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ترسل البحوث وجميع المراسلات المتعلقة بالمجلة إلى العنوان التالي:

كلية العلـــوم – جامعــة الزيتونــة – ترهــــونة

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أعزائي القراء والمهتمين بالمعرفة والعلم،

بحمد الله وتوفيقه تم صدور العدد العاشر من مجلة "روافد المعرفة"، الصادرة عن كلية العلوم بجامعة الزيتونة. إن هذا الإصدار الذي نقدمه لكم يعكس التفاني والتميز الذي يتميز به فريق العمل والباحثين الذين ساهموا في إثراء هذا العدد بمقالاتهم وأبحاثهم الرائعة.

مجلة "روافد المعرفة" تعد نافذةً مهمة لنشر العلم والبحث العلمي، وهي تسعى جاهدة لتعزيز التواصل العلمي وتبادل المعرفة بين الباحثين والمهتمين بالمجالات العلمية المختلفة. إن تنوع المواضيع المطروحة في هذا العدد يعكس الاهتمام الكبير بمجالات العلوم الطبيعية والتطبيقية، ويعزز الوعي والفهم العلمي للقراء.

في هذا العدد العاشر، ستجدون مقالات متنوعة تتناول العديد من المواضيع المميزة والمفيدة في مجالات العلوم الطبيعية والتطبيقية. ولذلك، نحن واثقون من أن هذا العدد سيثري ثقافتكم ويوسّع آفاق المعرفة لديكم.

في ختام كلمتنا، أود أن نعرب عن امتناننا العميق للفريق الذي عمل بجد واجتهاد لجعل هذا العدد حقيقةً، وأشكر جميع الباحثين الذين شاركوا معنا معرفتهم وخبراتهم. وأتمنى أن يكون هذا العدد بمثابة نقطة انطلاق لمزيد من النجاح والتألق في المستقبل.

نتمنى لكم قراءة ممتعة ومفيدة، ونحن في انتظار ملاحظاتكم وآرائكم القيّمة.

شكراً لثقتكم ودعمكم المستمر.

دمتم بخير وعلم نافع.

هيئة التحرير

اشتراطات النشر في مجلة روافد المعرفة

1- أن يكون البحث أصيلاً ومبتكراً ولم يسبق نشره في أي جهة أخرى، وتتوفر فيه شروط البحث العلمي المعتمدة على الأصول العلمية والمنهجية المتعارف عليها في كتابة البحوث الاكاديمية.

-2- أن يكون البحث مكتوباً بلغة سليمة، ومراعياً لقواعد الضبط ودقة الرسوم والاشكال – إن وجدت و مطبوعاً بخط Microsoft Word (Simplified Arabic) ببنط (14) للغة العربية، وخط (Times New Roman) ببنط (12) للغة الإنجليزية، وألا تزيد صفحات البحث عن (35) صفحة متضمنة المراجع والملاحق (إن وجدت).

-3- يجب أن يشتمل البحث على العناصر التالية - عنوان البحث باللغتين العربية والإنجليزية - - ملخص تنفيذي باللغتين العربية والإنجليزية في نحو 100 - 125 كلمة والكلمات المفتاحية (keywords) بعد كل ملخص .

-4 يتم توثيق الهوامش وفق طريقة الجمعية الأمريكية السيكولوجية (APA) بإصدارتها المختلفة.

-5- يُفضل أن تكون الجداول والاشكال مدرجة في أماكنها الصحيحة، وأن تشمل العناوين والبيانات الإيضاحية الضرورية، ويراعى ألا تتجاوز أبعاد الاشكال والجداول حجم حيز الكتابة في صفحة.

-6- أن يكون البحث ملتزماً بدقة التوثيق، استخدام المصادر والمراجع، وأن تثبت مصادر ومراجع البحث في نهاية البحث.

7- تحتفظ المجلة بحقها في اخراج البحث وإبراز عناوينه بما يتناسب واسلوبها في النشر.

