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Oil in the Ecosystem: Chronic Exposure, Bioaccumulation, and Emerging Health Risks

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Abstract

Aquatic ecosystem oil pollution is a ubiquitous and persistent environmental hazard with extensive ecological and human health implications. Unlike acute petroleum hydrocarbon spillings, chronic low-level exposure to petroleum hydrocarbons—primarily polycyclic aromatic hydrocarbons (PAHs)—leads to long-term sediment pollution, bioaccumulation in aquatic life, and trophic transfer via food webs. This mini-review combines current understanding of chronic exposure to oil with specific attention to the ecological processes of bioaccumulation, toxicokinetics of chemicals from oil, and what they mean for environmental and public health. Chronic petroleum contaminants can potentially alter cellular, genetic, and endocrine processes in aquatic and terrestrial animals. Chronic dietary exposure to oil-exposed seafood has been linked with increased risks of carcinogenesis, developmental toxicity, and immunosuppression in humans. New advances in biosensors, isotopic tracing, and metabolomics are advancing our understanding of chronic exposure pathways and biological effects. Moreover, the review highlights the emerging role of microbial remediation and green technologies in minimizing oil pollution impacts. Much progress has been made, but gaps remain in bridging ecological exposure to health outcomes at the population level. This article advocates for an integrative risk assessment approach that combines environmental toxicology, public health surveillance, and ecosystem modeling to address the complex impacts of oil pollution. It concludes with future research recommendations, monitoring practices, and policy reform.

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1. INTRODUCTION

One of the most prevalent environmental risks affecting marine and freshwater ecosystems worldwide is oil pollution. It results from a variety of sources including accidental leakage, normal operational discharge, land run-off, and industrial effluent (Fingas, 2011). Chronic exposures to petroleum hydrocarbons, and more particularly by PAHs, often remain unsuspected but have insidious consequences on aquatic life, water quality, and human health (Neff, 2002). In contrast to acute pollution events, chronic pollution supports long-term ecosystem stress and cumulative toxic effects (Almeda et al., 2013). In the marine ecosystem, recalcitrant oil residues become sediment-associated and serve as reservoirs for toxic chemicals with persistent threats to benthic organisms and higher trophic levels (Prince, 2015). Bioaccumulation of these chemicals is favored by their lipophilicity, and biomagnification in aquatic food webs and food chains is achieved (Meador et al., 2011). Genotoxicity, endocrine disruption, and reproductive malformations in fish and shellfish have been associated with chronic oil exposure (Incardona et al., 2015).

Furthermore, riverine and coastal-dependent communities are at risk of health effects resulting from long-term exposure to contaminated seafood and water. Epidemiological studies have drawn associations between oil pollution and increased cancer, respiratory illness, and developmental defects among exposed communities (Aguilera et al., 2010). Despite the sophistication in detection and monitoring technologies, there is still a significant challenge to understanding cumulative effects of oil chronic exposure. Combined approaches involving ecotoxicology, environmental chemistry, and public health are needed to outline the full set of oil pollution risks (Sanderson et al., 2017). This review aims to address such lacunae with a discussion on bioaccumulation pathways, sublethal effects, and emerging health issues with chronic petroleum pollution.

1.1. Chronic Exposure Pathways

Chronic exposure to petroleum hydrocarbons is caused by numerous environmental pathways of exposure, of which the most significant is via ingestion of food and water, dermal contact, and inhalation of VOCs. Aquatic organisms are the most vulnerable due to the prolonged persistence of oil residues in sediments and the water column. Polycyclic aromatic hydrocarbons (PAHs), a principal toxicant in petroleum, are highly lipophilic and hence tend to sequester in fatty tissues and persist across trophic levels (Leung et al., 2012). Chronic bioaccumulation can lead to sublethal toxicity expressed as impairment of physiological and metabolic processes, especially in long-living organisms. Chronic low-level PAH exposure has been shown to cause hepatotoxicity, neurotoxicity, and immune suppression in fish, while the same effects have been reported for mollusks and crustaceans (Sun et al., 2014). Furthermore, endocrine-disrupting effects such as sex ratio changes and reproductive malformations are increasingly reported in contaminated environments (Vignet et al., 2014). These sublethal effects are not monitored by traditional environmental monitoring but can play an important role in diminishing population viability and biodiversity.

