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**Potential of Environmental Transboundary Harm caused by Genetic Modified Organism as
Mechanism for Bioremediation: A Case Study in Coral Triangle Biodiversity Hotspot**

Rahmadhitya M Putra¹

Abstract

Biotechnology was introduced to the world of industries in the early 2000s. Its profound impact has continued shaping the mechanism of environmental cleanup. The development of biotechnology has received a wide variety of attention. Hence, bioremediation becomes integral to the notion of sustainability for environmental quality. Especially within the oil & gas sector, the damage can substantially affect the environment's longevity. Specifically, one of the most monumental in terms of potential harm is offshore oil & gas operations. On the other hand, the sophistication within oil & gas sector has become a rapid development over the last few years. It's based on the fact the oil & gas ought to be drilled deeper within the ocean floor. As the depth of drilling increase, so does the complexity of the oil composition. With this, regular bioremediation mechanism might not be able to handle the structural chemical complexity. Thus, a genetic modification appeared as the most efficient effort to reduce environmental damage and strike out the oil chemical complexity. However, it's easier said than done. This is because, ethically, the modification could harm the natural environment. Not just nationally but also transboundary. Therefore, the issue also discusses a new area of multidisciplinary approach where expected law meets an unprecedented amount of scientific efficiency.

Keywords: *Bioremediation, Coral Triangle Initiative, LMO, precautionary principle, transboundary harm*

A. Introduction

Oil drilling activities has been the core economic powerhouse for more than 50 years. Established in the 1800s offshore drilling has experienced substantial

growth ever since its first ocean concession.² Also the size, sophistication, and depth range of these offshore drilling has significantly enhanced in terms of

¹ Assistant Researcher at Indonesian Centre for International Law, Universitas Padjadjaran

² Sukumar Laik, *Offshore Petroleum Drilling and Production*, Boca Raton: CRC Press, Taylor & Francis Group, 2018, p.8

capabilities. If we examine the international economic value of oil between 1973-1990 it has financially received huge projections and will continue to be consumed until 2040. Albeit the value, oil drilling has a high risk environmental impact on the ocean.³

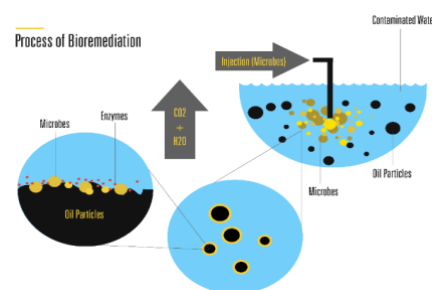
Regarding oil pollution cases, first, let's start with Torrey Canyon. A Liberian flagged vessel contains 119.000 tonnage of oil owned by British Petroleum was spilled into the ocean.⁴ Second, Piper Alpha in 1988. Located in North Sea an oil leak caused 165 people killed out of 326 people.⁵ Third, Deepwater Horizon in Mexican Gulf. This was caused by an explosion and fire. Consequently, the ocean ecosystem filled with biodiversity was damaged.⁶ Fourth, Montara Oil Spill in 2009. The oil concession was owned by PTTEP Australia that caused environmental damage to the community on the shores of Timor.⁷

Based on the mentioned facts and cases marine oil pollution can be categorized as transboundary harm. This concept is coherent with reciprocity in international law. Reciprocity constituted if a country received good treatment, then that country ought to do the same as a

causal link to that act. In this case, reciprocity prevents transboundary environmental harm toward other countries due to one country's activities.⁸ This can be noted within Art. 198-200 of the United Nations Convention on the Law of the Sea (UNCLOS) 1982, which stated the requirement to preserve the ocean environment.⁹

To answer the environmental hassle, bioremediation came up as a prominent solution to handle marine oil spills.¹⁰ Bioremediation is an environmental cleanup mechanism that utilizes biological elements, and it can be done both naturally and with genetic modification. Particularly to disintegrate the complex chemical compound from an oil spill.¹¹

Figure 1.1 below is the concrete form of bioremediation techniques.



³ Offshore energy will power the world: 2021-2040 FPSO forecast (worldoil.com), accessed Friday, 20/8/2021.

⁴ Torrey Canyon: The world's first major oil tanker disaster <https://safety4sea.com/cm-torrey-canyon-the-worlds-first-major-oil-tanker-disaster/>, accessed Sunday,

⁵ Marc Reid, *The Piper Alpha Disaster: A Personal Perspective with Transferrable Lessons on the Long-Term Moral Impact of Safety Failures*, Journal of ACS Chemical Health & Safety, 27, 2020, p.90-91.

⁶ Robert K. Perrons, *Assessing the Damage Caused by Deepwater Horizon: Not Just Another Exxon Valdez*, Journal of Marine Pollution Bulletin, No. 71, 2013, p.20-21.

⁷ Case of Montara Oil Spill: 10 Years, One Lawsuit, <https://icel.or.id/en/news/icel-in-the-news/case-of-montara-oil-spill-10-years-one-lawsuit/>, accessed Sunday, 21/11/2021.

⁸ Nita Ghei, *The Role of Reciprocity in International Law*, Cornell International Law Journal, Vol. 36, Issue 1, 2003, p 105.

⁹ Tim Stephens, *International Courts and Environmental Protection Cambridge Studies in International and Environmental Protection*, Cambridge: Cambridge University Press, 2009, p.40.

¹⁰ Abhishek Panchal, Lauren T. Swientoniewski, Marzhana Omarova, Tianyi Yu, Donghui Zhang, Diane A. Blake, Vijay John, Yuri M. Lvov, *Bacterial proliferation on clay nanotube Pickering emulsions for oil spill bioremediation*, Colloids and Surfaces B: Biointerfaces, Volume 164, 2018, Pages 27-33, ISSN 0927-7765, <https://doi.org/10.1016/j.colsurfb.2018.01.021>, p 28.

¹¹ Amitaya Rakshit, Manoj Parihar, Binoy Sarkar, Harikesh B. Singh, and Leondardo Fernandes Fraceto, CRC Press Taylor & Francis Group: Sao Paulo, 2021, p.3.

One advantage of bioremediation is that microbes become the primary component in reducing the oil concentration of dangerous chemicals within the ocean. This proved to be more environmentally friendly in tackling the chemical compound complexity of oil.¹² Despite its friendly nature, bioremediation has its fair share in disadvantages when it comes to time and capabilities. In this situation, an idea to use LMO (Living Modified Organism) surfaced to enhance the speed of bioremediation.¹³

It might be advanced on paper. Nonetheless, the environmental effects persist. LMO can be categorized as an invasive species to the natural ecosystem. Invasive species is flora, fauna, pathogen, or any organism that does not originate from a native ecosystem.¹⁴ The release of LMO in rich biodiversity areas is highly impactful.¹⁵ It requires detailed risk management considering the high environmental impact.¹⁶

As of now, the current legal framework for risk management of LMOs lies within Cartagena Protocol and CBD.