-8- - ترحب المجلة بنشر ما يصلها من ملخصات الرسائل الجامعية التي تمت مناقشتها وإجازتها على أن يكون الملخص من إعداد صاحب الرسالة نفسه.

9 - تُرسل نسخة من البحث مطبوعة على ورق بحجم (A4) إلى مقر المجلة، ونسخة إلكترونية إلى إيميل المجلة : wafedalmarefa@gmail.com او على رقم الواتساب 0921253199 على أن يدون على صفحة الغلاف اسم الباحث لقبه العلمي، مكان عمله، تخصصه، رقم هاتفه وبريده الإلكتروني.

10- يخطر الباحث بقرار صلاحية بحثه للنشر من عدمها خلال مدة شهرين من تاريخ استلام البحث.

11- في حالة ورود ملاحظات وتعديلات على البحث من المحكم ترسل تلك الملاحظات إلى الباحث لإجراء التعديلات اللازمة بموجبها على أن تعاد للمجلة خلال مدة أقصاها شهر واحد.

-12- الأبحاث التي لم تتم الموافقة على نشرها لا تعاد إلى الباحثين.

- 13- تؤول جميع حقوق النشر للمجلة.

ملاحظة.

البحوث المنشورة في هذه المجلة تعبر عن رأي أصحابها ولا تعبر بالضرورة عن رأي المجلة أو الكلية أو الجامعة.

المحتويات

Circumstances of Oil Spills in Libyan Coastal Waters: Recent Advancement for Cleanup Techniques

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الملخص
معظم عمليات استكشاف النفط الحالية والمستقبلية وخاصة التي تجري في البحر تكون عادة معرضة لحوادث تسربات النفط. ذكرت التقارير بأن تأثير هذه التسربات يبقى لفترات طويلة على البيئة وخاصة على الحياة المائية. بالرغم من التطور الحاصل في الإجراءات المتبعة في حال حصول مثل هذه التسربات والتي ساعدت في التعامل معها لإزالة متبقيات النفط بطريقة سريعة وامنة إلا أن بعض الطرق الأخرى والتي أعطت نتائج جيدة مثل استخدام الأحياء الدقيقة تحتاج لتسليط الضوء عليها بشكل أوسع. إن استخدام الطرق التقليدية مثل الكسح الميكانيكي أو الحرق أو استخدام ممصات لامتصاص النفط تكون صعبة التطبيق نتيجة الظروف الجوية المحيطة بمكان التسرب. في مثل هذه الحالات أعطت طرق استخدام الأحياء الدقيقة نتائج جيدة. حديثا تم تدعيم وزيادة كفاءة هذه التقنية عن طريق استخدام جزيئات النانو والتي تعمل كمستحلبات لإعطاء الأحياء الدقيقة مساحة أكبر يتم عن طريقها زيادة كمية النفط المزال. في هذه الورقة سيتم تسليط الضوء على أخر ما توصلت إليه الأبحاث المنشورة في هذا المجال.
الكلمات المفتاحية: البيئة، الأحياء البحرية، الأحياء الدقيقة، تسربات النفط، تقنية النانو.

Abstract

The risk of accidental oil spill in Libyan coastal areas might increase in the future. Ongoing and future oil exploration especially for marine argue the governments to plan for accidental oil spills. Despite the development in reported procedures which lead to quick and safe removal of contaminating oil, some other methods such as remediation methods need to be highlighted. In severe weather, the removal using the traditional methods such as skimmers, in situ burning, and sorbents is difficult to be implemented. For these cases, an alternative of using marine micro-organisms which consume spilled oil as a primary energy source in a method known as bioremediation. Recently, the introduction of nano-particles to areas contaminated by oil has showed a great result to enhance the oil degradation by marine micro-organisms. Therefore, managing the risk from such spills needs spatially resolved information. However, Libyan coast still have limited records on oil spill contamination events, oil production and oil tanker transportation. Therefore, studies about coastal resources and their existing condition have to be updated. Furthermore, there is a lack of coastal management infrastructure and coastal resources databases for assessing oil spill threats to habitats and human uses. This study develops the circumstances and knowledge for a discussion of coastline risk from oil spills in Libyan coastal area. In addition, a recent advancement for clean-up techniques from oil spills is highlighted with more emphasis on bioremediation as a newly developed area.
Keywords: : Libyan coast, marine, nanotechnology, oil spill cleanup, remediation.

