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Sustainable Earth Trends

Journal homepage: http://sustainearth.sbu.ac.ir

Distribution, abundance, and composition of microplastics in sediments along the Persian Gulf coast in 2024: a case study of the Genaveh, Deylam and imam Hassan ports

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A B S T R A C T

The increasing industrial activities have led to significant microplastic pollution, particularly in coastal regions, where human and industrial activities contribute to accumulating these pollutants. This study investigates the distribution and frequency of microplastics in beach sands along the Persian Gulf coastline in Bushehr, Iran, focusing on three key ports: Genaveh, Deylam, and Imam Hassan. Microplastics were extracted using density separation methods, and their types were identified via FTIR analysis. Results showed a higher concentration of microplastics in Genaveh and Deylam ports, with fibers being the most predominant microplastic type, likely due to textile production, fishing activities, and urban wastewater discharge. Polypropylene and polyethylene were the most common plastics found, highlighting the role of consumer products and industrial waste in pollution. The study emphasizes the impact of human activities on microplastic pollution and suggests that controlling plastic waste and improving waste management strategies are crucial for mitigating environmental and health risks. These findings contribute to global efforts to understand and manage microplastic contamination in marine ecosystems.

A R T I C L E I N F O

Keywords:
Coastal pollution
Environmental impact
Microplastics
Persian Gulf

Article history:
Received: 06 Oct 2024
Accepted: 18 Nov 2024

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Citation:
Gharaei, A. et al., (2025). Distribution, abundance, and composition of microplastics in sediments along the Persian Gulf coast in 2024: a case study of the Genaveh, Deylam and imam Hassan ports, *Sustainable Earth Trends:* 5(2), (27-36).

DOI: 10.48308/set.2024.237593.1082

1. Introduction

The increase in industrial activity has led to the release of significant amounts of solid waste into the environment, with plastic waste being one of the most notable examples (Wang et al., 2023). These wastes are broken down into smaller particles by factors such as sunlight exposure, physical abrasion, and wave action, among which microplastics can be identified (Emami et al., 2024; Wu et al., 2024). Microplastic pollution is considered one of the most serious environmental challenges of the twenty-first century (Le et al., 2024). Microplastics, small plastic particles measuring less than 5 millimeters, pose a severe threat to both aquatic and terrestrial ecosystems due to their high durability and non-biodegradability in the environment (Emami et al., 2024; Ya et al., 2021). Owing to their specific characteristics, such as lightness and resistance to degradation, these materials are easily transported in the environment and can enter food chains, leading to detrimental consequences for the health of all living organisms (Abbaszadeh et al., 2022). Microplastics enter the environment from various sources (Vivekanand et al., 2021). Primary sources include products that are initially manufactured as small particles, such as cosmetics and personal care products, as well as textiles (Mason et al., 2016; Ngo et al., 2019). Secondary sources involve the physical and chemical breakdown of larger plastics, which gradually decompose into smaller particles (Naik et al., 2020; Talukdar et al., 2024). Coasts and coastal areas, due to their direct connection with human and industrial activities, are considered some of the most significant sites for the accumulation of microplastics (Ronda et al., 2023).

One of the southern provinces of Iran is Bushehr, which holds significant economic importance due to its approximately 800 oil platforms and the annual passage of about 25,000 oil tankers (Mirmohammadvali and Solgi, 2018). The shores of the Persian Gulf are exposed to a variety of pollutants from both natural and human sources (Hosseini et al., 2020). Human activities, including transportation and shipping, the oil and petrochemical industries, agriculture, fishing, mining, ports, and commercial and residential sewage, are considered major contributors to pollution in the Persian Gulf and Oman Sea (Elhakeem et al., 2007; Shahri et al., 2022). The ports of Deylam, Genaveh, and Imam Hassan are among the coastal areas of Iran that are particularly vulnerable to microplastic pollution due to industrial, commercial, and tourism activities. These regions, due to their proximity to ports and industrial zones, have a high potential for receiving and accumulating microplastics from various sources. Beach sands, as a permeable environment, can serve as a reservoir for microplastics and play a significant role in the transfer of this pollution to other parts of the ecosystem.