Hence, a state is required to conserve and protect the environment.¹⁷ The notion of environmental protection in accordance with the precautionary principle is of utmost importance. This is because the sustainability of an ecosystem is highly dependent on how the environment is balanced between conservation and usage of LMO.¹⁸

Coral Triangle Initiative is the focus of this research. It has a total area of 91.700 km² filled with various high species such as corals, fish, sea plantations, and plankton.¹⁹ 20% of the world's biodiversity in coral reef exist within the CTI ecosystem.²⁰ Considering the size, coral ecosystems' role is pivotal in reducing the possibility of species extinction and increasing the variety of the species.²¹

This emphasizes the importance of ocean governance. As stated by Chris Rahman, CTI is one of the examples of ocean governance which covers auditing, data recording, and policy implementation.²² In addition, CTI also is moving in partnership with the implementation of SDGs (Sustainable Development Goals). The evidence lies within routine discussion by CTI

¹² *Petroleum Hydrocarbons (TPH) by Bioaugmentation and Biostimulation in Water with*

¹³ Khalid Sayed, Lavanla Baloo, and Naresh Kumar Sharma, *Bioremediation of Total Petroleum Hydrocarbons (TPH) by Bioaugmentation and Biostimulation in Water with Floating Oil Spill Containment Booms as Bioreactor Basin*, International Journal of Environmental and Research, MDPI, Vol. 18, No. 2226, p.11-12.

¹⁴ John Pauli, *Genetically Modified Organisms (GMOs) as Invasive Species*, Journal of Environment Protection and Sustainable Development, Vol. 4, No. 3, American Institute of Science, 2018, p.33.

¹⁵ John Pauli, *Genetically Modified Organisms (GMOs) as Invasive Species*, Journal of Environment Protection and Sustainable Development, Vol. 4, No. 3, American Institute of Science, 2018, p.33.

¹⁶ *Ibid.*

¹⁷ *Ibid.*

¹⁸ *Ibid*

¹⁹ IPBES (2018): *The IPBES regional assessment report on biodiversity and ecosystem services for Asia and the Pacific*. Karki, M., Senaratna Sellamuttu, S., Okayasu, S., and Suzuki, W. (eds). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. 612 pages, p.9.

²⁰ Reniel Cabral, Annabelle Cruz-Trinidad, Rollan Geronimo, and Protifirio Alino. *Opportunities and Challenges in the Coral Triangle*, Journal of Environmental Science and Technology, ACS Publication, 2012, p.7930.

²¹ P. F. Cowman & D. R. Bellwood, *Coral Reefs as Drivers of Cladogenesis: Expanding Coral Reefs, Cryptic Extinction Events, and the Development of Biodiversity Hotspots*, Journal of Evolutionary Biology, Vol. 24, European Society for Evolutionary Biology, p.2548.

²² Saraswati, A. L., & Pinatih, N. K. D. A. (2021). *Strategi Keamanan Maritim Indonesia terhadap Maritime Piracy di Laut Sulu Tahun 2016*. Jurnal Transformasi Global, 7(1), 114-143, p.115.

members for the conservation of regional biodiversity.²³ Thus, this cooperation is based on the implementation of SDG 14 known as "Life Below Water."²⁴

Presently, the international law provisions regarding ocean pollution still based on UNCLOS 1982 and CBD 1992 with its protocols in multilateral framework. Regardless of the multilateral approach, regional solutions are still applied. Kratochwill stated regional approach persists due to deep understanding of culture.²⁵ ILC (International Law Commission) stated the development of international law refers to "community interest" between countries as an implementation of treaty whether it's soft law or hard law.²⁶ The evidence can be found on the establishment of International Government Organizations (IGOs) which handle specific regional issues especially in context of Coral Triangle Initiative.²⁷

Regardless of its capabilities, bioremediation still lacks in mitigating transboundary harm caused by offshore oil drilling. This can be seen within the developing LMO usage as tool for bioremediation.²⁸ On the other hand, the ecosystem shall be preserved through cooperation by

countries to prevent damages based on Principle 21 and 22 of Stockholm Declaration 1972.²⁹ Bioremediation also widens the scope of LMO usage from just food products. This made oil clean up mechanism developed in the space of technology. The writer also foreseen the legal issues arise from LMO within bioremediation that is released to the ocean. This made the possibility of transboundary harm increase.³⁰

Hence, there are two issues from this research which are

1. Does the existing international law is sufficient in handling the technological development within bioremediation by LMO?
2. How is the application of precautionary principle of CTI member states in handling technological development of bioremediation?

This research aims to figure out the capabilities of international law in regulating transboundary harm caused by the usage of LMO in bioremediation program. Also, the steps taken by member states of CTI to prevent the transboundary harm from LMO is the prevention from harm for the CTI ecosystem.

²³ Kaewkamol Pitakdumrongkit, *Sustainable Development: Can ASEAN Lead the Process*, RSIS Commentary, Vol. 168, S. Rajaratnam School of International Studies, Nanyang Technological University, 2018, p.3.

²⁴ Julius Cesar Trajano, Lina Gong, Margareth Sembiring, and Rini Astuti, *Marine Environmental Protection in the South China Sea: Challenges and Prospects Part I*, NTS Insight, No. IN-17, RSIS, S. Rajaratnam School of International Studies, Nanyang Technological University, 2017, p.6,

²⁵ Adriana Sinclair, *International Relations Theory and International Law A Critical Approach*, Cambridge: Cambridge University Press, Cambridge: Cambridge University Press, 2010, p.28.

²⁶ Andrew Clapham, *Briely's Law of Nations Seventh Edition An Introduction to the Role of International Law in*

International Relations, Oxford: Oxford University Press, 2012, p.379.

²⁷ *Ibid*, p.380.

²⁸ Khanna, Tarun, Raffaella Sadun, and Susie L. Ma. "Engineering an Inclusive Bioeconomy." Harvard Business School Case 720-356, September 2019. (Revised August 2020.)

²⁹ Dinah Shelton, *Comments on the Normative Challenge of Environmental "Soft Law," in THE TRANSFORMATION OF INTERNATIONAL ENVIRONMENTAL LAW* 61–71 (Yann Kerbrat & Sandrine Maljean-Dubois ed., 2011), p.64.

³⁰ Kirk, Elizabeth. "Science and the international regulation of marine pollution." *The Oxford Research Handbook on the Law of the Sea*. Oxford University Press, 2015. 516-535.