1- Introduction

Oil transports across the world via water routes. During transportation of every barrel of oil, the environment would be in danger in case of spill. Despite the disaster causing by the spill, long-term damage depends on the speed of cleanup rather than the volume of oil spilled. As the oil reaches the surface, immediately the composition and properties of that oil changes. This can be appeared by several processes that happen after the initiation of oil spillage such as oil evaporation, oxidation, emulsification, sedimentation, biodegradation, and dispersion [United States Environmental Protection Agency, 2016] as depicted in Fig. 1.

The goal of this study is firstly to highlight the urgent need of an oil spill contingency plan, providing an effective process to develop and protect coastal areas. Also, to pay attention to some possible oil spill locations as a way to help planners identifying the possible negative economic and environmental effects of oil spill at Libyan coast, and finally to direct protection priorities and open a future research direction based on up-to-date techniques for cleaning strategies that might be implemented at Libyan coast.

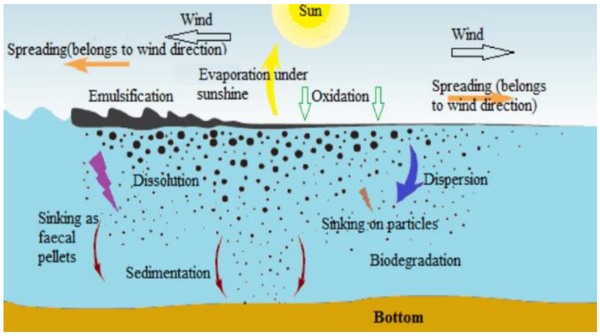

Fig. 1: Oil spill processes taking place [Hoang, et. al 2018]

2- Oil spill in Libyan coast

The coast of Libya is located in the southern boundary of the central Mediterranean Sea basin as depicted in Fig 2. It covers almost 1,770 km that make it essential for tourism, industrial and fishing. Additionally, Libya own the biggest amount of confirmed crude oil reserves in Africa. The major oil producing areas are distributed along three parts at Libyan coast. One location mapped at the western coast that is near Tripoli. The coast of the Gulf of Sirt mapped the other location, whereas the third one is located at the Eastern of the Libyan coast that is close to Tobruk city [National Oil Corporation of Libya, 2018]. Although the regular oil production before 2011 was over 1.65 million b/d, Libya’s oil and gas production have been substantially affected by civil unrest in the last few years. In addition to the oil and gas producing coastal areas, generally 84% of the Libyan crude oil is exported by the Mediterranean basin via pipelines and oil tankers towards the North Mediterranean and European countries such as Italy, Greece, Spain, France and Germany. In addition, almost 20% of worldwide oil transportation passes through Libyan waters [Abdulla and

Linden, 2008]. This high level of activity suggests the possible increase of risk towards marine environments as a result of spillages. In addition, oil spilt from tanker traffic, offshore drilling and exploration, and onshore sources would increase as a result of the poor infrastructure on the Libyan coast. Furthermore, there is a possibility of oil spillage as a result of the frequent spills through sewage pipes from releasing expired oil into the public sewage system. In addition, the oil spillage could be according to oil production activities into oil refining, oil export ports, offshore oil platforms and oil loading/unloading all over the coast of Libya.

