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Oil Translocation

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Publication Abstracts

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Updated on July 22, 2022

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5. X. Geng, M. Boufadel, K. Lee, and C. An, 2020. Characterization of Pore Water Flow in 3-D Heterogeneous Permeability Fields, Geophysical Research Letters, 47(3), e2019GL086879. https://doi.org/10.1029/2019GL086879
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Publication Abstracts

1

A review on the factors affecting the deposition, retention, and biodegradation of oil stranded on beaches and guidelines for designing laboratory experiments

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The distribution and persistence of oil within the matrix of a beach depends on the oil and beach properties, the presence of fines in the water column, and beach hydrodynamics and biochemistry. In this review, we attempted to provide an assessment of the journey of oil from offshore oil spills until it deposits within beaches. In particular, we addressed the disparity of spatial scales between microscopic processes, such as the formation of oil particle aggregates and oil biodegradation, and large-scale forcings, such as the tide. While aerobic biodegradation can remove more than 80% of the oil mass from the environment, its rate depends on the pore water concentration of oxygen and nutrients, both of them vary across the beach and with time. For this reason, we discussed in details the methods used for measuring water properties in situ and ex situ. We also noted that existing first-order decay models for oil biodegradation are expedient, but might not capture impacts of water chemistry on oil biodegradation. We found that there is a need to treat the beach–nearshore system as one unit rather than two separate entities. Scaling down largescale hydrodynamics requires a coarser porous medium in the laboratory. Unfortunately, this implies that microscopicscale processes cannot be reproduced in such a setup, and one needs a separate system for simulating small-scale processes. Our findings of large spatio-temporal variability in pore-water properties suggest that major advancements in addressing oil spills on beaches require holistic approaches that combine hydrodynamics with biochemistry and oil chemistry.

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Publication List

High pressure injection of chemicals in a gravel beach

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The remediation of beaches contaminated with oil includes the application of surfactants and/or the application of amendments to enhance oil biodegradation (i.e., bioremediation). This study focused on evaluating the practicability of the high pressure injection (HPI) of dissolved chemicals into the subsurface of a lentic Alaskan beach subjected to a 5 m tidal range. A conservative tracer, lithium, in a lithium bromide (LiBr) solution, was injected into the beach at 1.0 m depth near the mid-tide line. The flow rate was varied between 1.0 and 1.5 L/min, and the resulting injection pressure varied between 3 m and 6 m of water. The concentration of the injected tracer was measured from four surrounding monitoring wells at multiple depths. The HPI associated with a flow rate of 1.5 L/min resulted in a Darcy flux in the cross-shore direction at 1.15×10^{-5} m/s compared to that of 7.5×10^{-6} m/s under normal conditions. The HPI, thus, enhanced the hydraulic conveyance of the beach. The results revealed that the tracer plume dispersed an area of ~12 m^2 within 24 h. These results suggest that deep injection of solutions into a gravel beach is a viable approach for remediating beaches.

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Investigation into the oil removal from sand using a surface washing agent under different environmental conditions

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Spilled oil frequently reaches the shorelines and affects coastal biota and communities. The application of surface washing agents is an important shoreline cleanup technique that can help remove stranded oil from substrate surfaces with the advantages of high removal efficiency, low toxicity, and strong economic viability. In this study, the investigation into the oil removal from contaminated sand using a surface washing agent under variable environmental conditions was conducted. A preliminary test was conducted to obtain the optimal combination of operating factors of surface washing agent-to-oil ratio (SOR) 2:1, mixing speed 150 rpm, and mixing time 30 min. The results of single-factor experiments showed that high temperature and humic acid concentration of flush water contributed to the performance of a surface washing agent, while salinity and kaolinite concentration could inhibit its performance. The factorial analysis revealed the main effects of temperature and salinity, and the interactive effects of temperature and salinity as well as salinity and humic acid concentration that were significant to the washing efficiency of the surface washing agent. In addition, the comprehensive assessment of a surface washing agent from the aspects of toxicity, detergency, dispersion properties, and field trials was conducted. The results have significant implications for future application of surface washing agents in the shoreline cleanup.

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Publication List

Use of Nano-TiO_2 self-assembled flax fiber as a new initiative for immiscible oil/water separation

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In this study, an environmental friendly, reusable and low-cost functionalized flax fiber was fabricated to separate immiscible oil and water. Flax fibers were modified by plasma-induced poly(acrylic acid) (PAA) polymerization followed by nano-TiO_2 self-assembly. A two-level fractional factorial design was engaged to analyze the modification influencing parameters and their interactions. The modified fiber was comprehensively characterized by synchrotron-based Fourier transform infrared spectroscopy (FTIR) and X-ray fluorescence (XRF). For the first time, the concentration distribution of functional groups and TiO_2 nanoparticles (TiO_2 NPs) were explored on flax fiber surface. The TiO_2 NPs were found unevenly fixed on flax fiber surface with high concentration on abundant substrate. The hydrophilicity of nano-TiO_2 self-assembled flax fiber was significantly improved, with water contact angle decreasing from 97.4° to 25.9° and almost doubled maximum oil holding pressure. The modified flax fiber showed stable performance of oil/water separation in alkaline and salty conditions and could be used for multiple cycles. The modified flax fiber could be further constructed into oil barrier with special wettability to separate oil.

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Publication List

Characterization of pore water flow in 3-D heterogeneous permeability fields

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Subsurface heterogeneity could influence groundwater flow with implications on structure and productivity of aquifer ecosystems. Here we investigate effects of multifractal heterogeneity on topology of groundwater flow through MODFLOW simulations within a Monte Carlo framework. The results show that heterogeneity leads to focused groundwater advection and the creation of hotspots of bending-type vortex flow in the fields. We demonstrate for the first time that the vortex structures characterized by Q criterion are 3-D distributed and greatly deform surrounding pore-water flow. The structures exhibit scale-invariant features in multifractal fields and in stationary fields below the correlation scale, indicating that such vortex flow might be widely present with no characteristic scale. Complex spatial patterns of kinetic energy dissipation rate are identified for pore water flowing through heterogeneous porous media and correlate strongly with preferential flows. These findings are important for understanding solute fate and transport in aquifer systems.

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Numerical study of solute transport in heterogeneous beach aquifers subjected to tides

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A numerical study, based on a variably saturated groundwater flow model within a Monto Carlo framework, was conducted to investigate flow and solute transport in a heterogeneous beach aquifer subjected to tides. The numerical simulations were conducted based on our previous tracer experiments performed in a laboratory beach. Heterogeneity is assumed to be multifractal generated using the Universal Multifractal model. Our results show that heterogeneity greatly alters temporal and spatial evolution of the tracer plume migrating in the beach. The spreading coefficient of the plume shows very dynamic response to tides; it increases as the tidally driven recirculation cell overlaps with the plume and decreases as the recirculation cell moves far from the plume with tides. Descriptive statistics suggests that heterogeneity enhances spreading of the plume in the beach in an ensemble sense along with significant spatial and temporal variation. Due to heterogeneity, high spots of the pore water velocity are formed within the recirculation cell, creating transient preferential flow paths in the beach in response to tides. Contours of the Okubo-Weiss (*OW*) parameter show that coupling with tides, heterogeneity creates vorticity-dominated flow regions and also expands strain-dominated flow regions more downward, indicating complex local-scale mixing in the beach, compared to corresponding homogeneous case. Geologic heterogeneity also alters the spatial extent of the recirculating cell and induces highly variable transit time along the recirculating flow paths. The results provide insights into effects of geologic heterogeneity on seawater-groundwater mixing and associated solute transport processes in tidally influenced coastal aquifers.