B. Marine Bioremediation and International Law

1. Transboundary Harm

To understand this, the writer believes we ought to go back to the basics. In this case transboundary harm. Transboundary harm is a damage resulted from human activities. The nature of the damage is transboundary which crosses national jurisdiction. The concept of transboundary harm developed from several elements, which first, no-harm rule. No harm rule dictates states obligation to not causing damages that might harm other states. In Roman language also known as *sic utere*.³¹ Human activities often caused damage. In this case, damage arises from the utilization of natural resources. The concept of natural resources utilization is based on PSNR (Permanent Sovereignty over Natural Resources). PSNR is discussed within United Nations General Assembly Resolution in 1960 which stated natural resources within a respective jurisdiction can be utilized to its highest potential.³²

Truman Proclamation marked the initiation of PSNR after second world war. It states that the ownership for country towards natural resources within continental shelf consists of living and non-living resources.³³

Hence, United States began its exploration and exploitation of offshore oil. This practice justifies the coastal state to access

natural resources within continental shelf for living and non-living resources.³⁴

This practice has been marked as customary international law based on *opinio juris* and state practice. ICJ in *Armed Activities Case (Democratic Republic of Congo v Uganda)* stated natural resources utilization can be done at its highest potential in accordance with UNGA Resolution 3201 regarding New World Economic Order. (NIEO).³⁵

Albeit the sovereignty within Art. 2 par. 7 of UN Charter as inherent rights, states are also obliged to respect each other with reciprocity in return of good faith. This means states have rights not to be bothered with transboundary environmental damage.³⁶ First principle of transboundary damage is the precautionary principle, which contains elements of precaution and prevention. This principle become the basis of states to prevent environmental damage.³⁷

Second, due diligence principle means the prevention and comprehensive analysis in preventing environmental damage.³⁸ The concept of due diligence in international environmental law also known as Environmental Impact Analysis (EIA). Brownlie stated EIA is based on objective responsibility in the concept of international relations which becomes the standard of improvement. Moving on, Malcolm Shaw enhance Brownlie's

³¹ Oral, Nilufer. *The International Law Commission and the Progressive Development and Codification of Principles of International Environmental Law.*, FIU Law Review Vol. 13 No. 1075, 2018, p.1080.

³² Schrijver, N. (1995). *Sovereignty over natural resources: Balancing rights and duties in an interdependent world*. Groningen: University Library Groningen, p.108.

³³ Turk, H. (2021). *Questions Relating to the Continental Shelf Beyond 200 Nautical Miles: Delimitation, Delineation, and Revenue Sharing*. International Law Studies, 97(1), 18., p.7.

³⁴ Rudolf Bernhardt, *Encyclopedia of Public International Law, Law of the Sea, Air, and Space*, Max Planck Institute for

Comparative Public Law and International Law, 1989, p.109.

³⁵ *Armed Activities on the Territory of the Congo (Democratic Republic of the Congo v. Uganda)*, Judgment, I.C.J. Reports 2005, p. 168, par. 112.

³⁶ Malcolm N. Shaw, *International Law* 6th Edition, Oxford: Oxford University Press, 2008, p.123.

³⁷ *Ibid*, p.22.

³⁸ Lada Soljan, *The General Obligation to Prevent Transboundary Harm and its Relation to Four Key Environmental Principles*, Austrian Review of International & European Law, Vol. 3, 1998, p. 210-212.

opinion which stated in EIA strict liability applies thoroughly.³⁹ Bedjaoui stated the concept of prevention does not require evidence of fault but can be examined straight to the significant environmental damage based on concept of irreversible damage.⁴⁰

Principle 17 of Rio Declaration stated that a state shall act administratively to assess environmental damage by passing a law that guarantees environmental protection. This requirement is also stated within UNEP Principles of Conduct Principle 5 which stated an activity that is done by a respective state ought to have environmental impact analysis especially when there's possibility of a transboundary damage.⁴¹ EIA and no-harm principle are two principles that move in sync for countries to cooperate in mitigating environmental damage.⁴²

Third, is polluter pays principle which require polluter to pay financially towards the affected party of transboundary environmental harm. OECD (Organization for Economic Cooperation and Development) stated environmental damage culminate an economical damage that ought to be paid by the polluter. The value of payment is part of the application based on strict liability in environmental damage in accordance with Principle 16 of Rio Declaration.⁴³ This principle also examines the pollution concept by making a distinction between natural and unnatural elements of the environment

that caused sudden changes. Later, this cause an irreversible damage that ought to be mitigated.⁴⁴

In retrospect, the case of Trail Smelter 1938 along with Lac Lanoux Arbitration covers legal and environmental damage of transboundary harm. Lac Lanoux Arbitration stated significant environmental change requires states to hold consultation and give notification.⁴⁵ Furthermore, these two cases give a basis of financial claim in terms of transboundary environmental damage. However, the Stockholm Declaration 1972 brought distinction from these two cases.

Stockholm Declaration along with Rio Declaration enumerated extensive understanding of international environmental law. Millennium Development Goals (MDGs) became the stepping stone in 1970s around international community that was surrounded by prominent environmental issues.⁴⁶

Environmental crucial load acts as indicator to the ability of environment to absorb external components to the ecosystem. Albeit the outstanding response, MDGs still suffered setbacks. Hence, MDGs transformed into SDGs with a purpose of maintaining the sustainability of environment. The concept of "sustainable" within SDGs is a balance between environment and economic activities that consist sustainable

³⁹ Robert P. Barnidge JR., *The Due Dilligence Principle Under International Law*, International Community Law Review, Vol. 8, No. 81, 2006, p.84.

⁴⁰ *Ibid.*

⁴¹ Philippe Sands, *Principles of International Environmental Law 2nd Edition*, Cambridge: Cambridge University Press,

⁴² Malgosia Fitzmaurice, David M. Ong, and Panos Merkouris, *Research Handbook on International Environmental Law*, Cheltenham: Edward Elgar Publishing, 2010, p.255.

⁴³ Michael G. Faure and Roy A. Partain, *Environmental Law and Economics Theory and Practice*, Cambridge: Cambridge University Press, 2019, p.105-107.

⁴⁴ Thomas F. P. Sullivan, *Environmental Law Handbook 22nd Edition*, Maryland: Bernan Press, 2014, p.2

⁴⁵ Thomas F. P. Sullivan, *Environmental Law Handbook 22nd Edition*, Maryland: Bernan Press, 2014, p.2.

