmentally compatible [4-6].

Wetlands used to be considered worthless lands and were used as landfills or places for wastewater disposal in some parts of human history. Recently and after the Ramsar convention (1971), wetlands' aesthetic and other benefits for recreation, agricultural purposes, conservation, and water quality improvements have been highlighted [3]. Ramsar Convention draws significant attention to the wetlands' environmental functions and their socio-economic benefits for human societies [7]. Today, however, wetlands are globally valued and cherished for their role in improving water quality, flood attenuation, biodiversity, supporting aquatic habitats, and cultural, social, and economic services [3, 8].

Wetlands are pollution-catching powerhouses and can trap nitrogen and phosphorous with a unique potential. Wetlands can enhance compounds' retention by storing sediment, nutrients, and heavy metals and facilitate treatment by digesting organic compounds due to aerobic and anaerobic processes [8]. The ability of the wetlands to purify contaminations makes them an ideal treatment area for anthropogenic and natural pollutants. Such diverse capabilities made a growing interest in the simultaneous use of wetlands as a source of water, a place for pollution removal, and a recreation center for those wetlands located inside or near urban areas.

In the last few years, many investigations have been reported on the wetlands' efficiency for contamination removal [9-13]. Hammer [9] provides a detailed analysis of wetlands pollutant removal capabilities by reviewing the case studies from constructed wetland projects worldwide [9]. Craft et al. [10] overviewing the findings from numerous studies, focused on the removal processes of nitrogen, phosphorus, and sediment by the wetlands. The article discussed the importance of wetland design, vegetation, and hydrological conditions in achieving optimal removal rates. Mitsch and Gosselink [11] provide a holistic overview of wetlands ecology and their role in pollution removal through covering removal mechanisms on nutrients, heavy metals, and organic contaminants. Vymazal and Kröpfelová [12] reported an in-depth analysis of nutrient removal in different types of constructed wetlands. To optimize nutrient removal, they provide deep insights into the design and management practices of the constructed wetlands. Vymazal [13] discussed the role of plants, microorganisms, and substrates in enhancing pollutant removal in wetlands. Vymazal provided case studies and performance data from various constructed wetland systems.

Besides numerous field and laboratory studies, there has been always an ambition to develop a sort of interactive mathematical model to simulate wetland's ecological processes with the computer. Only recently and after new advancements in computing power and simulation techniques it has become possible. Through integrating hydrodynamics, water quality, and ecological processes, computer models are becoming able to provide a comprehensive understanding of wetlands' function as a pollution control measure.

So far, a few computer modeling techniques have been reported for the interactive simulation of wetlands' processes [14-20]. Somes et al. [14] used MIKE21 for the simulation of flow hydrodynamics in the Monash University Research wetland. Field data for six months were used for the model calibration, and the results show good agreement between the numerical model and field observations. Kazezyilmaz-Alhan et al. [15] developed a comprehensive hydrological and water quality model (Wetland's Solute Transport Dynamic, WETSAND) for surface flow and solute transport in a constructed wetland. The model incorporates surface water/groundwater interactions and accounts for upstream contributions from urbanized areas. Boutilier et al. [16] studied the fate and transport of E. coli bacteria in a full-scale surface flow wetland for treating domestic wastewater using the WASP model. The model was able to predict the average concentration of E. coli successfully but was not accurate in predicting the maximum and minimum number of E. coli in the wetland. Hydrodynamic and ecological laboratory (ECO Lab) modules of MIKE21 were used by Suntoyo et al. [17] to evaluate the water quality of the Porong River in the Madura Strait, Indonesia. The dispersion and dynamic of COD, TSS, phosphate, and nitrate were calculated and compared with the standard after model calibration with the field data at 4 different locations. Qiao et al. [18] also used MIKE21 to simulate the hydrodynamic properties and salinity transport in the Pink Beach wetland of the Liao River estuary, China. The effects of wetland plants on tidal flows were also investigated by

changing the Manning coefficient. Internal hydraulics and the effect of wind on the surface flow in a constructed wetland that is fed via agricultural drainages were investigated by Pugliese et al. [19]. The results showed that shallow areas with the wind in the opposite direction of the flow would lead to more mixing and rotation in the wetland. Thu Minh et al. [20] used MIKE 11 to quantify the spatiotemporal dynamics of water quality parameters in the Long Xuyen Quadrangle area of the Vietnamese Mekong Delta.

Reviewing the literature showed that developed computer models up to the current time were less interactive and limited to considering removal processes in the wetlands. The aeration processes and the dynamics of oxygen balance (O2 aeration and consumption) were not simulated and the influx of the hydrodynamic model on the ecological process was not fully considered. So, the current study aimed to provide a new template for the comprehensive ecological simulation of urban wetlands with a high inflow of domestic sewage. To reach the goal, the influencing processes on organic pollutant removal were extracted and a detailed insight into the transport, transformation, and degradation processes for each was provided. So a three-dimensional numerical model has been developed using MIKE 3 Flow Model (FM) and ECO Lab Module. ECO Lab interconnects hydrodynamic, water quality, and ecological processes and provides a possibility to modify or create the formulation that is needed for a specific water body. As a case study, the customized model has been tested for the Gole-Niloufar wetland, located in north of Iran. In the model, the processes of DO, BOD and coliform degradation, together with Nitrate and Phosphate removals were formulated through the causal relations that describe each specific phenomenon. For calibration purposes, a series of field measurements in even days of one month, and for model validation, sampling in different seasons of one year was performed and the results were tested and verified against the field data.

2. Materials and methods

The Flow Model (FM) along with ecological laboratory (ECO Lab) modules of DHI MIKE3 software are used to simulate the hydrodynamic and ecological features of the wetland. In the enclosed water bodies where species stratification occurs, the three-dimensional model should be used [21, 22]. The virtue of this modeling technique is that the hydrodynamic model is simultaneously interacting with the results of the ecological model. As a result, pollutants' mixing and dispersion and their decay and deposition due to aeration, evaporation, sunlight, bacterial decomposition, and plant uptake processes can be modeled at a time, more interactively. The modeling framework of this study is depicted in Figure 1.

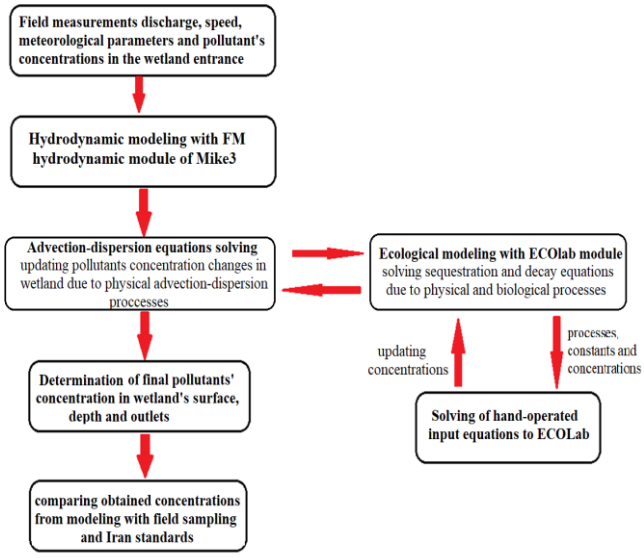


Figure 1. The overview of the modeling framework

2.1. Hydrodynamic model

The hydrodynamic or Flow Model (FM) is a standard MIKE3 tool for flow simulation in water bodies with three-dimensional structures, such as wetlands, bays and coastal areas. This model can simulate unsteady flows with density changes and external forces, including meteorological and tidal parameters [21]. The model is based on a flexible mesh method. The z-direction discretization can be either a sigma coordinate or a sigma/z-level coordinate, which uses a cell-centered finite volume method. The elements of unstructured mesh in x-y coordinate can be generated as triangular or quadrangular elements [22].

Mathematical modeling in the MIKE3 is based on the Navier-Stokes equations. It solves mass and momentum conservation equations and salinity and temperature transport equations with the help of the Reynolds-averaged method in three dimensions. In the Reynolds-averaged method, all the turbulent fluctuations are modeled and represented in terms of the mean-flow characteristics [23-24]. Therefore, the computational expenses for simulation are dramatically reduced, and solving the governing equations becomes possible for real engineering applications. These equations can be written in the Cartesian coordinate as follows [25]:

$$\frac{1}{\rho C_S{}^2}\frac{\partial P}{\partial t}+\frac{\partial u_j}{\partial x_j}=SS \qquad (1)$$

$$\frac{\partial u_i}{\partial t} + \frac{\partial (u_i u_j)}{\partial x_j} + 2\Omega_{ij} = \frac{1}{\rho}\frac{\partial P}{\partial x_i} + g_i + \frac{\partial}{\partial x_j}\left(v_T\left(\frac{\partial u_i}{\partial x_i} + \frac{\partial u_j}{\partial x_j}\right) - \frac{2}{3}\delta_{ij}\right) + u_i SS \quad (2)$$

$$\frac{\partial C}{\partial t} + \frac{\partial}{\partial x_j}(Cu_j) = \frac{\partial}{\partial x_j}\left(D_s \frac{\partial C}{\partial x_j}\right) + SS \quad (3)$$

$$\frac{\partial T}{\partial t} + \frac{\partial}{\partial x_j}(Tu_j) = \frac{\partial}{\partial x_j}\left(D_T \frac{\partial T}{\partial x_j}\right) + SS \quad (4)$$

Where t is the time, ρ is the density of the water, C_s is the speed of sound in seawater, u_i is the velocity in the x-direction, Ω_{ij} is the Coriolis force tensor, P is the fluid pressure, g is the gravitational acceleration, ν_T is the turbulent eddy viscosity, δ is Kronecker's delta, k is the turbulent kinetic energy, S and T are salinity and temperature, D_S and D_T are linked to dispersion coefficients. SS states as the respective source-sink terms, which is different from the equation to the equation.

In the flow model of Mike3, bed resistance can be identified as no bed resistance, quadric drag coefficient, and roughness height. In this study, a constant roughness height is considered. The bottom stress is calculated from the equation below:

$$\frac{\overline{\tau}_b}{\rho_0} = c_f \overline{u}_b |\overline{u}_b| \quad (5)$$

Where $\overline{u}_b$ is the flow velocity at Δz_b above the bottom, ρ_0 is the water density, c_f is the drag coefficient and is determined by the (6) equation:

$$c_f = \frac{1}{(\frac{1}{k}\ln(\frac{\Delta_{z_b}}{z_0}))^2} \quad (6)$$

In this equation, k is the von Kármán constant considered 0.4 and z_0 is the scale of bed roughness length. Generally, the roughness height range is between 0.01-0.3 m. The roughness value directly relates to friction, as considered in the model [25].

2.2. Ecological model

This study tried to consider major physical, chemical, and biological processes in the wetland. Therefore, a new template in the ecological laboratory module of MIKE has been developed to simulate pollution removal processes considering climate factors such as temperature, wind, natural aeration, evaporation, and sunlight together with the natural procedures of sedimentation, degradation, and bacterial and plant uptakes. ECO Lab is a flexible numerical laboratory for the ecological modeling of natural ecosystems. So as a process equation solver, it can calculate the rate of change of state variables, processes, and forces. The MIKE ECO Lab provides an open space for manual input of the equations for the reaction rate of state variables. One can make more accurate predictions with built-in templates or create a new model concept containing the necessary causal relations to describe a specific problem. The model can simulate the processes of transfer, dispersion, and degradation of pollution, in the simultaneous operation of the hydrodynamic model. Processes express the rate at which variables change in the wetland environment [25]. This change can be expressed as a set of coupled ordinary equations:

$$P_c = \frac{dc}{dt} = \sum_{i=1}^{n} process_i \quad (7)$$

In this equation, c is the state variable concentration in the module, and n is the number of processes involved for a particular state variable [25]. The processes are:

2.2.1. Oxygen balances

Modeling of the oxygen balance depends on the level of complexity chosen. There are four levels of complexity to describe the mass equation for DO. In this study, level 3 of the oxygen balance equations has been used, in which, besides the oxygen, changes in the concentration of nutrients are also effective:

$$\frac{dDO}{dt} = +reaeration - \text{BODdecay} - Y_1.nitrification + photosynthesis - respiration - sediment\ oxygen\ demand \quad (8)$$

Equation (8) includes aeration, nitrification, BOD degradation, photosynthesis, respiration, and the amount of oxygen demanded by sediments. Y1 is the yield factor for oxygen [25-26]. According to previous studies, Y1 ranges between 1.2 and 1.8, depending on the value of F/M (food/microorganism [27].

- **Aeration**

This is a process that describes the exchange of oxygen between dissolved oxygen and the atmosphere. This term refers to the level of oxygen saturation in water Cs, which depends on salinity and temperature.

$$d(\text{reaeration})/_{dt} = K_2(C_s - DO) \quad (9)$$

K_2 is the rate of the aeration process, which depends on W_V wind speed, V velocity, and water depth H, and its unit is 1/s:

$$K_2 = \frac{3.93V^{0.5}}{H^{1.5}} + W_V/H \quad (10)$$

W is obtained from the following equation, and its unit is m/s.

$$W_V = 0.728{W_V}^{0.5} - 0.371W_V + 0.0372{W_V}^2 \qquad (11)$$

The values of the flow velocity, wind speed, and water depth parameters are given to the model as a time series of measurements and meteorological information [25-26].

