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Review

A Comprehensive Review of Canadian Marine Oil Spill Response System through the Lens of Decanting Regulations and Practices

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Abstract: Marine oil spill response operations could generate a large volume of liquid oily wastes (e.g., emulsified oil, non-emulsified oil, and wastewater) that can be up to 30 to 40 times greater than the original volume of spilled oil. Oil decanting technologies are used globally for recovering spilled oil and handling liquid wastes. Canada follows the standards set out in the MARPOL 73/78 Annex 1 International regulations in most areas, with more strict discharge requirements in certain locations. For instance, inland waters discharge should not exceed 5 ppm, and in special areas, such as the Great Lakes, the discharge standard is under 0 ppm. In the event of an oil spill, decanted seawater should be barged to shore for disposal, which significantly constrains the response capacity and efficiency of oil recovery by skimmers due to limited temporary storage space in barges and the long time and high cost of transportation. This has become one of the greatest challenges the Canadian governments and oil spill response industries are facing in Canada. Moreover, when the spill response team decides that decanting is an appropriate way to handle the spilled oil, the approval process may take a long time, which negatively impacts the spill that has already occurred. Moreover, Canada uses a 10,000-tonne planning standard for oil spill preparedness, whereas the United States uses a worst-case scenario, and Europe uses a 60,000 m^3 planning standard. The existing planning threshold in Canada can cause the country to be not fully prepared when it comes to responding to a very large oil spill if one should occur. This study conducted a comprehensive review of the current Canadian oil spill response system and framework, regulations, roles and responsibilities of federal and provincial governments, existing decanting capabilities, and capacities of Canadian oil spill responders. More importantly, this study identified the gaps in the current oil spill response system and regulatory and technological barriers to oil decanting. Marine oil decanting regulations and practices in the US and selected European countries have also been reviewed to support addressing the challenges and improving the Canadian experience. It is expected that this study would help the stakeholders and professionals to better understand the oil spill response system and oil decanting status quo in Canada and facilitate Canadian governments and industries to better address the challenges in oil spill regulations and practices.

Keywords: spill preparedness and response regime; decanting regulations and practices; marine oil spill response system; gaps in Canadian oil spill regulations

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1. Introduction

Canada is a global leader in oil and gas production, and it is the fourth largest producer of crude oil and produces more than 1.5 times the oil compared to its total domestic demand [1]. This growing oil and natural gas industry contributes significantly to the economy by adding $105 billion to Canada's gross domestic product (GDP) and supporting more than 500,000 jobs across the country [2,3]. Moreover, global demand for oil is predicted to be increased by 106.3 million barrels per day in 2040; consequently, it is anticipated that

Canada's oil production will rise by 1.27 million barrels per day [4]. Even though the global value chain was impacted due to the pandemic initially, by May 2021, all merchandise exports, including crude oil, were 5.3% higher than their level from January 2020 [2,3].

As Canada is increasingly attracting the global oil companies for liquefied natural gas, oil sands, pipeline operations, and oil exploration, the activity in the Arctic is rising, as is the risk of oil spills from drilling operations, pipelines, and transportation by ship and tanker [5]. With that, upstream and downstream activities are growing at a rapid pace which is increasing the probability of oil spills in Canadian water. Despite the spills that have happened in Canada being mostly small (67% of ship-source spills between 2003–2012 were under 1000 L), Canada needs to prepare well for larger accidental spills.

Depending on the type and quantity of oil, the location of an oil spill, its behaviour in the marine environment, and the biological and ecological features of the affected region, oil spill events can leave negative impacts on the marine ecosystem and human and social life [6]. For example, during the SS Arrow tanker spill incident, biota was affected environmentally in the bay, such as shellfish, fish, plankton, aquatic plants, and seabirds. Oil spills may lead to habitat change, reproduction disturbance, and mortality [7,8]. Financially, an oil spill can negatively affect fishers, local businesspeople, and governmental agencies [9,10]. Overall, an oil spill incident not only raises human health concerns, but also threatens human livelihood activities, such as agriculture, coastal engineering, and sea salt production [8,11].

With increased shipping activities, Canada's ports have become busier over recent years. While some of these contain oil as cargo carried in tankers and barges, there has also been growth in the number of ships visiting Canadian ports. In the Arctic region, the growing rate of ice melt due to rising global temperatures has opened up the Northwest Passage to more ship traffic; however, the presence of ice further increases the of risk damaging oil rigs, large ice keels and ice islands dredging the seafloor, damaging pipelines, and of an oil spill and other environmental disasters. Accidental ship-source oil spills, including oil and hazardous substances spills, are one of the sources of marine water pollution, which can jeopardize the marine environment in both the short and long term. Though the spills that have occurred in Canadian waters are smaller, spills including bunker spills or vessel spills can happen more often than spills from tankers, which are subject to further safety measures.

These deviations in marine shipping support the need for a review of how well-equipped Canada is to respond to spills, should they occur. To this end, the current study presents a comprehensive review of the current Canadian oil spill response system and the framework, regulations, roles and responsibilities of federal and provincial governments in marine oil spill responses, existing decanting capabilities, and capacities of Canadian oil spill responders. Furthermore, marine oil decanting regulations and practices in the US and selected European countries have also been reviewed to support addressing the challenges and improving the Canadian experience. This study provides deeper insights and a critical review of the Canadian oil spill response system to identify the bottlenecks in the current oil spill response system and regulatory and technological barriers for oil decanting to better understand the response status quo and facilitate current authorities and industries to better address the challenges in oil spill regulations and practices.

2. Overview of Petroleum Industry and Oil Shipping Activities in Canada

2.1. Petroleum Industry in Canada

Canada is one of the largest oil producers in the world and it exports 98% of its produced oil to the US [2,3]. Each Canadian province plays an important role in the oil industry with active participation in oil production, exploration, and transportation. The technological advancement in this field has led Canada to be in third place in proven oil reserves with 10% of the total worldwide oil reserve share. Among Canadian provinces, Alberta is the richest province in oil sands [12,13]. British Columbia has been a pioneer in shipping high volumes of Canadian oil and has produced crude oil with an amount of

16,000 barrels per day [14]. Saskatchewan is the second province in oil production with 487,000 barrels per day. In northern Canada, Nunavut and Yukon produce 7500 barrels of conventional oil per day [14]. Almost 80.5% of crude oil production belongs to Alberta, with more than 76 billion dollars of the direct nominal gross domestic product [2,3]. The produced oil requires reliable transportation modes, such as railways, pipelines, trucks, and oil tankers to ship and distribute oil throughout Canada and the rest of the world. Transportation systems can be selected depending on geographic obstacles, cost, and product volume [15]. For instance, 7% of crude oil is annually exported to the US or to different parts of the world by marine vessels, whereas 85% is transferred by pipeline [16,17]. In terms of marine transport, the highest volume of oil (87%) in Canada is shipped through the Atlantic coast, the Great Lakes, the Gulf of St. Lawrence, and the St. Lawrence seaway and ports; and the remaining (13%) is shipped through Pacific coast ports. The Port of Vancouver, Port of Montreal, Port de Quebec, Newfoundland Offshore, Port Saint John, Port Hawkesbury, and Nova Scotia are seven major ports which support an enormous number of oil tanker movements [16,17].