⁴⁶ Michael Redclift and Delyse Springett, *Routledge International Handbook of Sustainable Development*, London: Routledge Taylor & Francis Group, 2015, p.317

ecosystem approach.⁴⁷ Environment becomes an important notion to SDGs since Gagliano stated environment becomes a prominent factor in the sociological human development which made it require a multidisciplinary approach including law.⁴⁸

Legally, SDGs derived from international soft law instruments. Regardless, it still brought significant evidence of customary international law with the presence of state practice and *opinio juris* within international community. Moving on, this concept changed international environmental concept that only covers responsibility into cooperation whether it's multilateral or regional. Accompanied with, integration of ecosystem preservation, which is the application of precautionary principle, polluters pay principle, and EIA.⁴⁹ ICJ within Advisory Opinion on the Legality of the Threat of Use of nuclear weapons stated states has a requirement to control such activity within national jurisdiction and respect other states. This proves, ecosystem within an environment is a part that ought to be manage with cooperation especially for transboundary ecosystem.⁵⁰

Road Construction Case (Nicaragua v Costa Rica/Costa Rica v Nicaragua) crystalized the development of international

environmental law within the scope of SDGs. It started from transboundary environmental damage. In this case there were two requirements consists of procedural obligation to analyze the environmental impact and substantial obligation towards sources of international based on Art. 38 (1) (b) ICJ Statute.⁵¹ Also, ICJ culminated the corrected analysis derived from ecosystem-based approach to count the possible compensation that shall be paid by Nicaragua. This is used to seek causality between Nicaragua's activities and environmental damage.⁵²

The development of environmental impact analysis obligation started from pre-enactment of such activities into cooperation. Pulp Mills case explain the importance of environmental analysis after the post-enactment of such activities for bordering states which is known as post-EIA.⁵³ This requirement is supervision and prevention of environmental damage towards the transboundary environmental region. It ought to be accompanied with notification and substantial obligation between neighboring states.⁵⁴

Environmental aspects also moved in sync with international law of the sea. It applies due to the sea can be acquired by states or have transboundary nature. International

⁴⁷ Diana M Liverman, *Geographic Perspectives on Sustainable Development Goals: Constructive Engagements and Critical Perspectives on the MDGs and the SDGs*, Dialogue in Human Geography Journal. Vol. 8 No. 2, University of Arizona, 2018, p.173.

⁴⁸ Anne Stephens, Ellen D. Lewis, and Shravanti Reddy,

⁴⁹ Christina Voigt, *Legal Aspects of Sustainable Development Sustainable Development as a Principle of International Law Resolving Conflicts between Climate Measures and WTO Law Volume 2*, Leiden-Boston: Martinus Nijhoff Publishers, 2009, p.14-16.

⁵⁰ Nico Schrijver and Friedl Weiss, *International Law and Sustainable Development Principles and Practice*, Leiden/Boston: Martinus Nijhoff Publishers, 2004, p.21.

⁵¹ Certain Activities Carried Out by Nicaragua in the Border Area (Costa Rica v. Nicaragua) and Construction of a Road in

Costa Rica along the San Juan River (Nicaragua v. Costa Rica), Judgment, I.C.J. Reports 2015, p. 665, par. 107-109.

⁵² Jason Rudall, *International Court of Justice, Monetary Damages Awarded—Method of Calculating Damages to the Environment—Overall Valuation—Pre- and Post-Judgment Interest*, American Journal of International Law, Vol. 112, No. 2, 2018, p.290-291.

⁵³ Tamar Meshel and Moin A. Yahya, *International Water Law and Fresh Water Dispute Resoultion: A Cosean Perspective*, 2021, Vol. 92, Journal of University of Colorado Review, p. 543.

⁵⁴ Slavko Bogdanovic, *The Internatoinal Law Association Helsinki Rules Contribution to International Water Law*, International Water Law 3.4, Brill, p. 88-90.

law of the sea culminated huge development with *Mare Liberum* and *Mare Clausul* principle. Hugo Grotious as the sole proposer of *Mare Liberum* stated the sea does not belong to one sole state. One other hand, John Salden as sole proposer of *Mare Clausul* stated the sea belongs to one sole state and it require that state to take care of it.⁵⁵

The value of ocean ecosystem also derived from CBD (Convention on Biological Diversity) 1992. Article 2 of CBD stated biodiversity is a variety of species from the sea and other aquatic environment, accompanied with its ever complexity from species and ecosystems. J. Oneill in his book "The Varieties of Intrinsic Value" stated ethically ecosystem culminated an intrinsic value that ought to be objectively preserved by humans and do not have a subjective nature.⁵⁶

Other than that. Article 5 of CBD stated countries ought to cooperate in maintaining environment outside national jurisdiction. Forwardly, Article 14 of CBD stated evaluation from the relevant country is crucial towards minimalizing the damage and prevention in accordance with Article 192 of UNCLOS.⁵⁷ Moving on, Jakarta Mandate enhance the passage of CBD with four core principles which are sustainable ecosystem-based approach, holistic conservation, socio-economic approach, and cultural consideration. Sands and Peel made an opinion which

stated ecosystem-based approach can be elaborated further to complement the intergenerational equity with procedural collaboration that prove to be utter importance.⁵⁸

Article 8 of CBD gives a requirement of in-situ conservation and Article 14 stated that public participation shall be enhanced to minimize damage towards biodiversity.⁵⁹ In addition, Article 22 of CBD stated that a cooperation is essential in enhancing conservation efforts. The effort ought to be accompanied by exchange of information between parties based on Article 17 of CBD.

2. LMO and International Law

The practice of oil drilling as an initiation of oil exploration gains significant attention due to its usage and the adverse risk of environmental damage. Commonly, the incidents often occurred in the phase of exploitation and production which can be caused by human errors, intangible pipe conditions, or poorly maintained oil storage.⁶⁰ Hence, bioremediation is sought to be the answer by using the application of biotechnology. By definition, Article 2 of CBD stated biotechnology is an application of technology using biological systems to utilize for specific purposes.⁶¹

Moving on, Article 8 (g) of CBD stated countries ought to have regulation that prevent or manage the risk of utilizing and

⁵⁵ Bardo Fassbender and Anne Peters, *The Oxford Handbook of The History of International Law*, Oxford: Oxford University Press, 2012, p. 207

⁵⁶ Michael Bowman, Peter Davies, Edward Goodwin, *Research Handook on Biodiversity and Law Research Handbooks in Environmental Law*, Cheltenham: Edward Elgar Publishing, 2016, p.43.

⁵⁷ Waseem Ahmad Qureshi, "Marine Biodiveristy Conservation: The International Legal and Framework Challenges", *Houston Journal of International Law*, Vol. 40, No. 5, 2018, p.867.

⁵⁸ Sands, Philippe. "Climate change and the rule of law: Adjudicating the future in international law." *Journal of Environmental Law*, Vol. 28., No. 1 (2016): 19-35., p.20

⁵⁹ Ed Couzens, Alexander Paterson, Sophie Riley, and Yanti Fristikawati, *Protecting Forest and Marine Biodiversity: The Role of Law IUCN Academy of Environmental Law Series*, Cheltenham: Edward Elgar Publishing, 2017, p.228.