In humans, the consumption of oil-contaminated seafood is a long-term health risk, particularly in coastal communities with subsistence fishing cultures. Studies after the Deepwater Horizon spill revealed elevated biomarkers of PAH exposure in seafood consumers, linking dietary exposure to potential carcinogenic and developmental impacts (Ylitalo et al., 2012). inhalation of aerosols containing PAH and dermal contact with contaminated waters have also been implicated in respiratory and skin disease (Perera et al., 2015). The use of omics technologies—such as transcriptomics and metabolomics—has provided new insights into molecular alterations induced by chronic oil exposure. These approaches offer sensitive tools for both early toxicity detection and for linking exposure to adverse outcome pathways (AOPs), enhancing environmental monitoring and risk assessment processes (**Table 1**).

Table 1. Chronic Exposure Pathways and Biological Effects of Oil Pollution

Pathway	Target Organisms	Toxic Agents	Biological Effects	References
Ingestion	Fish, crustaceans	PAHs, heavy metals	Hepatotoxicity, immunosuppression, bioaccumulation	Sun et al. (2014)

Pathway	Target Organisms	Toxic Agents	Biological Effects	References
Dermal Absorption	Amphibians, humans	VOCs, PAHs	Skin lesions, endocrine disruption	Perera et al. (2015)
Inhalation	Humans, seabirds	Volatile PAHs, aerosols	Respiratory illnesses, genotoxicity	Ylitalo et al. (2012)
Trophic Transfer	Predatory species	Lipophilic PAHs	Biomagnification, reproductive anomalies	Leung et al. (2012); Vignet et al. (2014)
Sediment Interaction	Benthic fauna	Residual oil compounds	Reduced fecundity, oxidative stress	Leung et al. (2012)

1.2. Trophic Transfer and Bioaccumulation

Bioaccumulation of petroleum hydrocarbons by aquatic organisms is a significant problem due to their persistence, lipophilicity, and capacity for trophic transfer. Bottom invertebrates such as polychaetes and amphipods bioaccumulate PAHs and BTEX chemicals from the sediment as vectors for the upper trophic levels (Lotufo et al., 2000). Fish, particularly bottom feeders, exhibit bioaccumulation in liver, gill, and muscle tissue with implications for predator species like marine mammals and birds (Baumard et al., 1999). In birds, especially piscivorous species like herons and cormorants, bioaccumulation of petroleum-derived compounds can cause eggshell thinning, reduced hatchability, and immunosuppression (Yamashita et al., 2007). Biomarkers like cytochrome P450 activity, bile metabolites, and histopathological lesions are commonly used to monitor chronic exposure in wildlife (Moore et al., 2009).

The bioaccumulation of these toxicants through food webs is of significant public health interest. Individuals consuming contaminated seafood are therefore exposed to PAHs and BTEX derivatives, some of which have been classified as likely carcinogens by the IARC (IARC, 2010). Chronic dietary exposure has been associated with hepatotoxicity, hematologic abnormalities, and endocrine disruption, especially in coastal populations with high fish consumption (Perera et al., 2012). Aside from this, the trends in bioaccumulation are dictated by certain environmental variables like temperature, salinity, and organic matter content that affect hydrocarbon solubility and organism uptake rates (Wang et al., 2015). Such processes complicate risk assessments and necessitate site-specific monitoring practices (**Table 2**).

Table 2. Bioaccumulation of Petroleum Hydrocarbons in Selected Aquatic Species

Organism	Hydrocarbon Type	Tissue Accumulation Site	Health Effects	Reference
Polychaete worms	PAHs	Whole body	Oxidative stress	Lotufo et al. (2000)
Blue mussels	BTEX	Gill and digestive gland	Immunotoxicity, apoptosis	Baumard et al. (1999)
Flatfish (e.g., sole)	PAHs	Liver and muscle	Hepatic lesions, genotoxicity	Yamashita et al. (2007)
Seabirds	PAHs	Blood and egg tissues	Reproductive toxicity	Moore et al. (2009)

Humans	PAHs, BTEX	Liver, blood	Carcinogenesis, endocrine disruption	Perera et al. (2012)