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Factors influencing the fate of oil spilled on shorelines: a review

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Accidental oil spills in ocean may occur during exploration, production, transportation and use. The spilled oil frequently reaches shoreline where it may harm more or less the ecosystem depending on the physicochemical properties of spilled oil. Here, we review the physicochemical behavior of petroleum hydrocarbons, such as crude oil and refined products, on various types of shorelines under various environmental conditions. During migration to the shore, the oil characteristics can change by evaporation, photooxidation, partition and aggregation. The penetration, remobilization and retention of stranded oil on shorelines are affected by the beach topography and the natural environment. We also discuss the attenuation and fate of oil on shorelines from laboratory and field experiments.

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Publication List

Exploring the use of cellulose nanocrystal as surface-washing agent for oiled shoreline cleanup

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Surface-washing agents are an option to enhance the removal of oil spilled or stranded on shorelines. The use of nanocellulose-based nanofluid as a surface-washing agent was studied by investigating its reactivity and effectiveness. Salinity was found to be the most influencial factor to facilitate oil removal with the nanofluids. Cations from salt can promote the adsorption of nanocellulose on the oil/water interface by reducing the surface charges. The experimental results revealed the nanocellulose could be effective at low concentrations but an excess of nanocellulose hindered oil removal due to an increase in fluid viscosity. A miscibility model was applied to verify this finding in a thermodynamics context. The biotoxicity tests showed that nanocellulose-based nanofluid did not have negative effects on algae growth and introducing nanocellulose into an oiled culture medium can actually mitigate the toxicity of the oil on algae. A comparison in removal efficiency with other surfactants demonstrated the potential value for shoreline cleanup due to the superior effectiveness of nanocellulose-based nanofluids. Overall, a nanocellulose has a high potential for application as a surface-washing agent for shoreline cleanup due to the low cost, low toxicity, and high efficiency.

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A framework for the evaluation and selection of shoreline surface washing agents in oil spill response

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The shorelines frequently suffer adverse impacts from oil spill accidents. As one important technique of shoreline cleanup, the application of surface washing agents (SWAs) can help achieve high oil removal from shoreline substrates with less damage to affected zone. In this study, a framework for evaluation and selection of SWAs in oil spill incidents was constructed to better understand and apply this technique. A decision tree was firstly developed to illustrate all possible scenarios which are appropriate to use SWAs in consideration of oil collectability, shoreline character, types and amount of stranded oil, and cleanup requirement. Based on literature review, theoretical modeling, and experts' suggestions, an integrated multi-criteria decision analysis (MCDA) method was then come up to select the most preferred SWA from five aspects of toxicity, effectiveness, minimal dispersion, demonstrated field test, and cost. Its suitability and rationality were proved by a hypothetical case. In addition, sensitivity analysis was performed by changing the weight of each criterion independently to check the priority rank of alternatives, and it also verified the robustness and stability of this model. The presented framework has significant implications for future research and application of SWAs in the shoreline cleanup.

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Inexact inventory-theory-based optimization of oily waste management system in shoreline spill response

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The oily waste generated from the cleanup operations during shoreline spill response can result in challenging environmental and socioeconomic problems. In this study, an inexact inventory-theory-based optimization model (ITOM) for oily waste management during shoreline spill response was developed to support the spill management team. The most appropriate facilities and optimal waste allocation scheme under uncertainty can be selected to achieve minimum total system cost. To satisfy the demand of oily waste treatment, these oily waste management facilities can be selectively opened depending on the situation. In the combination with the economic order quantity model of inventory theory, the developed model can provide the optimal solutions of batch size and order cycle for treatment facilities to minimize the inventory cost. A case study was used to demonstrate the application of ITOM. The obtained solutions include the facilities selection and waste allocation for waste collection and destocking stages under different risk levels. These solutions can provide a good guideline with managers to analyze the trade-offs between system cost and constraint-violation risks. The developed model has high application potential as a job-aid tool to manage the oily waste generated from oiled shoreline cleanup operations.

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An analysis of selected oil spill case studies on the shorelines of Canada

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After an oil spill, oil may wash ashore and there is only a short window of opportunity to respond. Analysis of historical incident data is valuable to guide future responses and cleanup practices. This study summarized the oil spill accidents that impacted the Canadian shoreline and analyzed the related information including location, incident characteristics, and shoreline treatment. Major spills due to tanker accidents in Canadian marine waters fortunately have been infrequent. Most of the accidents have happened on Canada’s Pacific coast, accounting for 52% of the total accidents recorded. The Atlantic coast accounted for 39% and the remaining accidents happened in the Arctic region. Regarding spilled volume, 55% of the accidents spilled oil volumes smaller than 100 m^3. Spilled volumes between 100 ~ 1000 m^3 represent 30% of the incidents and 15% had spilled volume greater than 1000 m3 . Bunker C fuel and diesel were the main types of the spilled oil, accounting for 33% of the spills, respectively. Within the oil spill accidents impacting Canadian shorelines, marine vessel accidents were the major sources accounting for 70% of the spill accidents. In terms of the shoreline treatment, the commonly employed treatments were manual, vacuum, mechanical, and sorbent removal. The dataset highlighted the significance of a more comprehensive record for response phase details and environmental effects monitoring.

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Exploring the effects of microalgal biomass on the oil behavior in a sand-water system

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This study focused on the impact of microalgal biomass on the oil behavior in a sand-water system. The microalgal biomass was characterized, and the interaction between microalgal biomass and oil was analyzed through Fourier transform infrared (FTIR) spectroscopy. The effects of different conditions including microalgal biomass dose, pH, temperature, and salinity on the oil behavior were investigated. A two-level factorial analysis was also used to further explore the interactions of these conditions. The microalgal biomass was found to be the most influential parameter for the residual crude oil on sand. Higher microalgal biomass dose resulted in less residual oil on sand. The remaining oil decreased with increasing solution pH from 4 to 7, and an increase of remaining oil was observed when the pH was further increased above 7. In addition, temperature and salinity could affect the removal of crude oil in the presence of microalgal biomass. Increasing the temperature could result in less residual oil on sand and there was higher oil removal at the high salinity. The effects of microalgal biomass on the oil behavior could also be impacted by environmental conditions. The results of this study indicate that the presence of algae in the oiled shoreline can be considered in the comprehensive evaluation of spill risk and prediction of oil fate.