⁶⁰ Jin Chenhao and Xu Yupeng, *Risk Analysis and Emergency Response to Marine Oil Spill Environmental Pollution*, IOP Conference Series: Earth and Environmental Science, No. 687, p.1

⁶¹ *Ibid*, p 4.

releasing LMOs which can cause substantial possibility of damages both for environment and human health.⁶² In addition, Article 19 of CBD stated cooperation in terms biotechnology utilization and exchange of information proved to be pivotal in preventing environmental damages.⁶³

Article 196 (1) of UNCLOS stated that countries must provide measures in prevent, reduce, and manage pollution resulted by technological usage under national jurisdiction or the release of an invasive species to the sea that cause significant impact for ocean ecosystem. This stems from Article 1 (4) of UNCLOS which states the definition of pollution that constitutes introducing foreign materials to the sea that cause changes within the ocean ecosystem.⁶⁴

Furthermore, Cartagena Protocol Article 1 stated the purpose of this protocol is to determine the degree to protect, contain, and use LMO derived from biotechnology. This is accompanied with the purpose of conservation, sustainable use, and supervision towards health especially in terms of transboundary movement. This is in accordance with Principle 15 of Rio Declaration regarding precautionary principle.⁶⁵

Next, Article 2 of Cartagena Protocol stated that the state party to this agreement ought to catalyze

administrative measures in implementing the protocol when it comes to development assurance, containment, transportation, including the release of LMO. By definition, Article 3 (g) of Cartagena Protocol stated LMO is an organism that has a composition of genetic material derived from modern biotechnology. In addition, Article 3 (i) organisms that have genetic materials is identified by the change of genetic composition within the organism outside the traditional taxonomy and natural selection.⁶⁶ This culminate the requirement for administrative approach based on regional economic integration to provide the particular procedure that falls under the responsibility of such states based on Article 3 (j). On the side note, Article 3 (k) stated “transboundary movement” is cross-border movement between party and non-party states from Cartagena Protocol in accordance with Article 17 and 24.⁶⁷

Moving on, Cartagena Protocol Article 4 covers the scope of transboundary movement which consists of transit, handling, and usage all LMO that provide substantial impact to conservation, sustainable use of biodiversity, and the risk of human health become an utmost consideration. This article explains the importance of information sharing, risk assessment, and the presence of Biosafety Clearing House (BCH) prior to the release of LMO into the environment.⁶⁸ The scope

⁶² Sabu Abdulhameed, N. S. Pradeep, and Shiburaj Sugathan, *Bioresources and Bioprocess in Biotechnology Vol. 1: Status and Strategies for Exploration*, Kannur: Springer Publishing, 2017, p 49.

⁶³ Simon Marsden and Elizabeth Brandon, *Regional Environmental Governance in Asia*, Cheltenham: Edward Elgar Publishing, 2015, p 39.

⁶⁴ Elise Johansen, Signe Veierud Busch, and Ingvild Ulrikee Jakobsen, *The Law of the Sea and Climate Change Solutions and Constraints*, Cambridge: Cambridge University Press, 2021, p 192.

⁶⁵ Sabu Abdulhameed, N. S. Pradeep, and Shiburaj Sugathan, *Op. Cit.*, p 50.

⁶⁶ Ruth Mackenzie, Francoise Burhenne-Guilmin, Antonion La Vina, and Jacob D. Werksman, *An Explanatory Guide to the Cartagena Protocol on Biosafety*, IUCN Environmental Law Center, IUCN World Conservation Union, 2003, p. 32-34.

⁶⁷ *Ibid*, p. 49-51.

⁶⁸ Christoph Bail, Robert Falkner, and Helen Marquard, *The Cartagena Protocol on Biosafety Reconciling Trade in Biotechnology with Environment & Development?*,

of Article 4 is being exempt within Article 5 which states LMO within this article do not apply to pharmacy products with a note risk assessment still applies to non-pharmaceutical products. In addition, Article 6 (1) stated the category of LMO that are not under the scope of AIA (Advanced Informed Agreement) procedure especially the products that are being checked in transit using domestic jurisdiction. Article 6 (2) stated the AIA procedure do not apply to the LMO within contained use category. However, the requirement for the AIA exception are as follows: (i) indication of transboundary movement, (ii) LMO falls under contained use (iii) contained use follows the procedure from the importing states accompanied with its administrative standards.⁶⁹

In the mechanism of contained use, the impact of Biosafety Clearing House becomes substantially important. This is due to the enactment of biosafety standards play a pivotal role in permitting the usage of LMO that is going to be release within national jurisdiction. A state that enacted administrative approach for LMO usage can identified with two categories which are (i) Research and Development (R&D) that falls under lab research (contained use) and closed field testing (confined use); and (ii) commercial purposes with the scope of unconfined use that is designed to fulfill commercial requirement. For example: export-import of LMO for processing or agriculture.⁷⁰ To add, BCH is also significant in applying the

precautionary principle especially in terms of the high-risk exposure from LMO.⁷¹

BCH is connected towards risk assessment within Article 15 of Cartagena Protocol each with approaches ranging from regional, bilateral, or multilateral. As explained in Article 16 of Cartagena Protocol risk assessment becomes a prominent parameter for LMO to be accepted in particular country before it is introduced into the environment. Hence, Article 17 of Cartagena Protocol stated administratively, states issued a notification to the country that is unintentionally affected by the movement of LMO.⁷² This is also what Article 14 CBD stated that notification ought to be given to the state that is directly affected by the activities of such state. This mechanism is derived from precautionary principle and Principle 18 of Stockholm Declaration that stated if disaster occurs cooperation countries ought to cooperate.⁷³

Consequently, risk assessment is also part of socio-economic consideration. Based on Article 26 of Cartagena Protocol the social impact of LMO usage shall be monitored since it has to be in accordance with conservation purposes and sustainability of biodiversity. This matter is addressed at COP (Conference of the Parties) 2018 which stated CBD change the terminology of “might be warranted” into “where appropriate” and “where appropriate” into “where applicable” to explain the eligibility of a place that can specifically be use for LMO.⁷⁴ These terminologies based

London: The Royal Institute of International Affairs, 2002, p. 289-29

⁶⁹ Ruth Mackenzie, Francoise Burhenne_Guilmin, Antonion La Vina, and Jacob D. Werksman, Loc. Cit., p. 70.

⁷⁰ Andre Rosado and Wendy Craig, *Biosafety Regulatory Systems Overseeing the Use of Genetically Modified Organism in the Latin America and Caribbean Region*, Journal of AgBioForum, Vol. 20, No. 2, 2017, p. 120-122.

⁷¹ WTO, DS 291 *European Communities-Measures Affecting the Approval and Marketing of Biotech Products*, Reports of the Panel, 2006, p. 168.

⁷² Ruth Mackenzie, Francoise Burhenne_Guilmin, Antonion La Vina, and Jacob D. Werksman, Loc. Cit., p. 103

⁷³ Ibid, p. 105.