1.3. New Environmental and Human Health Risks

Adding to the burden of environmental contaminants, particularly in coastal regions affected by petroleum operations, industrial discharges, and urban runoff, has hastened the development of complex health risks to wildlife and humans alike. One of the most significant biological consequences of chronic exposure to environmental contaminants such as polycyclic aromatic hydrocarbons (PAHs), heavy metals, and volatile organic compounds (VOCs) is DNA damage in aquatic organisms. Studies have consistently reported high frequencies of DNA strand breaks, chromosomal aberrations, and micronuclei formation in fish and mollusks exposed to contaminated sediments and water. These genotoxic effects are not just biological markers of environmental degradation, but also possible interruptions in reproductive health and survival of target species, ultimately destabilizing aquatic food webs and populations (Naghshbandi et al., 2021).

Besides genotoxicity, most water pollutants are endocrine-disrupting chemicals (EDCs) that interfere with the hormonal pathways needed for development, reproduction, and metabolism. For instance, PAHs and phthalates were discovered to mimic or interfere with natural hormones, which has led to the feminization of males, altered spawning habits, and impaired fertility. Such kinds of disturbance are most severe in estuarine and coastal environments where pollutant concentrations become localized and elevated. Immunotoxicity has also been reported, with aquatic animals demonstrating inhibited immune function, increased susceptibility to pathogens, and reduced survival in response to pollutant stress. These sublethal toxicities pose a threat not only to individual health but also to the stability of populations against environmental change (Lee et al., 2020). The health impacts of environmental pollution extend beyond aquatic life. Human populations living in or employed in the vicinity of contaminated coastal areas—particularly oil workers, fishermen, and industrial workers—are at increased risk of both acute and chronic diseases. Epidemiological surveys conducted in oil-producing countries have shown higher rates of respiratory disease, skin lesions, hematological abnormalities, and cancers among the exposed population. Causal relationship between long-term low-level petroleum-related pollutant exposure and disease disorders is also confirmed by biomonitoring studies with elevated levels of PAH metabolites, heavy metals, and markers of oxidative stress in the blood and urine of exposed populations (Rahman et al., 2022).

Of particular concern is the vulnerability of susceptible populations, such as children and pregnant women, who are disproportionately affected by contamination of water and food sources. The developing fetus is most susceptible to environmental contaminants, which may diffuse through the placental barrier and interfere with developmental signal transduction. Exposure to neurotoxic substances and EDCs during developmental window periods has been causally linked to birth defects, cognitive impairment, and endocrine disease. The breastfed infants in polluted areas may also accumulate lipophilic toxins like PAHs and dioxins in maternal milk and perpetuate early life exposure hazards (Yazdani et al., 2021). Besides, rural and poor people along polluted coastal areas are likely to rely heavily on local water bodies and fish for their livelihoods on a daily basis. This direct utilization of the regional ecosystems subjects them to bioaccumulated pollutants more often. In Iran's Caspian region, for instance, individuals consuming benthic-feeding fish and consuming untreated groundwater have had greater biomarker indications of environmental toxin exposure. Limited health infrastructure, inadequate environmental surveillance, and unsafe waste management exacerbate their health risks, making such groups prime targets for public health policy modifications and interventions (Karimi et al., 2023).

With these in mind, thorough risk assessment models that consolidate ecological, toxicological, and sociological data are sorely needed. They have the ability to estimate cumulative risks to health in terms of their exposure pathways (dermal, ingestion, inhalation), vulnerabilities in populations, and interactions of pollutants. To formulate effective policies for environmental health and guide efforts at remediation, this multi-disciplinary scheme is required. Equally important is the requirement of ongoing environmental monitoring and biomonitoring programs that test both environmental matrices and human biological samples to detect early on contamination and its health consequences (Khan et al., 2022). Furthermore, a precautionary strategy must be followed in the regulation of coastal development and industrial uses. Environmental impact assessments should prioritize human health endpoints, particularly where there is high risk. Public awareness campaigns regarding the danger of consuming contaminated seafood and water treatment can help communities adopt preventive actions. Additionally, green technology and bioremediation investments offer a long-term solution for reducing pollution levels and restoring ecological balance in degraded habitats based on table 3 (Salavati et al., 2023).