Investigating the frequency and distribution of microplastics in beach sands can provide important insights into the extent and sources of pollution (Gao et al., 2021). Such studies can help identify patterns in the distribution of microplastics and the impact of human activities on the increased levels of this pollution (Hosseini et al., 2020; Xi et al., 2022). Furthermore, data obtained from such investigations can contribute to the development of policies and management strategies aimed at reducing pollution and protecting coastal ecosystems (Shen et al., 2020; Xiang et al., 2023).

The importance of studies related to microplastics is undeniable due to their widespread and long-term impacts on the environment and public health (Azeem et al., 2021). These materials can affect the health of both humans and animals, directly and indirectly. For instance, consuming marine organisms contaminated with microplastics can result in the introduction of these substances into the human body, leading to serious health issues (Chen et al., 2021; Sunil et al., 2024). Additionally, microplastics can act as carriers of harmful chemicals by absorbing toxic substances, posing significant environmental risks (Alberghini et al., 2023; Mozafarjalali et al., 2023).

Therefore, a comprehensive understanding of the microplastic pollution status in coastal areas is essential. Such studies can provide a solid scientific foundation for protective and management actions, as well as raise public awareness about the importance of reducing plastic use and properly managing plastic waste. Consequently, the present study aims to examine the frequency and distribution of microplastics in sand samples from the shores of these regions, striving to take an effective step towards preserving and improving the quality of the coastal environment.

2. Material and Method

2.1. Study area

Bushehr province is one of the southern provinces of Iran and the seventeenth largest province along the Persian Gulf coastline. Notable ports in this province include Deylam Port and Imam Hassan Port, which are located 200 kilometers from Bushehr Port in the northwest of the province. Deylam Port is situated at a longitude of 50 degrees 9 minutes and a latitude of 30 degrees 3 minutes, with an elevation of 10 meters above sea level. Imam Hassan Port is located in Bushehr province, Deylam County, within the Imam Hassan district, and serves as the center of this district. Imam Hassan Port lies in the southeastern part of Deylam County, with coordinates ranging from 50°5′ to 50°35′ east longitude and 29°17′ to 30°47′ north latitude. Genaveh Port, another city in Bushehr province, is the center of Genaveh county. The current city of Genaveh is situated on the coast of the Persian Gulf, between the cities of Bushehr and Deylam, 18 kilometers east of the Imam Hassan estuary. The port city of Genaveh is located at a longitude of 50°31′ east and a latitude of 29°34′ north. Genaveh, the center of Genaveh County, is located 160 kilometers northwest of Bushehr along the Persian Gulf coast. The climate in Genaveh is hot and humid, with an average annual precipitation of 150 millimeters, and has two distinct seasons: a mild season (from November to late March) and a hot season (for the remaining seven months) (Fig. 1).

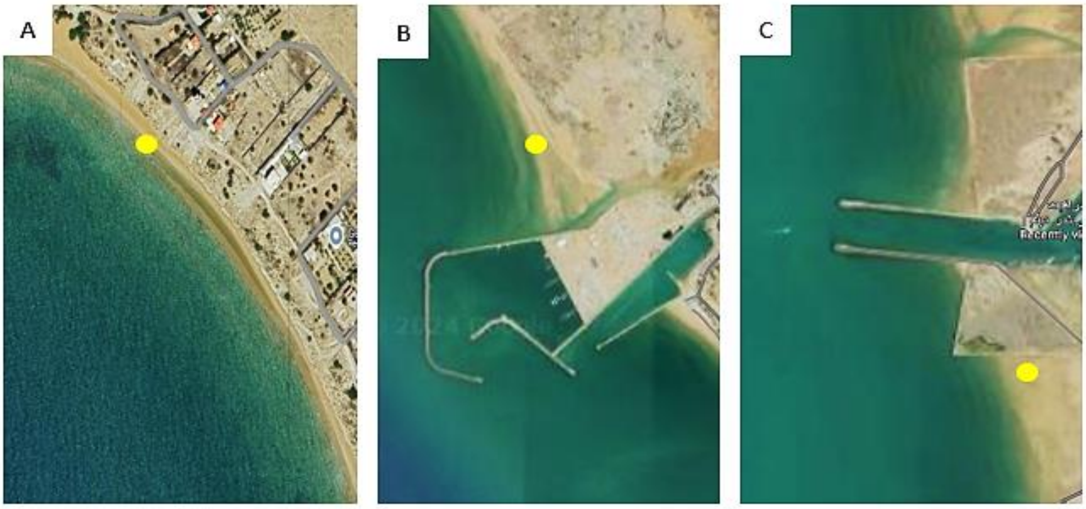


Fig. 1. Satellite images available on Google Earth of the studied coastal areas, marked with a yellow circle: a) Genaveh Port b) Imam Hassan Port c) Deylam Port.