⁷⁴ George Dalton R. , Kuiken Todd and Delborne Jason A., *Articulating ‘free, prior and informed consent’ (FPIC) for*

on COP decision *CBD/COP/DEC/14/19* is based on case by case study from the side effects of LMO usage towards civilians and natural ecosystem. This is ought to be noted upon since the effects of LMO release to the environment could be deemed unpredictable.⁷⁵

3. Biotechnology and Sustainable Development Goals

Biotechnology is one of the solutions to preserve environment. Humans that conducted exploitative activities of natural resources changed the natural element that already established by the previous microbes that has a beneficial role in the future of environment. The core element of biotechnology consists of microbes that already existed naturally. On the contrary, the rapid development of pollutants from technology culminate significant challenge for bioremediation.⁷⁶ SDGs Goal 7 stated energy is an important material in the usage of technology to clean the environment. This can be seen with the usage of bioremediation that is in high demand for oil drilling due to the complexity of oil and LMO becomes more crucial in ensuring the sustainability of the environment.⁷⁷

On the side note, the development of technology culminates the potential for convergence with the law. Kornhauser stated convergence between law and economy formed the rationality of legal

subject in understanding the law.⁷⁸ In this case, this is the basis of LMO usage to prevent oil spill based on cost-benefit analysis, which is the estimation of LMO usage in relation to the scale of environmental damage.⁷⁹ If we examine Kornhauser's argument it's true that the usage of technology to form international law is true due to the ever increasingly destructive pollutants.

Nevertheless, the problem is not only from legal, but also ethical especially in LMO development proceeded by its release to the environment. In international law, the concept of restraint that becomes utmost consideration in rights and obligation of states within the international community. David Roucher that quote the opinion from Samuel Rachel stated states has the capacity of restraint as a rationality of actions that will be done to prevent any damages towards other countries. In this case it's the marine environment.⁸⁰ From here, the concept of bioethics develops into the field of law. The benefit of technology has a huge benefit, at the cost of crippling natural ecosystem. This argument is strengthened by Tom Angier who quote Cicero that stated if a law is created for tranquility then to build human rationale it shall be in accordance with nature.⁸¹

Philosophically, the concept of bioethics also plays a role in the development of international community. This is due to the

engineered gene drives Proc. R. Soc. 2019, B. **286**2019148420191484, <http://doi.org/10.1098/rspb.2019.1484>, p. 3-4.

⁷⁵ United Nations Environment Program, Conference of the Parties to the Convention on Biological Diversity, *CBD/COP/DEC/14/19* 30 November 2018.

⁷⁶ Kenneth Timmis, et. al, "The Contribution of Microbial Biotechnology to Sustainable Development Goals", *Journal Microbial Technology*, Vol. 10 No. 5, 2017, p. 985.

⁷⁷ Angela Sherry, et. al, "How to Access and Exploit Natural Resources Sustainably: Petroleum Biotechnology", *Journal Microbial Technology*, Vol. 10, No. 5, p. 1206-1207.

⁷⁸ *Ibid.*

⁷⁹ Dr. Danrivanto Budhijanto., *Teori Hukum Konvergensi*, Bandung: PT Refika Aditama, 2014, p. 22.

⁸⁰ David Roucher, *The Limits of Ethics in International Relations Natural Law, Natural Rights, and Human Rights in Transition*, Oxford: Oxford University Press, 2009, p. 45

⁸¹ Tom Angier, *The Cambridge Companion to Natural Law Ethics*, Cambridge: Cambridge University Press, 2019, p. 196-199.

fact lots of genetic modification has been used to solve environmental issues. Bioethics also proof prominent in maintaining the ocean since Glomar Challenger exploration stated results from ocean exploration can make environment conservation derogated by economic means.⁸² Bonnie Steinbock who quote Henry Richardson stated there are three important elements in applying bioethics, which are: (i) application of case by case study, (ii) finding the balance between modified genetic products and environment, and (iii) qualitative specification for a biotechnology that can be utilized.⁸³

This notion prove international organization has an important role in explaining the development of technology and international law from the perspective within sources of international law whether its hard law or soft law.⁸⁴ The development of technology, especially LMO triggered the urgency of routine collaboration to handle the matter of international environmental law based on Article 38 (1) of ICJ Statute.⁸⁵

C. LMO Usage in Bioremediation of Offshore Oil Spills in Coral Triangle Initiative Ecosystem

1. Offshore Oil Spill

The case of offshore oil spill is a common phenomenon in international community due to its high-risk nature. If we examine, the number of offshore oil spills decreases, but the risk becomes higher due to the volume and the depth of the drilling.⁸⁶ This condition is contradictory to the economic goals of offshore drilling that has justification from sovereign rights.⁸⁷

Other than that, the damage from offshore oil spills caused economy, environment, and social impacts. As the offshore activities increases, the risk of an incident becomes higher.⁸⁸ The risk is derived from oceanic pressure that can increase the risk of an oil blowout that cannot be controlled.⁸⁹ Concretely, the marine ecosystem will be polluted by hydrocarbon and cause the coral, algae, and animals to be affected by high toxicity.⁹⁰

Hence, the choice in terms of mitigation for an offshore oil spill can be done as follows:

1. Oil Boom. This method is a cleaning of an oil by separating the

⁸² Jessie Hohmann and Daniel Joyce, *International Law's Objects*, Oxford: Oxford University Press, 2018, p. 272.

⁸³ Bonnie Steinbock, *The Oxford Handbook of Bioethics*, Oxford: Oxford University Press, 2007, p. 18.

⁸⁴ Kolb, Robert. "To What Extent May Hard Law Content Be Incorporated into Soft Instruments." *Swiss. Review. Internationall & European. Law. Vol. 29* (2019): 335, p. 336.

⁸⁵ Peter G. Staubach, *The Rule of Unwritten International Law Customary Law, General Principles, and World Order*, New York: Routledge Taylor & Francis Group, 2018, p. 27.

⁸⁶ Stephen Leahy, Exxon Valdez changed the oil industry forever—but new threats emerge (nationalgeographic.com), accessed Monday, 4/10/2021 22:56.

⁸⁷ ABS Consulting, *2016 Update of Occurrence Rates for Offshore Oil Spills*, Bureau of Ocean Energy Management, Arlington: Bureau of Safety and Environmental Enforcement, 2016, p. 25.

⁸⁸ Lucia Muehlenbachs, Mark A. Cohen, and Todd Gerarden, "The Impact of Water Depth on Safety and Environmental Performance in Offshore Oil and Gas Production", *Journal of Energy Policy*, Vol. 55, 2013, p. 704.

⁸⁹ Schlumberger Oil Glossary, blowout | Oilfield Glossary (slb.com), accessed Thursday, 7/10/2021.

