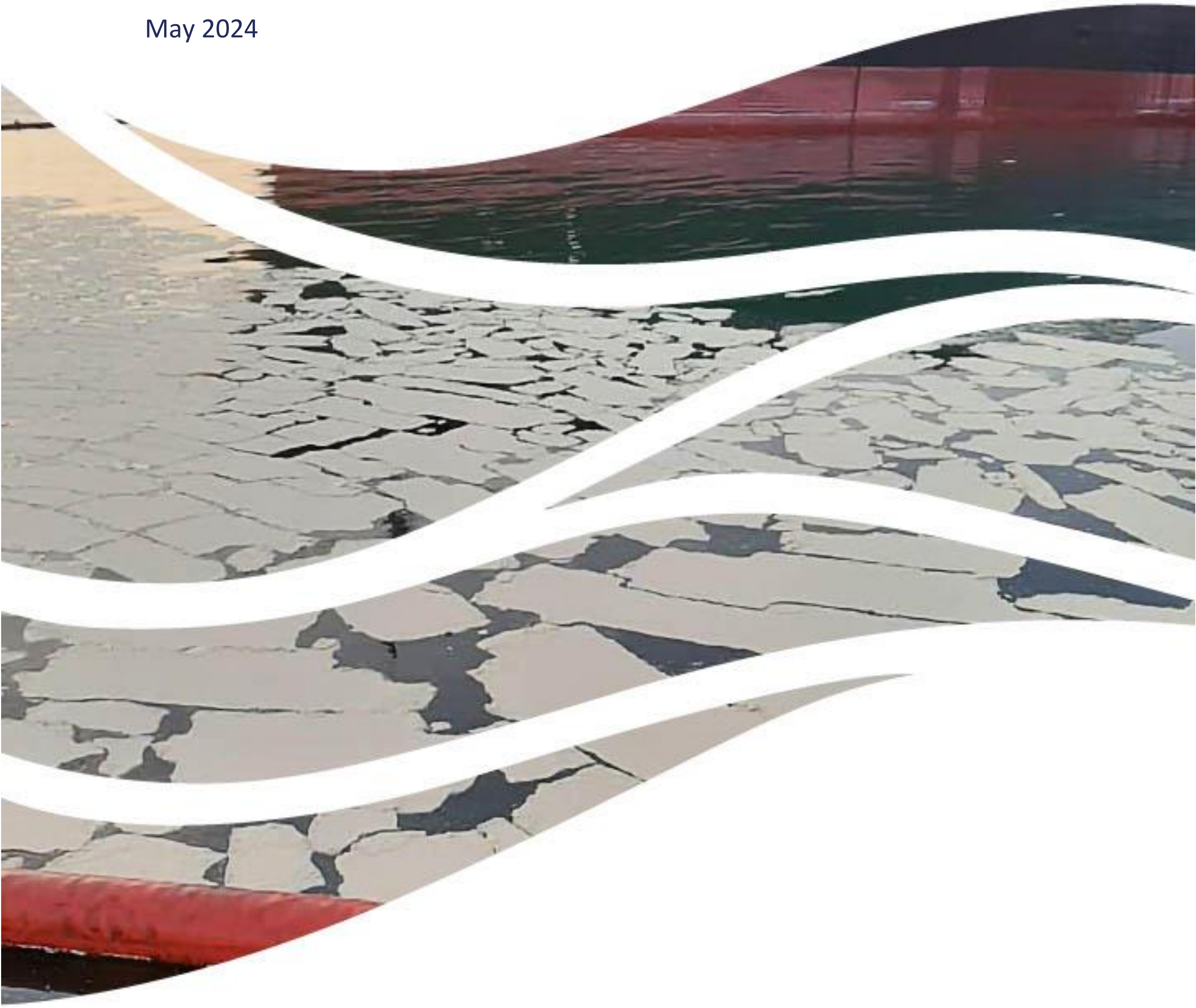
ITOPF

PROMOTING EFFECTIVE SPILL RESPONSE

FATE, BEHAVIOUR AND POTENTIAL DAMAGES & LIABILITIES ARISING FROM A SPILL OF BIOFUELS INTO THE MARINE ENVIRONMENT

Report for the International Group of P&I Clubs Alternative Fuels Working Group

May 2024



I. Introduction

ITOPF, as part of the International Group of P&I Clubs Alternative Fuels Working Group, has been requested to provide a series of brief summary documents to describe the expected fate and behaviours of the following alternative fuels and to outline the possible damage and liabilities that may arise from incidents involving vessels carrying these fuels as bunkers.