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Publication List

Use of biomass-derived adsorbents for the removal of petroleum pollutants from water: a mini-review

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Over the past decades, a large amount of petroleum pollutants has been released into the environment resulting from various activities related to petrochemicals. The discharge of wastewater with petrochemicals can pose considerable risk of harm to the human health and the environment. The use of adsorbents has received much consideration across the environmental feld as an efective approach for organic pollutant removal. There is a particular interest in the use of biomass adsorbent as a promising environmentally-friendly and low-cost option for removing pollutants. In this article, we present a review of biomass-derived adsorbents for the removal of petroleum pollutants from water. The features of diferent adsorbents such as algae, fungi, and bacteria biomasses are summarized, as is the process of removing oil and PAHs using biomass-derived adsorbents. Finally, recommendations for future study are proposed.

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Exploration of nanocellulose washing agent for the green remediation of phenanthrene-contaminated soil

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Polycyclic aromatic hydrocarbons are hazardous contaminants existing ubiquitously in polluted soil. In this study, using nanocellulose (CNC) fluid as an eco-friendly agent was proposed for the first time in the remediation of phenanthrene (PHE) contaminated soil. The effects of environmental factors on the mobilization of PHE in soil by CNC nanofluid was investigated using factorial analysis. The results showed that temperature and ionic strength had a significant influence on PHE removal, which were associated with the viscosity and zeta potential change in the nanofluid. The analysis based on two-dimensional correlation spectroscopy integrated with FTIR and synchrotron-based XRF imaging revealed that metals and minerals in soil played important roles in PHE detachment. The hydroxyl groups on CNC bonded with Fe–O, Si–O, and Mn–O in soil as time went on, and eventually achieved PHE mobilization through the interruption of PHE/SOM-metal/mineral linkages. The complexation and transport of PHE/SOM-metals/minerals from soil particles to the aqueous phase could be the primary PHE removal mechanism. Besides, the biotoxicity study displayed a detoxification effect of CNC nanofluid on PHE contaminants in soil. This study offers new insight into a cost-effective and biodegradable nanocellulose washing agent, which can be a good alternative to the available site remediation options.

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Publication Abstracts

Examining an oil spill plume mapping method based on Satellite NIR Data

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Reliable information on the spreading of oil plume on water caused by massive oil spills is essential for making proper clean-up measures. Satellite remote sensing technology has advantages over other methods in terms of larger coverage and without expensive operating costs to detect oil spills. In this study, an oil plume delineation method based on the Near-Infrared (NIR) satellite data is used to examine oil spill plume area and size for the BP Deepwater Horizon Oil Spill in the offshore water of Gulf of Mexico and for the recent Norilsk oil spill in a Northern inland water region. To get accurate results noise signals such as land from the data are masked out using SNAP based DEM data and Normalized Difference Water Index method, whereas cloud signals are removed using MODIS cloud masking. Cox-Munk model is used to compute the sun glint radiance. Results of DP oil spill case depicts a 4838.84 km^2 thicker oil plume along with the 20635.53 km^2 thinner portion of the oil slicks using MODIS NIR data at a 500-meter resolution. It is subsequently applied to the recent Norilsk Oil Spill using higher resolution Sentinel-2 NIR data to test the method for detecting spill plume in an inland river water system. Reasonable high-resolution results at 10 meter have been obtained for the smaller scale oil spill onto river water compared to larger offshore area, considering that the river site has complex conditions including shallow water and river reddish soil close to oil color. The developed method is suitable for detecting thick oil plume in ocean or deep inland water bodies.

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Publication Abstracts

Decision support tools for oil spill response (OSR-DSTs): Approaches, challenges, and future research perspectives

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Marine oil spills pose a significant threat to ocean and coastal ecosystems. In addition to costs incurred by response activities, an economic burden could be experienced by stakeholders dependent on coastal resources. Decision support tools for oil spill response (OSR-DSTs) have been playing an important role during oil spill response operations. This paper aims to provide an insight into the status of research on OSR-DSTs and identify future directions. Specifically, a systematic review is conducted including an examination of the advantages and limitations of currently applied and emerging decision support techniques for oil spill response. In response to elevated environmental concerns for protecting the polar ecosystem, the review includes a discussion on the use of OSR-DSTs in cold regions. Based on the analysis of information acquired, recommendations for future work on the development of OSR-DSTs to support the selection and implementation of spill response options are presented.

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Publication List

A review of response options to accelerate the recovery of oiled shorelines

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The rate at which oil on shorelines weathers and attenuates is a function of the character of the oil on the shoreline (type and volume), the character of the shoreline materials, and the environmental setting (physical and biological). Some light crude oils or products have a very short half-life and may persist for only hours or days whereas other oils may persist for months to years. The objective of this review is to summarize how and why the different commonly used and available response options can contribute to accelerating shoreline recovery and to explain the potential consequences of these actions. Globally, the most widely used shoreline treatment activity is simple physical removal by manual or mechanical cleanup methods with off-site disposal. The explanation for this situation lies in the fact that this method is typically quick, easy, and requires no special skill sets or dedicated equipment. The second most widely used treatment method is low-pressure flushing or washing. A concern with this option is that typically little or no oil is recovered, unless the oil loading on the shore is very high and, although some of the oil may be broken down and dispersed in the water column and then biodegraded, if the method generates oil residue-sediment aggregates these may be negatively buoyant when the sediments are granular (> 1 mm) or coarser. Many guides and manuals describe the mechanics and implementation of these and other treatment methods; this review evaluates the state-of-the art with respect to currently available and widely applicable treatment options to accelerate oiled shore- line recovery. This knowledge is intended to support the creation of a science-based Shoreline Response Program (SRP) Decision Support Tool that is under development as part the Fisheries and Oceans Canada Multi-Partner Research Initiative (MPRI) program. The primary benefit of this tool is to enhance the quality of strategic planning regarding shoreline response intervention and non-intervention decisions related, in part, to Alternative Response Technologies for shoreline treatment.

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Publication List

A review of numerical models for oil penetration, retention, and attenuation on shorelines

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Oil spills that reach shorelines greatly increase risks to coastal resources. Understanding how long oil is likely to remain on a shoreline is important in deciding response priorities, areas to clean, and the degree of intervention recommended. Wave action, tides, and currents can relocate oil laterally along the beach, cause oil to penetrate vertically into the sediments, and remove oil from the shoreline. Physico-chemical processes transfer some hydrocarbons to the atmosphere and to the adjacent water column resulting in diminished oil on the shoreline. Oil dispersion, through formation of oil-particulate aggregates, and microbial degradation processes can break down a large fraction of the residual oil remaining on and within shorelines. A comprehensive review of the scientific literature reveals that although there are many models that describe and predict oil transport, behavior, and fate in the sea, few numerical models have been developed for oil stranded on shorelines. Canada's Multi-Partner Research Initiative Program aims to develop a model-based "Decision Support Tool" that can predict the rates of oil loss that can be achieved from natural attenuation processes and the application of active spill response strategies. This model is built on the understanding of factors controlling: penetration, holding capacity, retention, and the residual capacity (persistence) of oil stranded on shorelines derived from the results of case histories, laboratory, meso-scale tests and field trials. Output from the model is intended to support spill response decision-making by allowing spill responders and the public to visualize the results achieved by natural attenuation versus remedial strategies.