⁹⁰ L A S Arum, Y. E. Pawestri, M.Zakil, M.H. W., Mahendratha, N. Awaliya, dan M. M. A. Pratama, *An Overview on Carbon Nanotubes as Innovative Absorbent for Marine Oil Spill*, IOP Conference: Earth Environment Science, Vol. 847.

oil and water with sorbent material and skimmers to absorb and divide the section of oil and water.⁹¹

2. Chemical dispersant. This method is a mix between chemical substances with the purpose of dissolving the spillage matter from the oil when it's on the water surface. This made the cleanup process easier.⁹²
3. In-situ burning. This method utilize fire to directly burn the oil spill within the ocean.⁹³

2. Practice of Bioremediation in Oil Spills

Even though the method of oil spill cleanup provides lots of choices, the writer believes the cleanest method is bioremediation. Microorganisms that live in the ocean can be utilize to dissolve the oil spill.⁹⁴ The reason that bioremediation is environmentally friendly due to the materials can naturally integrated into the natural ecosystem.⁹⁵ Other than that, the natural process do not add foreign or poisonous substances into the ocean.⁹⁶ Concretely, the usage of bioremediation can be identified form two cases.

First, Exxon Valdez 1989. This case is about a supertanker that brought 53 million gallons of oil using the Trans-Alaskan

pipeline. However, the ship crashed into a coral that caused the ship spill 10,8 million gallons of oil to the Prince William Sound environment.⁹⁷ This case began with the bad communication between the shipmaster Joseph Hazelwood which was under the influence based on the US Coast Guard Report. This report culminated the civil and criminal process for the shipmaster.⁹⁸

The important aspect of this case, is the oil cleanup process due to the loss endured by the people of Prince William Sound. This is because the quality of life worsened due to the decreasing water quality, change of birds migration, and behavioral change of animals.⁹⁹ In addition, the amount of animals that died were estimated 250.000 birds, 2.500 fishes, 3.000 sea otters, 300 sea lion, 250 bald eagles, and 22 killer whales and made the ecosystem cannot generate any revenue.¹⁰⁰

Bioremediation that was used on Exxon Valdez 1989 was adding nitrogen fertilizer towards the microbes. The fertilizer were spread out in 2.237 spots along the coastline to clean up the oil spill.¹⁰¹ Nitrogen was added when bioremediation occurred in 1989-1992 to enhance the lack of nutrition and oxygen within the area

⁹¹ Mervin Fingas, *Oil Spill Science and Technology Prevention, Response, and Cleanup*, Oxford: Gulf Professional Publishing Elsevier, 2011, p. 303.

⁹² Adriana C. Bejaranao, "Critical Review and Analysis of Aquatic Toxicity Data on Oil Spill Dispersants", *Journal of Environmental Toxicology and Chemistry*, Vol. 37, No. 12, 2018, p. 2989.

⁹³ Mervin Fingas, *Op. Cit.*, p. 739.

⁹⁴ *Ibid*, p. 9.

⁹⁵ Vivek Kumar, Manoj Kumar, and Ram Prasad, *Microbial Action on Hydrocarbons*, Singapore: Springer Nature Singapore, 2018, p. 303.

⁹⁶ Tariq Purivatra, *Modelling and Experimental Validation of a Sponge Filter in A Column System*, Thesis Submitted in Conformity for the Degree of Master of Applied Sciences, Graduate Department of Mechanical and Industrial Engineering, University of Toronto, 2021, p. 6

⁹⁷ Charles S. Borah, *What Comes After: The Exxon Valdez Oil Spill*, Young Historians Conference, Lakeridge Highschool. Portland State University, 2019, p. 2

⁹⁸ *Ibid*, p. 4.

⁹⁹ Stanley Rice, Charles Peterson, *the evolution from species-specific damage assessment to ecosystem centric studies over the multi-decade period following the Exxon Valdez oil spill*, Deep Sea Research Part II: Topical Studies in Oceanography, Volume 147, 2018, p. 1.

¹⁰⁰ Exxon Valdez Oil Spill, <https://www.history.com/topics/1980s/exxon-valdez-oil-spill>, accessed Monday 11/10/2021.

¹⁰¹ Ronald Atlas and James Bragg, "Bioremediation of Marine Oil Spills: When and When Not- the Exxon Valdez Experience", *Journal of Marine Biotechnology*, Vol. 2, No. 2, 2009, p. 213.

that was affected by the oil spill.¹⁰² From laboratory testing there is a need to monitor the proportional nutrition that ensure bioremediation is use to its maximum potential.¹⁰³

Second, the case Deepwater Horizon in 2010 at the Mexican Gulf. This is one of the biggest oil spills after Exxon Valdez 1989. The estimated volume of the spill amounted around 31 million barrels of oil spilled into the ocean. The environmental risk becomes increasing which, not only caused by 2100 kilometer of reachability, but also the situation of deep ocean ecosystem.¹⁰⁴ Texas RAT (Rapid Assessment Team) stated the damage from Deepwater Horizon caused environmental damages in five different states which are, Texas, Louisiana, Missouri, Alabama, and Florida.¹⁰⁵

Bioremediation was chosen as response in cleaning up the oil spill. This is also accompanied by chemical dispersant and in-situ burning at the same time. The activity of in-situ burning was conducted around 411 times with the amount of oil burned amounted 220.000 barrels until 310.000 barrels.¹⁰⁶ Moving on, the chemical dispersant that was used to clean up the oil spill on the ocean surface was 2,2 million gallons. This method was

successfully prominent in reducing the spilling of oil under the surface which occurred around 87 days based on the report by US Court.¹⁰⁷ Finally, the bioremediation in Deepwater Horizon utilized the indigenous microbes around the environment of the spill. Despite the familiarity, the organisms that is use on bioremediation depends on the environmental conditions within the scope of oil spill.¹⁰⁸

3. LMO Technology in Bioremediation

Bioremediation have several types. First is biostimulation which is the method of adding a dispersant to remove an iron contamination in water. Dispersant that utilize consist of nitrogen fertilizer that enhance the capability of microbes in bioremediation.¹⁰⁹ Biostimulation pinpoints the usage of indigenous microbes in oil spill clean up.¹¹⁰

Second, is bioaugmentation. Bioaugmentation is the introduction of biologically processed organism to the natural environment for the purpose of enhancing bioremediation process.¹¹¹ The writer believes that LMO falls under the category of bioaugmentation. This is because the bioaugmentation uses the advancement of genetic technology which

¹⁰² Michel C. Boufadel, Adane M. Bobo, and Yuqiang Xia, "Feasibility of Deep Nutrients Delivery Into a Prince William Sound Beach for the Bioremediation of the Exxon Valdez Oil Spill", *Journal of Ground Water Monitoring & Bioremediation*, Vol. 31, no. 2, 2011, p. 80-81.

¹⁰³ *Ibid*, p. 83.

¹⁰⁴ Jonnsy Beyer, Hilde C. Trannum, Torgeir Bakke, Peter V. Hodson, and Tracy K. Collier, "Environmental Effects of the Deepwater Horizon Oil Spill: A Review", *Journal of Marine Pollution Bulletin*, 2016, p. 6-8.

¹⁰⁵ Zachary Nixon, Scott Zengel, Mary Baker, Marla Steinhoff, Gail Fricano, Shahrokh Rouhani, and Jacqueline Michel, Shoreline Oiling groom the Deepwater Horizon Oil Spill, *Journal Marine Pollution Bulletin*, Vol. 107, 2016, p. 175.