The alternative fuels covered are:

- Biofuels
- Liquefied Natural Gas (LNG)
- Liquefied Petroleum Gas (LPG)
- Hydrogen
- Ammonia
- Methanol

ITOPF has also been requested to provide a summary document for lithium-ion batteries as a new technology for vessel propulsion.

A review of Nuclear as a means of vessel propulsion will be described separately, with the summary report provided by ENCO.

This report focuses on **biofuels** as a non-traditional marine fuel.

Biofuel is a generic term used to describe fuels produced directly or indirectly from organic material, including vegetable oils, other plant materials and animal waste (but not from fossilised organic material, as with traditional fuel oils). Biofuels are seen as viable 'transition fuels' as, although not being zero-carbon, their upstream life cycle emission levels (also known as 'well to tank' emissions for fossil-derived fuels) are significantly lower than conventional hydrocarbon fuels because they are typically produced from renewable feedstocks.

Demand for biofuels is set to grow with some predictions forecasting increases in global production from 11 million tonnes of oil equivalent (Mtoe) per year currently, to between 500 and 1,300 Mtoe by 2050 as shipping, and other transport sectors, look to decarbonise without significant reconfiguration of engines and auxiliary infrastructure.[1]

This report will specifically focus on **biodiesels**, namely **fatty acid methyl esters** (**FAME**) and **hydrotreated vegetable oils** (**HVO**).

Note that in some instances, the term 'biofuels' can also relate to LNG and methanol derived from biomass (bio-LNG and bio-methanol).

The use of dual-fuel engines is increasingly commonplace within the shipping industry and allows for flexibility between alternative gaseous fuels, such as LNG and methanol, and more conventional fuel oils such as heavy fuel oil, marine diesel oil, but also biofuels. This means that, in the event of an incident, there is potential for biofuels as well as gaseous alternative fuels to be spilled simultaneously. This could result in a combination of the risks and hazards outlined in ITOPF's alternative fuel summary documents. An incident of this type would require a complex and highly specialised response to be mounted to counteract these risks.

Biodiesels have primarily been tested as blends with traditional fuel oils, ranging from B5 (5% biofuel: 95% conventional fuel) up to B100 (100% biofuel). This report focuses on pure biofuels (B100), but it should be noted that in biofuel blends, the lower the proportion of biofuels added (e.g. B5, B10), the more likely the fuel will behave like a traditional fuel oil. This variability in composition has allowed an increasing knowledge among engine-manufacturers and operators about their impact on engine operations and tank- and fuel-supply

[1] DNV-GL. 2023. *"White Paper: Biofuels in Shipping"*, DNV-GL. Høvik, Norway

systems.[2] The most prevalent biodiesels on the market are currently considered to be FAME and HVO, with their share of the biofuel market rapidly increasing.[2]

FAME is a colourless liquid produced from transesterification of bio-oil (such as rapeseed and palm oil) and methanol or ethanol, which results in a mixture of fatty acid methyl esters. Studies from a bunkering trial in Singapore in 2022 noted CO_2 reductions of between 36 – 62% by using pure FAME instead of conventional fuels.[3]

HVO is a colourless liquid produced from hydrotreatment and refinement of bio-feedstocks such as vegetable or cooking oils and animal fats. The result of this process is a mixture of straight-chain hydrocarbons, similar to conventional diesel. The Singapore bunkering study observed CO_2 reductions of 88% while using pure HVO.[3]