- **Nitrification**

Nitrification is another process that affects oxygen balances in the wetland regarding the fact that in the nitrification process, oxygen is consumed when ammonia is converted to nitrite.

$$d(nitrification)/dt = K_4.NH_3.{\theta_4}^{(T-20)}.\frac{DO}{DO + HS\_nitr} \qquad (12)$$

In this equation, K_4 is the rate of nitrification at 20° C (1/day), θ_4 is the temperature coefficient for nitrification, T temperature (°C) and HS_nitr are the semi-saturated concentration for nitrification (mg O_2/l) [25]. The water temperature in the wetland is given to the model in a time series. Based on the previous studies and research, the value of K_4 is between 0.1 to 0.5, the value of θ_4 is considered to be 1.08 [26], and HS_nitr is also suggested to be less than 2 [28].

- **Photosynthesis**

Oxygen production by photosynthesis is associated with the highest production at noon and varies with the time and the length of the day.

$$d(\text{photosynthesis})/dt = \begin{cases} P_{max}.F_1(H).\cos 2\pi\left(\frac{\tau}{\alpha}\right).{\theta_1}^{(T-20)} & if\ \tau \in [t_{up}, t_{down}] \\ 0 & if\ \tau \notin [t_{up}, t_{down}] \end{cases} \qquad (13)$$

This amount of photosynthesis shows the actual production of oxygen in a day (g O_2/m^2/ day). In this equation, P_{max} represents the maximum production at noon (g O_2/m^2/ day), θ_1, the coefficient of temperature for respiration/production in the process of photosynthesis, τ, the real-time of noon, α, the actual length of day, t_{up}, t_{down}, the length, and sunset. $F_1(H)$ is a light adjustment function obtained from the following equation:

$$F_1(H) = e^{-k.H} \qquad (14)$$

In this function, k is the light decay coefficient (m^{-1}), H is the water depth (m), τ, α, t_{up}, t_{down} are parameters that are entered into the model based on time and date as a time series [25]. According to previous studies, in most cases, θ_1 is considered equal to 1.4-2 [29]. Also, the P_{max} value can vary between 3-100 g O_2/m^2/day. Also, the value of k has been suggested between 0.44-0.99, which is considered to be about 0.68 in similar studies [30].

- **Respiration**

Autotrophs and heterotrophs' respiration use oxygen and is described as temperature-dependent.

$$d(\text{respiration})/dt = R_1.F_1(H).{\theta_1}^{(T-20)}) + R_2.{\theta_2}^{(T-20)} \qquad (15)$$

R_1 and R_2 are photosynthetic respiration rates (autotrophs) and animal and bacterial respiration rates (heterotrophs) at 20 °C (g O_2/m^2/day), respectively. θ_2 is the coefficient of temperature for heterotrophic respiration. Respiration determines the actual rate of respiration by plants, bacteria, and animals (g O_2/m^2/day) [25]. According to previous studies, R_1 and R_2 are in the range of 14-24 and 0.036-0.057 $\frac{\mu mol}{m^2}/s$, respectively [31].

- **Sediment oxygen demand**

Sediment oxygen demand due to organic matter that does not come from pollution degradation is described separately. Sediment oxygen demand (SOD) depends on oxygen concentration and temperature as follows:

$$d(sed\ oxygen\ demand)/dt = {\theta_3}^{(T-20)}.\frac{DO}{HS\_SOD + DO} \qquad (16)$$

HS_SOD is the half-saturation concentration for sediment oxygen demand [25]. In this study, sediment modeling has been neglected.

2.2.2 Fecal and total coliform

The majority of commonly occurring waterborne pathogens are linked to human or animal feces. Coliform bacteria are organisms found in the feces of humans and other warm-blooded animals. These bacteria are unlikely to cause disease. Their existence in water resources shows that pathogenic organisms may be present in the environment. Three different groups of coliform bacteria are 1) total coliform, 2) fecal coliform, and 3) Escherichia coli (E.coli). The total coliform group includes an extensive collection of different types of bacteria. Fecal coliforms are part of the total coliform found mostly in human and animal feces, and E.coli is a subsection of fecal coliforms. Typically, there are hundreds to millions of

coliform bacteria per cubic centimeter of untreated wastewater, so the amount of coliform is introduced in terms of number per 100 milliliters.
This model has been developed to track the decay and dispersion of total and fecal coliforms. Bacterial death can be defined as follows:

$$\frac{dC_F}{dt} = -K_{dF}.C_F \qquad (17)$$

where C_F is the concentration of fecal coliforms (1/100 ml) and K_{dF} is the fecal coliforms decay coefficient (1/day). Also, C_F and K_{dF} can be replaced with C_T and K_{dT} to calculate the total coliform decay [25]. According to previous studies, coliform decay coefficient is in the range of 0.26-1 [16].

2.2.3. BOD

The amount of oxygen consumed by microorganisms for degradable materials oxidation within five days is called the 5-day biological oxygen demand or BOD5. Biological oxygen demand is an important indicator for measuring the level of water pollution. Water pollution is the introduction of foreign substances to a body of water which changes the physical, chemical, and biological properties of the water in a suspended or dissolved form. Obviously, the higher number of foreign substances will lead to higher pollution in the water. Measuring the amount of foreign matter through the BOD index is key to determining water pollution level. So, its reduction is considered as an indicator of the wetland's ability for natural purification [32].
Biological oxygen demand is generally divided into three parts: soluble, suspended, and precipitated, each of which can be calculated separately, so one or more equations can define the relation between BOD changes over time. In this study, due to the difficulties in measuring each part separately, the total BOD as the aggregation of three BODs in one equation, has been used in the formulations [25]. Thus, by combining the three parts of BOD in one equation, the rate of BOD changes can be written as follows:

$$\frac{dBOD}{dt} = -BOD_{decay} \qquad (18)$$

The BOD_{decay} itself is defined using the following equation:

$$BOD_{\text{decay}} = K_3.BOD.\theta_3^{(T-20)}.\frac{DO}{DO + HS\_BOD} \qquad (19)$$

BOD is the actual biological oxygen concentration in mgO_2/l, K_3 is the organic matter reduction coefficient at 20°C (1/day), θ_3 is the Arrhenius temperature coefficient, DO is the actual oxygen concentration in mgO_2/l and HS_BOD is the semi-saturated oxygen concentration for BOD ($mg\ O_2/\ l$) [25-26]. In general, the rate of BOD degradation increases with increasing access to oxygen. However, due to the oxygen saturation factor, this increase can be grown to a certain amount of dissolved oxygen concentration as oxygen is soluble in water to a certain extent. The oxygen saturation coefficient, as an experimental value, enters into the equation in the form of a semi-saturated concentration constant at the rate of BOD degradation and varies from system to system. The oxygen saturation coefficient in water depends on salinity, temperature, and air pressure (due to differences in altitude). Dissolved oxygen generally decreases when salinity and temperature increase [33, 34]. According to Chapra [26], K3 and θ3 are in the range of 0.05-0.5 and 1.02-1.09. Also, HS_BOD is proposed equal to 0.128 in similar studies.

2.2.4. Nutrients

2.2.4.1 Nitrogen

The presence of nitrogenous compounds in the sewage can have several adverse impacts on the quality of the receiving waters. Nitrogenous pollution includes compounds with positive and negative charges, including ammonium ions, nitrite, and nitrate. Some adverse effects are [32]:

- The reduction of dissolved oxygen in the receiving waters,
- Toxicity to aquatic life,
- The eutrophication (overgrowth of algae and aquatic plants), and
- Health problems and diseases.

Nitrogen has a complex biological-chemical cycle with multiple biotic/abiotic states, including seven capacities of +5 to -3. These compounds include a variety of inorganic and organic forms of nitrogen that are essential for biological life. The most important mineral form of nitrogen is ammonium (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-). Gaseous nitrogen may be present in the form of dinitrogen (N_2), nitrogen oxide (N_2O), nitric oxide (NO_2 and N_2O_4), and ammonia (NH_3) [12].
The change in the main nitrogen states in the wetlands is given in Table 1. Different forms of nitrogen are constantly involved in the chemical conversion of inorganic to organic compounds and the return from organic to inorganic. These processes require energy and are typically derived from an organic carbon source. Other processes release energy, which is used by organisms for growth and survival [12].

Table 1 The transformation of nitrogen in wetlands

Transformation	Process
ammonia-N (aq)→ammonia-N (g)	Volatilization
organic-N→ammonia-N	Ammonification
Nitrification ammonia-	Nitrification

N→ nitrite-N→ nitrate-N	
nitrate-N→ammonia-N	Nitrate-ammonification
nitrate-N→nitrite-N→ gaseous N2, N2O	Denitrification
gaseous N2→ ammonia-N (organic-N)	N2 Fixation
ammonia-, nitrite-, nitrate-N→ organic-N	Plant/microbial uptake (assimilation)
	Ammonia adsorption
	Organic nitrogen burial
ammonia-N→gaseous N2	ANAMMOX (anaerobic ammonia oxidaton)

- **Ammonium**

The ammonium / ammonia equation is defined as follows:

$$\frac{dNH3}{dt} = +ammonium\ yield\ from\ BOD\ decay - transfromation\ of\ ammonium\ to\ nitrate - ammonium\ uptake\ by\ plants - ammonium\ uptake\ by\ bacteria + heterotroph\ respiration \quad (20)$$

This equation includes BOD degradation, nitrification, plant and bacterial consumption, and heterotrophic respiration.

1- Ammonium resulting from BOD degradation is obtained from the following equation:

$$\frac{d(ammonium\ yield\ from\ BOD\ decay)}{\mathrm{dt}} = Y_{BOD}.K_3.BOD.\theta_3^{(T-20)}.\frac{DO}{DO+HS_{DO}} \quad (21)$$

Y_{BOD} is the amount of nitrogen in organic matter in mg NH_3-N/mg BOD. This constant is obtained, based on ammonia nitrogen available. In this study, in spring and summer, Y_{BOD} assumed equal to 0.1018 and 0.1008, based on the ammonia and input BOD [25].

1- The conversion of ammonium to nitrate is expressed as follows:

$$\frac{d(transfromation\ of\ ammonium\ to\ nitrate)}{\mathrm{dt}} = K_4.NH_3.\theta_4^{(T-20)} \quad (22)$$

2- Ammonium consumption by plants

According to the level of complexity that was initially considered, the plant consumption is expressed as follows:

$$\frac{d(ammonium\ uptake\ by\ plants)}{dt} = UN_p.(P - R_1.\theta_1^{(T-20)}) \quad (23)$$

UN_p is the rate of ammonia uptake by the plant (mg N/mg DO)

3-The amount of ammonium absorbed by the bacteria is as follows:

$$\frac{d(\text{ammonium uptake by bacteria})}{dt} = UN_b.K_3.BOD.\theta^{(T-20)}.\frac{NH_3}{NH_3+HS_{NH_3}} \quad (24)$$

UN_b is the rate of ammonia uptake by bacteria (mg N / mg DO) and HS-NH_3 is the semi-saturated concentration for nitrogen uptake by bacteria (mg N/l).

4- Heterotrophic respiration is obtained from the Equation below [25]:

$$\frac{d(heterotroph\ respiration)}{dt} = UN_P.R_2.\theta^{(T-20)} \quad (25)$$

- **Nitrite**

The reactions that affect the mass balance of nitrite are as follows:

$$\frac{dNO_3}{dt} = +\text{transformation of ammonia to nitrite} - \text{transformation of nitrite to nitrate} \quad (26)$$

Equation (26) consists of two terms: ammonia to nitrite conversion and nitrite to nitrate conversion, which are obtained from equations (27) and (28), respectively:

$$\frac{d(\text{transformation of ammonia to nitrite})}{dt} = K_4.NH_3.\theta_4^{(T-20)} \quad (27)$$

$$\frac{d(\text{transformation of nitrite to nitrat})}{dt} = K_5.NO_2.\theta_5^{(T-20)} \quad (28)$$

K_5 is the specific rate of conversion of nitrite to nitrate at 20 °C and θ_5 are the coefficient of conversion of nitrite to nitrate [25]. K_5 and θ_5 for the same conditions are considered equal to 0.5 and 1, respectively [35].

- **Nitrate**

The reactions that affect the nitrate mass equation are as follows:

$$\frac{dNO_3}{dt} = +\text{transformation of nitrite to nitrate} - \text{denitrification} \quad (29)$$

The conversion of nitrite to nitrate is determined from Equation (28) and denitrification is determined from the following equation:

$$\frac{d(\text{denitrification})}{dt} = K_6.NO_3.\theta_6^{(T-20)} \quad (30)$$

K_6 is denitrification rate (1/day) and θ_6 are Arrhenius temperature coefficient (DHI 2014). According to previous studies, $K_6$and θ_6 are in the range of 0.003-1.02 and 1.16, respectively [36].

2.2.4.2 Phosphorus

Phosphorus is a nutrient required by all organisms for the basic processes of life. Phosphorus exists in water in either a particulate phase or a dissolved phase. Particulate matter includes living and dead materials. The dissolved phase also includes inorganic phosphorus and organic phosphorus. Phosphorus in aquatic ecosystems is usually found in the form of phosphates (PO_4^{-3}). Phosphates can be in inorganic form such as orthophosphates and polyphosphates, or organic form such as organically-bound phosphates.