¹⁰⁶ Scott A. Stout and James R. Payne, "Chemical Composition of Floating and Sunken In-situ Burn Residues

from the Deepwater Horizon Oil Spill," *Journal of Marine Pollution Bulletin*, Vol. 30, 2016, p. 2

¹⁰⁷ Odd G. Brakstad, Alun Lewis, and C. J. Beegle-Krause, "A Critical Review of Marine Snow in the Context of Oil Spills and Oil Spill Dispersant Treatment with Focus on the Deepwater Horizon Oil Spill", *Journal of Marine Pollution Bulletin*, Vol. 135, 2018, p. 347.

¹⁰⁸ Raj Boopathy, Sara Shields, and Siva Nunna, "Biodegradation of Crude Oil from the BP Oil Spill in the Marsh Sediments of Southeast Louisiana", *Journal Applied Biochemistry and Biotechnology*, Vol. 167, p. 1562.

¹⁰⁹ *Ibid*.

¹¹⁰ M. Nikolopoulou, N. Pasadakis, and N. Kalogerakis, Evaluation of Autochthonous Bioaugmentation and Biostimulation during Microcosm-Simulated oil Spills", *Marine Pollution Bulletin*, Vol. 72, 2013, p. 166.

¹¹¹ Robert J. Steffan, Loc. Cit., p. 44.

made the construction of such microorganism can be implemented rapidly and effectively.¹¹² One of the ways of LMO within bioremediation is the cloning of *Pseudomonas Fluorescens HK4*. The expected result coming from this bioremediation is the advancement to dissolve a complex oil hydrocarbons.¹¹³

The bioaugmentation process gives the possibility of higher effectivity than biostimulation. The process is adding LMOs into the cleanup tools for oil spills on the ocean surface.¹¹⁴ Supplements also play a pivotal role in enhancing the capability of microbes that is being used in oil-clean up. Essentially, bioaugmentation required the microorganism outside natural environment.¹¹⁵ This is done to handle the complexity of oil structure as the core expectation of effectivity and efficiency.¹¹⁶

Compare with biostimulation, bioaugmentation bring more promising results. The process in bioaugmentation that brings outside organisms promises to clean more oil than biostimulation.¹¹⁷ One of the points that become an essential is the formidability of microorganism towards oil exposure during bioremediation

process. As such, bioaugmentation is an essential method that will be done in an extreme environment.¹¹⁸

Figure 1.2 explains the method of bioaugmentation:



Source: <https://www.wur.nl/en/project/Biostimulation-of-aromatic-hydrocarbon-mixture-degradation-in-a-former-gaswork-site-1.htm>

bioaugmentation. The process of genome sequencing becomes the essential part of bioaugmentation. Furthermore, the genome sequencing is needed to remove the toxic component within oil material.¹¹⁹ Hence, the bioaugmentation component for bioremediation has a better resistance than biostimulation.¹²⁰

Regardless, the effectivity of bioaugmentation still needs to be considered. Consideration is ought upon the adding of energy and organic oxidation

¹¹² *Ibid*, p. 89.

¹¹³ Sunita J. Varjani, Avinash Kumar Argawal, Edgard Gnansounou, *Bioremediation: Applications for Environmental Protection and Management*, Springer Publishing: Singapore, 2018, p. 55.

¹¹⁴ Rea Hosokawa, et. All, "Autochthonous Bioaugmentation and its Possible Application to Oil Spills", *World Journal of Microbiol Biotechnol*, Vol. 25, No. 1519, 2009, p. 1521.

¹¹⁵ Khalid Sayed, Lavania Baloo, and Naresh Kumar Sharma, "Bioremediation of Total Petroleum Hydrocarbons (TPH) by Bioaugmentation and Biostimulation in Water with Floating Oil Spill Containment Booms as Bioreactor Basin", *International Journal of Environmental Research and Public Health* 18.5 (2021): 2226.

¹¹⁶ Mehdi Hassanshahian, et. All, "Bioremediation (Bioaugmentation/Biostimulation) trials of oil polluted

seawater: As Mesocosm Simulation Study", *Marine Environmental Research Journal* Vol. 30, 2013, p. 2.

¹¹⁷ *Ibid*.

¹¹⁸ Prince Emeka Ndimele, Abdulwakil O. Saba, Deborah O. Ojo, Chinatu C. Ndimele, Martins A. Anetekhai, Ebere S. Erundu, Chapter 24 - Remediation of Crude Oil Spillage, *The Political Ecology of Oil and Gas Activities in the Nigerian Aquatic Ecosystem*, Academic Press, 2018, Pages 369-384.

¹¹⁹ Chatterjee, S., *Oil Spill Cleanup: Role of Environmental Biotechnology*. In: Kaushik, G. (eds) *Applied Environmental Biotechnology: Present Scenario and Future Trends*. (2015). Springer, New Delhi. https://doi.org/10.1007/978-81-322-2123-4_9

¹²⁰ *Ibid*.

to prevent oil spills. Moving on, the consideration for microorganism resistance becomes the issue that needs a deep consideration.¹²¹

4. Risk of LMO Usage

On the side note, bioremediation using genetic modification is needed to fasten the process in dissolvment of hydrocarbon. This made the genetic product increases from number, capabilities, and the produced variants.¹²² SDGs 9 stated inovation in terms of technology is crucial in handling environmental issues. This is an important base for bioremediation since inovation that is formed is to mititgate environmental issues.¹²³

However, the case of Monsanto proved otherwise since usage of LMO caused skin problems and becomes an important attention if LMO is going to be used at sea. Consequently, the usage of LMO in bioremediation can cause high damages to the ocean ecosystem.¹²⁴ The beginning of Monsanto started from genetic modification of plants. Thus, the critical point from this case is the application of precautionary principle regarding LMO.¹²⁵ Of course, the release of LMO cannot be underestimated. It needs a comprehensive supervision in maintaining the sustainability.¹²⁶

¹²¹ Fang Ma, et. All, Application of Bioaugmentation to Improve the Activated Sludge System into the Contact Oxidation System Treating Petrochemical Wastewater, *Journal of Bioresource Technology*, Vol. 100, 2009, p. 598.

¹²² *Ibid*, p. 2151.

¹²³ *Ibid*, p. 2152.

¹²⁴ Sunita J. Varjani, Avinash Kumar Argawal, Edgard Gnansounou, *Bioremediation: Applications for Environmental Protection and*

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Amitaya Rakshit, Manoj Parihar, Binoy Sarkar, Harikesh B. Singh, and

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¹²⁵ Karine Peschard & Shalini Randeria, "Taking Monstanto to Court: Legal Activism around Intellectual Property in Brazil and India", *The Journal of Peasant Studies*, Vol.47, No. 4, 2020, p. 795.

¹²⁶ *Ibid*, p. 797.

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