The main difference between FAME and HVO is how they are produced, and as a result their chemical composition. Due to this, FAME's properties slightly differ from conventional diesel, whereas HVO's properties more closely match. HVO is generally considered to be a more advanced and higher quality biofuel in comparison to FAME and is sometimes referred to as a 'second generation' biofuel (produced from waste, residues and non-food crops including used cooking oil) in comparison to FAME, which can be referred to as a 'first generation' biofuel (produced from conventional feedstocks such as food crops, sugar/starch and vegetable oils).[3]

ITOPF has not yet provided technical advice for any incidents involving a release of biofuels. However, given that vegetable oils are a common feedstock for biodiesels, and their behaviour when released in the marine environment can be considered similar to pure biodiesel, Table 1 provides details of the five incidents relating to vegetable oils for which ITOPF has provided technical advice. In the experience of ITOPF, the causes of vegetable oil spills, carried as cargo, are the same as for those related to persistent hydrocarbons. These include release following grounding of the vessel, release during discharge/pumping operations and releases caused by a collision with another vessel or structure. ITOPF expects that the causes of biofuel spills would also be similar.

Table 1: Incidents involving vegetable oils

Vessel Name	Date	Location	Incident Type	Cargo	P&I Club
AMADEO 1	28th Aug 2014	Kirke Canal, 40 NM of Puerto Natales, Chile	Grounding	Waste vegetable oil in drums	Standard Club
ANIKA	8th Jul 2018	Lianyungang Port, China	Release during discharge operations	Palm olein	Skuld
GLAFKOS	3rd Aug 2014	Naples Port, Italy	Release during internal transfer operations	Palm oil	Britannia
GLOBAL APOLLON	3rd Aug 2017	Guangzhou Port, China	Release following collision	Palm stearin	Japan P&I
STAVANGER	20th Apr 2020	Yuzhny Port, Ukraine	Release during discharge operations	Palm olein	London P&I

2 EMSA. 2022. *"Update on potential of biofuels in shipping"*, ABS, CE-DELFT and ARCSILEA. Lisbon, Portugal

3 Singapore Shipping Association. 2022. *"FAQ on bunkering of biofuels for ocean-going vessels in the port of Singapore"*, SSA, Singapore

II. Storage and transportation

At ambient conditions, biodiesel is a liquid, and therefore does not require storage and handling under pressure or at the refrigerated or cryogenic temperatures of other alternative fuels. Storage and handling requirements are generally the same as for traditional hydrocarbon fuel oils. In some cases, depending on the biodiesel's pour point, it may have to be heated to reduce viscosity prior to bunkering or other transfer operations, especially for FAME.

FAME has a higher oxygen content than petroleum diesel, which leads to reduced oxygen stability. In the presence of moisture, this can lead to fuel degradation, microbial growth and generation of solids at low temperatures.[2] This can result in difficulties in storage and transport, although additives are sometimes incorporated within the biodiesel to offset these properties.

HVO does not have this issue as its processing method removes any oxygen content. This results in higher energy efficiency as well as a much longer shelf life than FAME, due to reduced risk of fuel oxidation.[2]

III. Fate and behaviour of biofuels when spilled in the marine environment

The Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) categorises biodiesel as a persistent floater (Fp). Some of its key properties that play a role in its expected fate and behaviour when released into the marine environment are listed in Table 2.

Table 2: Summary of key biodiesel (FAME and HVO) properties dictating its fate and behaviour[4,5,6]

	FAME	HVO	Behaviour
Boiling Point	182 – 338 °C	150 – 315 °C	At ambient conditions, biodiesels are liquid.
Specific Gravity @ 15 °C	≈ 0.89	0.78 – 0.79	Biodiesels are less dense than water; therefore, will float if spilled on water.
Viscosity @ 40 °C	≈ 4.5 mm²/s	2.5 – 3.5 mm²/s	Biodiesels have a low viscosity at ambient temperatures.
Pour Point	- 4 – 16 °C	-35 – -15 °C	Biodiesels, below this temperature, will no longer be free flowing.
Solubility	Insoluble	Insoluble	Biodiesels will not dissolve in water (run-offs) or seawater.
Flash Point	> 101 °C	> 70 °C	Below these temperatures, biodiesel will not produce flammable vapours.