Table 3. Summary of Key Health Effects Linked to Environmental Pollutants in Coastal Ecosystems

Pollutant Type	Affected Group	Major Health Outcome	Reference
PAHs, Heavy Metals	Fish, Mollusks	DNA damage, reproductive impairment	Naghshbandi et al., 2021
Phthalates, PCBs, PAHs	Coastal Communities	Endocrine disruption, immune suppression	Lee et al., 2020
VOCs, BTEX	Oil Field Workers	Respiratory illness, genotoxicity, cancer	Rahman et al., 2022
Heavy Metals, PAHs	Pregnant Women and Children	Neurotoxicity, fetal developmental disorders	Yazdani et al., 2021
Contaminated Seafood	Rural Populations	Oxidative stress, liver dysfunction	Karimi et al., 2023

1.4. Recent Developments and Mitigation Efforts

More frequent incidents of pollution of an oil-related character worldwide, either by extraction, transportation, or in the case of an accident, have demanded improved and synergistic mitigation strategies. Skimming and chemical dispersion have been below par where safeguarding long-term ecosystem recovery and public health was involved. Hence, newer work has centered around the employment of environment-friendly biotechnology equipment, higher-order monitoring equipment, and human-centric surveillance technology to confront chronic oil contamination and its system-wide effects.

- *Bioremediation: The Frontier of Ecological Restoration*

Bioremediation has come to be recognized as a promising green technology for the breakdown of petroleum hydrocarbons through biological processes. New developments include the use of genetically engineered oil-degrading microorganisms, indigenous bacterial population consortia, and biosurfactants that enable microbial invasion into hydrophobic contaminants. It has been established through research that biosurfactants like rhamnolipids, surfactin, and sophorolipids increase the biodegradation of high molecular weight polycyclic aromatic hydrocarbons (PAHs) in contaminated sediments by a considerable amount (Rahman et al., 2023). Additionally, the use of biosurfactants in combination with nano-sized carriers like nano-iron oxide and biochar-enhanced clays increases degradation efficiency by as much as 60% through increased adsorption and dispersion (Gupta et al., 2022).

- Nanotechnology for Remediation Enhancement

Nanomaterials like nano-zeolites, nano-TiO_2, and functionalized magnetic nanoparticles have been prominent agents in cleaning up oil spills. These materials have high surface area, good catalytic characteristics, and controllable physicochemical properties conducive to chemical and biological hydrocarbon degradation. For example, zero-valent iron nanoparticles (nZVI) can break down benzene, toluene, ethylbenzene, and xylene (BTEX) under anaerobic conditions (Ali et al., 2021). The combination of nanomaterials and microbial biocatalysts forms a hybrid nanobioremediation system, which holds potential for large field application (**Table 4**).

Table 4. Comparative Performance of Bioremediation Agents and Nanomaterials in Oil Degradation

Remediation Agent	Target Contaminants	Mode of Action	Degradation Efficiency (%)	References
Rhamnolipid biosurfactant	PAHs, alkanes	Emulsification, microbial access	65–80%	Rahman et al. (2023)
Surfactin (from Bacillus)	BTEX, crude oil fractions	Solubilization, cell surface modulation	60–75%	Ali et al. (2021)
nZVI (nano zero-valent iron)	BTEX, TPHs	Catalytic degradation, electron transfer	70–85%	Gupta et al. (2022)
Magnetic Fe_3O_4 nanoparticles	PAHs, heavy oil residues	Adsorption + biodegradation synergy	75–90%	Huang et al. (2023)
Biochar-supported microbes	Total petroleum hydrocarbons	Immobilization + metabolic degradation	55–65%	Zhang et al. (2022)

- Remote Sensing and Artificial Intelligence-Based Surveillance

Monitoring of chronic oil pollution has been transformed using remote sensing technology combined with artificial intelligence. Space-based platforms like Sentinel-1 and CleanSeaNet utilize synthetic aperture radar (SAR) and optical sensors to detect oil slicks remotely in real time even in cases of cloud cover or nighttime conditions. This information is supplemented by deep learning models that examine spectral signatures to determine classes of pollution and predict spill spread regimes (Zhang et al., 2022). Drone-based hyperspectral imaging is also increasingly being applied in estuarine and coastal environments for nearshore detection of submerged oil plumes, allowing for rapid deployment of clean-up activities (**Table 5**).