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A practical model of the natural attenuation of oil on shorelines for decision support

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Oil stranded on shorelines naturally weathers and attenuates at rates that are a function of the character of the oil on the shoreline (type and volume), the character of the shoreline materials, and the environmental setting (physical and biological). Some light crude oils and refined products have a very short half-life and may persist for only hours or days. However, if stranded oil is not exposed to light, oxygen or physical shore-zone processes, such as in asphalt pavements or if buried by marine or river sediments, it may take long time periods to fully degrade, or in a few extreme cases may not degrade at all. This review assesses the current state-of-knowledge of the natural weathering and attenuation of oil on shorelines as this relates to decisions regarding a shoreline treatment program. This knowledge is critical for the creation of simulation models for natural attenuation. The Shoreline Response Program-Decision Support Tool, currently under development, considers the various translocation (transport) pathways of oil on shorelines into the atmosphere or the marine environment and the attenuation processes that lead to the final transformation of stranded petroleum hydrocarbons into non-hydrocarbon materials. This ultimate transformation to a non-hydrocarbon is only achieved during chemical attenuation processes associated with biodegradation or photodegradation acting on exposed oil surfaces. Understanding the processes that act on the stranded oil and the rates by which oil is transformed into non-hydrocarbon materials is crucial in the decision process on whether to let Nature take its course or to intervene to remove the oil and/or accelerate the weathering and attenuation processes. This review evaluates the current state-of-understanding regarding the initial behavior and ultimate fate of oil on shorelines, identifies knowledge gaps regarding the behavior and ultimate fate of oil on shorelines, and recommends topics for further investigation and future research.

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Publication List

An OMA-SIM approach to study OMA kinetics for the cleanup of marine oil spill

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Breaking waves can break oil slicks into fine droplets and entrain them in the water column. An interesting hypothesis has emerged in recent years that oil droplets and mineral fines may form Oil-Mineral Aggregates (OMAs) and enhance oil dispersion in aquatic environments. The present research investigated physical processes of marine oil spills, including oil slick breakup, the formation of OMAs, and oil/OMAs vertical mixing. In this study, a modeling approach is developed for simulating the formation and vertical mixing of oil droplets and OMAs, namely Oil Droplet and OMAs Simulation (OMA-SIM). This integrated modeling tool combines the oil vertical mixing model and density-based OMAs formation model to examine the dispersion of oil droplets and OMAs. The OMA-SIM is validated using data obtained from a mesoscale wave tank experimental study. Simulation results show that the energy dissipation rate of breaking waves is the predominant factor affecting the concentration and particle size of formed oil droplets and OMAs. It also confirms that oil viscosity has a significant influence on dispersed oil concentration. High temperature, low oil viscosity, together with more formed OMAs lead to a higher concentration of dissolved oil. Other findings based on the validated OMA-SIM approach include that: the dispersants reduce oil/water interfacial tension and decrease the size of oil droplets and OMAs, and the application of mineral fines facilitates the formation of OMAs. This study indicates that the OMA-SIM is an effective modeling tool for examining the vertical dispersion of spilled oil with or without the use of dispersant and other green particle materials like mineral fines under breaking waves.

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Transport and formation of OPAs in rivers

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A numerical framework was developed to study oil-particle aggregate (OPA) formation by incorporating NEMO3D code and the A-DROP model into an open-source platform, OpenFOAM. The developed framework was then used to study oil transport and OPA formation in a two-dimensional (2D) hypothetical river at a depth of 3.0 m. The river's hydrodynamic profile was used in conjunction with the A-DROP model to simulate OPA formation, whereas the NEMO3D model was used to track the movement of the oil droplets and OPAs. Results suggest that an increase in buoyancy results in a decrease in the streamwise variance and spreading coefficient. The small (i.e., 50 μm) droplets became entrained in the deep water column at high-energy dissipation rates, which enhanced OPA formation. The large (i.e., 200 μm) droplets aggregated much more rapidly than the small ones in the same turbulence environment owing to differential sedimentation. In general, OPA formation in the upper rivers was dominated by collisions caused by differential sedimentation, while in the deep water column, collision caused by turbulence shear plays a more critical role. The aggregation rates of the formed OPAs were less than 60% within a short period (20 min) in a river with relatively mild turbulence ($\varepsilon<5\times10^{-4}$ W/kg).

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Publication Abstracts

Recent advances in developing cellulosic sorbent materials for oil spill cleanup: A state-of-the-art review

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Despite advances in technology and safety measures, accidental releases of crude oil and refined products into marine and freshwater environments remains a major environmental concern. To minimize the impacts of future spills on our aquatic ecosystems and human health, numerous studies have been refocused on the development of novel approaches to remove oil from water. An emerging low-cost, eco-friendly method is based on the use non-toxic and biodegradable cellulose-based sorbents for oil retrieval and recovery from water. Herein we seek to succinctly analyze the progress of cellulose-based materials developed to date in terms of their effectiveness as an oil sorbent and development potential into a commercial product for oil spill recovery operations. The results of the review highlight the potential use of cellulose nanocrystals and cellulose nanofibrils as sorbent materials with highly desirable properties for oil spills cleanup. With unique hydrophobic and oleophilic properties (in terms of oil selectivity) and physical and mechanical properties (high surface area and small pore size), cellulose-based sorbents may be an ideal alternative material for use in cleaning up oil spills. Combining both hydrophobic and magnetic properties by introduction of iron oxide nanoparticles offers high reusability and functionality, easy operation and facile separation of the cellulose-based sorbents; thus, it would offer a new approach against oil spills and fouling challenges. Furthermore, their reusability after oil uptake serves as additional steps to sustainability. Nevertheless, work is still required to determine and figure out the practical levels of utility of the cellulose-based sorbents on a commercial scale, facilitating the control and management of minor oil spills.

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Multiphase CFD simulation of the nearshore spilled oil behaviors

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Oil spills are a serious environmental problem. To better support risk assessment and pollution control for oil spills, a good understanding of oil transport in the environment is required. This study focused on the numerical simulation of the nearshore oil behaviors based on computational fluid dynamics. Based on the Navier-Stokes momentum equations for an incompressible viscous fluid and volume of fluid (VOF) method, a 3D numerical model of three-phase transient flow was developed. The wave number, averaged flow velocity and oil properties would affect the oil spread extent and the oil volume fraction. The higher the averaged flow velocity and wave number, the lower the oil concentration, and the faster the horizontal movement of the oil. The spilled oil may move to contact the seafloor by increasing the averaged flow velocity at the inlet boundary. Through increasing the wave number, the oil would stay near the water surface. In the nearshore, where the wave is the main seawater motion, the oil containment boom should be set preferentially to the direction of wave transmission for oil cleaning. This study shows that by doubling the wave number and increasing the averaged flow velocity (ten times) at the same time, the maximum oil volume fraction would be reduced by around 32%. Finally, the water temperature had no significant impact on the oil migration, and the impact of evaporation should be considered in the simulation.