When spilled into the marine environment, biodiesels will typically behave similarly to conventional diesel in the initial stages of a spill. They will float and spread on the water, forming a slick on the surface (Figure 1). Biodiesels will not mix with water due to their insolubility but unlike conventional diesels, pure biodiesel will not evaporate due to its low vapour pressure and will therefore remain on the sea surface for a longer period in comparison to

[4] ECOFYS. 2012. "Potential of biofuels for shipping: final report". ECOFYS, Utrecht, Netherlands

[5] Kuronen, M. Mikkonen, S. 2007. *"Hydrotreated vegetable oil as fuel for heavy duty diesel engines"*. SAE International Technical Paper Series, 2007-01-4031.

[6] IEA-AMF N.D. Fuel information: FAME: properties. https://www.iea-amf.org/content/fuel_information/fatty_acid_esters/ [Accessed: 22nd Feb 2024], IEA, Paris, France

conventional diesels.[7,8] If biodiesel is blended, the propensity to evaporate may increase with increasing percentage of conventional diesels. The temperature of the receiving water body and the biofuel's pour point (the temperature at which a liquid loses its fluid properties) will determine its fate and behaviour when spilled.

Warm/temperate environments

If spilled in warm water (>10 °C), it is likely that both FAME and HVO will remain as low viscosity liquids, spreading over a large area to form a thin slick on the water's surface under the influence of metocean conditions.

Cold environments

If spilled in cold water conditions (<10 °C), the viscosity of HVO would likely increase, reducing its lateral spread on the sea surface. However, the water temperature is unlikely to fall below its pour point (-35 to -15 °C) and therefore the HVO is likely to remain as a free-flowing liquid.

If FAME were to be spilled in cold water, its viscosity would significantly increase. If the water temperature were to fall below the pour point of FAME (- 4 to 16 °C), it would lose its fluid properties and become semi-solid.

During the incidents listed in Table 1, when vegetable oils have been spilled into waters with a temperature below the pour point of the oil, the oils solidify into balls, lumps or discs of up to 60 cm in diameter. These fragments were observed to remain in a concentrated area near to the initial release location within the first 24 hours. After this time, the solid oil gradually breaks into smaller pieces (<10 cm), forming a small slick under the influence of metocean conditions. After approximately 72 hours, the slick will break-up further into pea/rice-sized pieces, sparsely scattered over a wide area (200 – 300 km^2). Pure biofuels are expected to exhibit similar fate and behaviour to these oils. However, when biofuels are blended with conventional fossil-based hydrocarbons, this behaviour will differ, with the degree of deviation increasing as the ratio of conventional hydrocarbons in the biofuel blend increases.

The main weathering processes that break down biodiesel in the marine environment are biodegradation and oxidation. Although the rates of these processes depend on many environmental factors, such as temperature, pH and nutrient, oxygen and microbial availability, biodiesels degrade approximately four times faster than conventional diesel[9,10] One study released 20 litres of FAME into a plume tank and noted that after 28 days, almost all the spilled volume had undergone biodegradation.[7]

The rate at which biodiesel disperses depends on the amount of mixing in the aquatic environment, influenced by tidal currents and wind-induced wave action but studies have shown an increased dispersibility in comparison to petroleum diesels[11]. In comparison to other alternative gaseous or volatile fuels, a large release of biodiesel

[7] Jezequel, R. Duboscq, K. Valladeaud, F. LeFloch, S. 2019. *"Fate, Behaviour, and Impact Assessment of Biodiesels in Case of an Accidental Spill*", Proceedings of the Forty-second AMOP Technical Seminar, Environment and Climate Change Canada, Ottawa, ON, Canada, pp. 919-939, 2019.