Free orthophosphate is the only inorganic phosphorus that can be used directly by algae and macrophytes. Therefore, it makes a significant link between the two cycles of organic and inorganic phosphorus in wetlands. Another group of inorganic phosphorus compounds is dense linear and cyclic polyphosphates. Organic phosphorus is also found, in phospholipids, nucleic acids, nucleoproteins, phosphorylated sugars, or dense organic phosphates [37].

BOD contains phosphorus, and it is released in the form of orthophosphate when BOD is degraded. According to orthophosphate uptake in algal growth, the equation is interpreted as a function of orthophosphate concentration as below:

$$\frac{dPO_4}{dt} = +phosphorus\ yield\ from\ BOD\ decay - phosphorus\ uptake\ by\ plants - phosphorus\ uptake\ by\ bacteria - heterotrophic\ respiration \quad (31)$$

Equation (31) includes phosphorus from BOD degradation, phosphorus absorbed by plants, phosphorus absorbed by bacteria, and heterotrophic respiration, as the equations (32), (33), (34), and (35):

$$\frac{d(phosphorus\ yield\ from\ BOD\ decay)}{dt} = K_3.BOD.Y_1.\theta_3^{(T-20)}.\frac{PO_4}{PO_4 + HS\_PO_4} \quad (32)$$

$$\frac{d(phosphorus\ uptake\ by\ plants)}{dt} = UP_p.(P - R_1.\theta_1^{(T-20)}) \quad (33)$$

$$\frac{d(phosphorus\ uptake\ by\ bacteria)}{dt} = UP_b.K_3.BOD.\theta^{(T-20)}.\frac{PO_4}{PO_4 + HS\_PO_4} \quad (34)$$

$$\frac{d(heterotrophic\ respiration)}{dt} = UP_P.R_2.\theta^{(T-20)} \quad (35)$$

In these equations, Up_p is the rate of phosphorus uptake by plants and UP_b is the rate of phosphorus uptake by bacteria. HS_PO_4 indicates the semi-saturated concentration of phosphorus absorbed by bacteria [25]. Based on previous studies HS_PO_4 is a function of temperature and phosphate content. For the wetlands, a value equal to 0.065 has been proposed [30].

As mentioned, a customized ecological model has been used to simulate a range of important ecological processes on pollution removal in wetlands. The process formulations consisted of mathematical relations, built-in functions, numbers, constants, and state variables. The arguments were separated by operators and the syntax used for other expressions. The ECO Lab predefined functions like mathematical and built-in functions have been used by referring to them while the other process descriptions were formulated by the user. Hence, the developed model was used to act as a post-processor to calculate the removal dynamics while other models were used to calculate flow and transport processes at each time step. To evaluate the capabilities of the model, the simulation model has been developed for an urban wetland and calibrated based on the field observations.

3. Study area

Gole-Niloufar wetland is an artificial wetland located in the city of Babol, Mazandaran Province, north of Iran. The wetland is placed in the legal territory of the town, surrounded by residential areas and agricultural and barren lands. The wetland's total area is about 38 hectares of common property. The farmers use the outflows for their rice farms. The average depth of the wetland is approximately 2.5 meters. It was constructed and exploited long ago (the exact time is unclear to the authors) by getting water from the Babolroud River through a handmade creek (Aqaroud). The Gole-Niloufar wetland is an Abbandan as defined by Ramsar convection and is constructed by excavation and borders of soil dykes around it (ramsar.org). The Abbandon is a shallow artificial pond in the lowlands south of the Caspian Sea, and its development goes back to hundreds of years. It was used to supply water for rice farming while no pump was available and constant irrigation was needed during the summer growing season. Besides water supply reservoirs in the very flat plains

of the region, Abbandans were always a reliable source of protein for local farmers. Therefore, Abbandans used to play a crucial role in supporting biodiversity and the restoration of the local ecosystem. Although part of these wetlands has been destroyed or degraded, many are still operational, mainly on the city's outskirts. The Gole-Niloufar wetland is probably between a few of those that were left inside the cities, intact and healthful. In the beginning, farmers only used this wetland to irrigate rice and to farm fish. However, since 2017, with the partnership of Babol municipality, it has been restored and allocated as an urban recreation center. The location of the Gole-Niloufar wetland and its inlet creek and outlets are shown in Figure 2.

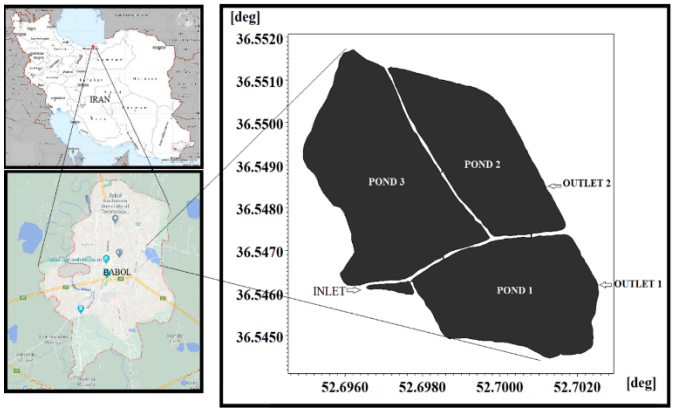


Figure 2. The location of the Gole-Niloufar wetland in the north of Iran and its inlet and outlets

This wetland is composed of 3 ponds that are connected from the below. The wetland's surface is covered with Lotus during the growing seasons, and Phragmites australis also grows in the ponds, which are periodically trimmed. The wetland has one inlet from Aqaroud creek and some outlet pipes; two are opened during growing seasons to discharge water into downstream farms (Figure 2). The diameter of the outlets and ponds connecting pipes is 50 centimeters. A spillway and floodgate control the flow rate at the wetland entrance point. The water's inflow in different seasons –except for special flood events or outflow from upstream- is not much variable due to the flow control for recent recreation purposes. Approximately the same inflow is discharged from the wetland to irrigate the surrounding lands in spring and summer.

The wetland is located in a densely populated area with high human activities and receives domestic sewage from the upstream. A settling pond has been installed at the entrance of the wetland to filter out heavy suspended solids and floating garbage. Due to the wetland's long retention time (about 20-60 days), the incoming contamination is partially treated, especially in the growing seasons. So, the wetland showed a high ability to purify the incoming pollution from Aqaroud Creek. As a result, the turbid and gray water of the inlet becomes clear while leaving the wetland. Due to the presence of Lotus and Phragmites australis, carbon is highly stabilized and fixed in the wetland. The floating plants also uptake nutrients (phosphate and nitrate).

In enclosed and shallow water bodies like wetlands, wind is a crucial factor to create flow at the water surface and depth. Wind-driven circulation is often sufficient to keep the water column well-mixed. Wind data with appropriate temporal and spatial resolution together with the air temperature, evaporation, and precipitation data were obtained from nearby synoptic station (Qarakhil station). The station is located 12 km from the wetland and is the closest synoptic station.

Wetland bathymetry, inflow rate, and velocities at the inlet and outlet were collected from the field measurements. Figure 3 shows the bathymetric map and computational grids for this wetland.

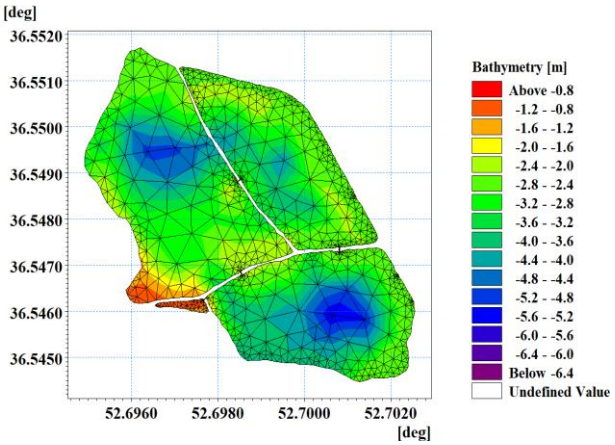


Figure 3. Bathymetric map and computational grids of the Gole-Niloufar wetland

3.1. Calibration process

Hydrodynamic model

More over to bathymetry and computational domain, the hydrodynamic module requires meteorological data and initial and boundary conditions for water level, discharges, and velocities. Infiltration condition, solar irradiance and sink and sources are other important features that need to be defined for the model. Due to the heavy clay soil of the wetland floor, the infiltration was ignored. Figure 4 shows wind speed and direction for Qarakhil station in the summer months i.e. June, July, and August. External forces like the wind will change the hydrodynamic structure of the wetlands. Based on the existing conditions (soil type) and suggested range, bed roughness (K_{dF}) is assumed to be 0.05 in the hydrodynamic model [25].

The effect of wind on surface currents for three periods of high wind was investigated for the performance evaluation of the hydrodynamic model. Wind direction and speed were compared to the resulting velocity in the ponds. Figure 5 shows that the model was properly able to simulate the effects of wind on the surface current. For example, in Figure 5a for the wind maximum speed, 7 m/s, flow also reaches

its maximum (0.225 m/s) at the wetland's surface. The closed boundaries in the wetland lead to the formation of a current on the deeper parts. Therefore, boundaries force surface currents to move downwards and generate weaker currents in the opposite direction. In closed lakes and water bodies, wind is not the only force that produces currents. The other forces are momentum due to flow inlet and changes in temperature and density. These forces, however, were found to be uninfluential due to the low flow rates at the inlet and the wetland's freshwater and non-freezing conditions.

For the flow model validation, floating objects were released at the pond's surface on different occasions, and their movement was tracked visually for some hours before any modeling started for that period. Good agreements were observed later comparing field observations and the results of hydrodynamic simulations. The sensitivity analysis also indicated that the model is sensitive to wind speed and direction changes, and these parameters are the most effective in flow hydrodynamics in the wetland.

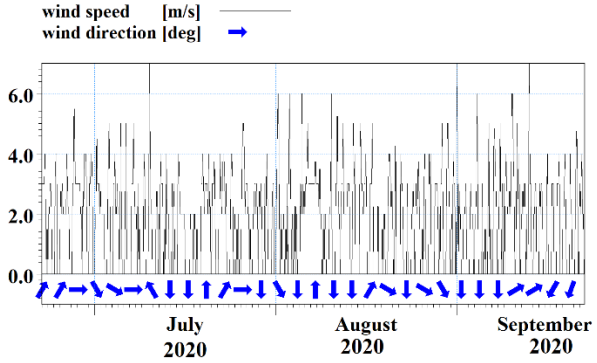
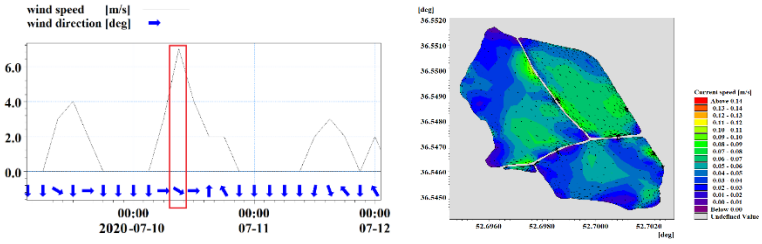
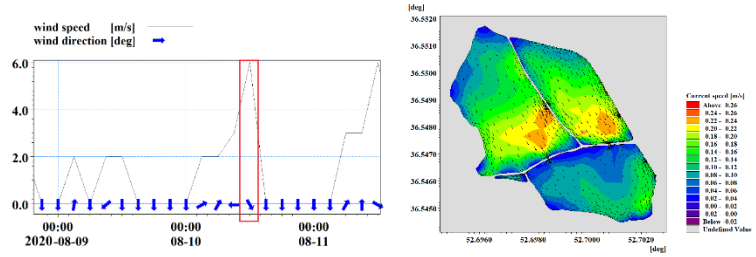


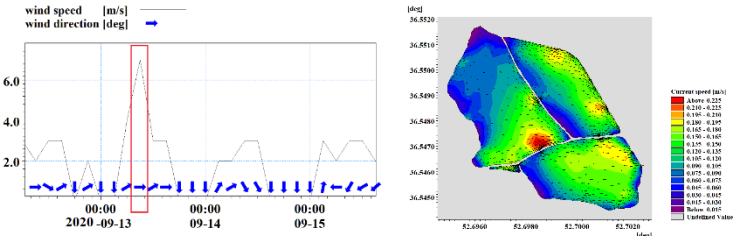
Figure 4. Changes in wind speed and direction during the 2020 summer months, Qarakhil Station



a) Time step 139: 9/7/2020 at 9 o'clock



b) Time step 396: 10/8/2020 at 12 o'clock



c) Time step 667: 19/9/2020 at 9 o'clock

Figure 5. Wind speed and the resulting surface current in three periods of high wind in the wetland-Pond1

Ecological model

To calibrate the ecological model, BOD_5 concentration was measured at the inlet and outlet of pond 1 at every other day for one month during the summer of 2020 (Table 2). Regarding no changes in water level, the wetland hydrodynamic condition assumed steady state, and the ecological model was calibrated for the natural conditions of Pond 1. Wetland field conditions on Day 1 were set as the model's initial conditions. The coefficients used in the kinetic of each pollutant are critical factors for ecological modeling. Performing different coefficients for the degradation in the proposed ranges, eventually K3, θ3, and HS_BOD were determined equal to 0.2, 1.02, and 0.128 to reach the closest to field observation in the process of BOD_5 calibration. Up to 90% similarity was observed between the results and field measurements using the aforementioned coefficients.