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Exploring the use of alginate hydrogel coating as a new initiative for emergent shoreline oiling prevention

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Marine oil spills are often reported as a result of activities associated with oil exploration, production and transportation. The spilled oil may reach the shoreline, and then the stranded oil can persist for a long time, exerting many negative effects on coastal ecosystems. Conventional shoreline cleanup methods cannot effectively remove the oil residues from affected areas and are very expensive. Therefore, the use of alginate hydrogel coatings was proposed as a new initiative for emergent shoreline oiling prevention. The alginate hydrogel-coated gravels showed high surface roughness, as well as remarkable water wetting and low-oil-adhesion properties. There was a low oil adhesion on the coated gravels in the continuous test with oil/water emulsion flow, indicating the excellent oil-repellent properties of the coated substrate. The results of batch oil-repellent tests showed that independent of the kind or weathering degree of the oil used, oil can be easily washed out from the coated gravels. The coated gravels had good environmental stability and the slightly partial de-crosslinking of alginate structure would not reduce the oil repellence performance. Moreover, the performance of the alginate hydrogel-coated gravel was further proved with a laboratory shoreline tank simulator, in which more stranded oil floated to the water surface and less oil remained on gravels and entered into subsurface. This proposed oiling prevention method can be used not only for shorelines but also for coastal piers, seaports, and solid manmade shorelines. The coating material is derived from the biomass in the ocean and can be degraded under natural conditions. This study may provide a unique direction for the future development of green oil spill control strategy.

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Publication List

Assessing the coastal sensitivity to oil spills from the perspective of ecosystem services: A case study for Canada's pacific coast

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Coastal environment is one of the most important ecological and socioeconomic areas. However, increasing energy demand and economic development lead to a continuous gas and oil exploration, production, and traffics, which notably raise the risk of oil spill accidents in coastal areas. Sensitivity assessment aiming to determine the coastal features that would be severely impaired by spill incidents is a crucial part of the response planning. In this study, an innovative framework for coastal sensitivity mapping that incorporated ecosystem service (ES) valuation and multidimensional assessment was proposed. Sensitivity was computed by valuing physical, biological, and social-economical indicators from ES perspective and separating each indicator into specific coastal domains. For different ES typologies, provisioning services contributed most to the overall ES value followed by culture services, supporting services, and regulating services. For ES value in different coastal domains, the highest value was recorded in the water column followed by water surface, shoreline, and seabed. However, the shoreline ranked highest regarding the ES value per ha. Sensitivity assessment revealed that sensitive areas differed in different domains, both in distribution and extent. Compared with the scoring method, the ES valuation method showed more coincidence with Ecologically and Biologically Significant Areas (EBSA), representing a more precise and practical approach for sensitivity assessment. A three-dimensional (3D) oil spill model was also applied to generate maps of oil contamination probability in shoreline, water surface, and water column. The obtained results highlighted the significance of incorporating different coastal domains into oil spill responses, and the urgent demand to broaden and deepen our understanding of ecological processes across the vertical coastal zones.

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Formation of oil-particle aggregates: Impacts of mixing energy and duration

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Spilled oil slicks are likely to break into droplets offshore due to wave energy. The fate and transport of such droplets are affected by suspended particles in local marine environment, through forming oil particle aggregates (OPAs). OPA formation is affected by various factors, including the mixing energy and duration. To evaluate these two factors, lab experiments of OPA formation were conducted using kaolinite at two hydrophobicities in baffled flasks, as represented by the contact angle of 28.8° and 37.7° (original and modified kaolinite). Two mixing energies (energy dissipation rates of 0.05 and 0.5 W/kg) and four durations (10 min, 30 min, 3 h, and 24 h) were considered. Penetration to the oil droplets was observed at 3-5 μm and 5-7 μm for the original and modified kaolinite by confocal microscopy, respectively. At lower mixing energy, volume median diameter d50 of oil droplets increased from 45 μm to 60 μm after 24 h mixing by original kaolinite; for modified kaolinite, d50 decreased from 40 μm to 25 μm after 24 h mixing. The trapped oil amount in negatively buoyant OPAs decreased from 35% (3 h mixing) to 17% (24 h mixing) by original kaolinite; and from 18% to 12% after 24 h mixing by modified kaolinite. Results indicated that the negatively buoyant OPAs formed with original kaolinite at low mixing energy reaggregated after 24 h. At higher mixing energy, d50 decreased from 45 μm to 17 μm after 24 h mixing for both kaolinites. And the trapped oil amount in negatively buoyant OPAs increased to 72% and 49% after 24 h mixing for original and modified kaolinite, respectively. At higher mixing energy, the OPAs formed within 10 min and reached equilibrium at 3 h by original kaolinite. For modified kaolinite, the OPAs continued to form through 24 h.

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Publication List

Dispersion modeling of particulate matter from the in-situ burning of spilled oil in the northwest Arctic area of Canada

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In-situ burning can be used to prevent oil spreading in oil spill response. In this study, a steady-state Gaussian plume model was applied to analyze the concentration distribution of fine particulate matter produced by in-situ burning, as well as to assess the health risks associated with different combustion methods and ambient conditions, in reference to three simulation scenarios. The spatial and temporal distribution of emission sources can affect the dispersion pattern. The distribution into an array of different burning locations ensures better dispersion of emissions, thereby preventing the formation of high concentration regions. The wind and atmosphere stability play an important role in pollution dispersion. Lower wind and temperature inversion can seriously hinder the diffusion of pollutants. The health risk to technical staff adjacent to the burning areas is a serious concern, and when the community is more than 20 km away from the burning zone, there is few risks. Through simulation, the influences of combustion methods and natural factors on the concentration and diffusion of pollutants are evaluated. The results can help provide an optimized burning strategy for oil spill response in the Arctic area.

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Hypersaline pore water in Gulf of Mexico beaches prevented efficient biodegradation of Deepwater Horizon beached oil

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The 2010 Deepwater Horizon (DWH) blowout released 3.19 million barrels (435 000 tons) of crude oil into the Gulf of Mexico. Driven by currents and wind, an estimated 22 000 tons of spilled oil were deposited onto the northeastern Gulf shorelines, adversely impacting the ecosystems and economies of the Gulf coast regions. In this work we present field work conducted at the Gulf beaches in three U.S. States during 2010–2011: Louisiana, Alabama, and Florida, to explore endogenous mechanisms that control persistence and biodegradation of the MC252-oil deposited within beach sediments as deep as 50 cm. The work involved over 1500 measurements incorporating oil chemistry, hydrocarbon-degrading microbial populations, nutrient and DO concentrations, and intrinsic beach properties. We found that intrinsic beach capillarity along with groundwater depth provides primary controls on aeration and infiltration of near-surface sediments, thereby modulating moisture and redox conditions within the oil-contaminated zone. In addition, atmosphere–ocean–groundwater interactions created hypersaline sediment environments near the beach surface at all the studied sites. The fact that the oil-contaminated sediments retained near or above 20% moisture content and were also eutrophic and aerobic suggests that the limiting factor for oil biodegradation is the hypersaline environment due to evaporation, a fact not reported in prior studies. These results highlight the importance of beach porewater hydrodynamics in generating unique hypersaline sediment environments that inhibited oil decomposition along the Gulf shorelines following DWH.