[8] Hollebone, B. Yang, Z. 2009. "Biofuels in the environment: a review of behaviours, fates, effects and possible remediation techniques". Proceedings of the 32nd AMOP Technical Seminar on Environmental Contamination and Response 1, 127-139. 2009

[9] Kass, M.D., Sluder, C.S., Kaul, B. 2021. *"Spill behaviour, detection, and mitigation for emerging nontraditional marine fuels."* Oak Ridge National Laboratory. Report no. ORNL/SPR-2021/1837. US Department of Energy.

[10] Kimble, J. 2016. *"Biofuels and Emerging Issues for Emergency Responders: An Introduction to Basic Response Guides and Case Study Examples from Biofuel Spills."* US Environmental Protection Agency Region 5.

[11] Hollebone, B.P., Fieldhouse, B., Landriault, M. 2008. *"Aqueous solubility, dispersibility and toxicity of biodiesels."* IOSC Proceedings. 2008 (1): 929-936. Emergencies Science and Technology Division, Environment Canada. Ontario, Canada.

will be more persistent and, if no mitigating action is taken, could remain in the environment in the order of weeks to months.

IV. Hazards of biofuels in the marine environment

Generally, the hazards of biofuels are similar to those related to conventional oils due to the similarities in their fate and behaviour. The primary environmental impacts of biodiesels on the environment are caused by smothering of wildlife and possible reduction in oxygen availability following biodegradation. The acute toxicity hazards of conventional diesels are significantly less for biodiesels. Health and safety hazards are considered to be similar to conventional oils and minimal in comparison to other alternative fuels such as ammonia, hydrogen and methanol.

Physical Smothering

The primary impacts are likely to be to surface dwelling organisms (e.g. seabirds, marine mammals) that have been in physical contact with the slick. The oil is likely to smother and coat the surface of the animals, particularly if the oil is of low viscosity (i.e. in warm/temperate waters). This can result in impacts on movement, feeding, respiration, thermal control and reproduction. In the event that water temperatures are below the oil's pour point and the oil therefore forms a solid, the potential impact on surface dwelling organisms will be significantly reduced.

Oxygen Availability

As biodiesel is readily biodegradable, when spilled in the marine environment, it will serve as a feedstock for microbial organisms present in the water column. If the biodiesel is abundant following a spill, microbial populations will increase exponentially and subsequently so will oxygen consumption due to microbial respiration. As dissolved oxygen concentrations decline in the water column, other organisms such as fish, crustaceans and aquatic plants will not be able to function due to hypoxic or anoxic conditions and this can lead to local mortalities. Some microbial organisms are able to function under hypoxic or anoxic conditions and will continue, undertaking anaerobic biodegradation of the oil. In open water, anoxic conditions are unlikely to occur due to constant aquatic mixing and the buffering capacity of the ocean. However, anoxic conditions could occur in a sheltered bay or inland waterway with little turbulence and mixing.

Ecotoxicity

The GESAMP hazard profile for FAME states that the substance has a moderately low aquatic toxicity and has no bioaccumulation potential.[12] Bioaccumulation occurs when a substance is absorbed by tissues of an organism at a greater rate it can be metabolised, excreted or degraded. Studies have been undertaken to compare the toxicity of biodiesel with petroleum diesel and due to the lack of polycyclic aromatic hydrocarbons (PAHs) in both FAME and HVO,[5] pure biodiesels are considered to be at least five times less acutely toxic than conventional diesels. However, toxicity varies widely depending on feedstock and additives.[8]

Flammability

Flammability risk from biodiesel is considered to be low due to its high flash point (> 70 °C for HVO and >101 °C for FAME) and its low vapour pressure, when compared to petroleum diesel.[10]

[12] GESAMP. 2023. "Hazard Evaluation of Substances Transported by Ships". PPR.1/Circ. 13. 30 June 2023. IMO. London, UK

Toxicity

Similarly to conventional hydrocarbon diesel, biodiesel can cause skin and eye irritation if exposed.[12] Vapours can be harmful, however due to its low flash point, biodiesel would require significant heating to produce vapours.