2.2. Oil Shipping and Marine Oil Spill Incidents in Canadian Oceans

More than 82 million tonnes of petroleum are transferred through three ports of Atlantic Canada, including Newfoundland and Labrador, Port Hawkesbury in Nova Scotia, and Saint John in New Brunswick. In Quebec, there are 39 ports, through which 25 million tonnes of oil are transported [2,3]. Moreover, the geographic location of Canada positions the country to have a great number of international shipping routes connecting North America to other parts of the globe, including Maersk Line, Hapag-Lloyd, Mediterranean Shipping Company, Hanjin Shipping, and so on. However, it is expected that in the future, the rate of shipping transit will rise because of increasing industrial activities, melting sea ice, simplifying navigation, and expanding urban life in this area [1], which subsequently increase the probability of oil spill risks.

Based on the public works and government services in Canada, oil spill incidents in Canada have been small-scale in comparison with world statistics. These incidents were the results of spills and leaks from a variety of vessel types, most of which were abandoned and derelict, including fishing boats, cruise ships, pleasure craft, ferries, tugboats, commercial ships, and barges, as well as mystery spills. A list of major oil spill incidents in Canada is shown in Table 1. In 2018, off the Newfoundland coast, 219 tonnes of oil were released, and it has been the largest oil spill incident in Canada in recent years [18]. The volume of marine pollution spills varies from year to year, and a single major spill can drastically affect the total volume. For instance, in 2021, 83% (14,688 L) of the total volume detected originated from vessels, while spills caused by sunken vessels, oil platforms, and land-based spills accounted, respectively, for 8% (1414 L), 5% (890 L), and 4% (659 L) [19]. However, an oil spill affects fish, birds, and the environment significantly because of its toxicity [20]. For instance, during the Nestucca oil spill incident, the dispersed oil slick reached Vancouver Island, Canada, and south to Oregon, US; over 13,000 oiled seabirds were displaced and rehabilitated.

Table 1. Oil Spill Incidents in Canada.

Location	Incident Reason	Name	Type	Year	Spill Size (Tonnes)	Reference
Nova Scotia	Grounding	SS Arrow	Tanker	1970	10,000	[21,22]
Quebec	Bunkering Spill	Golden Robin	Tanker	1974	400	[21,22]
Nova Scotia	Allision	Kurdistan	Tanker	1979	8000	[21,22]
Nova Scotia	Grounding	Odyssey	Tanker	1988	132,000	[23]
Washington US and British Columbia	Collision	Nestucca	Fuel Barge	1988	800	[21,22]

Table 1. *Cont.*

Location	Incident Reason	Name	Type	Year	Spill Size (Tonnes)	Reference
Ontario	Bunkering Spill	Nancy Orr Gaucher	Tanker	1989	102.41	[21,22]
Quebec	Grounding	Rio Orinoco	Tanker	1990	81.93	[21,22]
Quebec	Leak	MV Saraband	Tanker	1998	8.12	[21,22]
Newfoundland	Mechanical Failure	Terra Nova	Floating Production Storage and Offloading	2004	60.03	[21,22]
British Columbia	Grounding	Queen of the North	RORO Ferry	2006	81.22	[21,22]
British Columbia	Leak	MV Marathassa	Bulk Carrier	2015	0.95	[21,22]
British Columbia	Grounding	Nathan E. Stewart	Tug Boat	2016	38.84	[21,22]
Alberta	Leaking a ball valve	Enbridge Pipelines Inc	Pipeline	2017	1.05	[24]
British Columbia	Leaking spool piece	Trans Mountain Pipeline	Pipeline	2018	1.69	[25]
Newfoundland and Labrador	Leak in a flowline	Sea Rose FPSO production ship spill	Vessel	2018	219	[18]
Alberta	Rupture	Bonterra Energy Corp.	Pipeline	2019	14.12	[18]
Alberta	Leakage	Trans Mountain Pipeline	Pipeline	2020	67.09	[18]
British Columbia	Leak	Trans Mountain Pipeline	Pipeline	2020	184.87	[18]

3. Canadian Marine Oil Spill Response System and Practice

3.1. International Conventions/Acts/Treaties/Legislations

Canada is a member of the following international conventions/acts/treaties/legislations:

3.1.1. International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)

As of today, 156 states partake in the convention, being flag states of 99.42% of the world's shipping tonnage [26]. The convention contains regulations with an aim to prevent and minimize pollution from ships, including accidental pollution and pollution from routine operations. The convention currently includes six technical annexes. Each country is responsible for endorsing domestic laws to implement the convention and conform with the convention, annexes, and associated laws of other nations. Under the MARPOL 73/78 act, the release of oil by vessels into the sea is not permitted, with the exemption that the oil content of the discharge should not exceed 15 ppm, except in special areas, such as the Antarctic or the Great Lakes, where no oil content is permitted.

3.1.2. International Maritime Organization (IMO)

IMO is accountable for measures to improve the security and safety of international shipping and has 173 member states. Its primary resolution is to advance and maintain a complete regulatory framework for shipping, and its responsibility comprises safety, legal matters, environmental concerns, technical cooperation, maritime security and the effectiveness of the shipping. IMO has a number of technical sub-committees which have

executed a series of agreements, including the prevention of marine pollution by ships, preparedness and response to events including oil and hazardous substances, preclusion of the usage of harmful anti-fouling systems, and the international convention on bulk water management to prevent the blowout of harmful aquatic organisms in ballast water. Regulations enforced by national and local maritime authorities are regularly ratified by IMO in its member countries, such as the International Regulations for Preventing Collisions at Sea. It also enacted a Port State Control authority, consenting domestic maritime authorities such as coast guards to examine foreign-flag ships calling at ports among the port states.

3.1.3. International Convention on Oil Pollution Preparedness, Response, and Cooperation (OPRC)

OPRC is an international maritime convention with 112 member states that established measures for dealing with marine oil pollution incidents. According to this convention and its annex, state parties are required to undertake individually or jointly all required actions to prepare for and respond to oil spill incidents. All types of vessels operating in the marine environment are obliged to follow the convention requirements as well as fixed or floating offshore installations or structures involved in gas or oil search or exploitation, construction activities, or the loading or unloading of oil, and seaports and oil handling facilities (OHF) (i.e., seaports oil terminals, pipelines, etc.). According to the IMO convention, all ships should have a standardized shipboard oil pollution emergency plan. Authorities in control of seaports and OHF under the jurisdiction of the parties are also obliged to have oil pollution emergency plans or similar provisions in compliance with the national oil pollution response system [27].

3.1.4. Civil Liability Convention (CLC)

The International convention on civil liability for oil pollution damage is referred to as the CLC convention and it refers to an international maritime treaty managed by the IMO to guarantee that satisfactory compensation is offered if oil pollution damage is caused by maritime casualties involving oil tankers (i.e., ships that carry oil as cargo). In total, 138 states, representing 97.75% of the world's fleet, are contracted parties to the CLC Protocol. The alterations of the CLC protocols in 2000 raised the compensation limits by 50% compared to the limits set in the 1992 Protocol [28]. The convention also outlines strict obligations for shipowners. If the shipowner is found to be guilty in the case of an oil spill incident, the convention does not cap liability.