In the sampling month, BOD_5 concentration at outlet 1 changed between 8.09 to 11.12 mg/l. The numerical model calculated BOD_5 concentration at the end of summer equal to 11.45 mg/l in outlet 1 (Figure 6) while the observed value in the field was 11.12 mg/l. Thus, the model prediction was quite close when validated with the field data (Figure 6). To make a long story short, the kinetic of Coliform, Nitrate, and Phosphate in the model was calibrated using the same procedure with the lower sampling frequency. The final coefficients that were employed in the equations above are listed in Table 3.

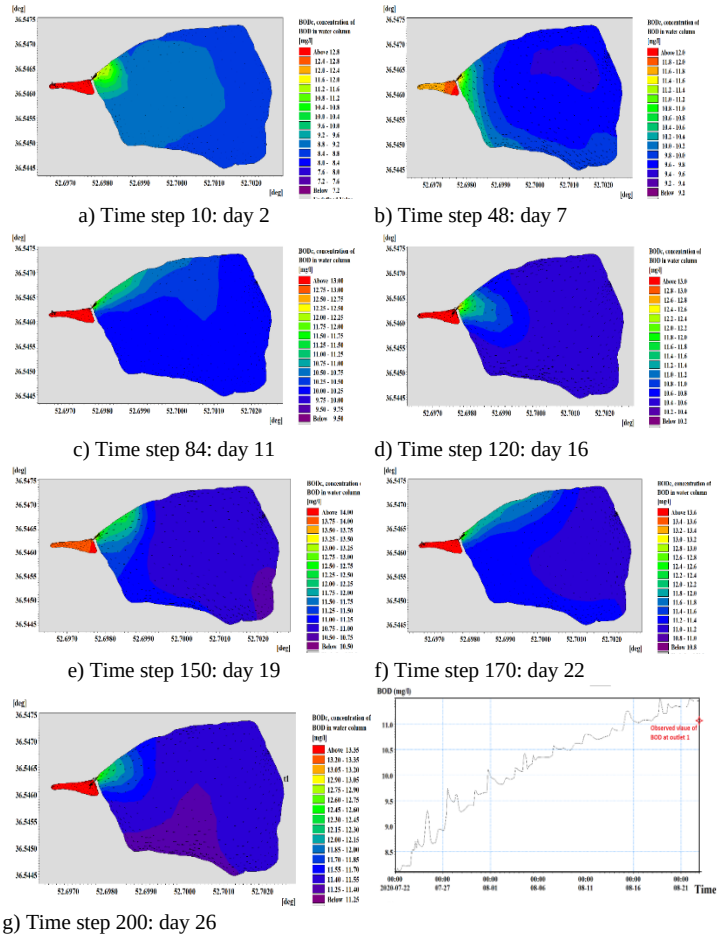
Table 2. The observed values for BOD_5 in outlet 1 during one-month sampling in summer 2020 (mg/l)

Days	Q (m^3/s)	BOD_5 at inlet	BOD_5 at outlet
day 1	0.025	12.078	8.091
day 3	0.0225	13.188	9.03
day 5	0.0246	13.884	8.94
day 7	0.024	13.545	9.53
day 9	0.031	11.78	8.807
day 11	0.0223	13.476	9.622
day 13	0.022	13.242	9.93
day 15	0.022	12.99	10.024
day 17	0.022	13.2	10.41
day 19	0.023	13.386	10.12
day 21	0.026	14.04	10.513

day 23	0.0244	13.9	10.52
day 25	0.0242	13.85	10.89
day 27	0.0235	13.71	10.85
day 29	0.0221	13.44	11.12

Table 3. The proposed coefficient for the equations of processes

Coefficient	Magnitude	Coefficient	Magnitude
k	0.68	K_{df}	0.4
θ_1	1.6	K_{dt}	0.5
K_3	0.2	R_1	20
θ_3	1.02	R_2	0.152
K_4	0.5	HS_BOD	0.128
θ_4	1.088	HS_nitr	1.9
K_5	0.5	HS_SOD	0.7
θ_5	0.5	HS_PO_4	0.065
K_6	0.5	Y_1	1.5
θ_6	1.16	Y_2	1.2
P_{max}	Spring= 50 Summer= 100	Y_{BOD}	Spring= 0.1018 Summer= 0.1008



a) Time step 10: day 2 b) Time step 48: day 7

c) Time step 84: day 11 d) Time step 120: day 16

e) Time step 150: day 19 f) Time step 170: day 22

g) Time step 200: day 26

Figure 6. BOD's distribution at the wetland's surface and BOD_5 changes at outlet 1 for the sampling month in summer 2020

4. Results

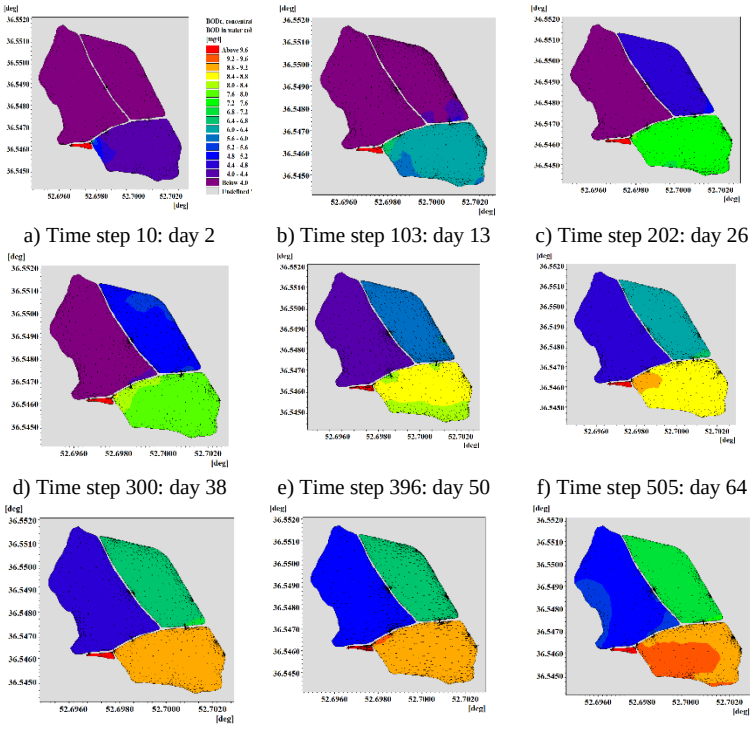
Following the calibration process, the ecological model was run for two scenarios i.e. only the summer season, and next, spring and summer together. These periods were identified wetland growing seasons with the maximum dynamics. For each series of simulations, field observations were made to find the required data, including the inflow rate, discharge values, and velocities. Wetland inflow was measured equal to 0.153, 0.157, 0.273, and 0.217 m^3/s for spring, summer, fall, and winter. Based on the observation made, the water level was found not to change significantly (almost constant) during the spring and summer seasons. The coliform count, BOD, and nutrient concentrations at the inflow and outlets were measured by sampling in different seasons of 2021. For this purpose, a black bottle of 300 ml was used to collect the water sample. The bottles were sealed and sent to a local laboratory for analysis on the same day. Using the standard methods (Rice et al. 2012), BOD meter, MPN technique, and spectrophotometry the concentration of BOD, coliform, nitrate, and phosphate in the sampling water were determined. The obtained results are shown in Table 4. Also, for the numerical simulations, time intervals equal to 3 hours and 735 timesteps, equivalent to one season, were set for each run.

For the first scenario, the initial condition for concentration was set equal to the field observation at the beginning of summer while in the second scenario, two consecutive seasons, i.e., spring and summer, were simulated with the data of the field that has been modified during the run. In the second scenario, the model has warmed up in the spring season and the data at the end of spring were used as the initial conditions of summer. For verification, results were compared to the field data at the beginning of summer and fall. In the case of only summer simulation, the results were lower than field measured concentration while they were closer to the field data in the second scenario. Therefore, simulations for two consecutive seasons i.e. spring and summer were selected as the case with better accuracy. Figure 7 shows the distribution of BOD_5 concentration at the surface of the wetland for this scenario in summer 2021. As exhibited in the figures, BOD_5 decreases in the wetland while water moves away from the inlet point. In outlets 1 and 2, BOD_5 gradually increases up to reaching maxima at the end of summer. According to our numerical results, shown in Figure 8.a, BOD_5 concentration reached 9.1 mg/l at outlet 1 and 6.9 mg/l at outlet 2 at the end of summer while in the field BOD_5 measured equal to 5 and 3.5 mg/l at this time (beginning of fall season).

Table 4. Total Coliform number, BOD, COD and Nutrition concentration at sampling points in Gole-Niloufar wetland

Fecal coliform			Total coliform		
Inlet	Outlet 1	Outlet 2	Inlet	Outlet 1	Outlet 2

-			25	38	35	Spring
more than 1600	-	-	more than 1600	-	-	Summer
less than 30	less than 30	less than 30	less than 30	less than 30	less than 30	Fall
23	15	7	43	30	15	Winter
COD (mg/l)			BOD (mg/l)			
10	25	25	5.5	14	14	Spring
18	9	9	10	4.9	4	Summer
23	9	6	11	5	3.5	Fall
65	60	55	31	28	26	Winter
Phosphate, PO_4, (mg/l)			Nitrate, NO_3 (mg/l)			
290.14	-		23.66	-		Spring
20	247.37	185.92	4.8	17.94	21.46	Summer
17	38.7	26.9	4	3.5	2	Fall
-	-	-	-	-	-	Winter



a) Time step 10: day 2 b) Time step 103: day 13 c) Time step 202: day 26

d) Time step 300: day 38 e) Time step 396: day 50 f) Time step 505: day 64

g) Time step 590: day 74 h) Time step 667: day 84 i) Time step 735: day 93

Figure 7. The distribution of BOD at surface of the Gole-Niloufar wetland in the summer of 2021

Similarly, the model calculated the extent of changes in pollutant concentrations for total coliform, nitrate and phosphate as shown in Figure 8 b, c and d. For the study condition, coliform concentration was more than 1600 MPN/100 at the inlet point. Figure 8.b shows the changes in total coliform at outlets 1 and 2 during the summer of 2021. According to the existing trends, after increases in total coliform at the beginning of summer it reaches 1402 MPN/100ml at outlet 1 and 869 MPN/100ml at outlet 2 at the end of summer. So the results show a slight reduction in total coliform while the contaminated water flows through the wetland. During the springtime, the load of coliform was low but in summer it grew from 13.75 to 1400 MPN/100ml in outlet 1 and from 21.7 to 870 MPN/100ml in outlet 2.

Figure 8. c shows the dynamic of nitrate removal in outlets 1 and 2. According to these curves, at the end of summer nitrate reaches 6.18 mg/l in outlet 1 and 9.92 mg/l in outlet 2. During the summer, the factors that consume nutrients in the wetland are more active and it leads to distinctive decreases in the concentration of nitrate. Transformation of nitrogenous compounds, heterotrophic respiration, and the consumption by plants and bacterial uptake are the main processes of nitrogen consumption in wetlands. Figure 8.d also demonstrates the changes in phosphate concentration in outlets 1 and 2 in the summer of 2021. According to these curves, at the end of summer, phosphate reaches 29.96 mg/l in outlet 1 and about 56.86 mg/l in outlet 2. Because the plants are fully grown in the summer, wetlands could significantly decrease phosphate concentration in this season. Bacterial activity in the wetland is also at its maximum in the summer which leads to a good removal of nutrients in wetlands.

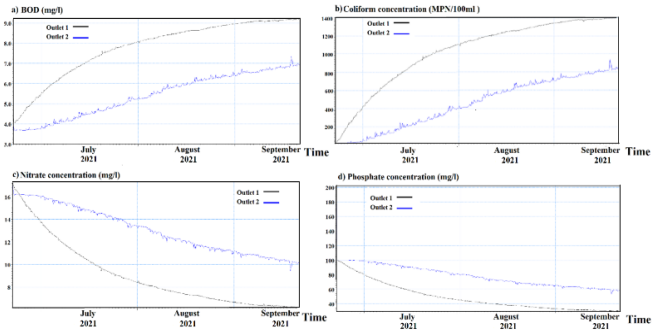


Figure 8. The changes of a) BOD concentration b) total coliform number c) nitrate d) phosphate in Gole-Niloufar wetlands' outlets 1 and 2 in summer 2021

Quality standards

Table 7 shows the water quality standards for different uses based on Iran's environmental regulations [38]. There are Iran's national water quality standards for BOD, COD, and coliform content in agricultural use (raw and non-raw crops), recreation, aquatic life, fish farming, and water supply [39]. Comparing the data obtained from the field sampling and model with the standards, it can be concluded that this wetland was not suitable for cold-water fish farming in spring due to excessive BOD. It, however, was in the range for warm-water fish farming. BOD and COD of water at outlets 1 and 2 were found to be suitable for agricultural purposes. Besides the concentration of organic matter, the microbial load is an important parameter for water's different uses. The amount of fecal and total coliform was relatively low in the spring, so the water can be used for all purposes except drinking. Due to excessive BOD, the water entering the wetland was not suitable for both cold and warm-water fish farming in the summer. Wetland's outflow, however, was suitable for rice

farming in terms of BOD and COD in summer, while was highly contaminated in terms of microbial pollution for direct contact. From the matter of the microbial content, the wetland's water was unsuitable for recreation, in which, people must be prohibited from direct contact (swimming or showering) for whole seasons.