V. Damage and liabilities arising from incidents involving biofuels

Pure biodiesel (FAME and HVO) carried as bunkers is not covered specifically by an International Convention at present, with liabilities relating to a release, or risk of release, a result of national legislation. The current wording within the International Convention on Civil Liability for Bunker Oil Pollution Damage, 2001 (2001 Bunkers Convention) does not include biofuels under the definition of oil as biomass-based oil is not considered as a "mineral oil". There is no wording within the 2001 Bunkers Convention that states whether biofuels blended with mineral oils are admissible.

Biodiesel, carried as cargo in bulk, is covered by the International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea, 2010 (2010 HNS Convention). While not in force at the time of writing, this Convention sets out the potential liabilities arising from damage caused by HNS substances. Furthermore, while this Convention does not apply to HNS carried as bunker fuel the same damage can be expected equally from an incident involving biodiesel carried on-board to power the ships' engines and are set out below.

Clean-up and Preventive Measures

In comparison to the costs associated with clean-up and preventive measures from a traditional spill of hydrocarbon bunker fuel oil, the costs for this claim heading for a spill of biodiesel would, generally, be similar.

As biodiesel is an insoluble liquid that floats and, in the event of a large spill, is expected to persist on the sea surface, established oil pollution clean-up measures are likely to be appropriate (e.g. collection and recovery using booms and skimmers).

Similarly to persistent conventional fuels such as residual fuel oils, at-sea and shoreline clean-up response would be expected in the event of a large spill of pure biodiesel. Despite the high biodegradation rate of biodiesel, it is expected to persist for several weeks while being influenced by metocean conditions. Therefore, there is potential for biofuel to travel over long distances before stranding on the shoreline. The main claim types under this heading are likely to be i) source control; ii) detection and monitoring; iii) active at-sea and shoreline response including waste management and iv) possible bunker fuel removal.

- i) Source control would include costs associated with repairing the vessel and preventing further biodiesel releases.
- ii) Monitoring would include the use of aircraft to undertake aerial surveillance in the event of oil on water or undertaking shoreline surveys to confirm presence/absence of shoreline oiling. Note that biodiesel's clear appearance will make aerial surveillance more difficult with possible specialist equipment required. Claims could also include the use of expert oil trajectory modelling to evaluate the trajectory of oil on the water, which can inform the associated response.
- iii) Costs associated with clean-up operations would include the use of vessels and specialist oil spill response equipment to contain and recover any oil. In the event of shoreline oiling, there would be costs associated with mounting a shoreline response and associated waste management, including final disposal of collected oil. In previous ITOPF incidents involving solidified vegetable oils, the collected oil was recycled to biodiesel.

iv) The removal of biodiesel bunker fuel from a casualty could fall under the 2007 Nairobi Convention if so decided, although note this convention refers to bunker fuel oil and it is unclear whether that includes biomass-based oils.

The cleaning and rehabilitation of wildlife is another potential cost associated with clean-up and preventive measures. Possible impacts on wildlife would be as a result of physical smothering and potential impacts caused by low-oxygen conditions. In the event of a large number of animals impacted, costs associated with mounting a wildlife response would be appropriate. If hypoxic or anoxic conditions are noted in a sheltered area, costs related to oxygenation of the water body might be appropriate to counteract these conditions, if conditions allow it to be undertaken effectively. In addition, the potential recovery of dead wildlife and any associated costs related to this would fall under clean-up and preventive measures.

Note that if a spill of blended biodiesel with a large percentage of conventional diesel (e.g., B5 biodiesel) were to occur, at-sea and shoreline response may not be necessary as the oil will likely behave more similarly to conventional diesel and is likely to evaporate and disperse in the hours and days following a release.

Environmental Damage

The environmental impacts of biodiesel in the marine environment are not as widely researched as those associated with spills of conventional hydrocarbon oils. Due to the similarities in fate and behaviour of biodiesel and conventional fuels, environmental impacts are also expected to be similar. The damage may not be confined to the immediate spill area as biodiesel, under the influence of metocean conditions, can travel large distances and potentially impact areas far from the spill site.