2.2. Sampling and processing

Sampling and microplastic extraction methods were adapted from the European Commission (Hanke et al., 2013), the National Oceanic and Atmospheric Administration (Masura et al., 2015), and the guidelines by Loder and Gerdts (2015) (Loder and Gerdts, 2015). The sampling protocol involved delineating a metal frame (1 × 1 meter) parallel to the high tide mark, within which ten random 50 × 50 cm frames were defined, each separated by a minimum of 5 meters. Samples were collected from the surface layer (5 cm depth), mixed, and transported to the laboratory. The collected samples (over 1 kg) were dried in an oven at 60°C, and 500 grams of the dried material was separated for further processing. Microplastic extraction was carried out using density separation in two stages (Fig 2) (Maynard et al., 2021). Initially, a 1-liter solution of sodium chloride (NaCl, ρ = 1.2 $g \cdot cm^{-3}$) was mixed with each 500 grams of sand for 2 minutes and allowed to rest for 2 hours. Surface particles were collected, and the extraction process was repeated. The second stage involved replacing the NaCl solution with zinc chloride ($ZnCl_2$, ρ = 1.5–1.7 $g \cdot cm^{-3}$), which was mixed and left for 5 hours. Afterward, the surface particles were collected and stored alongside the particles obtained in the first stage (Maynard et al., 2021).

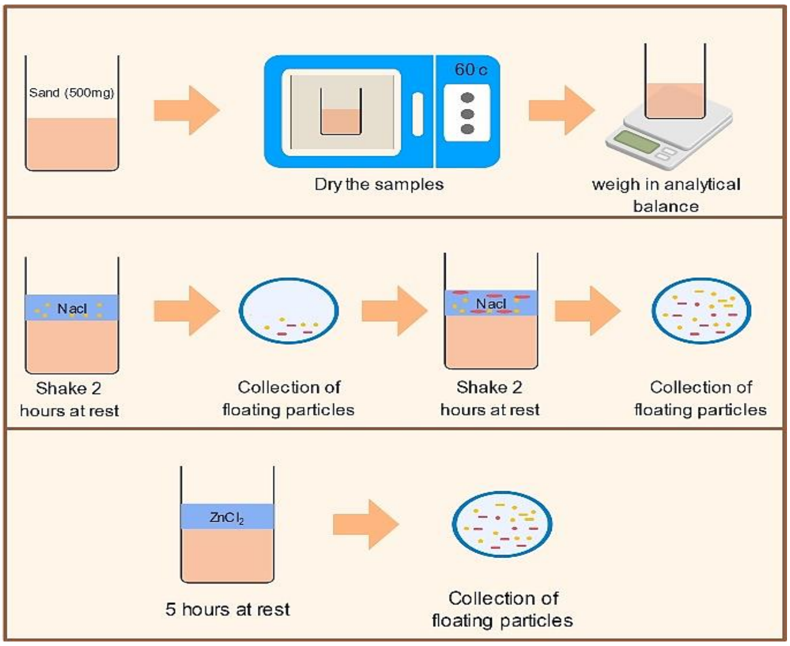


Fig. 2. Schematic diagram of microplastic extraction from sediments (Maynard et al., 2021).

2.3. FTIR analysis

Infrared spectroscopy can be used to examine and identify functional groups and determine the type of microplastics (C. Liu et al., 2023; Martin et al., 2018). For polymer sample preparation, for example, to create suitable films from thicker samples or granules, the sample is heated to above its softening temperature and then pressed to produce thin films (less than 55 micrometers thick) for direct use in FT-IR spectroscopy (Gorce and Spells, 2002).

3. Results and discussion

FTIR analysis results showed that coastal sediments at all sampling sites contained microplastic particles of various types (Table 1). The level of contamination in the sediments of Genaveh Port and Deylam Port was higher compared to Imam Hassan Port. This difference is likely due to the proximity of these stations to residential areas, the discharge of household waste and sewage, as well as the presence of a greater number of tourists and residents visiting these beaches for recreation. Furthermore, industrial activities and proximity to river mouths may also contribute to increased microplastic pollution. Rivers transport a significant amount of microplastic particles, which eventually settle in sediments. Recent studies confirm that polluted rivers often act as the primary source for transferring microplastics and macroplastics into marine environments (Zhao et al., 2018).