Table 5. Iran's standards for water use in recreation, water supply, and agriculture [38,39]

Fecal coliform	Total coliform		
400	1000	The standard for discharge to surface water	
400	1000	Irrigation standard	
less than 100	-	Crops that consumed raw, sports fields, public parks	Agricultural uses
doesn't have a limit	-	Grains, industrial products, forage, pasture, and trees	
400	2000	Direct	Direct recreational uses
2000	5000	Indirect	
20	50	Water quality standards for drinking water resource	
100	460	Water quality standards for swimming	
COD	**BOD_5**		
60	30	Limitation for discharge to surface water	
200	100	Irrigation	
-	less than 3	group 1*	
-	less than 6	group 2**	
-	less than 3	quality standards for drinking water use	

*Group 1: Ecosystems suitable for cold-water fish
**Group 2: Ecosystems suitable for warm water fish

Discussion

Comparing calculated data from our numerical simulations with the field observations generally showed that the Gole-Niloufar wetland was particularly effective at removing excess nutrients, such as nitrogen and phosphorus, from water while was not that effective on BOD and coliform degradations to the expected extent. Gole-Niloufar wetland acts as a nutrient sink, capturing and retaining nutrients through various processes i.e. plant uptake and microbial processes. However, wetland showed limited capability to break down and remove organic pollutants and mineralize them. Natural treatment and inactivation of pathogens in wetlands depend on vegetation and the physical, chemical, and biological conditions and our findings have shown that the warm climate of summer in the study area will make wetlands to be less effective in that aspect of coliform removal.

Results also show that despite considering various chemical and biological processes, the model was able to only evaluate the generic trends of wetland impact on downstream water quality and could not accurately estimate pollutant concentrations or removal rates. Simulating the fate and transport of pollutants in the wetland is a very complex process and needs very high data resolution of pollutant loadings, environmental conditions, and wetland characteristics. Although the model exhibited good accuracy in the process of calibration when simulated with high-resolution data for one month in pond 1, the results were not same good for the whole season when load changes of contamination during the simulation period were not considered. So, the model was good in ecosystem services modeling to assess the overall benefits provided by wetlands but not reliable for long-term modeling of the complicated conditions of pollutant loadings, complex geometries, and imprecise environmental states. The authors believe that considering other processes that were ignored here like sorption, desorption, sedimentation and precipitation, volatilization, nutrient cycling, and microbial reactions in future studies will help to increase model comprehensiveness and sufficiency.

5. Conclusions

Wetlands and cities have always been in an uneasy relationship and disparate mutual effects. Healthy wetlands are a critical element to sustainable cities, as they can provide a natural defense against extreme floods and can filter water from human-caused activities. In this study, a new template has been developed for the ecological modeling of urban wetlands from the perspective of wetlands' natural ability to retain contaminants and improve water quality. Wetlands are multi-purposed ecosystems that can purify water through flow retention, nutrient uptake, removal of organic matter, microbial degradation, and transformations besides sustaining local biodiversity. In the model, the kinetic of complex biological and chemical transformation of organic pollutants, together with the physical processes of pollutant removal and purification, were disclosed and mathematically simulated. The main objective was to develop a customized template for the modeling of both hydrodynamic and ecological features in urban wetlands. So, a numerical model has developed to solve the equations of state variables for the affecting process. The model has been tested for a wetland in the north of Iran, at the Babol city. The city has several wetlands in its territory and neighborhood and is located only 190 km from the city of Ramsar, where the wetland world-known convention was born. Wetland was first simulated for one month in the summer of 2020, and then the results were compared to the field data for model calibration and validation. To ensure model accuracy, the model was run for 2 seasons, i.e., spring and summer of 2021, each equivalent to 93 days with 735 timesteps. The results showed concentration reduction for BOD, total coliform, phosphate, and nitrate up to 45%, 44.96%, 44.8%, and 43.47%, respectively. The results were found to be reasonably close to the field data. Wetland's ability to improve water quality for the designated applications, i.e., recreation, agriculture, and fish farming was also evaluated by comparing

them to Iran's environmental quality standards for water use. Wetlands water was found to be often suitable for warm-water fish farming and agriculture while it was unappropriated for swimming or recreation purposes.

According to the observations made, it can be concluded that the wetland in its active season (summer) works well in terms of natural treatment and could reduce pollution to a desirable level. This newly developed setup of ECO Lab template can be used for the purification prediction in natural and constructed wetlands while still, degradation kinetics and reaction rate of the pollutants need to be locally investigated.

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Reduction of Air nitrogen oxide by cement composites facade containing nanomaterials

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ABSTRACT

Nitrogen oxides are released in the combustion process of fossil fuels and when combined with some volatile organic compounds in the air, they create dangerous soot in cities. Health experts always warn that exposure to a high concentration of nitrogen oxides causes very dangerous and acute respiratory problems for citizens. The use of nano zinc oxide in concrete to absorb this pollutant in the air reduces the dirtiness of the surfaces and the amount of pollutant in the air. 6 samples each with 3 nitrogen oxide absorption brings the number of statistical population to 18. To perform these tests, UV tests were taken from the samples. This test will be done according to ASTM C642 method. The addition of the highest percentage of zinc oxide compared to other percentages (5%) and 3% nanosilica results in greater density and the highest percentage of nitrogen oxide absorption up to 8.6% of the original sample. As a result, adding a higher percentage of zinc oxide up to 5% and nanosilica up to 3% will be effective in reducing and absorbing about 8.6% of nitrogen dioxide in the air, which can be used in environmental concrete for sustainable development.

1. Introduction

Nanotechnology is not only a technology for creating special spaces, but also seeks to find a way to create an optimal building. Based on the principles of sustainability, every building should be designed in such a way as to

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[4)] professor
[5)] Associate professor

minimize the use of new resources and at the end of its useful life, create a resource for creating other structures, while most of the resources in the world are used to create environments. Artifacts have been used, repairing and improving the condition of current buildings to reduce the effects of destroying the environment has the same importance as creating new structures, which can be developed in the use of recycled materials. . When the access to new resources is minimized, solutions are proposed with which buildings with one use can be converted into multi-functional buildings; But some necessary changes can become the main form of the structure or building. Such as nanotechs, which can be included by changing the materials, changing the use and thus changing the space, or nano coatings and nano robots, which are the simplest results of nano science, can understand their surroundings or show that reaction; Materials that undergo changes due to movements caused by earthquakes or possible stresses; Or sensors that are getting smaller day by day and nanocomposites that have the ability to repair themselves. Reconstruction and modification of materials at the atomic level is locally one of the important engineering issues that laser advances and atomic nanotubes have been developed in line with this goal to force the atom to go back and spend less energy in the positions. Be right on your own. It is even possible to use nanoparticles in the form of nanoparticles (nano patches) to fill them inside. Also, with the construction of new materials in the field of construction technology, we will have structures that, by changing the arrangement of atoms in the nano scale, phenomena such as acid rain, air temperature, and chemical mechanisms during execution and construction will no longer be destructive factors. And the limiter will not be discussed [1].

The direct and substantiated proof of the direct interaction of nanotechnology with architecture are materials (physical products) that generally give different uses to buildings. Such materials create new possibilities for completing and improving the architectural object and thinking about a new form of life [2].

In 1660 AD, John Olin raised the issue that the polluted air of the city of London causes the color change and depreciation of the facade stone of the buildings. At the end of the 18th and 19th centuries, painters and writers dramatically illuminated the soot-filled and polluted urban areas in their works and presented the harmful effects of atmospheric pollution in an interesting way. Recently, efforts have been made to systematically and scientifically study the characteristics of atmospheric pollution and their effects on buildings [3].

Atmospheric pollution means that the characteristics of the air atmosphere change under the influence of human efforts. The efficiency of the natural or polluted atmosphere varies from place to place and in different periods of time. For example, coastal areas usually have more salt in the atmosphere, but dry areas do not. Compounds such as carbon dioxide, sulfuric acid, nitrogen oxides and particles such as soot are among the atmospheric pollutants that have destructive effects on stone facades. Carbon dioxide, which is a well-known greenhouse gas and the cause of global warming, can combine with water in the atmosphere and form carbonic acid, which means that normal precipitation is a weak solution of carbonic acid with a pH It is about 5.6 (for your information, pH equal to 7 is neutral and zero pH gives the maximum amount of acidic property) and if the amount of carbon dioxide in the air increases too much, the amount of acidity of rainfall will not increase significantly. It is the reflection of other pollutants suspended in the air such as sulfur dioxide and nitrogen oxides, which causes more acid rains, so that sulfur dioxide reacts with water in the atmosphere and sulfuric acid (H2SO4) establishes; A process known as (acid rain). Despite this pollutant, the acidity level can increase to 4.5 or even 3.5. Nitrogen oxides suspended in the air also create such acidity by creating nitric acid. The mentioned polluted gases are created as a sign of industrial, commercial and residential activities in urban areas, and recently in rural areas. Carbon dioxide is a by-product of many industrial activities and movements, and is evenly distributed in the British atmosphere. Rains containing sulfuric acid are caused by the activity of power plants and are common in areas where coal is used for heating. By the 1950s, the use of coal for domestic heating had created a thick layer of soot in London's skies. that this type of pollution has had many devastating effects on British stone buildings [3].

Pollutants such as carbon dioxide also affect the climate of the region. It is predicted that by the next 50 years, we will have a temperature increase of 2 to 5 degrees Celsius and the sea level will also increase; Of course, the mentioned figures are averages and there may

be different figures in different regions. It is likely that the southern part of the UK will experience longer periods of drought and reduced seasonal rainfall. Human-made pollution will cause more droughts and storms. Such changes will cause the erosion of buildings as well, but the amount of detail cannot be predicted. For example, the duration and intensity of rainfall may increase due to high wind speed and storminess. At the same time, rainwater may penetrate the stone more. The amount and direction of movement of flowing water due to rainfall will also change. An increase in rainfall will cause water to flow in areas that have not had a history of heavy rainfall, and the large volume of sulfates suspended in the air will turn into sulfuric acid as a sign of pollution with the formation of rain, which will increase the penetration of rain into the rock and The processing of salt solutions and their accumulation in the middle of the stone. When salt solutions are formed, they flow to other places and after drying, salt crystals are formed. The pores can be inserted and the stone can be crushed. Therefore, with the formation of salt crystals, the rate of rock weathering also increases. The amount of weathering, in addition to air pollution, also depends on the ingredients of the rock and weathering records [3].

The prosperity of the population and the process of urbanization has brought an influx of all kinds of pollutants and dangerous toxic substances to the city dwellers all over the world, and therefore scientists are always looking for new solutions - from the invention to the production of catalytic converters to the application Substitute fuels have been used to reduce the emission of pollutants - along with creating better conditions for the lives of communities living in big cities. Swedish and Finnish scientists have introduced the latest invention of the world of architecture to the world. Engineers and researchers of Skansa company, whose headquarters is located in Stockholm, the capital of Sweden, have conducted their recent research activity as part of a Swedish-Finnish project worth one million seven hundred thousand dollars. This project was designed and implemented in order to produce catalytic cement and new concrete compounds with titanium oxide coating for covering and facade of buildings. Titanium oxide is a special chemical compound that is often used in white paints and toothpaste. According to chemists, this substance has unique properties and characteristics, so that when exposed to the ultraviolet rays of the sun, it becomes a highly active and reactive substance. Swedish researchers state that this characteristic of titanium dioxide causes ultraviolet rays to cause a catalytic reaction, which results in the destruction of molecules of various pollutants, including nitrogen oxides. It should be mentioned that nitrogen oxides are released in the process of burning fossil fuels and when combined with some volatile organic compounds in the air, they create dangerous soot in cities. Health experts always warn that exposure to a high concentration of nitrogen oxides causes very dangerous and acute respiratory problems for citizens, although studies have shown that these pollutants can easily and with a rain fall. They are removed from the air. This report adds: The catalytic reaction created in the new building materials has other important properties, so that the reactivity and intense chemical activity of these materials in the vicinity of ultraviolet rays can prevent the adhesion of bacteria and dirt. It prevents on the walls and buildings and causes these pollutions to be easily washed off the walls by a rain.

The by-products formed after the occurrence of this chemical reaction, which is called photocatalysis, are safe. In fact, the type of by-products created during this reaction depends on the type of compounds that enter and participate in the reaction, so that the carbon-containing molecules of the organic compounds involved in this reaction turn into carbon dioxide and They turn into water, while nitrate salts will remain from the molecules of various nitrogen oxides.

For example, we can see stone sculptures in Italy at risk of erosion and air pollution [3] as shown in Figure (1).

Figure 1. Stone sculptures in Italy at risk of erosion and air pollution [3].

Nanosilica can reduce cement consumption, improve concrete quality and increase its efficiency [4, 5].

The incorporation of TiO2 into cementitious composites has been investigated by some researchers. Sanaf et al. (2012) added fractions of different volumes of Nanosilica and Nano TiO2 to the mortar mixture and evaluated the hardened properties. It has been reported that when the content of nanosilica and TiO2 is low, mechanical strength is not significantly affected, but with increasing weight percentage of nanosilica and TiO2, mechanical strength increases by 3% and 12%, respectively [6].

In a study, the effect of using nanosilica (NS) and microsilica mixtures on the mechanical properties of ultra-high performance cementitious composites (UHPCs) is presented.