As is often the case with hydrocarbon oil spills and because there is potential for mortality/harm, post spill studies to establish the severity and extent of environmental damage following a release of biodiesel would be appropriate. Restoration projects may be undertaken if impacts are considered to be significant.

Property Damage

Costs arising from this claims heading may be similar to conventional fuels. However, due to biodiesel's colourless appearance in comparison to the visible black appearance of conventional oils, damage may not be as noticeable. Although considered relatively persistent, natural attenuation via biodegradation will be more rapid than traditional oils and damage may not be as long-lasting. In addition, if the water temperature is below the pour point, solid oil is likely to cause less impact than liquid oil that can smother/stain surfaces.

Property damage such as oiling of port structures, vessel hulls (commercial, leisure or fishing), shoreline buildings, fishing gear and aquaculture facilities are likely to occur if located in close proximity to the casualty or within the trajectory of the slick. Cleaning and possible cosmetic repair (repainting of oiled vessels/port structures/buildings) could be considered as appropriate remedies following a spill. With prior warning of a slick's trajectory, mitigation measures (e.g., boom placement, lift out of vessels) could be undertaken to reduce property damage. These actions would be included within the clean-up and preventive measures claims heading.

Economic Loss

Economic loss can be split into "consequential loss", whereby compensation is payable for loss of earnings suffered by the owners of property, which have been impacted and "pure economic loss", whereby compensation is payable for loss of earnings suffered by persons whose property has not been impacted. In the event of a biodiesel incident, it is likely that both consequential and pure economic loss would be experienced.

In the event of a spill, loss of earnings/income claims from oiled commercial, leisure or fishing vessels and other property (e.g., beachside hotels), could be liable for compensation. If aquaculture facilities were directly impacted by the oil, mortality of stock and associated loss of earnings would be appropriate. As biodiesel has been noted to be less toxic than conventional fuels, the impacts to fisheries/aquaculture might be comparatively less for this fuel type.[8]

Pure economic loss could be experienced as loss of earnings from those impacted by any fishing bans imposed by authorities or in the unlikely event of fish mortalities. In addition, if vessels are delayed due to port closures or hull cleaning operations, demurrage costs may apply, which could be significant. Losses due to the closure of ports and other areas identified as being oiled may also be claimed.

An interruption of flow to water intakes may also cause pure economic loss claims and these costs may be significant. Finally, impacts to the local tourism industry may be experienced. The GESAMP hazard profile states that biodiesel can have a moderate impact on amenity value and could lead to closure of impacted sites including beaches.[12] Following shoreline stranding, it has been noted that vegetable oils can emit pungent odours due to biodegradation, which may impact beachgoers and users of tourist destinations. This could impact local businesses including hotels and restaurants.

VI. Conclusions

In conclusion, biodiesel's relatively similar fate and behaviour in comparison to conventional fuels means that claims arising from a spill would be similar to those associated with conventional hydrocarbon oil spills.

Claims arising from **clean-up and preventive measures** are expected to be similar with possible differences in timeframes due to biodiesel's faster rate of biodegradation. The main claim types would be linked to source control, detection and monitoring of the incident, mobilisation of clean-up operations, bunker removal operations and wildlife response. Claims arising from **environmental damage** are likely to be in line with conventional fuels as significant negative impacts are expected from a large spill of biodiesel. Post spill studies may be appropriate to establish the severity and extent of damage. Restoration measures may also be appropriate if studies show medium- to long-term damage. **Property damage** claims involving cleaning, cosmetic repair and replacement of oiled property, such as vessel hulls, fishing gear and oiled structures, is expected. Finally **economic loss** claims resulting from a spill could include port closure/disruption and associated demurrage costs, aquaculture losses from mortality of stock, and local losses resulting from fishing bans. Impacts to commercial water intakes and tourism may also occur.