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A green initiative for oiled sand cleanup using chitosan/rhamnolipid complex dispersion with pH-stimulus response

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The released oil can affect the vulnerable shoreline environment if the oil spills happen in coastal waters. The stranded oil on shorelines is persistent, posing a long-term influence on the intertidal ecosystem after weathering. Therefore, shoreline cleanup techniques are required to remove the oil from the shoreline environment. In this study, a new shoreline cleanup initiative using chitosan/rhamnolipid (CS/RL) complex dispersion with pH-stimulus response was developed for oiled sand cleanup. The results of factorial and single-factor design revealed that the CS/RL complex dispersion maintained high removal efficiency for oiled sand with different levels of oil content in comparison to using rhamnolipid alone. However, the increase of salinity negatively affected the removal efficiency. The electrostatic screening effect of high ionic strength can hinder the formation of the CS/RL complex, and thus reduce removal efficiency. The pH-responsive characteristic of chitosan allows the easy separation of water and oil in washing effluent. The chitosan polyelectrolytes aggregated and precipitated due to the deprotonation of amino groups by adjusting the pH of the washing effluent to above 8. The microscope image demonstrated that the chitosan aggregates wrapped around the oil droplets and settled to the bottom together, thus achieving oil–water separation. Such pH-stimulus response may help achieve an easy oil-water separation after washing. These findings have important implications for developing the new strategies of oil spill response.

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Investigation into the impact of aged microplastics on oil behavior in shoreline environments

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Understanding the interactions between oil and other particles in shoreline can help determine the environmental risk and cleanup strategy after oil spill. Nevertheless, far less has been known regarding the impact of aged MPs on oil behavior in the shoreline environment. In this study, the aging course of polyethylene (PE) in shaking seawater and ultraviolet (UV) radiation conditions was investigated. The seawater aging mainly affected the physical properties of MPs, increasing its surface pores and hydrophilicity. UV aging significantly affected both the physical and chemical properties of MPs, which increased its hydrophilicity and crystallinity, decreased its mean particle size and introduced oxygen-containing functional groups onto MPs. The two-dimensional correlation spectroscopy (2D COS) analysis confirmed the evolution of oxygen-containing functional groups from C-O to C=O. The effects of aged MPs on oil behavior in water-sand system were further explored. The oil remaining percentages were non-linearly changed with the increasing aging degree of MPs. The particle size of the aqueous phase after washing was inversely related to the oil remaining percentage. Further FTIR analysis revealed that C-O and C-H functional groups played an important role in the process of oil adsorbed on MPs.

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Green biomass-derived materials for oil spill response: recent advancements and future perspectives

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Intensive energy production and consumption are associated with many oil spill accidents which can result in environmental pollution and other socio-economic impacts. Oil/water separation and surface washing strategies have been adopted to remove oil from both water and shorelines. Recently, green biomass-derived materials have attracted tremendous interest from researchers since they are low-cost, non-toxic, widely available, and environmentally friendly. This review comprehensively summarizes recent advances using such green materials for oil spill treatment, namely, oil/water filtration, oil sorption, and surface washing. The preparation methods, wettability characteristics, oil removal performance, and stability of green biomass-derived materials were introduced. The perspectives for future challenges and prospects of green materials in oil spill response are also proposed.

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Treatment of oiled beach sand using a green and responsive washing fluid with nonionic surfactant-modified nanoclay

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Marine oil spills may cause huge economic loss and detrimental effects to the coastal ecosystem and communities. In this study, a green and responsive washing fluid was developed by modifying the nanoclay with a nonionic surfactant to wash the stranded oil on beach sand. The characterization results showed changes in the basal spacing, absorption peaks, thermal degradation, surface morphology, and element weights after modification, indicating the surfactant was successfully loaded onto the nanoclay. Batch tests were conducted to investigate the effect of washing time, temperature, salinity, pH, and the modified nanoclay concentration on washing performance. The two-level factorial analysis revealed that salinity was the most significant environmental factor to the oil removal efficiency. It also indicated the interactions of temperature with salinity and salinity with the modified nanoclay concentration were significant to the response. The separation tests suggested the addition of calcium chloride could dramatically reduce the turbidity and the oil concentration in the washing effluent. In addition, the thermodynamic miscibility model was applied to explore oil/water miscibility in the presence of the modified nanoclay, and the results were in good agreement with experiments. The proposed green and responsive washing fluid with nonionic surfactant-modified nanoclay in this study has great potential in shoreline cleanup.

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Publication List

Cleanup of oiled shorelines using a dual responsive nanoclay/sodium alginate surface washing agent

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Oil spills may affect ecosystems and endanger public health. In this study, we developed a novel and dual responsive nanoclay/sodium alginate (NS) washing fluid, and systematically evaluated its application potential in oiled shoreline cleanup. The characterization results demonstrated that sodium alginate combined with nanoclay via hydrogen bonds, and was inserted into the interlayer spacing of nanoclay. Adding sodium alginate reduced surface and interfacial tensions, while increasing the viscoelasticity of the washing fluid. Batch experiments were conducted to investigate oil removal performance under various conditions. Additionally, the factorial design analysis showed that three single factors (temperature, oil concentration, and salinity), and two interactive effects (temperature/salinity; and oil concentration/HA) displayed significant effects on the oil removal efficiency of the NS washing fluid. Compared to the commercial surfactants, the NS composite exhibited satisfactory removal efficiencies for treating oily sand. Green materials-stabilized Pickering emulsion can potentially be used for oil/water separation. The NS washing agent displayed excellent pH- and Ca^{2+}- responsiveness, generating transparent supernatants with low oil concentration and turbidity. Our work opens an interesting avenue for designing economical, high performance, and green washing agents.

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Publication List

Modeling oil biodegradation and bioremediation within beaches

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Modeling oil biodegradation and remediation has become an increasingly important means to predict oil persistence and explore potential in-situ bioremediation strategies for oil-contaminated beaches. Beaches involve complex mixing dynamics between seawater and groundwater. Thus, numerically predicting oil biodegradation within beach systems faces major challenges in merging highly dynamic biogeochemical conditions into microbial degradation models. In this paper, we reviewed recent advances in modeling oil biodegradation from aspects of oil phases, reaction kinetics, microbial activities, environmental conditions, and beach hydrodynamics. We identified key controlling factors of oil biodegradation, highlighted the importance of fate and transport processes on nearshore oil biodegradation, and suggested some advances needed to achieve for developing a robust numerical model to predict oil biodegradation and bioremediation within beaches.