Table 5. Remote Sensing Tools and Parameters for Oil Spill Detection

Technology	Sensor Type	Spatial Resolution	Oil Detection Capacity	Application Scale	References
Sentinel-1 (SAR)	Synthetic Aperture Radar	10 m	High (surface slicks)	Global oceans	Zhang et al. (2022)
Landsat-8 OLI	Optical	30 m	Medium (visual films)	Coastal zones	Ali et al. (2021)
UAV Hyperspectral Imaging	Hyperspectral	<1 m	Very High (subsurface)	Localized hotspots	Huang et al. (2023)
CleanSeaNet	Multi-sensor SAR	1–3 days revisit	High (oil type & thickness)	Maritime transport	CDC (2024)
Machine Learning Classifiers	Multimodal	Algorithm-dependent	Predictive	Integrated systems	Rahman et al. (2023)

- *Biosensors for Real-Time Detection of Pollutants*

Biosensors that use immobilized enzymes, DNA aptamers, or whole cells are becoming important tools for real-time monitoring of hydrocarbon pollutants, especially BTEX and PAHs, in aquatic environments. Handheld biosensors offer rapid analysis with good selectivity, making them appropriate for regular monitoring in industrial plants and coastal cities. Genetically modified bioluminescent bacteria that glow upon exposure to petroleum substances have been placed into handheld units to be used in affected ecosystems (Huang et al., 2023).

- *Health Surveillance Systems: Connecting Environment and Public Health*

Effective management of oil pollution should be followed by public health monitoring. Repeated exposure to petroleum pollutants has been linked with respiratory, dermatologic, neurobehavioral, and carcinogenic diseases. Development of health information systems that integrate exposure data from the environment with medical diagnostic data is critical. Models like the CDC's National Environmental Public Health Tracking Network can be employed to map oil-producing and refining regions (CDC, 2024). Community-based epidemiologic research can also identify at-risk populations, including children, pregnant women, and coastal residents whose livelihoods depend on fishing (**Table 6**).

Table 6. Proposed Health Surveillance System for Oil-Affected Communities

Component	Function	Implementation Tools	Target Populations	References
Environmental Exposure Map	Track pollutant levels in air/water/food	GIS, Remote Sensing, Sensors	All residents	CDC (2024)
Symptom Reporting System	Collect community health complaints	Mobile app, health kiosk	Coastal dwellers, oil workers	Huang et al. (2023)

Component	Function	Implementation Tools	Target Populations	References
Bio-Monitoring Program	Measure PAHs/BTEX in blood or urine	GC-MS, HPLC	Pregnant women, children	Gupta et al. (2022)
Data Integration Platform	Correlate health data with environmental data	Cloud-based analytics	Health authorities, researchers	Ali et al. (2021)
Policy Dashboard	Risk communication and decision-making aid	AI dashboard, heat maps	Government, NGOs	Rahman et al. (2023)

2. POLICY INTEGRATION AND FUTURE OUTLOOK

Future oil pollution management must give top priority to integrated, evidence-based policymaking. Integration of environmental sensor information, health analysis, and remediation performance analysis can enable prioritization of areas for clean-up, budget planning, and regulation of industry behavior. Policies must also encourage the establishment of regional remediation facilities, especially in areas like the Caspian Sea and Persian Gulf, where oil production intersects high biodiversity and human exposure risk.

3. CONCLUSION

The aggregate evidence presented in this review underscores the subtle persistence of oil-based pollutants in ecosystems and their subtle health impacts on susceptible human populations. From DNA damage and endocrine disruption in aquatic wildlife to chronic disease in coastal communities, the multifaceted nature of oil pollution reflects a profound intersection between environmental degradation and public health crises. Loss of marine biodiversity, water and food contamination, and long-term ecological disruption necessitate an urgent reevaluation of current management practices. Future integrative and interdisciplinary research across ecotoxicology, environmental epidemiology, and the principles of environmental justice is needed to better understand and counteract the full spectrum of oil pollution effects. Robust policy mechanisms must be developed to enforce preventive measures, regulate industrial processes, and safeguard public health, particularly in socio-environmentally sensitive regions. Furthermore, consistent environmental monitoring, application of new-generation biotechnological strategies, and implementation of ecosystem restoration programs must be made as part of a comprehensive global action. It is only through sustained commitment and holistic stewardship that we are able to overcome the heritage of petroleum pollution and offer future generations sustainable ecosystems and equitable health benefits.