3.2. International Boundary Considerations

According to the CCG's National Contingency Plan, the CCG has adopted certain sections of the US National Incident Management System's Incident Command System (ICS) as the response system which is meant to be used in all incidents covered by the Contingency Plan, Regional Contingency Chapters, and Area Contingency Chapters. In order to keep up with the lead/resource agency system, the CCG does not use the Unified Command within its incident management system. It also stated that the CCG will respond to all incidents within its mandate to which a polluter is known, first as the Federal Monitoring Officer (FMO), and then, if the polluter is unable or unwilling to respond, as the On-Scene Commander (OSC). Under the current response management system (RMS), the polluter would be the Incident Commander (IC), with the CCG serving as an FMO. In Canada, the IC of the Organization/Agency that is paying for the response would have the final call, regardless of whether they are a government agency or private corporation, therefore a Transboundary Response could see the Polluter's IC having the final say in Canadian waters, whereas the US Coast guard (USCG) would have the final say in US waters (in case consensus could not be achieved in Unified Command).

However, it is not clear whether the CCG would assume the FMO or the OSC role during a transboundary spill, even though the Joint Contingency Plan and annexes suggest

that the CCG would assume the OSC role for a transboundary spill. As Canada and the US share waters, they established the Canada–US Joint Marine Pollution Contingency Plan in 1974 to meet the need for a marine pollution contingency plan for their joint waters [29]. The plan was most recently revised in 2017 to provide guidance to authorities including the CCG and USCG on coordinating preparedness and response operations. The plan is split into annexes regions of adjacent waters [30]. The annexes also provide detailed information required for response planning and implementation, including regulations regarding waste disposal and waste management in the geographic area.

Canada also has a joint contingency plan with Denmark for the waters between Canada and Greenland. The Canada–Denmark Agreement for Cooperation Relating to the Marine Environment (1983) was created to ensure cooperation between Canada and Denmark for the prevention, preparedness, and response to marine oil pollution incidents in the waters between Canada and Greenland. According to the agreement, actions taken by either party should be consistent with the relevant legislation and regulation [31]. These regulations would often include requirements for waste management.

3.3. National Oil Spill Preparedness and Response Regime

The IMO conventions provided an international framework for ship-source oil spill preparedness and response regimes. Every country has their customized regulations to deal with oil spills and Canada has a comprehensive process to ship-source oil pollution that comprises three major necessities as follows:

Prevention: Legislative and regulatory frameworks that govern tanker and vessel safety, comprising construction standards, pilotage, inspections, navigation, crew certification, vessel traffic management as well as surveillance and monitoring.

Preparedness and Response: Legislative and regulatory instruments that establish and preserve oil spill preparedness and response capability in Canada, including rules for vessels, oil handling facilities, and ROs, the oversight and monitoring of the industry's compliance with these rules.

Liability and Compensation: The multi-tiered, international and domestic outline for liability and compensation, comprising the strict liability of the shipowner and the cargo owner's financial contribution to the Ship-source Oil Pollution Fund and the International Oil Pollution Compensation Funds for ship-source oil spills.

3.3.1. The Regime since 1995

The government of Canada, in association with industry, established a regime based on a public–private partnership following a review in the early 1990s and informed by developments internationally. This regime provides a framework for preparedness to respond to ship-source oil spills in the Canadian marine environment. Industry, as the generator of the risk, bears the liability and accountability to respond in the event of a marine oil spill incident in Canadian waters and hence is charged with the operational materials of the regime. The government offers the legislative and regulatory outline for the regime and oversees the industry's preparedness and arrangements during a spill, should one happen. In general, there are three legal tools that form the basis of the current regime, including the Canada Shipping Act, 2001; the Response Organization (RO) and Oil Handling Facilities (OHF) Regulations; and the Environmental Response Arrangements Regulations. The CCG manages the private sector's response to a spill.

To operate in Canada, vessels and oil handling services are mandated to have prearranged planning with an RO as set out in legislation. Furthermore, Transport Canada (TC) sets out operating standards that ROs should follow in order to operate in Canadian waters in the Response Organization and Oil Handling Facilities Regulations. These comprise a regulated preparedness capacity to respond to spills up to 10,000 tones within prearranged time standards and operating environments. In general, TC oversees ROs' compliance with the preparedness requirements through a triennial certification procedure. In the event of a spill where the polluter is unknown or unable or unwilling to respond, the

CCG takes responsibility for the response system as the OSC. In any other conditions, the CCG accomplishes the role of the FMO. Supplementary parts of the legislation are also set out for other government divisions such as Environment Canada, which offers scientific, environmental, and wildlife guidance and expertise in the event of a marine incident.

3.3.2. Federal Regulations and Organizations under the Regime

Canada's Marine Oil Spill Preparedness and Response Regime outlines the roles and responsibilities of various federal agencies, including guidelines for preparedness and the response procedure to marine oil spill incidents (Table 2).

Table 2. Roles and Responsibility of Various Federal Agencies Marine Oil Spill Incidents.

Transport Canada	Canadian Coast Guard	Environment Canada
• Lead for legislative and regulatory oversight • Certification of ROs	• Lead agency for ensuring response • FMO—Takes charge of response as OSC when polluter is unknown, unable, or unwilling to respond	• Provides scientific, environmental, and wildlife advice, with support from Fisheries and Oceans Canada

Canada collaborates with other countries to further prepare for and respond to ship-source spills. Canada and the US have been collaborating closely on preparedness and response for cross-boundary spills since before the formation of the Regime. Initially, a combined contingency strategy for marine pollution was first promulgated in the mid-1970s in order to synchronize an international response to an oil spill in the Great Lakes area. With a revision in 2003, the current Canada–US Marine Pollution Joint Contingency Plan, contains five annexes for detailed geographic regions.

There have not been any major spills involving oil tankers or other vessels in the Canadian marine environment since the formation of Canada's Ship-source Oil Spill Preparedness and Response Regime. This could be attributed to the significant enhancements in prevention measures that have been realized over the past few decades. While the current Canadian spill preparedness and response regime has met current needs, it has not been revised in its entirety since its inception, and the dynamics of oil transportation and marine shipping have since transformed significantly. Moreover, there has been significant growth in the natural resources division in Canada and an increase in oil production and oil exports. Subsequently, both the volumes of oil transported in Canadian waters and the number and size of the vessels transporting it have grown consequentially.

Furthermore, recent advancements in the research and development of alternative response techniques offer responders more choices to limit the environmental and socioeconomic influences of spills. It should be noted that these developments are not captured in the Canadian Regime and there has also been a gradual weakening of the Regime in other respects. For instance, over time, and in the absence of any major oil spills, knowledge and skill sets within the government have eroded.

3.4. Current Capacity and Response Practices

In an effort to identify operational gaps within the oil spill response, a thorough analysis was completed on general response procedures carried out in Canadian waters. This analysis focused on three aspects of the response regime. First, a basic structure of the response network was defined, and the roles of the actors within that network were outlined. Next, the general response procedure carried out through a collaboration between the government and industries was assessed and outlined. Finally, a comprehensive assessment was completed on the Canadian oil spill response capacity, with a focus on the Canada Coast Guard and the four response organizations as major players.