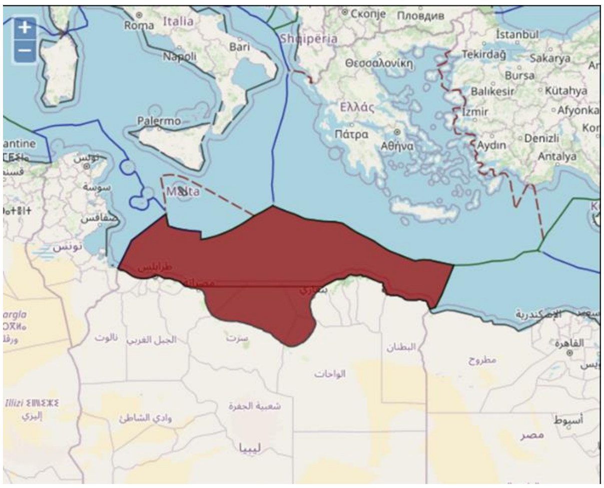

Fig. 2: Libyan maritime boundaries [Marine Regions, 2023]

Information about oil spillage that take place in Libya is limited and unpublished. Unlike reports in the north part of Mediterranean, the south part which includes Libyan coast exhibits lack of information about oil spills and environmental contamination. Therefore, the sources of pollution need to be collected through the fieldwork and through Libyan authorities' reports [Environmental General Authority, 2005]. This data need to be analyzed to establish the levels of risk of oil spill accordingly with coastal economic and associated activities.

Some industrial activities are located nearby the coast which include salt industry. This industry depends on salt flats, which become salt deposits following evaporation of seawater. In Libya, salt industry is located nearby the cities of Zwara, Azawia, Misrata, Sirte and Benghazi region. Some saltpans are located on the foreshore, between 1 and 50 m from the water's edge. Therefore, accident of oil spills could significantly impact the salt industry.

Libyan desalination plants, as another industrial activities, are also located at Libyan coast. A particular problem in these plants is taking place as a result of the addition of chlorine to the pumped seawater. The chlorine acts as a protected agent from biofouling by marine organisms. In the case of oil spills, environmental pollutants and carcinogenic compounds such as trihalomethanes are formed due to the reaction of chlorine with organic molecules. Furthermore, the spilled oil might stick to water tanks and pipes which reduce the desalination efficiency process and eventually damage the plant [Al Malek and Mohamed, 2005].

Although publications on the fishing industry are limited, it is remarked as one of the major resources for the Libyan economy behind the oil industry sector [Khalfallah et al., 2015]. This is attributed to the fact that Libya has the longest coast at south part of Mediterranean states with more than 250 coastal and marine species recorded in shallow and deep-sea habitats. As of these days, this industry is decreasing due to oil pollution and overfishing.

Another promised economical activity comes from important places of Libyan coastal for tourism. This places include summer resorts and open swimming beaches. At oil spillage, these places suffer income losses and property damages, and as a consequence needs time to cleanup. In addition, protection strategies for the coast would definitely have a cost. Despite the protection needs, the majority of the coastal resorts in Libya are protected by sandy beaches, this industry is still under oil pollution pressure during oil spills. In addition to the tourism activities in summer resorts and open swimming beaches, there still some heritage sites in Libya such as Cyrenaica, Leptis Magna, and Sabratha. Although, no available official list of database for cultural heritage for all local sites of interest at the coast of Libyan, the majority of evidence support their location close to the shoreline. These sites are at risk, due to direct or indirect contact with oil pollution. The aforementioned activities suggests the need for understanding the circumstances that influence on Libyan coast during oil spill.

In addition, wave energy is crucial for environmental and coastal classifications. In Libyan marine, wave energy is reflecting by winds blowing over the sea surface. Factors that affect this wave include the wave originate directions during seasons especially in summer and winter, the wave heights, the average wind speeds, and the characterized pattern of northern coast compared to the eastern coast which own lower wave energy [National Centre for Meteorology, 2017]. Although the speed and direction of winds and wave energy are important factors, the type and amount of spilled oil, shoreline shape and coastal topography also influence the movements of the oil slick [Olita et al., 2012]. The current is another factor, which has a much influence on oil movement at sea in comparison with the area at coast. The Libyan offshore currents coast are weak [Robinson and Leslie, 2001]. In winter, the Mediterranean current flows in a westerly direction, from near the southwest of Malta, and from the north to the south of the Gulf of Sirt. However, in summer, the current direction generally continues north-westerly direction toward the Gulf of Sirt [Gerin et al., 2009].