To do this, two concrete groups with and without silica fume with a ratio of water to fixed cement and fixed cement were designed. Commercial NS used in partial replacement of cement with weight of zero percent, 0.5 percent, one percent, two percent and 3 percent. The results show that among the different contents of NS, UHPC containing 2% NS showed the best results in compressive strength, tensile strength, modulus of elasticity, flexural strength, load handling behavior and rupture energy in 90 days. UHPC samples containing cementitious materials (NS and SF) gave better results than concretes containing only NS. In addition, the effect of 1% NS is approximately equal to 10% SF [7].

In one study, the photocatalytic activity of TiO2-coated self-compacting glass-containing mortars (SCGMs) was investigated in terms of removing air pollutants and inactivating bacteria. TiO2-impregnated glasses were used as controls to compare performance [8].

Nitric oxide (NO) and Escherichia coli K12 were used as air pollutants and bacterial pollutants, respectively. In addition, the weathering resistance of TiO2 coated samples was investigated. Regarding NO removal, it is clear that no significant difference was observed between TiO2 and SCGM impregnated glass, and both showed high NO removal efficiency when using conditions 1 (C1, without weathering) (for EtOH mortar, Up to 14.33 mg per square meter H1).

However, after a period of abrasive weathering, condition 3 (C3, abrasive process), the ability to remove NO from TiO2-impregnated glass samples almost disappeared. In contrast, the ability to remove NO from SCOM with TiO2 coating remains high performance (for EtOH mortar, 8.75 mg / m2 H1). The porosity of the SCGM surface with the coating appears to help maintain the desired TiO2 particles after abrasion. For antibacterial activity, a general inactive action of E. coli removal was observed in TiO2-impregnated glass and SCGM samples within 60 min of UV irradiation.

After the wear process (C3), the inactivation of E. coli in TiO2-impregnated glass is almost negligible, whereas, the concentration of E. coli remaining on the surface of TiO2-coated SCGM is only about 105 to 103 CFU / ml. Dropped. The results indicate that TiO2 is retained in the porosity of the coated SCGM and can still play a role in inactivating E. coli. Considering all the results, it can be concluded that inactivation of photocatalytic bacteria is a more complex process and the results of photocatalytic activity of NO removal can not always be transferred to photocatalytic antibacterial activity. The results of this research are presented in Figure (2) [8].

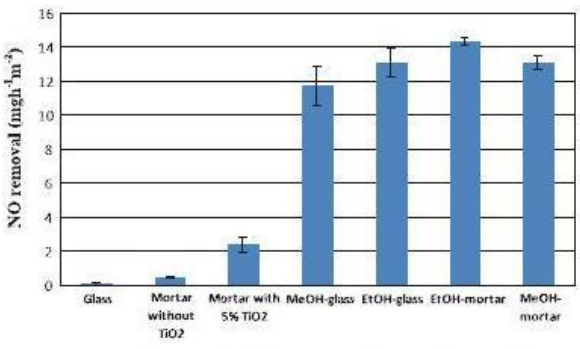

Figure (2) Comparison of NO removal by different samples subjected to UV testing in 60 minutes [8].

In all experiments, a commercial nano TiO2 powder (P25, Degussa) was available and used as a photocatalyst. The size of TiO2 was 20-50 nm, BET with a specific surface area of 15 50 50 m2 / g and ordinary white Portland cement (WC, TAIHEIYO) product of Japanese cement and metakaolin (MK) were used as samples. Recycled glass (RG) from post-beverage glasses was used as a fine material in SCGM. The light green glass bottles are washed and then crushed by a mechanical crusher, followed by a sieve with a particle size of less than 5 mm. Self-compacting glass mortar (SCGM) was prepared by compression of 50 MPa resistance (28 days) using a mixture ratio of 0.8: 0.2: 0.2: 0.4 (WC, MK, RG, water). In order to evaluate the effectiveness of TiO2 on the photocatalytic activity of mortar, a amount of 5% (cement mass) of nano TiO2 in the complete mixture was used. The mixing schemes used are given in Table (1) [8].

Table (1) Mixing schemes used to test water absorption percentage [8].

Sampels	Status of projects
Mortar without TiO2	Self-compacting glass mortar (SCGM) without TiO2
Mortar with 5% TiO2	Self-compacting glass mortar (SCGM) with 5% TiO2
Glass	Reference glass without TiO2 coating
EtOH-glass	TiO2-impregnated glass suspended in ethanol and glycerol solution at 450 ° C for 120 min
MeOH-glass	TiO2 impregnated glass suspended in methanol solution at 60 ° C for 120 min
EtOH-mortar	Mortar impregnated with TiO2 suspended in ethanol and glycerol solution at 120 ° C for 120 min
MeOH-mortar	Mortar impregnated with TiO2 suspended in methanol solution at 60 ° C for 120 minutes

In an article to determine the effect of cement containing titanium dioxide, nanosilica and the presence of waste glass in cement mortar for its potential application in self-cleaning facades.

Studies have shown that waste glass can be a successful alternative to sand, especially when part of it is mixed with sand. In addition, a positive effect of nanomaterials was observed due to self-cleaning and mechanical properties. Visual observation of rhodamine B discoloration on cement mortar surfaces showed that the presence of waste glass did not affect the cleaning properties of titanium-containing commercial cement. The use of waste glass in general can neutralize the negative effect of high nanosilica water demand. Hence, nanosilica can be successfully incorporated and embedded in cementitious composites without the aid of any additional material. The use of nanosilica improves the cohesion between the glass aggregates and the cement due to its paste property and consequent compaction of the cement mortar structure. The use of 3% by weight of nanosilica significantly increases the flexural and compressive strength of specimens containing waste glass materials [9].

The importance of corrosion protection of reinforced concrete in aggressive and corrosive environmental conditions and protection against water absorption has led to the allocation of 150 publications of the Program and Budget Organization entitled Environmental Concrete Structures (translated by ACI 350-89) [10].

2. Methods

6 samples each with 3 tests of nitrogen oxide absorption brings the number of statistical population to 18. To perform these tests, UV tests were taken from the samples. Testing will be done according to ASTM C642 method. Table 1 shows the plans related to the mixture of this study.

In this article, a set of devices were used to measure the concentration of nitrogen monoxide. According to Figure 3, from the left, they are:

1- Data logger device or sensor measurement system that can measure nitrogen monoxide gas and record it in its internal memory and then transfer it to the computer.

2- The second device is a nitrogen monoxide gas generator. The concentration of nitrogen monoxide can be adjusted. The gas is transferred to the third device by the blue hose.

3- The third device has an inlet hose and a free outlet hose. The gas output from the second device is at a constant flow of 3 liters per minute. The gas concentration (PPb) is 2000.

We place a concrete sample with dimensions of 10 x 10 cm and a height of 16 mm in the third machine. The tested plans are according to Table 2. LED lamps shine on the surface of the samples. Inside the body of the third device, sensors for measuring the concentration of nitrogen monoxide were installed. The lamps above the sample are a combination of LED and normal lamps, it includes a wide light spectrum of 50 watts, 25 watts of which is UV and 25 watts of which is the visible spectrum, and we have this radiation on the surface of the sample in a combined form.

The measurement is done in a period of 3 minutes and usually at the same time we reach the stability of the final result for each sample, which results are according to Tables 3,4 and 5.

Table 2. The Mix designs and Replacement percentage in the tested designs

Mix designs	Replacement percentage				
	Cement content (kg/m^3)	Nano Zn	Nanosilica	Water	superplasticizer
1	800	0	0	0.4	0.004
2	800	0.025	0	0.4	0.004
3	800	0.05	0	0.4	0.005
4	800	0	0.03	0.4	0.006
5	800	0.025	0.03	0.4	0.007
6	800	0.05	0.03	0.4	0.007

Figure 3. Device for determining the amount of reduction of nitrogen oxide adjacent to the samples in the tested designs

Figure 4. Device for determining the amount of reduction of nitrogen oxide adjacent to the samples in the tested designs

4

Figure 5. The input of nitrogen oxide gas from the tank to the surface of the sample in the test device to determine the reduction of nitrogen oxide adjacent to the samples in the tested designs.

Figure 6. The output and input of nitrogen oxide gas from the tank to the surface of the sample in the test device to determine the amount of reduction of nitrogen oxide adjacent to the samples in the tested designs.

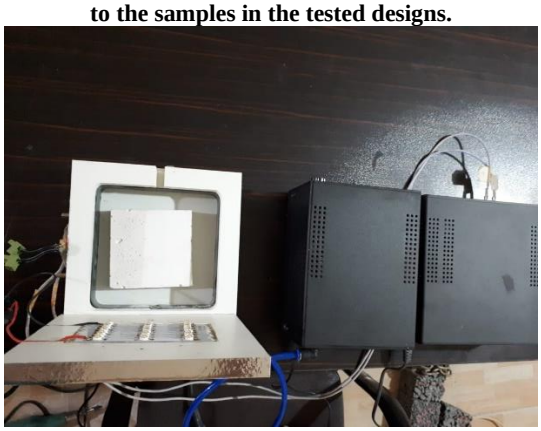

Figure 7. Placing the concrete sample in the device to carry out the photocatalytic activity of concrete to absorb nitrogen oxide gas around the surface of the sample in the test device.

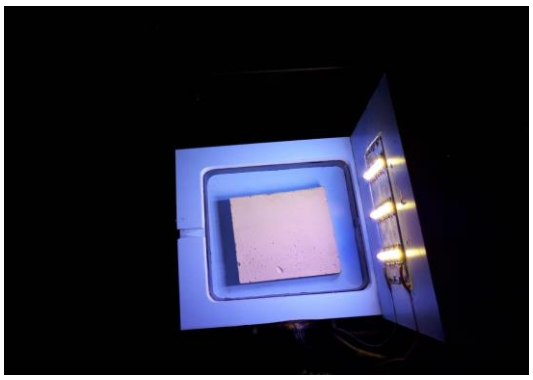

Figure 8. Radiant light spectrum on the surface of concrete to carry out the photocatalytic activity of concrete to absorb nitrogen oxide gas around the surface of the sample in the test device.

Figure 9. Starting the test for the radiant light spectrum on the surface of concrete to perform the photocatalytic activity of concrete to absorb nitrogen oxide gas around the surface of the sample in the test device.

3. Results and Discussions

Table 3. The density and amount of nitrogen oxide adjacent to the samples in the tested designs

Mix No.	Density(kg/m3)	Density (kg/m3)	NO Base Conc. (PPb)
1	1901	1896	2005
2	1908	1905	2001
3	1911	1917	2003
4	1925	1933	2004
5	1936	1941	2000
6	1945	1940	1997

Table 4- Nitrogen oxide rate of the samples in the tested plans

Mix No.	NO Base Conc. (PPb)	Output NO Conc. (PPb)		
		Specimen 1	Specimen 2	Specimen 3
1	2005	1896	1888	1889
2	2001	1893	1895	1889
3	2003	1884	1887	1881
4	2004	1759	1762	1765
5	2000	1760	1752	1753
6	1997	1746	1750	1741

Table 5- Nitrogen oxide absorption percentage of the samples in the tested designs

Mix No.	NO Removal (%)	NO Removal (%)	NO Removal (%)
1	5.4	5.8	5.8
2	5.6	5.5	5.8
3	6.0	5.9	6.2
4	12.3	12.1	12.0
5	12.2	12.6	12.6
6	12.9	12.7	13.2

The addition of the highest percentage of zinc oxide compared to other percentages (5%) and 3% nanosilica results in greater density and the highest percentage of nitrogen oxide absorption up to 8.6% of the original sample. As a result, adding a higher percentage of zinc oxide up to 5% and nanosilica up to 3% will be effective in reducing and absorbing about 8.6% of nitrogen dioxide in the air, which can be used in environmental concrete for sustainable development.

4. Conclusions

Considering that cement base materials cover a wide range of life and urban communities, it seems that in addition to the function of encapsulating nanoparticles by the cement matrix, it can be used as a potential for removing organic pollution in highways and underpasses with The high wall, which causes the trapping of nitrogen oxide polluting gas resulting from the combustion of fossil fuels, benefited a lot. In this article, 6 designs with 3 nitrogen oxide absorption experiments bring the number of statistical population to 18. To perform these tests, UV tests were taken from the samples. This test was performed according to ASTM C642 method. The results show that by adding nanosilica from designs 4, 5 and 6, compared to the first 3 designs, the percentage of nitrogen oxide absorption does not change much. In schemes 4 to 6, it was observed that the addition of nano-zinc oxide in a constant ratio of nano-silica increases the absorption percentage of nitrogen oxide.

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Survey of Marine Debris on the Southern Coasts of the Caspian Sea and Pattern of Spreading

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ABSTRACT

One of the major environmental problems in the southern coasts of the Caspian Sea is that the marine and coastal debris is being deposited and accumulated due to industrial, urban and tourism activities. Study, sampling and analysis on the type, size, amount and origin of human-made (anthropogenic) waste in the coastal areas of this sea can be very effective in implementing management, cultural and informative programs to reduce marine environmental pollutants. Investigation on marine litter distribution under impact of seawater dynamics was performed for the first time in this research. The rate of entry and distribution of marine and coastal pollutants and wastes, which are mainly of urban, tourist and hospital origin, has multiplied on the southern shore of the Caspian Sea in the last decade. According to the results, the two most important sources of hospital waste in the coastal areas are Tonekabon and Mahmoudabad. In this case, the effect of dynamic parameters of seawater such as flow (with speeds of up to about 1 m/s) and waves, as well as the flow of rivers leading to the shoreline are also influential factors in the distribution of marine litter in the region. Marine litters in the southern coastal region were transported from west to east by the shallow waters of the southern Caspian Sea. In other words, the marine debris density has been observed more in the eastern part.