3.4.1. Canadian Oil Spill Response Network

The efficient function of the response network is dependent upon a few key members responsible for many of the actions taken during a response. The oversight of the regime falls to Transport Canada as a regulator, with the Canada Coast Guard serving as operational leaders, and the four response organizations providing the bulk of the response capacity. The rest of the network is highly dependent on these three actors and serves under their leadership. An overview of the Network and its dependencies is outlined in Figure 1 below:

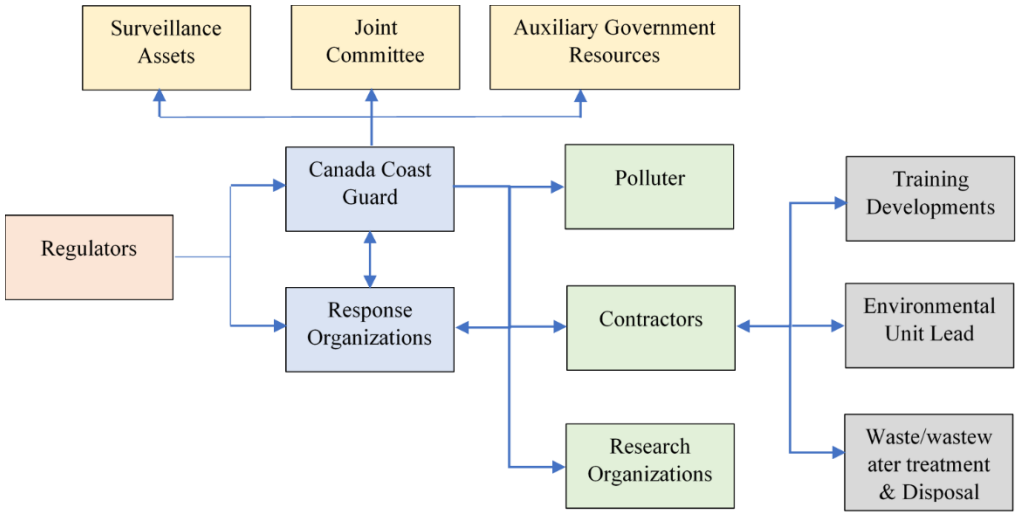

Figure 1. Canadian Oil Spill Response Network.

Regulators

The current state of the Canadian oil spill response network is a direct result of the regulatory and legislative efforts carried out by relevant departments within the government. Most of the plans and procedures adopted by Canadian lawmakers as they related to oil spill response come from international conventions, regulations, and guidelines. In particular, the International Convention on Oil Pollution Preparedness and Cooperation has been the source of several practices currently employed by the Canadian response network. The Convention outlines the "polluter pays" system, which Canada utilizes. This system lays the entirety of the financial responsibility of any response effort on the polluter. The implementation of this system generated the need for Canadian response organizations, which are a core component of most response efforts [32]. Additionally, originating from the international convention is the requirement for ships to have on-board emergency oil pollution plans—a requirement that has been extended to Oil Handling Facilities operating on Canadian soil [33].

There are a few key documents that outline procedures and requirements for various actors in the response effort. Most of these documents repeat standards that were created or updated within the Canada Shipping Act 2001. The CCG procedures are described in the Marine Spills Contingency Plan, which highlights key activities the CCG may carry out during a response, as well as the general response structure. Response organizations and oil handling facilities are subject to their respective standards, and there is a periodical assessment of the response regime through the Marine Oil Spill Preparedness and Response Regime.

Canada Coast Guard

The CCG plays a central role within the oil spill response network [34]. Most of the infrastructure utilized during the earlier stages of a response is maintained by the CCG, and they are largely responsible for optimizing initial response times to spill incidents.

During a response effort, the CCG coordinates efforts between responding parties and acts as the operational commander until the response activities can be handed off to the most appropriate party. The CCG is responsible for training environmental response personnel and providing qualified response officers to be appointed by the Minister of Fisheries and Oceans [34].

Surveillance Assets

The National Air Surveillance Program (NASP) provides most of Canada's capacity in terms of detecting and verifying spills in Canadian waters. The NASP maintains three surveillance aircraft—one each in Moncton, New Brunswick, Ottawa Ontario, and Vancouver British Colombia regions. From 1992 to 2011, NASP increased patrol hours by 98.4% and observed an 80.3% reduction in the number of spills [32]. Besides increasing detection rates, surveillance data provided to the CCG by the NASP has been essential to the planning of robust response efforts. The NASP has also collaborated with international oil spill response efforts. Aerial surveillance and coordination were essential to this response due to the sheer expanse of the slick [32]. Canada Ice Service (CIS) partnered with the NASP for the first time in 2005 for an arctic pollution surveillance operation, eventually giving rise to regular patrols in the arctic during busy shipping periods. The CIS utilizes the same satellite imagery analysis techniques to inform response operations in terms of slick destinations and climate forecasts [35].

Joint Committees

Arctic Council

In an effort to increase response capacity in the arctic, the eight Arctic states, including Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden, and the US, formed an Agreement on Cooperation on Marine Oil Pollution Preparedness and Response in the Arctic. This agreement outlines a commitment to provide mutual assistance to a Nation should its capacity be exceeded, and to collaborate on the improvement of the mutual response regime.

United States Coast Guard

In any spill incident crossing Canada's Southern Border, there is assumed to be a significant level of cooperation between the CCG and the USCG. Both serve crucial roles in their respective response regimes and will both direct resources from their country during a collaborative response effort. Depending on the nature of the spill, one of the Coast Guards will assume a more supportive role, thereby allowing the entity with the stronger jurisdictional claim over the spill to more ably direct a suitable response [32].

Auxiliary Government Resources

Transport Canada

During a response effort, Transport Canada may conduct onboard investigations of affected vessels to ensure responder safety and vessel integrity [32]. TC also investigates spill events originating from Oil Handling Facilities and serves as the lead agency during any necessary salvage operations. The CCG depends heavily on TC during a response operation for expertise on ships and shipping activities [32]. In an extreme event, the CCG may mandate a cascade of resources from any appropriate source. This may warrant a contribution of personnel or vessels by TC to the response effort.

Environment and Climate Change Canada

Environment and Climate Change Canada is mostly a provider of expertise during response efforts [32]. The CCG relies on ECCC for environmental advice and for many of the activities carried out during the "post-mortem" process of a spill response. ECCC chairs the Regional Environmental Emergency Team, which provides an environment that encourages the exchange of novel technical information relating to pollution events. The

REET can also provide a consolidated package of environmental and technical advice to CCG in response to a spill incident and assists with inter-departmental coordination.

Response Organizations

There are currently four response organizations certified by Transport Canada in 3-year periods as being qualified to respond to oil spill events in Canadian waters [36]. These ROs are the Western Canada Response Corporation (WCRC), the Eastern Canada Response Corporation (ECRC), Point Tupper Marine Services Ltd. (PTMS), Point Tupper, NS, Canada, and the Atlantic Emergency Response Team (ALERT). Each RO has a distinct area of responsibility, with WCRC providing coverage for most of the Pacific coast and ECRC covering the Great Lakes and most of the Atlantic region. Both PTMS and ALERT are smaller response corporations operating locally in Atlantic Canada and rely on ECRC to complement their capacity for larger spills [36]. Each organization was created as an industry response to Canada's current stance on polluter responsibility. The Government holds the industry responsible for cleaning up its own spills, and every designated vessel plying Canadian waters should have a valid agreement with the most appropriate Response Organization. During a response effort, the ROs provide most of the equipment and resources needed for the cleanup and support the CCG's commanding role during the operation [32].