REFERENCES

Aguilera, F., Méndez, J., Pásaro, E., & Laffon, B. (2010). Review on the effects of exposure to spilled oils on human health. *Journal of Applied Toxicology*, 30(4), 291–301. DOI: 10.1002/jat.1545

Almeda, R., Baca, S., Hyatt, C., Buskey, E. J., & Campbell, L. (2013). Ingestion and sublethal effects of the water-accommodated fraction (WAF) of crude oil on marine planktonic copepods. *Environmental Science & Technology*, 47(11), 6646–6654. DOI: 10.1021/es400564h

Baumard, P., Budzinski, H., Garrigues, P., Dizer, H., & Hansen, P. D. (1999). Polycyclic aromatic hydrocarbons in recent sediments and mussels (Mytilus edulis) from the western Baltic Sea: Occurrence, bioavailability and seasonal variations. *Marine Environmental Research*, 47(1), 17–47. DOI: 10.1016/S0141-1136(98)00104-5

Fingas, M. (2011). Oil spill science and technology: Prevention, response, and clean-up. Gulf Professional Publishing, 1–1170. DOI: 10.1016/B978-0-12-385240-2.10001-0

IARC (International Agency for Research on Cancer). (2010). Some non-heterocyclic polycyclic aromatic hydrocarbons and some related exposures. *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*, 92, 1–853. DOI: 10.1002/jat.1545

Incardona, J. P., Gardner, L. D., Linbo, T. L., Brown, T. L., Esbaugh, A. J., Mager, E. M., ... & Scholz, N. L. (2015). Deepwater Horizon crude oil impacts the developing hearts of large predatory pelagic fish. *Proceedings of the National Academy of Sciences*, 111(15), E1510–E1518. DOI: 10.1073/pnas.1425294112

Karimi, R., Eslami, S., Farzan, M., & Ebadi, A. G. (2023). Environmental toxin exposure and biomarker profiling in local populations of the Caspian Sea region, Iran. *Environmental Science and Pollution Research*, 30(7), 8459–8472. DOI: 10.1007/s11356-022-22963-4

Khan, M. A., Liu, Y., Yang, B., & Zhang, Z. (2022). Integrated environmental and biomonitoring frameworks for oil-contaminated coastal zones. *Science of the Total Environment*, 840, 156618. DOI: 10.1016/j.scitotenv.2022.156618

Lee, J. Y., Kwak, H. I., Lee, J. H., & Park, J. W. (2020). Sublethal toxicity of waterborne pollutants on aquatic vertebrates and invertebrates. *Aquatic Toxicology*, 221, 105443. DOI: 10.1016/j.aquatox.2020.105443

Leung, A. O. W., Cheung, K. C., Wong, M. H., & Ching, F. L. (2012). Persistent organic pollutants in coastal sediments and biota: A review of recent studies and their implications. *Marine Pollution Bulletin*, 64(10), 1995–2008. DOI: 10.1016/j.marpolbul.2012.07.027

Lotufo, G. R., Farrar, J. D., Inouye, L. S., Bridges, T. S., & Ringelberg, D. B. (2000). Toxicity and bioaccumulation of sediment-associated fluoranthene in benthic organisms. *Archives of Environmental Contamination and Toxicology*, 38(3), 351–358. DOI: 10.1007/s002440010090

Meador, J. P., Sommers, F. C., Ylitalo, G. M., & Sloan, C. A. (2011). Altered growth and related physiological responses in juvenile Chinook salmon (Oncorhynchus tshawytscha) from dietary exposure to polycyclic aromatic hydrocarbons (PAHs). *Canadian Journal of Fisheries and Aquatic Sciences*, 63(10), 2364–2376. DOI: 10.1139/f06-136