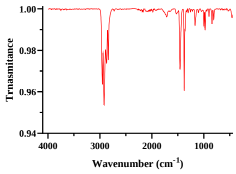
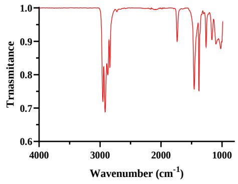
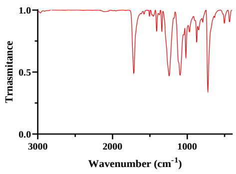
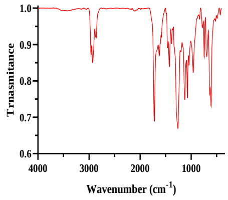
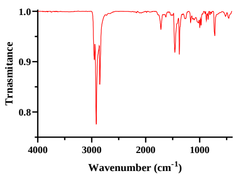
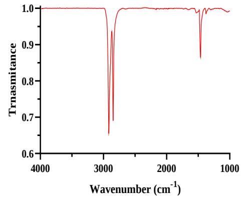
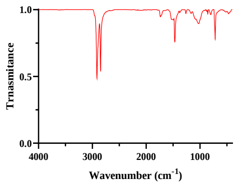
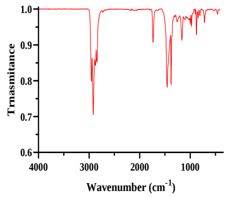
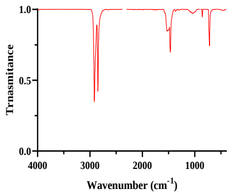
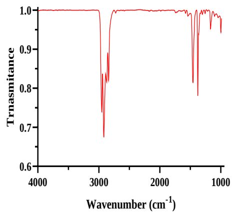
Classifying microplastics based on identifying sources, and particle shapes, and examining their potential for faster degradation under environmental factors plays a crucial role in understanding how these particles transform into microplastics (Koongolla et al., 2018). The results of this study indicate that the predominant microplastics identified are mainly fibers, which aligns with findings from other similar research. For example, Naji and colleagues (2017) reported fibers as the most common form of microplastics in the coastal sediments of the Hormuz Strait in the Persian Gulf. Additionally, a high prevalence of fibers has been documented in the coastal sediments of northern Tunisia (Abidli et al., 2018) and the sandy shores of the Baja California Peninsula in Mexico (de Jesus Pinon-Colin et al., 2018).

The high prevalence of fibers in sediments is an expected phenomenon, as studies indicate that these particles often originate from textile production and washing processes. During the washing of clothes, textile fibers may break down in washing machines and enter the environment through wastewater. Additionally, marine activities such as fishing, which involve the use of nets made from synthetic fibers (Zhao et al., 2018; Zhang et al., 2019), contribute to the release of fibers into the environment. Furthermore, the application of sewage sludge containing synthetic fibers as fertilizer in agriculture may lead to an increase in the concentration of fiber-based microplastics in the environment (Constant et al., 2019).

Among the studied stations, the lowest prevalence of fibers was observed at Imam Hassan Port, indicating that sewage is not the primary source of microplastics at this station. The main activity near this station is related to the oil industry, and the presence of film and fragment microplastics is likely the result of the degradation of plastic coatings used in agriculture, as well as larger plastic remnants along the shore (Bayo et al., 2019).

The highest prevalence of foam microplastics in sediments was observed at Deylam Port, likely due to fishing activities near this station and the presence of tourists (Fig 3). Foam plastics are used for transporting fish and as floaters due to their insulating and buoyant properties (Piperagkas et al., 2019). Foam is also used in packaging containers and as insulation materials in the construction industry. Additionally, some studies have confirmed the presence of mercury in foam plastics, which can pose a serious threat to living organisms (Abidli et al., 2018; Gholamhosseini et al., 2022; Zeidi et al., 2023a; Gholamhosseini et al., 2023; Banaee et al., 2023; Zeidi et al., 2023b; Gholamhosseini et al., 2024; Eamami et al., 2024).