Polluters

The largest potential for spills certainly lies in the shipping industry, which transports over 326 million tonnes of oil through Canadian waters each year [21,22]. A large majority of shipping activity occurs in Canada's Atlantic region, and seven large ports across Canada support most tanker movements. The largest tankers in Atlantic waters are Ultra-Large Crude Carriers holding approximately four million barrels of oil. Technological and regulatory improvements have reduced the risk these large tankers pose to the environment. These improvements have resulted in 78% of spills greater than 10,000 L between 2003 and 2012 involving fuel oil rather than oil as cargo [21,22].

There is also potential for pollution at any oil handling facility, especially when operations are underway to transport oil from ship to shore. There are currently four categories of OHF regulated in Canada, determined by the maximum oil transfer rate possible for one single transfer [30]. Each OHF should demonstrate preparedness to respond to a spill incident of a size corresponding to the category of OHF [19]. The four categories, their respective transfer rates, and the minimum spill size corresponding to each category is outlined in Table 3 below:

Table 3. Oil Handling Facility Categories.

Category	Maximum Oil Transfer Rate	Minimum Oil Spill Size
Level 1	150 m^3/h	1 m^3
Level 2	750 m^3/h	5 m^3
Level 3	2000 m^3/h	15 m^3
Level 4	>2000 m^3/h	50 m^3

Many small spills originate from smaller vessels such as pleasure crafts, fishing vessels, and transport ships. These incidents do not usually justify a full-scale response but are often in close proximity to other vessels or to the shore. A rapid response time is therefore just as important in these cases as in larger events. Mystery source spills usually originate from these smaller vessels and there is a reliance, especially in remote areas, on surveillance assets and members of the public for the detection of said spills.

Contractors

Especially in the event of a very large spill, contractors may be employed by responders to boost the capacity of the response efforts. Various engineering firms and treatment

facilities often become involved in the operation, usually managing much of the onshore cleanup. To respond better, advisors and experts might also be brought to the scene to inform the commanding party on the best paths forward for dealing with the spill. Most of the training programs and exercises carried out by the CCG, other government bodies, and the ROs are developed by private sector companies specializing in response efforts [32]. The final treatment and resale of the recovered oil are also handled by private contractors. There is little or no capacity within the CCG or ROs to treat this oil. Large spills are rare, and maintaining enough equipment to deal with these accidental spills is financially infeasible. It is therefore in practice to rely on private companies to take on treatment responsibilities as they already possess the necessary facilities.

Research Organizations

In 1977 the Government of Canada launched the Arctic and Marine Oil-spill Program (AMOP), and the first Technical Seminar was held less than a year later in 1978. The purpose of this first seminar was to allow AMOP contractors to present the results of past studies and to encourage future ones. The Seminar has since become an international forum for the discussion of the prevention, assessment, and treatment of pollution events of all types in all environments [12,13].

4. Overview of Decanting Regulations and Practices in Canada

4.1. Decanting Process

Decanting is a method of oil spill response with significant applications abroad and yet has found very limited use within Canadian oil spill response operations. Decanting can be described as a vessel-based oil spill response operation, where seawater and spilled oil are collected. The mixture of oil and water is then stored in a temporary storage container. Once the mixture has settled for the appropriate time, the oil is separated from the water by gravity separation. The oil comprises the top layer, while the free water forms the bottom layer. The free water layer is where decanting is implemented. The oil in the top layer is recovered, while the free water layer is repeatedly decanted to recover as much of the chemical contaminants as possible. An example of typical storage containers (TSCs) used to collect seawater and spilled oil is shown in Figure 2.

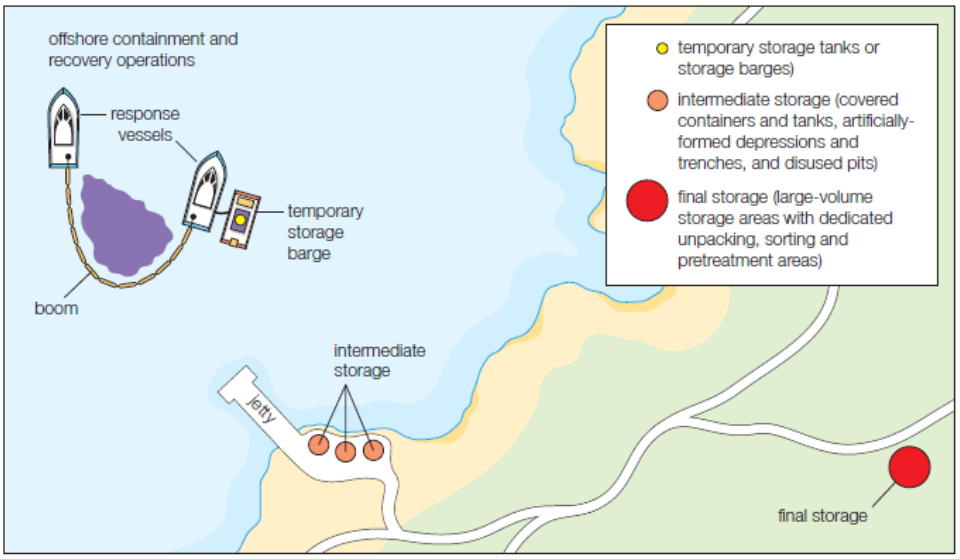

Figure 2. Transportation and Storage Requirements Associated With Onshore Transfer of Recovered Oil and Water During Oil Spill Response (Source: IPIECA-IOGP Joint Industry Project, 2013).

The free water will still comprise hazardous contaminants that do not allow the free water to meet Canadian wastewater discharge standards. Therefore, the decanted free

water requires additional treatment before it can be deemed acceptable to be discharged back into the marine environment. The IMO Marine Pollution standard, referred to as "MARPOL", requires that no water be put back into the ocean unless it contains less than 15 ppm oil-in-water content. Wastewater discharged into special areas, where "special areas" are deemed so by regional and national legislation, cannot exceed 0 ppm of oil-in-water content. Special areas include areas such as the Great Lakes [37]. Each country has their own regulatory standards that either are below or meet the MARPOL standard. Canada specifically requires 15 ppm or less when concerning the oil content in water [38].

As a result of the regulatory framework for oil spill response and wastewater quality, current oil spill response efficiency is inhibited. Under the constraints of several Canadian regulations, such as the Canada Fisheries Act and Canada Shipping Act, the direct discharge of decanted water is interpreted by Response Organizations (ROs) to be prohibited [39,40]. As a result, decanted water should be brought to shore for disposal, which has a direct impact on the response capacity and the efficiency of oil recovery. Specifically, the length of time, the high cost of transportation and the limited storage space all affect the efficiency of oil recovery. A breakdown of the transportation and the necessary storage requirements related to the onshore transfer of recovered oily wastewater can be seen in Figure 2.

As shown in Figure 2, the current decanting response practices require recovered fluids to be transferred multiple times prior to reaching the treatment stage. In the example shown in Figure 2, the recovered fluids are contained within the boomed area and transported into the temporary storage barge. From there, the recovered fluids are brought onto the shore, where the fluids are placed in covered storage containers. Finally, the recovered fluids are transported for final storage, where the final separation of oil and water occurs, and the decanted water is then sent for further treatment. The following section provides a regulatory review and comparison of Canadian regulations to others across the globe. Canadian regulations are then reviewed and directly compared to other areas including the US, Norway, and Europe.