1. Introduction

One of the newest environmental problems in the coastal communities is the distribution of marine litter and consequently, spread of pollution in swimming areas, along the coastline and seawater adjacent to the coast. Marine and coastal debris is mainly pronounced as one of the utmost pervasive marine environmental pollution problems, for the reason that it is observed from the most remote beaches in the world to the most visited and accessible beaches [1]. The spread of marine debris not only pollutes the environment, but also affects the tourism industry and fishing economic activities. For many years, marine debris has been known and considered and recognized as a marine pollution and problem [1-3]. Due to the increase in population and the growing trend of waste production, environmental problems are still observed [1]. Marine litter or marine debris is described by United Nations Environment Program (UNEP) as discarded or waste persistent material in the coastal and marine areas [4]. Marine debris is any produced or processed waste material that enters from any source to coastal zone or marine environment [2,3,5-7]. The accumulation of debris, especially types of plastic in the world's oceans and seas is a main concern now and amount of marine debris shown a steady increase in time [2,3,5,8-11]. Marine debris has both marine and coastal sources. Sea-based waste is mainly the result of offshore activities such as shipping, sailing, fishing, and aquaculture, in-sea industries (oil and gas, military). Land based debris remained through tourists, local people, industry, construction, agriculture activities, which are mostly not decomposed and marine currents transfer them to other areas. Ocean current patterns, tides, and the proximity to urban, industrial and recreational areas, shipping lanes, and fishing grounds are affecting the Floating Marine Debris (FMD) composition, distribution, and density [2,3,5,8-12]. In most studies

reported that a huge portion of marine debris has land-based sources [13-14]. Recently, due to increasing the human societies on the coasts and developing human activities along the boundaries of the seas and oceans, the production and dispersal of anthropogenic litters on the marine and coastal environments has extensively increased. Distribution of the beach and marine litters can act as a huge threat for the health of the world's seas and ocean environment [4,13]. All of mentioned pollutants including beach and marine debris introduce an important threat for marine biodiversity processes and coastal environment [13,15-17]. The distribution of floating debris in the ocean depends on its mass, floating and stability [18] also are distributed due to winds and ocean currents, which scatter. The floating marine debris is reported all over the world's oceans and seas [12,14,19-24]. Based on the literature review, there is no various studies has been carried out on the southern Caspian Sea marine debris. This study is the first work to study on distribution of the marine litter in the southern coastal waters of the Caspian Sea. The main goal of this research is to identifying significant litter issues on coastal and marine environments of the Caspian Sea.

2. Methods

2.1. Study Area

The study area covers the coastal areas and waters of the continental shelf on the southern border of the Caspian Sea (Fig.1). The mentioned area includes the mouths of large rivers such as Sardabroud, CheshmehKileh, Chalosroud and Babolroud. Monitored area is located between N36.6˚ and N37˚ latitude and between E47.7˚ and E53.2˚ longitude. The study method was based on field studies, coastal sampling and laboratory analysis at the Caspian Oceanographic Center (subdivision of Iranian National Institute for Oceanography and Atmospheric Science (INIOAS)). Physicochemical parameters of coastal waters were collected using Ocean Seven profiler device.

2.2. Coastal Sampling

The project implementation method was based on two methods of field operations (Oceanography department) and laboratory services (Environmental Laboratory in the Caspian Sea Oceanography Center) and using the facilities and knowledge available at the National Institute of Oceanography and Atmospheric Sciences. NOAA and CSIRO standard methods were used for sampling and analysis of results. Data of each site was counted and photographed along 4 transects. There was a distance of 200 to 250 meters from each other over the shoreline. The length of transect designed around 1000 meters from the shoreline. Some of the collected waste was transfer to the laboratory for more analyzing.

During the marine debris samplings, the following data were collected: time of record, GPS positions, sea conditions (wind direction and speed, swell, and visibility), and sighting effort (1=active sighting or 0= inactive sighting) also use binoculars to search for debris. As this is the first effort to analyze floating marine debris within Caspian Sea waters, the gathered results in the study area are important. Samples collected in areas near to Tonekabon, Nowshahr, and Amirabad ports. These samples were sent to laboratory, separated, counted and analyzed. During sampling, the boat was moving at a speed of 8 knots and its position was logged using a GPS system.

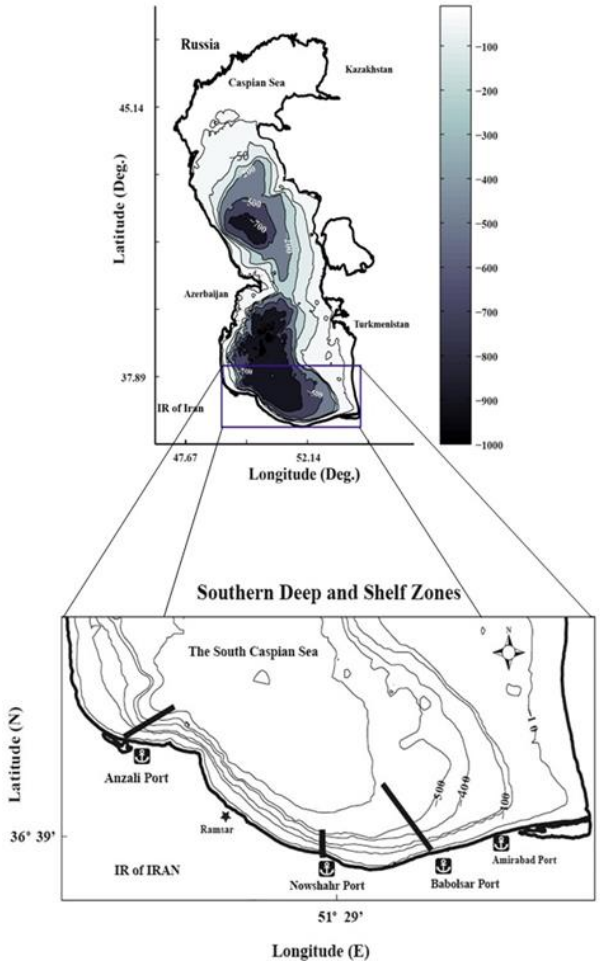

Figure 1. The southern basin of the Caspian Sea

The duration of sample collection was between 90 and 130 minutes. After each sampling all debris from bag were collected. The first monitoring of coastal waste in the southern boundary was carried out on the three selected sites in Mazandaran province. In addition, the data and samples of marine litter collected from four transects with 250m distant from each other. The length of transects was considered around 1km from the coastline. In order to collect the marine debris samples in the coastal waters a manta trawl was designed and used. The rectangular mouth of the trawl

dimensions were 80 cm height and 100 cm width. In addition, the net mesh size was selected about 3 mm with two wings for floating balance. The manta trawl was fixed at the end of the vessel. Following data were collected when FMD was sighted: time, GPS position, type, size, source, color, radial distance and angle (data taken with binoculars).

3. Results and Discussion

This research is based on a new method which is a combination of measurement (and evaluation of the dynamic pattern of the area) and environmental sampling and monitoring. Based on the field observations in recent years, marine litter has become one of the environmental problems of the Caspian Sea due to lack of proper waste management, irresponsible tourism, illegal or unauthorized construction, lack of proper management of rivers and coasts. In the southern coast of the Caspian Sea, litter has two sources: shallow waters over the continental shelf and coastal areas. Waste with marine source is mainly the result of offshore activities such as shipping, boating, fishing, aquaculture, offshore industries (oil and gas, military) and land source (offshore) mainly through tourists, indigenous peoples, industry, construction and They are instruments, agriculture, etc., which are mostly un-decomposed and remain the same, and the sea currents transfer them to other areas.

In recent decades, the study of marine litters has become a very important issue. Such studies are necessary to understand the effects of the distribution of such marine litter on living organisms and to assess the damage to the marine ecosystem in the short and medium term. Marine litter is man-made and used items that are dumped directly into rivers or the sea, or indirectly into the sea through sewage, rivers, winds, storms, or water currents. Marine and coastal litters pollute the environment for years, moves with the wind and enters rivers and water canals, resulting in clogged waterways and in many cases due to the static water reproduction of insects. Seawater pollution can play a role in the spread of infectious diseases, regardless of changes in the flora and life of the sea itself. In addition, visual pollution caused by marine litter can play a significant role in tourism. The transport of floating marine debris (FMD) by ocean currents is important in environmental science and oceanography because they can act as a trace of ocean currents, and conversely, our knowledge of ocean currents can help us find Contaminated pathways [25] as well as the study of invasive species [26] help. Extensive studies of large-scale FMD have also been performed in the North Pacific [25]. Another study examined the different effects of wind and water currents as well as recreational activities on large wastes on ISLE beaches. Distribution of this waste in the coastal area using D-GPS and aerial photography by drones and the results of this analysis showed that the characteristics of the bed and the presence of vegetation are both major factors influencing the distribution of this waste [27]. Winds, ocean surface currents and other factors cause the destruction of lightweight materials such as some plastics in the water and they float, and some of them are pressurized by wind as well as surface currents. These materials are known as windy.

The distribution of floating debris in the ocean depends on their mass, buoyancy, and stability (Moor, et.al, 2001), and their distribution is due to the influx of wind and ocean currents, which scatter them [28,29]. So far, no study has been done on Caspian Sea marine litter and the effect of surface currents on them, so this project tries to fill this gap and study the effect of these currents on marine litter in the Caspian Sea. So that the results It should be used for managerial purposes. Tonekabon site with manipulated sandy beach conditions for tourism was about 2000 m long. Marine litter including fishing gear abandoned in the water and some litter of plastic origin were found. Nowshahr site had rocky, sandy and untreated coastal conditions and the length of the beach was about 500 meters and most of the waste was local waste. At Babolsar coast in the eastern part of the border, large amounts of wooden pieces and ionolites were brought to shore by water flow. Remains of wood and burnt waste from the activities of tourists along the coast were visible. Due to the continuous rainfall area and river discharge in the sampling, a large amount of waste was observed. According the high rains and floods of the local rivers the movement and collecting the land-based wastes in the river mouths was increased.

The obtained results showed in figures 2-6. Figure 2a shows the percentage of total waste by material on each site. Amount of plastic waste covers a larger volume, which was at highest levels in Amirabad and Nowshahr sites. Figure 2b shows the amount of non-plastic waste by material at each site, of which glass, old clothes, rubber, metals were the highest in terms of amount, respectively. Figure 2c shows the amount of plastics in the sites in question that the type of Styrofoam in Nowshahr site was the most observed. The results showed that the amount of Styrofoam waste was due to construction. In addition, soft plastic waste was more than all the waste in each site in Nowshahr site.

According to the results, the highest percentage of Styrofoam type waste was found in Tonekabon site. Also, the amount of soft plastic was the most in Amirabad site. Waste sizing according to the NOAA standard (2013) used in this project is zero to 0.5 mm (micro), 0.5 to 2.5 cm (meso), more than 2.5 cm (macro), respectively.

The highest amount of micro size was observed in Amirabad and Babolsar sites. At all sampling sites, the amount and percentage of light-colored and colorless waste was more than dark-colored waste.

The amount of waste by marine or land source is shown in Figure 4a. The results of the analysis show that most of the waste at all sites was of land originated.

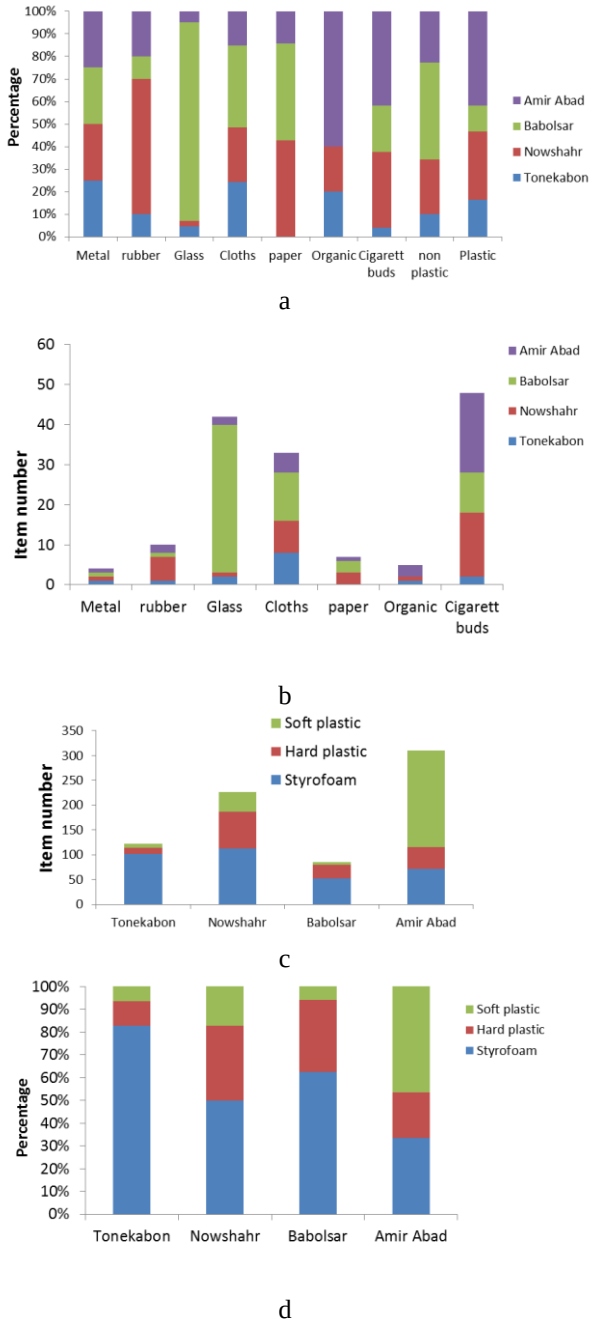

Figure 2. Waste quantities by material and type in different sampling sites in the southern coast of Caspian Sea

Figures showed the amount of waste per surface unit. The results show that the volume of plastic is higher than other types of waste in the study area. According to the fact that so far there was no documentation of the amount and type of marine litter in the Caspian Sea, the results of sampling and also the reports of local trustees indicate a high volume of litter in the southern Caspian Sea, especially plastic in micro and meso sizes, which is very dangerous for marine life.