Table 1. FTIR spectra of microplastics found in sediments in sediments in Genaveh, Emam Hasan and Deylam coast.

No.	Compound Name	FTIR chart	No.	Compound Name	FTIR chart
1	Copolymer (Berkley Polypropylene, Olefin Fiber)		6	Bonneville Blue (84% herculon, 11% polyester, 5% cotton)	
2	ComFortrel (Foaming agent, Polyester)		7	Highly Softened Foam	
3	Copolymer (Poly Propylene, Poly Ethylene)		8	LDPE (Low Density Polyethylene, Escorene)	
4	Copolymer (Poly Propylene, Poly Ethylene Terephthalate)		9	Polypropylene, Moplen	
5	Polyethylene		10	Olefin Fiber	

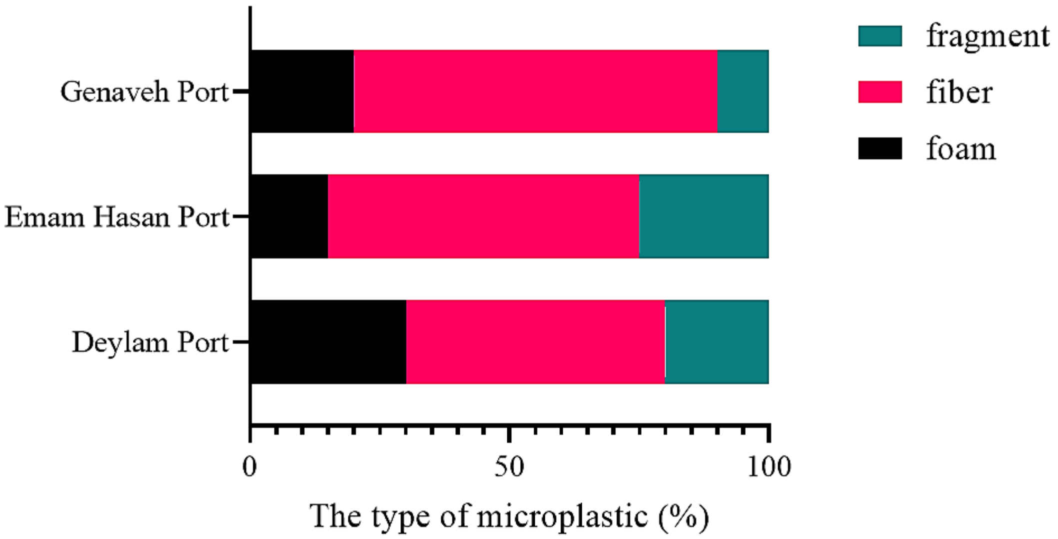


Fig. 3. Classification of different shapes of microplastics in sediments in Genaveh, Emam Hasan, and Deylam coast.

Microplastic particles accumulate in sediments at varying rates based on characteristics such as size, shape, density, and coastal features, including wave intensity, beach slope, sediment grain size, and human interactions in the area (Wang et al., 2019; Zhang et al., 2019).
In sediments, after fibers, the highest number of particles were plastic fragments. This indicates that plastic fragments, with higher density and a rounder shape, are more likely to settle in sediments compared to lighter microplastics with a larger surface area (usually in the form of films and foams) (Piperagkas et al., 2019). However, in the sediments, the lowest frequency was observed for foam microplastics. Despite this, foam particles, due to their lightness and larger size compared to other microplastic forms, are still present in sediments.
In this study, the predominant colors of the observed microplastics included blue, black, brown, and green, which are likely related to the impacts of human and industrial activities in the region. Various studies have also highlighted the prevalence of colored microplastics in sediments (Li et al., 2018; Wang et al., 2019; Alvarez-Zeferino et al., 2020). The prevalence of colored microplastics in sediments is generally attributed to the degradation of colored plastic products in coastal environments. The coloring of plastics is often done to attract consumers and enhance the appeal of plastic products (Chouchene et al., 2019). Furthermore, according to the classification obtained, the results showed that the highest concentrations of microplastics, in order, were polypropylene and polyethylene, which were found in high amounts at all three stations (Fig 4). This indicates that plastic fragments may originate from single-use containers, toys, bottled water containers, and so on. Several studies have reported similar findings (Chouchene et al., 2021; Montero et al., 2023).
The presence of microplastics in various ecosystems has been studied extensively. For example, microplastics have been reported in the coastal regions of the Bohai Sea in China (Yu et al., 2016). Significant amounts of these particles have also been identified in the coastal sediments of northern Tunisia in the Mediterranean Sea (Abidli et al., 2018). The sandy beaches of the Baja California Peninsula in Mexico have also been a site for microplastic accumulation (de Jesus Pinon-Colin et al., 2018). In Spain, coastal sediments of the Mar Menor lagoon are to be contaminated with microplastics (Bayo et al., 2019). Additionally, the levels of microplastics in the coastal sediments of northwest Mediterranean France have been examined (Constant et al., 2019). In Iran, microplastics have been detected in the coastal sediments of Chabahar Bay in the Oman Sea (Hosseini et al., 2020). Finally, a study in northern China revealed that the sediments of the Fu River estuary to Baiyangdian Wetland also contain microplastics (Zhou et al., 2021). Furthermore, the presence of microplastics in the mangrove ecosystem of Singapore has been noted (Nor and Obbard, 2014).