4.2. Current Decanting Practice in Canada

Canada follows the standards set out in the MARPOL 73/78 Annex 1 International regulations. The international standard for the discharge of oily wastewater is 15 ppm. Canada follows this standard in most areas but also operates more strict discharge requirements in certain locations. Inland waters in Canada should not exceed 5 ppm [37] and special areas, such as the Great Lakes, are under a 0 ppm discharge standard [39,40]. According to the Fisheries Act, "Throwing overboard of certain substances prohibited 36 (1) No one shall (a) throw overboard ballast, coal ashes, stones or other prejudicial or deleterious substances in any river, harbour or roadstead, or in any water where fishing is carried on;" [39,40]. Moreover, oil is categorized as a deleterious substance, so it is prohibited to be thrown overboard where fish are present, which includes most bodies of water.

The Canadian Environmental Protection Act disables any discharges of substances into the sea without a Canadian permit [39,40]. This required an approved permit to be obtained by oil spill responders prior to discharging anything into the sea. In the case of decanting aboard a ship, the seas move the ship enough to promote mixture and, therefore, decanting will not work effectively in most cases. For this reason, decanting is not currently the most effective method for oil spill response at sea.

Canadian ROs certified with Transport Canada completed a response plan for the 10,000-tonne spill planning standard. This implies that Canadian ROs should maintain the adequate amount and tonnage of equipment to appropriately respond to a 10,000-tonne oil spill within their geographic area of response. In comparison to the US, Canadian ROs are unprepared for very large spills, relying heavily on collaboration between ROs and cascading resources for such events. The key difference between the two states is that US ROs base their response plans on a worst-case scenario basis [41] rather than on a set spill tonnage standard.

Through expert surveys and telephone interviews, it was also found that Canadian oil spill response regulations have not been updated nor adapted to the capacities of Canadian Ros. As the technologies are growing and developing, the regulations have yet to account for new capacities, therefore limiting responders on how they are able to respond and treat decanted wastewater.

4.3. NEBA Process for Decanting Approval

The Net Environmental Benefit Analysis (NEBA) is utilized in the selection of spill response tools that can remove oil effectively, are feasible to use safely in certain conditions, and eventually will minimize the effect of the spill on the overall environment. The goal is to support the selection of a fixed strategy for oil spill response, which has been learned by a systematic assessment and estimation of various factors, with participation from a number of stakeholders. The NEBA is applied before and during a spill to aid the selection and optimization of response options. Irrespective of the stage during a spill at which it is employed, the process does not change. Before a spill, it allows the parties to identify potential spill scenarios that arise offshore, nearshore, onshore, or inland. The selection of response options will vary depending on where the oil spill occurs. During the contingency planning phase, the NEBA is used to identify and agree on response strategies for each selected scenario. During a spill, it allows these strategies to be validated and adjusted as conditions evolve.

During an oil spill event, the determination of the response endpoints is formed through the NEBA which comprises four stages: firstly, to compile and evaluate data to identify an exposure scenario and assess the implication of any regulatory requirements or thresholds. Secondly, to predict the outcomes, i.e., comparing the effects of 'no response action' with different combinations of continuing/adapting response options. Thirdly, to balance trade-offs of response options, especially considering whether continuing active clean-up may reduce the effectiveness and/or cause undesirable environmental impacts. Fourthly, to select the best response options by defining the point at which active response should cease. Generally, multiple stakeholders are involved in the NEBA process, including governments, industry, and communities to ensure that informed response decisions can be followed which take all perspectives and viewpoints into account.

5. Decanting Regulations and Practices around the World

5.1. United States

The United States National Response Team (NRT) is divided into Regional Response Teams (RRT) and Area Response Teams (ART). Each response team operates within the National Contingency Plan, a Regional Contingency Plan, and an Area Contingency Plan. The United States NRT consists of 13 different RRTs, each with different policies for decanting. Decanting may be a last resort, not discussed, pre-approved, or on a case-by-case approval depending on the RRT. The United States NRT complies with the international regulation of discharging wastewater that contains 15 ppm or less of oil. This measurement is based on a 24 h composite test. Certain areas in the US have created more stringent discharge level requirements, such as King County and Washington, where RRTs and ARTs are only able to discharge wastewater with 10 ppm of oil or less [42].

The United States NRT also operates under the Environmental Protection Agency (EPA). The EPA oil spill prevention program consists of Spill Prevention, Control and Countermeasure rules as well as Facility Response Plan rules that include guidelines to prevent oil discharge as well as a response plan to handle a worst-case scenario oil discharge event [41]. Nevertheless, the US Federal On-Scene Coordinator (FOSC) can decide on elimination from the National Pollutant Discharge Elimination System (NPDES) certificate condition for releases. Most Area Contingency Plans have comprehensive directions on the USCG strategy concerning decanting and many comprise sample forms for demanding authorization to decant from numerous State and other establishments. However, in Great Lakes, decanting is not allowed. The Maine and New Hampshire ACP states that when oil

is spilled on the water, mechanical recovery of the oil is the principal approved method of responding.

The practice of decanting is currently recognized as a necessary and routine part of response operations and utilized to drain off recovered water from portable tanks, internal tanks, collection wells, or other storage containers. In many cases, the decanting process requires the discharge of the excess water for efficient skimming operations and to minimize overall environmental damages. These actions can only be approved by the FOSC and/or SOSC since the cleared water will be significantly less detrimental to the environment than permitting the oil to persist on the water and be subject to spreading and weathering. In the current practice, to use decanting during a response, the response contractors or the responsible party would request permission from the FOSC and/or SOSC authority to decant to recover the oil so that response operations do not become impaired. Moreover, incidental discharges related to mechanical recovery operations are not considered prohibited discharges. Nonetheless, the Area Committee adopts this policy to deliver an expeditious approval process and provide necessary guidance related to incidental discharges and decanting to the OSCs, responsible parties, response contractors, and other members of the spill response community.

While approving decanting, the FOSC and/or SOSC consider the following aspects to find Reasonable and Prudent Measures to minimize and avoid negative impacts, including the location of the spill, the location of the vessels employing sweep booms, the retention time for oil holding, the containment boom to minimize loss of decanted oil, the visual monitoring of the decanting area, and non-vessel decanting is subjected to the same rules as vessels.

5.2. Europe

The European Marine Safety Agency (EMSA) was originally established to ensure a high, uniform, and effective level of maritime safety and prevention of pollution by ships [42]. After the creation of this agency, the European Union (EU) adopted a law which guarantees funding for the work of the EMSA to fight pollution at sea under the Oil Spill Actions Plan. From the development of this law, the EMSA has been providing technical expertise and operational assistance to improve maritime safety, pollution preparedness and response and maritime security. Most of the tasks are preventive actions to reduce pollution in the sea surrounding Europe. These preventive actions include monitoring how certain laws are being applied and evaluating their overall effectiveness. One of the reactive tasks includes providing EU countries with oil recovery ships in the event of a major spill and detecting marine pollution through satellite surveillance. The EMSA also provides governments and authorities with detailed and reliable information about what happens at sea in real time so that maritime policies could be implemented effectively. The EMSA works closely with the European Border, the Coast Guard Agency, and the European Fisheries Control Agency (EFCA). The EMSA has vessels all along the coastal countries of Europe and should legally sustain operational readiness through dedicated oil response drills and exercises [43,44]. As for oil decanting in Europe, all EMSA ships are equipped with pumping, decanting, and discharging systems on the vessels. Each vessel is able to decant excess water in order to maximize the utilization of the onboard storage capacity. Excess water should follow the international standard of 15 ppm oil-in-water prior to discharge into the sea [43,44].