Therefore it could be concluded that several parameters affect the coastal oil risk. As of Libyan long coastal area, it is important to narrow the area under study by focusing on the frequency of oil spill occurrence to develop maps for potential oil risk area and assessing oil spill in the coastal area. As can be suggested earlier, the likely of oil spill in Libyan coast is high, which is attributed to poor coastal infrastructure and a lack of management facilities. This makes the oil spill more complicated and harder to remove.

3. Cleanup methods

These techniques classified to mechanical methods (booms, sorbents, and skimmers), thermal methods (in situ burning), chemical methods (dispersion), and natural methods (bioremediation) [Dave and Ghaly, 2011]. Recently, the use of nanomaterials technique for the purpose of enhancing bioremediation have been considered. Additionally, some circumstances inhibit the use of nanomaterial in cleaning of oil spill and consequently the needs of growing this field to enhance bioremediation as highly efficient and environmentally friendly oil spill mitigation.

3.1. Mechanical Methods

In these methods, booms as floating barriers exhibit effectively at spills containing different viscosities and thicknesses of oil. However, booms are expensive and need special handling below the surface. Skimmers can be used in conjunction with booms to prevent spreading of oil especially from the sea surface. In general, skimmers are classified into three types: weir skimmers, oleophilic skimmers, and suction skimmers. The most commonly used are weir skimmers. They collect oil by the force of gravity [Hammoud, 2006]. Moreover, oleophilic skimmers remove the oil spill through belts, disks, or chains of oleophilic materials [Hoang and Quang Chau, 2018]. Furthermore, suction skimmers remove the oil spill from the water surface. Although skimmers considered as a quick method to remove oil spill but they are high demand of labor and consequently not ideal for health hazards associated with oil spill cleanup. Sorbents (adsorbent or absorbent) are normally used to eliminate the remaining traces of oil which is closer to shores. Straw, sawdust, hair, feathers, cotton, hay, clay and sand can be used as inexpensive sorbents [Choi, 1996]. The problem of using sorbents that if they are not removed in a timely manner, they can begin to sink to the ocean floor. Recently, some studies reported the efficiency of using sponge-like materials to uptake oil selectively and withstand extreme weather conditions [Barry et al, 2018 and Barry et al, 2017]. As can be postulated from the above information, weather conditions greatly affect these methods. The sorbents work perfectly by staying on the surface of water. Therefore, calm waters are preferred to overcome clogging of skimmers.

3.2. Thermal Methods

In situ surface burning is working efficiently compared to other methods, but there is a time limited period when in situ burning is effective, due to the natural emulsification of the oil. When used in calm waters prior to the slick emulsifying in water, the removal might be as high as 95% [Mullin and Champ, 2003]. However, the problem of using this method include severe air pollution, sinkage of burned residue, and risks for secondary fires or explosions.

3.3. Chemical Methods

Chemical agents are used to prevent spreading and decrease oil spill impact. In this method, the emulsifiers and dispersants break down the slick into smaller droplets. The oil collecting agents as oil herders are then contract or herd the oil into a thickened, water insoluble slick which can be ignited for in situ burning [Buist et al, 2011]. The advantages that these methods could be used for the most weather conditions. In this method, the role of surface-active agents is to dissolve oil into water instead of removing oil [Fiocco and Lewis, 1999] by decreasing the oil-water interfacial tension and stabilize the emulsion droplets. The most chemical oil herders are silicone-based, nonbiodegradable materials, which have environmental and biological impact [Buskey et al, 2016].