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Publication List

A pH-responsive phosphoprotein surface washing fluid for cleaning oiled shoreline: Performance evaluation, biotoxicity analysis, and molecular dynamic simulation

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Oil spill accidents can cause negative impacts on the shoreline ecosystem and endanger public health. In the present study, an innovative green surface washing method based on sodium caseinate (NaCas) was proposed for the cleanup of oiled sand that is removed from the shoreline and treated by washing ex-situ. The comprehensive performance evaluation, biotoxicity analysis, and molecular dynamic simulation were conducted to explore the washing process. The addition of NaCas was able to decrease both surface and interfacial tensions, thereby facilitating oil diffusion and leading to a higher oil removal performance. NaCas fluid displayed a comparable washing performance with some surfactants. The factorial analysis demonstrated that three individual factors (temperature, pH, and NaCas concentration) and three interactive effects (temperature/salinity, temperature/pH, and salinity/pH) had a significant impact on the washing performance of NaCas fluid. Notably, the washing effluent displayed good pH responsiveness, generating a super-clean supernatant with low turbidity and oil concentration. Moreover, biotoxicity tests proved that the presence of NaCas could relieve the toxicity caused by oil droplets by enhancing the chlorophyll concentration and decreasing the reactive oxygen species (ROSs) content, respectively. The molecular dynamic simulation further revealed that NaCas could break the oil layer on the sand surface and move the oil droplets away from the sand. NaCas fluid is a promising candidate for oiled shoreline cleanup due to its low cost, good biocompatibility, pH responsiveness, and high oil removal efficiency.

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Publication List

Numerical simulation of benzene transport in shoreline groundwater affected by tides under different conditions

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The release and transport of benzene in coastal aquifers were investigated in the present study. Numerical simulations were implemented using the SEAM3D, coupled with GMS, to study the behavior of benzene in the subsurface of tidally influenced beaches. The transport and fate of the benzene plume were simulated, considering advection, dispersion, sorption, biodegradation, and dissolution on the beach. Different tide amplitudes, aquifer characteristics, and pollutant release locations were studied. It was found that the tide amplitude, hydraulic conductivity, and longitudinal dispersivity were the primary factors affecting the fate and transport of benzene. The tidal amplitude influenced the transport speed and percentage of biodegradation of benzene plume in the beach. A high tidal range reduced the spreading area and enhanced the rate of benzene biodegradation. Hydraulic conductivity had an impact on plume residence time and the percentage of contaminant biodegradation. Lower hydraulic conductivity induced longer residence time in each beach portion and a higher percentage of biodegradation on the beach. The plume dispersed and the concentration decreased due to high longitudinal dispersivity. The results can be used to support future risk assessment and management for the shorelines impacted by spill and leaking accidents. Modeling the heterogeneous beach aquifer subjected to tides can also be further explored in the future study.

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A review on the use of nanoclay adsorbents in environmental pollution control

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Clay is a natural substance widely existing in the environment. Nanoclays have small particle size, large surface area, and high porosity. Due to their special characteristics, nanoclays can be used in many different industrial applications. There is also an emerging trend for the use of nanoclays in environmental applications. Nanoclays can be used as adsorbents for the removal of various pollutants from water and gas. The suitability of nanoclays for certain type of application will depend on the requirement for pollution control, as well as the specifications of nanoclays. This article provided a comprehensive review of the specific characteristics of different types of nanoclays. The industrial applications of nanoclays were summarized. The environmental applications of nanoclays for water and gas emission treatment, as well as their toxicity, were discussed. The challenges and recommendations for future study were also proposed.

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Physicochemical change and microparticle release from disposable gloves in the aqueous environment impacted by accelerated weathering

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The explosive growth of disposable gloves usage in cities around the world has posed a considerable risk to municipal solid management and disposal during the COVID-19 pandemic. The lack of the environmental awareness leads to glove waste being discarded randomly and ending up in the soil and/or the ocean ecosystem. To explore the physicochemical changes and environmental behaviors of disposable glove wastes in the aqueous environment, three kinds of glove (latex, nitrile and vinyl) were investigated. The results showed that the physicochemical characteristics of disposable gloves made of different materials were altered to different degrees by UV weathering. Nitrile gloves were more stable than latex and vinyl gloves after being exposed to weathering conditions. Although the chemical structures were not clearly demonstrated through FTIR after weathering, the SEM results showed significant microscopic changes on the surfaces of the gloves. Analysis of the leachate results showed that UV weathered gloves released leachable substances, including microparticles, organic matter, and heavy metals. Latex gloves were more likely to release microparticles and other substances into the water after UV weathering. The release of microparticles from gloves can also be impacted by sand abrasion. The appropriate strategy needs to be developed to mitigate the environmental impact caused by the discarded gloves.

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Publication List

Publication Abstracts

Transport of microplastics in shore substrates over tidal cycles: Roles of polymer characteristics and environmental factors

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Tidal zones providing habitats are particularly vulnerable to microplastic (MP) pollution. In this study, the effects of tidal cycles on the transport of MPs (4–6 μm polyethylene, PE1; 125 μm polyethylene, PE2; and 5–6 μm polytetrafluoroethylene, PFTE) in porous media combined with various environmental and MPs properties were systemically investigated. The results indicated that smaller substrate sizes exhibited higher retention percentages compared to those of larger substrate sizes under different tidal cycles. In terms of the size of MPs, a larger size (same density) was found to result in enhanced retention of MPs in the column. As the number of tidal cycles increased, although the transport of MPs from the substrate to the water phase was enhanced, PE1 was washed out more with the change in water level, compared to PTFE. Additionally, more MPs were retained in the column with the increase of salinity and the decrease of flow velocity under the same tidal cycles. Ultraviolet and seawater aged PE1 showed enhanced transport, while aged PTFE showed enhanced retention under the same tidal cycles. These results can help understand the MP behaviors in the shoreline environment and provide support for future cleanup and sampling in tidal zones.

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Publication List

Sources, behaviors, transformations, and environmental risks of organophosphate esters in the coastal environment: A review

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The rapid growth in the global production of organophosphate esters (OPEs) has resulted in their high environmental concentrations. The low removal rate of OPEs makes the effluents of wastewater treatment plants be one of the major sources of OPEs. Due to relatively high solubility and mobility, OPEs can be carried to the coastal environment through river discharge and atmospheric deposition. Therefore, the coastal environment can be an important OPE sink. Previous studies have shown that OPEs were widely detected in coastal atmospheres, water, sediments, and even aquatic organisms. OPEs can undergo various environmental processes in the coastal environment, including adsorption/desorption, air–water exchange, and degradation. In addition, bioaccumulation of OPEs was observed in coastal biota but current concentrations would not cause significant ecological risks. More efforts are required to understand the environmental behaviors of OPEs and address resultant environmental and health risks, especially in the complicated environment.