5.3. Norway

Although Norway is not a part of the European Union, the EMSA still works with and supports Norway. Norway also operates under the MARPOL standard of 15 ppm oil-in-water for decanting. As per the Pollution Control Act, the national contingency system is divided into three areas, including private, municipal, and governmental, each with specific roles and responsibilities. All the contingency plans and area-specific organizations are standardized and synchronized. However, in the event of a major spill of a national

emergency scale, the national contingency system would work as an integrated response organization [23].

Norway is one of the few countries in the world that allows oil to be discharged into the sea for the determination of testing equipment and measures. These annual oil-on-water exercises have played a significant role in the development of the Norwegian Clean Seas Association for Operating Companies' oil response equipment and competence [45]. Decanting is allowed in all of Europe; presumably, decanting is also pre-approved in Norway. The use of oil spill dispersants is allowed as a secondary response option if this follows their emergency response plan [46]. In Norway, petroleum activity-produced water should be cleaned prior to discharge to the sea. The oil content in water discharged to the sea should be as low as possible. In any event, the oil content should not exceed 30 ppm oil in water as a weighted average for one calendar month. Facilities that discharge produced water, should perform environmental risk assessments of the discharges.

6. Analyzing and Identifying Gaps in Canadian Regulations and Current Practices

6.1. Analyzing and Identifying Gaps in the Oil Spill Response System

After analyzing the current Canadian oil spill response system, regime, capacity, and preparedness, it is important that ROs have cascading resources and prearranged agreements with necessary authorities to ensure an efficient and faster response system to address a worst-case spill in their Areas of Response. It is also important to implement a risk-based Area Response Planning modelling system to strengthen the preparedness and response capacity for ship-source oil spills. The current regime needs to be reviewed regularly by TC and necessary amendments are required in the national Risk Assessment (RA) framework to develop a consistent methodology for RA in each area of response to marine oil spills in Canadian waters. A standardized procedure for risk-based area response planning needs could be developed by TC through collaboration with the CCG, Environment Canada, and ROs.

As the CCG is the lead agency to respond to an oil spill incident, it could lead the area response planning procedure for each area of response in association with relevant agencies and authorities, including TC, Environment Canada, and ROs. The area response plans should identify the capacity including, equipment, skilled personnel, management, and approval systems essential to accommodate all probable spill scenarios in the area of response. The scenario should also include worst-case discharge and required cascading resources and necessary mutual assistance agreements. In addition, ROs should develop detailed geographic response plans to abate possible negative impacts of the spill on key environmental and socio-economic sensitivities. The geographic response plans should also contain detailed time standards and classify the capacities and resources that need to be preserved locally.

Transport Canada should have monitoring tools to guarantee that ROs meet the requirements delineated in their area response plans. A strategy and response framework needs to be established for the timely and efficient disposal of oily waste, in accordance with the area response planning model. The government needs to increase the effectiveness of the legislative and regulatory framework of administering and monitoring the oil handling facilities (i.e., stringent inspection, enforcement program).

Another significant difference would be that Canada uses a 10,000 tonnes planning standard for the preparation of oil spills, whereas the US uses a worst-case scenario and Europe uses a 60,000 m^3 planning standard. This small planning standard in Canada can cause the country to be somewhat unprepared when it comes to responding to the very large oil spills that can occur. A larger planning standard, similar to the US and Europe would help Canada be more prepared when a very large spill occurs.

6.2. Analyzing and Identifying Gaps in Decanting Regulations and Practices

Table 4 below summarizes the difference in regulations across the different study areas. Various gaps that have arisen in the Canadian regulations are outlined based on the comprehensive review of oil spill regulations in Canada, the US, Norway, and Europe.

Table 4. Regulatory Gap Identification.

	Discharge Requirement	Approval for Decanting	Emergency Response Plan	Planning Standard	Spill Monitoring	Training
International	<15 ppm	Country decision to decant or not	Emergency plan onboard for 400 gross tonnage including: Procedure for master to report and handle incident, list of contacts, actions to control incident			
Canada	<15 ppm everywhere <5 ppm inland 0 ppm special locations (Great Lakes)	Case-by-case approval		10,000 tonnes planning standard	24 h calling for response and satellite surveillance	Transboundary (Joint) Planning with US
US	<15 ppm most states/localities <10 ppm Kings County and Washington Area	Case by case, pre-approval, not discussed or last resort depending on region	EPA Oil Spill Prevention Program (includes response plan for worst-case scenario spill)	Worst Case scenario		
Norway	Target of zero <15 ppm		Pre-approval to use oil spill dispersants as secondary option in emergency response plan -Standardized contingency plan			-NOFO conducts roughly 100 dry scenario/year -Annual oil-on-water scenario
Europe	<15 ppm	Pre-approval		60,000 m^3 capacity	Satellite Surveillance	

Table 4 above presents the identified gaps in the marine oil spill regulations for Canada. All countries operate under the international regulations outlined in this table; therefore, if no new information is outlined in the country's specific row, they are assumed to simply follow the international regulation as mentioned. As shown in Table 4, decanting is only permitted on a case-by-case approval in Canada, whereas Europe and certain areas of the US work on a pre-approval basis. In Canada, when the spill response team decides that decanting is an appropriate way to handle a spill, a request for approval to decant will be put forward. This approval can take a long time to obtain, which negatively impacts the spill that has already occurred.

Decanting would more likely be favoured in Canada if the process to obtain approval was not taking longer time. Areas that operate under this pre-approved basis do not have to wait for this approval and can respond immediately with the use of decanting. In addition to studying the regulations and identifying gaps through the existing literature, interviews with NuStar Energy, Servosystems, Triox, S.L. Ross, and the CCG were completed. A

summary of challenges communicated from the interviews are as follows: A more seamless agreement between facilities is required to respond efficiently. Moreover, regulations have not changed with changes in technologies over the years for the Canadian regime. A case-by-case approval for decanting in Canada means it is challenging and time-consuming. More clarity on the regulations and responsibilities of response organizations is required. Through reviewing the limitation of the Fisheries Act "Throwing overboard of certain substances is prohibited 36 (1) no one shall throw overboard ballast, coal ashes, stones or other prejudicial or deleterious substances in any river, harbour or roadstead, or in any water where fishing is carried on", where oil falls under the deleterious substance, and finding probable decanting technologies that can be performed in Canadian harsh sea conditions efficiently and effectively.

7. Conclusions

In this paper, a comprehensive review of oil spill response and oil decanting regulations, framework, and strategies in Canada was presented. Moreover, the roles and responsibilities of federal and provincial governments in marine oil spill responses and existing decanting capabilities and capacities of Canadian oil spill responders were reviewed. In addition to the Canadian context, marine oil decanting regulations and practices in the US and selected European countries have also been reviewed to support addressing the challenges and improving the Canadian experience. The following section outlines the main bottlenecks and challenges in different aspects following some recommendations.

7.1. Canadian Spill Preparedness and Response Regime

The Canadian spill preparedness and response regime has not been revised in its entirety since its creation more than 20 years ago, and the dynamics of oil transportation and marine shipping have since transformed meaningfully. Over the years, and in the absence of any major oil spills, the capacity, knowledge, and skill set within the government and response organizations have eroded. Canada still lacks a solid national outline for chemical spills, also called hazardous and noxious substances. A strategy and response framework in accordance with the Area Response Planning model is recommended to be developed. Introducing provisions or new legislation related to the deployment of suitable response equipment, technologies, or facilities in different environmental conditions could be considered with the cooperation of indigenous people who have sufficient knowledge about the local environment.