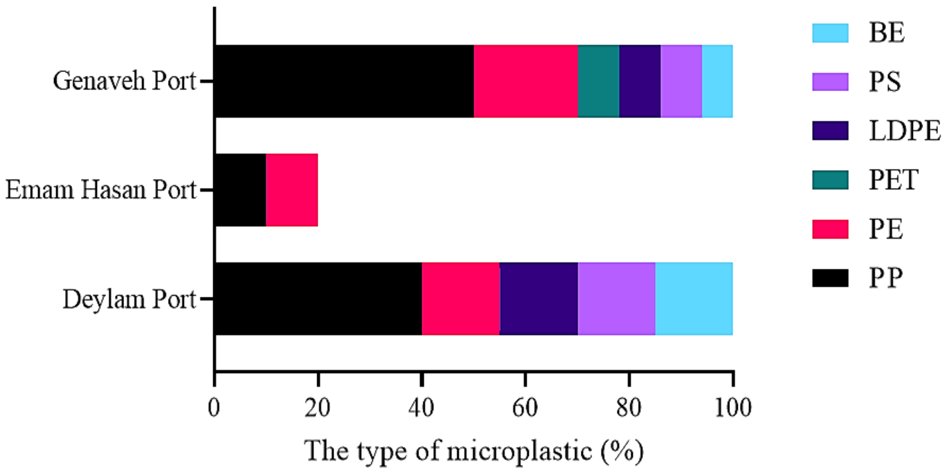


Fig. 4. Classification of different types of microplastics in sediments in Genaveh, Emam Hasan, and Deylam coast.

4. Conclusion

The results of the present study showed that microplastic particles were found in all of the sediments examined. The highest concentration of microplastics was typically observed in areas with high human population density and significant human activities. FTIR analysis of the microplastics revealed various types of plastics categorized into different groups across the three stations: Bandar Genaveh, Bandar Imam Hassan, and Bandar Deylam. Additionally, the plastic classification revealed that the most prevalent type of plastic was fibers, which were more abundant in the Genaveh and Deylam ports. After fibers, fibrous particles were the most abundant in the studied areas. In terms of microplastic types, polypropylene, and polyethylene were the most prevalent, likely due to marine activities such as fishing, proximity to residential areas, tourism, and the discharge of urban and industrial wastewater in this region. Obtaining information on the characteristics of microplastics, such as color, shape, and size, can help identify the sources of pollution, pathways of their transfer to sediments, and the potential for their entry into and accumulation in the food chain. The findings of this study highlight the global distribution of microplastics and the importance of managing and reducing marine waste worldwide. Overall, the results suggest that preventing the release of plastics into coastal areas is crucial to reducing the frequency of microplastic particles. It is recommended that coastal management programs be implemented to regulate tourist activities, prevent the discharge of untreated wastewater, and ensure the collection of waste along the coasts.

Acknowledgments

This paper is based on the results of a PhD student thesis undertaken at the Department of Environmental Engineering, Faculty of Natural Resources and Environment, University of Birjand. All of the authors gratefully acknowledge the kind cooperation of the personnel of the laboratories, the Shahid Bahonar University of Kerman, Behbahan Khatam Alanbia University of Technology and the University of Birjand over the course of the research.

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