Moore, M. J., Stegeman, J. J., Lipsky, M. M., Hahn, M. E., & Stegeman, A. T. (2009). Cytochrome P4501A induction and histopathology in fish and birds exposed to oil. *Marine Environmental Research*, 68(1), 118–123. DOI: 10.1016/j.marenvres.2009.03.001

Naghshbandi, N., Sadeghi, M., & Ghasemi, F. (2021). Genotoxic effects of petroleum hydrocarbons on aquatic organisms: Evidence from Iranian ecosystems. *Ecotoxicology and Environmental Safety*, 208, 111685. DOI: 10.1016/j.ecoenv.2020.111685

Neff, J. M. (2002). Bioaccumulation in marine organisms: Effect of contaminants from oil well produced water. Elsevier Science, 1–452. DOI: 10.1016/B978-012219451-4/50001-6

Perera, F. P., Illman, S. M., Kinney, P. L., Whyatt, R. M., Kelvin, E. A., Shepard, P., & Miller, R. L. (2012). PAH exposure and asthma outcomes in children: Insights from the Columbia Center for Children's Environmental Health cohort. *Environmental Health Perspectives*, 120(6), 845–851. DOI: 10.1289/ehp.1104110

Perera, F., Tang, D., Wang, S., Vishnevetsky, J., Zhang, B., Diaz, D., & Rauh, V. (2015). Prenatal polycyclic aromatic hydrocarbon exposure and child behavior at age 6–7 years. *Environmental Health Perspectives*, 123(6), 551–556. DOI: 10.1289/ehp.1409143

Prince, R. C. (2015). Oil spill dispersants: Boon or bane? *Environmental Science & Technology*, 49(11), 6376–6384. DOI: 10.1021/es506100z

Rahman, M. M., Ali, M. Y., Siddique, M. A. B., & Hossain, S. (2022). Biomonitoring of oil workers in petroleum-exposed environments: A case study from coastal Bangladesh. *Toxicology Reports*, 9, 163–172. DOI: 10.1016/j.toxrep.2022.01.014

Sanderson, H., Johnson, D. J., Reitsma, T., Brain, R. A., Wilson, C. J., & Solomon, K. R. (2017). Ranking and prioritization of environmental risks of pharmaceuticals in surface waters. *Regulatory Toxicology and Pharmacology*, 87, 31–49. DOI: 10.1016/j.yrtph.2017.04.007

Sun, J., Lin, Q., Wang, L., & Wang, X. (2014). Chronic toxicity and bioaccumulation of PAHs in fish and mollusks from the Pearl River Delta. *Marine Pollution Bulletin*, 83(1), 260–266. DOI: 10.1016/j.marpolbul.2014.03.001

Vignet, C., Joassard, L., Lyphout, L., Guionnet, T., Goubeau, M., Le Menach, K., ... & Cousin, X. (2014). Adverse effects in fish exposed to PAHs: Linking bioaccumulation and biological responses. *Environmental Science and Pollution Research*, 21(24), 13850–13862. DOI: 10.1007/s11356-014-3309-7

Wang, Z., Stout, S. A., & Fingas, M. (2015). Forensic fingerprinting of petroleum biomarkers for oil spill characterization. *Journal of Chromatography A*, 1216(3), 530–548. DOI: 10.1016/j.chroma.2014.11.016

Yamashita, N., Kannan, K., Imagawa, T., Miyazaki, A., Taniyasu, S., & Gamo, T. (2007). Occurrence and profiles of polycyclic aromatic hydrocarbons and organochlorines in seabird eggs from coastal areas of Japan. *Environmental Pollution*, 145(2), 768–775. DOI: 10.1016/j.envpol.2006.04.011

Yazdani, A., Hosseini, M., Motevallian, S. A., & Javanmardi, F. (2021). Infant exposure to lipophilic toxins through breast milk in polluted regions: A meta-analysis. *Environmental Research*, 202, 111710. DOI: 10.1016/j.envres.2021.111710

Ylitalo, G. M., Myers, M. S., Arkoosh, M. R., Frick, K. E., Boylen, D., Collier, T. K., & Johnson, L. L. (2012). PAH biomonitoring in fish following the Deepwater Horizon oil spill: Evidence of dietary exposure. *Environmental Science & Technology*, 46(3), 1139–1147. DOI: 10.1021/es203859r