3.4. Bioremediation Methods

Crude oil composition is varied to include compounds such as alkanes, aromatics, and resins. Each oil degrading micro-organism species has the metabolization ability for a limited range of hydrocarbons [Ollivier and Magot, 2005]. Several species, including fungi, algae, and bacteria, are capable of degrading oil in water and/or soil [Zheng et al, 2018; Atyah and Al-Mayaly, 2018; and Hassan Nazifa et al, 2018]. The natural process of oil degradation by indigenous micro-organisms known as bioremediation. The efficiency of microbial degradation depends on the bioavailability of the oil and nutrients. Therefore, enhancing bioremediation takes place by increasing the growth, but this might enlarge the time prior to the cells begin to replicate which known as microbial lag time and ultimately the cleanup time. On the other hand, bioaugmentation is a well known historically technique for supplementing indigenous marine communities with hydrocarbonoclastic species and increasing the number of compounds that can be degraded [Tyagi et al, 2011]. This might speedup remediation efforts in areas where indigenous microbial communities are unable to degrade all the available hydrocarbons due to oil exposure [Tyagi et al, 2011]. The organisms added to the system could be cultured prior to isolation from a previous site or genetically modified in order to enlarge biodegradation. Therefore, for successful bioaugmentation, knowledge of oil composition and indigenous species is crucial.

Furthermore, most hydrocarbonoclastic micro-organisms form biofilms that allow the cells to attach to a solid surface or liquid−liquid interface and consequently formed microbial communities. Therefore, these biofilms have to be utilized to enhance bioremediation and to recreate this external protection by immobilizing cells. Immobilized cells could be used for wastewater bioremediation. They show enhancement in bioremediation of oil spills [Li et al, 2017; Zommere and Nikolajeva, 2017]. In addition, the role of surfactants are generally to reduce oil droplet size, increasing the surface area per unit volume and obviously the bioavailability of the oil. However, they might reduce the bacterial adhesion to the droplets due to lowering the oil-water interfacial tension. Therefore, the best surfactant application for the cleanup process has to be carefully considered as a result of competing effects, i.e., increasing bioavailability/interfacial area and decreasing surface adhesion of bacteria [Dewangan, and Conrad, 2018]. Furthermore, Genetic approach improved oil-degrading micro-organisms by manipulating their DNA. The hydrophilicity of the cells would need to be overcome or the use of a hydrocarbonoclastic bacterium as a host should be investigated. Genetic approach can also modify the metabolic pathways in which microbes utilize oil, converting the organic pollution into useful products, such as polyhydroxyalkanoates [Sabirova et al, 2006]. The problem of using this approach is the long-term implications on indigenous species and the larger effects on the marine ecosystem due to the supplement of genetically modified organisms which have been undetermined. Moreover, Biostimulation is the addition of growth limiting nutrients for the indigenous microbial communities which involves the use of oleophilic fertilizers that can supplement inorganic nutrients nitrogen, phosphorus, and potassium which led to increased growth of oil-degrading species [Wang et al, 2012].

3.5. Nano-based Methods

The nano-particles have been utilized rapidly for oil spill remediation over the last years. Recently, several researches for nano-based bioremediation are on the lab scale. They focus on the way to overcome the low indigenous microbial concentration through bioaugmentation (i.e., adding microbes with previous exposure to hydrocarbons), biostimulation (i.e., adding growth limiting nutrients), or might be a combination of both. However, one of the shortcomings that each site has a unique consortium of indigenous species where no universal bacteria that could be used at every spill site.

On the other hand, several materials have been used as carriers for the immobilized cells. These carriers have to be nontoxic, nonbiodegradable, highly stable, inexpensive, with easy regeneration and easy separation of cells from media. Researchers have investigated the use of some materials such as chitosan, inorganic clays, inorganic polyelectrolyte coatings, and organic polymer materials as depicted in Table 1.