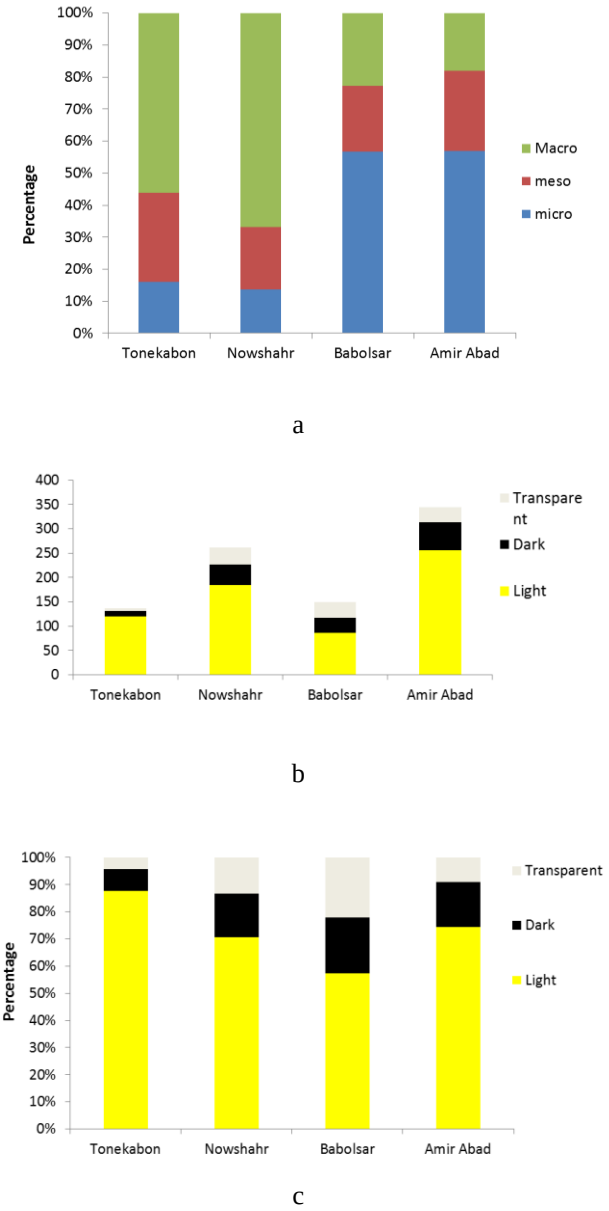

Figure 3. Evaluation of marine debris size in sampling sites of the southern Caspian Sea

In addition, the presence of sewage, unpleasant odor around Nowshahr and fish losses (which were observed on the water surface) even without laboratory results can indicate the large volume of urban and rural sewage entering these coastal areas. Coastal area management and marine environmental studies must be done. Large amounts of wood and felled trees from the previous rainfall and storms were

observed in the area during the sampling. Abandoned or proven fishing nets and equipment were also being a large part of the coastal waste that was observed in the sampling area of this project.

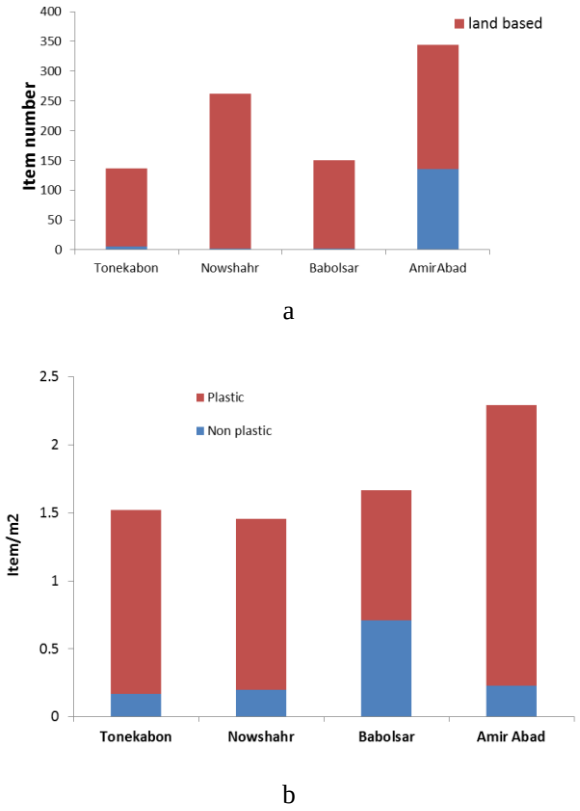

Figure 4. Marine and land litters in different sampling sites in the study area

Hospital waste, respiratory sprays and used syringes were among the wastes that were sampled as well as both coastal and floating debris. Based on the obtained samples, it can be understood that a large amount of waste is caused by restaurant activities (including organic materials and disposable tablecloths, plastic spoons and forks). It seems that due to the recreation centers in the tourist area, it is necessary to implement more serious management of coastal and tourist areas. In general, the large volume of plastic indicates the excessive and uncontrolled use of this material. Due to the dangers of spreading pollutants in the coastal and marine environment, it is recommended to take immediate action to address this problem by informing and increasing public culture.

The results of sampling showed that marine litters (soft plastic) by micro and meso sizes have mainly been observed in the eastern part of the region. However, macro size marine litters (hard plastic) have mostly been observed near areas of Nowshahr site. The analysis of the results raised the hypothesis that the soft and smaller-scale seawater litters can travel long distance by the current along the coast. The origin of the most coastal based and marine litters was tourist activities, which gathered in the middle and western parts of the southern shores (Tonekabon-Nowshahr).

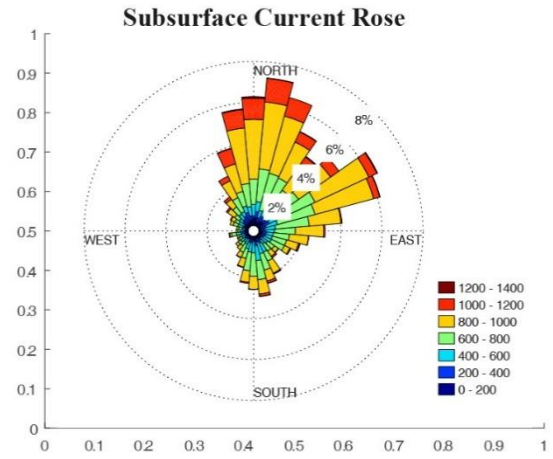

Figure 5. The general pattern of current in the southern coastal waters of the Caspian Sea

To date, very limited studies have been performed in the Caspian targeting to evaluate the quantities, composition and spreading of marine debris. Based on the scuba diving searches at the sampling stations in the coastal waters, it was observed that amounts of marine debris sink to the bottom (such as garbage patches, plastics, wood plats, fishing nets …) and accumulated on the sea bed. In addition, floating plastics and woods accumulated along the shore (Fig.6). The estimations and site monitoring confirmed that the litter in the southern Caspian Sea originates from land-based rather than sea-based sources. Marine debris on beaches in the Caspian originates from tourism and aquatic recreational activities are composed generally of plastics (bags, caps/lids, tire, bottles), aluminum (cans, pull tabs) and glass (bottles). Debris from smoking related activities may account for 40-45% (collected items on sampling sites in the beaches) which is considerably high. In terms of debris floating on the seawater, plastics and woods account for more than 75%. For debris on the sea-bed plastics, glass and woods were principal ranging from 35% to 80%. Fishing related litter including nets prevails in commercial fishing ports and near the mouth of rivers. Enhancing amounts of litter in the Caspian marine environment gives rise to a wide range of commercial and social impacts and harmful environmental effects are often also interrelated. General understanding of the mentioned

influences in the Caspian Sea remains limited. There is little or no consistent information and data on what the exact budgets are. The loss of tourism related incomes due to marine debris has not been estimated in detail.

Figure 6. Photos of sampled marine debris collected in the boat during the field operation in the study area

The chronic problem of municipal and marine litter in the southern shores of the Caspian Sea has become a national threat. This requires a sufficient understanding of the situation to guide an optimal management approach. The spread of waste (urban and hospital litters) in coastal and marine environments of the Caspian causes many problems such as in human health, ecosystem life (health of migratory birds of Siberia, fish productivity) and coastal management aspect. Recently (during January and February 2021), a large number of migratory birds in Gorgan Bay and Miankaleh Wetland have died due to water botulism. Pollution of the seas has many destructive effects on humans and other living things. The most important impact of waste on wildlife has been reported through ingestion by birds and aquatic animals as well as entering the food cycle in the waters. The erosion of plastic waste by aquatic

animals and seabirds and the entry of micro plastics due to incomplete decomposition of waste in the marine food chain annually kill thousands of species of aquatic animals such as seals, turtles and seabirds. Involvement of organisms in plastic waste and their suffocation is also a more deadly risk [30].

Land based debris originated from beaches, local rivers (see [31-33]) and coastal villas while sea-based litters originated from commercial ships, harbor activities (such as Nowshahr and Amirabad ports) in the southern region. Depending on the size, composition and also the degree of buoyancy of the waste relative to the physical characteristics of the Caspian Sea water, marine litters travels by wave and current (Fig.6) along the eastward direction or sink on various depths of the continental shelf. According to the results, the two most important sources of hospital waste in the coastal areas are Tonekabon and Mahmoudabad. The effects of marine litter dispersion are so great and varied that review of existing scientific literature suggests that litter-free coastal and marine environments now look like a dream. Among the executive works and management of coastal areas to reduce pollution in the southern border of the Caspian Sea, the following can be mentioned.

- Evaluation of litters sources and transporting ways to the coastal zones
- Marine debris can influence the eco-tourism industry, especially in the southern coast if the Caspian Sea. Introduce the benefits of public efforts to reducing waste
- Introducing benefits use of degradable plastics by the governance and NGOs
- Identification of water sports and tourist areas by municipalities and governorates and transfer of their operation to the private sector
- Organizing incentive programs and increasing the level of public awareness by installing advertising posters to prevent the spread of garbage by swimmers and tourists
- Placing bins in tourist areas and forest parks near the coast
- One of the most effective ways is to encourage people to deliver their renewable waste to beachfront collection centers.
- Promote circular economy thinking in the community.
- Providing coastal and marine waste collection centers and transfer services.
- Trying to keep the beaches clean at all times. Pay money for the collection of debris.
- Change people's behavior and create a nature-friendly ethics.
- Creating financial benefits for coastal waste collectors.
- Offer and consider incentive tax on waste generating by restaurants and beach food courts.
- Require the companies that pollute to pay charges
- Establishment and operation of at least 2 waste incineration plants on the south coast (Sari and Nowshahr)
- Efforts to establish regional cooperation to achieving coastal and marine litter reduction target
- Establish incentive policies and grants for industries to use fewer plastic materials

The entire above-mentioned items can be done and achieved in the southern region of the Caspian Sea. Beach monitoring and coastal surveys in the southern boundary of the Caspian are widely viewed as the simplest method for evaluation of marine debris in the selected sites. It seems that it is the most cost-effective technique and consequently are the most frequently executed. During the last decade there is no significant monitoring of marine litter influences on aquatic environment and biota in the southern region of the sea, but we have started and aimed the scientific efforts and technical foundation to growing it. The use of NGOs and academic research projects for monitoring ingested litter in the Caspian Sea is suggested for enhancing general information and knowledge to decreasing marine debris.

4. Conclusions

Marine and coastal wastes dispersed in the southern coastal areas of the Caspian Sea were sampled, analyzed, and discussed. Also, the type, size, and origin of the collected marine litters were investigated. In the study area, rivers are one of the most important factors for transferring the coastal debris to the shallow water and near the shoreline. Coastal swimming and tourism areas were also some centers of which the waste is distributed in the region. Also, the discharge of the hospital garbage in the beaches of the sea has created many environmental problems. An executive solution for managing the distribution of marine litter along the coast and shallow water is the installation of garbage collection nets across the Chalosroud, Sardabroud, Tonekabon and Sefidroud rivers (that river is not suitable for sailing). Due to the establishment of a waste incinerator plant in the study area in the last two years, the collection and transfer of infectious and hospital waste was very effective factor in the managing of coastal and marine debris. Promoting of public culture in coastal and tourism zones was also one of the issues that have been practical and useful in recent years.

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