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Publication List

Exploring the effects of substrate mineral fines on oil translocation in the shoreline environment: Experimental analysis, numerical simulation, and implications for spill response

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Mineral fines act a pivotal part in determining the fate and behavior of oil. In this study, the infiltrations of oil emulsion in simulated sediments and natural shoreline sediments were investigated using a fixed bed experiment. Oil infiltration process was simulated based on fixed-bed dispersion model. The role of mineral fines in oil release was explored using simulated and natural sediments. Although mineral fines exhibited a higher affinity for oil, it was found that increasing fines fractions decreased the flow rate of oil emulsion, thereby decreasing the oil retention in the sediment column. In terms of oil release from the sediment, the highest level of oil mass was observed in the oil-mineral flocculation phase compared to the water column and the water surface compartments. Compared to light crude oil, the release of engine oil from sediment was less. The effects of mineral fines on oil infiltration and release were also confirmed by using natural shoreline sediments. Results of our detailed field studies also showed that current shoreline classification datasets do not characterize the presence and fraction of mineral fines at a level of detail required to accurately predict the significance of oil translocation following spill incidents.

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Development of a calcium alginate-cellulose nanocrystal-based coating to reduce the impact of oil spills on shorelines

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It is well known that oil stranded on shoreline substrates can be difficult to remove and cause serious environmental effects. To address this issue, a calcium alginate-cellulose nanocrystal (CA-CNC)-based coating with a unique surface structure and superhydrophobic properties was developed to reduce the extent of shoreline oiling. The results of batch washing test showed that not only did the introduction of CNC not reduce the oil removal efficiency; it also improved the environmental stability of the coating to resist the effects associated with seawater immersion and erosion (especially in the case of 0.4 wt% of CNC). The oil-repellent performance of the coated gravels implied that both oscillation time and oil concentration had almost no effects on the amount of adhered oil. Assessment of oiling prevention based on the laboratory shoreline tank simulator proved the coated gravel performed very well as more oil floated and less oil remained on substrates and penetrated into the subsurface. Biotoxicity analysis showed that the coating powders reduced impacts on the toxicity of the oil to algae at low doses. There is a good potential for the use of this CA-CNC based coating technique to improve shoreline oil spill response.

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Environmental impacts and challenges associated with oil spills on shorelines

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Oil spills are of great concern because they impose a threat to the marine ecosystem, including shorelines. As oil spilled at sea is transported to the shoreline, and after its arrival, its behavior and physicochemical characteristics change because of natural weathering phenomena. Additionally, the fate of the oil depends on shoreline type, tidal energy, and environmental conditions. This paper critically overviews the vulnerability of shorelines to oil spill impact and the implication of seasonal variations with the natural attenuation of oil. A comprehensive review of various monitoring techniques, including GIS tools and remote sensing, is discussed for tracking, and mapping oil spills. A comparison of various remote sensors shows that laser fluorosensors can detect oil on various types of substrates, including snow and ice. Moreover, current methods to prevent oil from reaching the shoreline, including physical booms, sorbents, and dispersants, are examined. The advantages and limitations of various physical, chemical, and biological treatment methods and their application suitability for different shore types are discussed. The paper highlights some of the challenges faced while managing oil spills, including viewpoints on the lack of monitoring data, the need for integrated decision-making systems, and the development of rapid response strategies to optimize the protection of shorelines from oil spills.

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Buoyant oleophilic magnetic activated carbon nanoparticles for oil spill cleanup

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In response to oil spills, it is imperative to develop efficient and eco-friendly sorbent materials. Oil remediation techniques are limited, prompting researchers to look into using nanotechnology for oil cleanup. Therefore, magnetic Fe3O4 composite nanoparticles (MNPs) were synthesized by the chemical co-precipitation method. The MNPs were then coated with activated carbon (AC) layer, followed by soybean oil/stearic acid surface decoration. The morphology and surface properties of the material were characterized using a scanning electron microscope (SEM), Brunauer-Emmett-Teller (BET), and contact angle (CA) analyses. The results showed an excellent amphiphilicity with water CA of 0° and oil CA of nearly 0°. In terms of applicability for oil recovery operations, the fabricated nanocomposite revealed sorption capacities greater than 6.5 g/g for a range of oils. In addition, the sorbent can be reused at least five times with advantageous characteristics for selective oil recovery on surface waters owning to its intense super-paramagnetic properties. Considering our results, we suggest that there is a practical application for magnetic AC nanomaterials in spilled oil response.

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Publication List

Publication Abstracts

Exploring the characteristics, performance, and mechanisms of a magnetic-mediated washing fluid for the cleanup of oiled beach sand

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In the present study, an innovative, environmentally benign recyclable, and magnetically mediated surface washing fluid based on water-dispersible magnetite nanoparticles has been designed and investigated for the cleanup of oiled beach sand. The characterization results showed that the as-prepared magnetite nanoparticles had a spherical morphology with an average diameter of around 250 nm and the particle surface was successfully functionalized with carboxyl groups. The magnetite nanoparticles could be easily re-dispersed by lightly shaking the dispersion after withdrawing the magnet. In addition, prolonging the magnetic field strength and response time promoted the oil recovery from the washing effluent. Thermodynamic modeling was applied to theoretically elucidate the mechanism and the results were in alignment with the experimental findings. Four mechanisms were identified to likely affect surface washing performance. The magnetic fluid had a relatively low operation cost and good reusability for a number of multiple cycles. In terms of other operational limitations, it was noted that washing performance declined as clay (kaolinite) concentrations and salinity values increased. Based on these findings, the proposed stable, low-cost magnetite fluid formulation warrants further investigation as the basis for an operational system for the cleanup of sand beaches contaminated by oil spills.

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Publication List

Experimental and modeling studies of the efects of nanoclay on the oil behaviors in a water–sand system

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When oil is released into the oceans, spilled oil may get to the shoreline driven by wind and wave. This study comprehensively explored the effects of bentonite nanoclay on the oil behaviors in a water-sand system from both experimental and modeling perspectives. Four factors including nanoclay concentration, temperature, salinity, and pH have been studied. The increasing nanoclay concentration resulted in the decrease in remaining oil on sand. Higher temperature and salinity were associated with less residual oil on sand in the presence of nanoclay. The lower residual oil on sand with coexisting nanoclay was found to be at pH 7. The factorial analysis results indicated that the nanoclay concentration showed the most significant impact among these factors. Miscibility modeling results showed an increasing temperature was favorable to the nanoclay miscibility. Moreover, the effect of nanoclay on oil behavior was further revealed through the dynamic simulation, in which it can be seen the nanoclay could penetrate into oil droplets and promote the oil detachment from solid substrate. The results of this study can help understand the role of fine particles in the fate and transport of oil on shoreline and support the risk assessment and response planning after oil spill.

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Upcoming Event

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