Table 1. Impact of various technologies on biodegradation [Pete et al, 2021]

Technology	Material	Species	Contaminant	Experimental
Biostimulation	Fertilizer	Consortia	Crude oil: total detectable hydrocarbons	after 109 days 63% degradation
Immobilization	Chitosan beads	Bacillus sp., metagenomic clones	n-alkanes	after 10 days 90% degradation; after 30 days 100% degradation
Immobilization , biostimulation, and bioaugmentation	Polyvinyl alcohol	mixed consortium of bacteria, fungi, and yeasts	Oil and grease	after 32 days 30% degraded by biostimulation, 37% by bioaugmentation, 48% by immobilization, 54% by coimmobilization
Surface modification and immobilization	Encapsulated in poly(allylamine hydrochloride) with poly(styrene-sulfonate) immobilized in disodium phosphate	Bacillus cereus	Tetradecane, crude oil	after 5 days 75% degraded by immobilized bacteria, 97% by modified and immobilized bacteria
Surface modification	Iron oxide nanoparticles	Brevibacillus parabrev	Tetradecane	after 16 days 90% degradation
Biostimulation	Nontronite flakes	Alcanivorax borkumensis	Alkanes, naphthalene	after 37 days 58% degradation
Pickering emulsions	Carbonized kaolinite sheets	Alcanivorax borkumensis	Hexadecane	after 6 days 90% degradation
Pickering emulsions	Polyvinylpyr rolidone coated magnetite nanoparticles	Halomonas sp., Vibrio gazogenes, Marinobactera hydrocarbonclasticu s	Crude oil	after 48 h 100% by bacteria and nanoparticles
Nanoparticles	Graphene oxide quantum dots	Bacillus cereus	Phenanthrene/ant hracene	after 3.5 days 53% degradation

The nanomaterials can be functionalized for very specific purposes. For example, the functionalization of nano emulsifiers can increase the stability of Pickering emulsions. Natural clay nanoparticles, as an example, may serve as an environmentally friendly alternative to conventional emulsifiers. Halloysite is an abundant, naturally occurring aluminosilicate capable of forming oil-in-water Pickering emulsions that are stable for months [Sadeh et al., 2019]. Furthermore, the modified inorganic silica forms stable Pickering emulsions. However, neat silica is ineffective at making Pickering emulsions due to its highly hydrophilic nature. The oleic acid-modified nanoparticles enabled the formation of Pickering emulsions of long-chain alkanes [Sadeghpour et al., 2013].

Additionally, sorbents are insoluble in both oil and water. However, they recover oil through absorption, adsorption, or a combination of the two. They can swell to more than one and half times their original size [Teas et al., 2001]. The effectiveness of sorbent depends on several factors such as rate of sorption, oil retention, ease of

have low oil retentions and are not selective, soaking up both oil and water. Therefore, nano-materials tend to overcome this shortcoming by developing materials with high selectivity in the uptake of oil. Also, nano-particles have a larger surface area to volume ratio, which increases their sorption capacity and oil retention. In addition, nanoparticle sorbents can be engineered for their hydrophobicity and selective uptake of oil. Iron oxide based magnetic as nano sorbents have gained increasing popularity because they can be removed in a contactless manner. Iron oxide nanoparticles have an ideal solution to enhance sorbents as a result of their magnetic properties. The main challenge with using iron oxide particles for oil spill remediation is that the neat particles are tended to aggregation and require a shell to protect the iron oxide core [Qiao et al., 2019]. In addition, functionalized magnetic nano sorbents have shown potential to repel water while retaining oil and have shown reusability, suggesting their sustainability as an alternative to conventional sorbents.

On the other hand, some chemical dispersants can be toxic to marine life and increase the toxicity of the oil, preventing bioremediation. Pickering emulsifiers such as nanoparticles and the synthesised ones from natural precursors may be a

The hydrophobicity of the surface increases the rate at which the microbes adhere to the oil-water interface. In addition, this cell modification can increase oil removal by increasing the

application, and removal. However, sorbents.

green alternative. There has been evidence that biofilm-forming bacteria (i.e., most hydrocarbon clastic bacteria) prefer to form biofilms on hydrophobic solid surfaces [De-la-Pinta et al., 2019]. This is because the surface energy of bacteria is often less than the surface energy of the seawater-air surface, and this difference leads to the attraction of the microbes to the particle-stabilised droplets. In addition, clay nanoparticles have shown potential as sustainable Pickering emulsifiers, as discussed earlier. Due to the high availability of clay, this Pickering emulsifier has the potential to be scaled for large environmental applications. The cell surfaces of microbes can also be modified to make them magnetically responsive, as shown in Fig. 3.

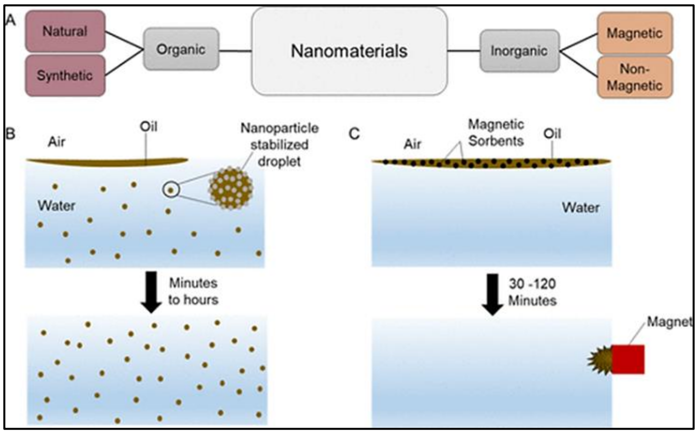

Fig. 3: Nano-technology oil spill processes [Pete et al, 2021]

interfacial adhesion of the bacteria with magnetic nanoparticles, which can be removed using an external magnetic field. This modification led to nearly complete removal of the oil, but the growth rate of the cells was significantly hindered [Cunningham et al., 2004]. Modified microbes were also demonstrated to form stable Pickering emulsions, which were then removed with an external magnetic field [Cheng et al., 2020].

Nanoparticles can be loaded with growth-limiting nutrients, which would decrease the risk of the nutrients being metabolised by non-oil-degrading species and consequently decrease dilution. Mesoporous silica nanoparticles, which are hydrophobically responsive, can be loaded with vital growth-limiting nutrients such as nitrogen, potassium, and phosphorus.

Despite evidence that bioremediation might be enhanced with nano-particles as an environmentally friendly option for post-oil spill response, future advancements should focus on larger-scale studies, including the biological and environmental impacts of the introduction of nano-particles to the marine ecosystem, as well as the difficulty of scale-up and cost analysis to verify that nano-materials enhance bioremediation technologies.

4. Conclusion

This paper highlighted the direction guidance for the Libyan coastal research strategy for an oil spill. The development of potential risks of oil spills as well as the evaluation of environmental sensitivity in Libyan coastal areas are new approaches to oil spill strategy. This can be achieved by developing a theoretical framework strategy for quick response to oil sspillswthatis based on uup-to-datetechniques aand has the otential tto spilloil sthroughcoastal and marine.

The advancements made by bioremediation and nanoscience for oil spill remediation are a promising field of study, and more research is needed. The areas of study include sustainable and environmentally friendly materials that can be used as alternatives to traditional oil spill techniques. Another area of study should focus on increased microbial proliferation in oil droplets in comparison with toxic chemical dispersants. Furthermore, efficient removal of oil with magnets is superior to easily clogged skimmers and sorbents, which often sink. However, there would be limitations that needed to be overcome, including the difficulty of predicting the best method for enhancing biodegradation due to variations in temperature, pH, salinity, and other environmental conditions. In addition, the separation of nanomaterials from seawater

Although most of the reported oil spills from Libyan platforms were due to operational failures and human error, the Libyan ports mostly suffered oil pollution due to a lack of oil spill monitoring and poor infrastructure. Additionally, despite the fact that Libya follows most of the Mediterranean Sea countries and the United Nations environmental and oil spill protocols, it still needs to update this protocol frequently according to the updated methods.

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