7.2. Coordination among Regulatory Authorities

The federal government is responsible for oceans and inland seas; they are the regulatory agency responsible for marine oil spill incidents. However, when spills reach the shoreline, they could affect the land above the high-water line. The land above the high-water line is the responsibility of the province. Oily waste, once collected and brought to the shore, should be stored, transported, treated, and disposed of. These activities result in the application of Provincial regulations in various capacities. Therefore, there needs a better and more comprehensive definition of federal and provincial responsibility in the event of a spill, should one occur. Additionally, regulations related to post-spill monitoring should be further improved in Canada.

7.3. Current Capacities

Currently, there is little or no capacity within the CCG or ROs to treat recovered oil. Large spills are rare, and maintaining enough equipment to deal with these irregularities is financially challenging. More temporary storage on site or nearby sites is required to be identified and established with consideration for heavier oils, heating, pumping, etc. Intermediate storage and long-term disposal sites are chosen on a case-by-case basis. Subsequently, this limits the adequate preparation for accidental large spills. It is recommended that the area response plan should recognize the capacities of facilities and equipment

in all response areas based on the worst-case scenario and the maximum most-probable discharge perspective and risk-assessment-based approach. Local capacities, such as oil recovery storage, response boats, onshore response equipment, and disposal facilities should be further developed in the Arctic; moreover, efficient damage control actions to decrease response times in harsh Arctic weather should be established.

7.4. Decanting Regulations and Practices

According to the current regulations and practices, Canada is not prepared for more than 10,000 tonnes of oil spill incidents. Mechanical equipment, such as booms, skimmers, and pumps cannot be fully practical in the Arctic due to the harsh environment. There are concerns about the use of containment equipment, such as the vessel availability and capability for response and the limited capacity of temporary storage. Moreover, being far away from a shore demands more time and a number of trips to the shore which can worsen the situation. Using gravity separation is a common technique for oil decanting, however, it is not adequate, and more advanced on-site technologies are required. Furthermore, it is recommended to ease the restriction on decanting provisions in regulations, such as the fisheries act. Additionally, decanting is only permitted on a case-by-case approval process in Canada whereas Europe and certain areas of the US work under a pre-approval basis which can be further considered. Using novel oil decanting equipment and high-capacity vessels can increase the preparedness of Canada in oil decanting based on what has been learnt by the US and Europe.

This study identified the regulatory and technological barriers and bottlenecks in the oil spill response system and the application of oil decanting during an oil spill to strengthen the oil spill response system and improve the status quo of oil decanting applications and facilitate current authorities and industries to better address the challenges in oil spill regulations and practices. The recommendations provided in this study could be adopted to improve various aspects of the oil spill response system, contingency plans, and oil decanting regulations and practices in Canada for federal and provincial authorities and stakeholders.

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References

1. Lee, K.; Boufadel, M.; Chen, B.; Foght, J.; Hodson, P.; Swanson, S.; Venosa, A. *Expert Panel Report on the Behaviour and Environmental Impacts of Crude Oil Released into Aqueous Environments*; Royal Society of Canada: Ottawa, ON, Canada, 2015. Available online: https://www.rsc-src.ca/sites/default/files/OIW%20Report_1.pdf (accessed on 20 July 2021).
2. Government of Canada. Crude Oil Facts. 2020. Available online: https://www.nrcan.gc.ca/science-data/data-analysis/energy-data-analysis/energy-facts/crude-oil-facts/20064 (accessed on 20 May 2021).
3. Government of Canada. Get the Facts on Oil Tanker Safety in Canada. 2020. Available online: https://tc.canada.ca/en/marine-transportation/marine-safety/get-facts-oil-tanker-safety-canada (accessed on 27 July 2021).

4. CAPP. Crude Oil Forecast. Markets and Transportation. 2019. Available online: https://www.capp.ca/wp-content/uploads/2019/11/338843.pdf (accessed on 17 January 2021).
5. Hafezi, M.H.; Daisy, N.S.; Liu, L. A Cluster-Based Technique for Identifying and Grouping Oily Waste Types Generated from Marine Oil Spill Response Operations. *Front. Environ. Sci.* **2022**, *10*, 590. [CrossRef]
6. Daisy, N.S.; Hafezi, M.H.; Liu, L. *Dalhousie MBR Survey*; Department of Civil and Resource Engineering, Dalhousie University: Halifax, NS, Canada, 2021.
7. Dalaklis, D. Safety and security in shipping operations. In *Shipping Operations Management*; Springer: Cham, Switzerland, 2017; pp. 197–213. [CrossRef]
8. ITOPF. Effects of Oil Pollution on the Marine Environment, Technical Information Paper. 2020. Available online: http://www.itopf.org/fileadmin/data/Documents/TIPS%20TAPS/TIP_13_Effects_of_Oil_Pollution_on_the_Marine_Environment.pdf (accessed on 20 July 2021).
9. Beson, M. View of the Arrow Spill and Its Effects on the Chedabucto Bay Area. Guysborough County Inshore Fishermen's Association. Retrieved from a View of the Arrow Spill and Its Effects on the Chedabucto Bay Area (stfx.ca). 2001. Available online: https://people.stfx.ca/rsg/srsf/GCIFA/ArrowSpill.html (accessed on 15 April 2021).
10. European Parliament and Council. Regulations (EC) No 1406/2002 of the European Parliament and of the Council of 27 June 2002 Establishing a European Maritime Safety Agency. EUR-Lex Access to European Union Law. 2002. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1595007378388&uri=CELEX:32002R1406 (accessed on 14 July 2020).
11. ITOPF. Effects of Oil Pollution on Social and Economic Activities, Technical Information Paper. 2020. Available online: https://www.itopf.org/knowledge-resources/documents-guides/document/tip-12-effects-of-oil-pollution-on-social-and-economic-activities/ (accessed on 20 July 2021).
12. Government of Canada. Oil Resources. 2019. Available online: https://www.nrcan.gc.ca/energy/energy-sources-distribution/crude-oil/oil-resources/18085 (accessed on 15 April 2021).
13. Government of Canada. Environmental Response Regulations: SOR/2019-252. 2019. Available online: http://www.gazette.gc.ca/rp-pr/p2/2019/2019-07-10/html/sor-dors252-eng.html (accessed on 15 April 2021).
14. CAPP. British Columbia's Oil and Natural Gas Industry. 2020. Available online: https://www.mineralsed.ca/site/assets/files/3453/british-columbias-oil-and-natural-gas-industry.pdf (accessed on 10 May 2021).
15. Government of Canada. Petroleum Products Distribution Networks. 2016. Available online: https://www.nrcan.gc.ca/energy/energy-sources-distribution/refining-sector-canada/petroleum-products-distribution-networks/5897 (accessed on 20 July 2021).
16. Canada Energy Regulator. Crude Oil Annual Export Summary—2019. 2020. Available online: https://www.cer-rec.gc.ca/en/data-analysis/energy-commodities/crude-oil-petroleum-products/statistics/crude-oil-summary/crude-oil-annual-export-summary-2019.html (accessed on 14 June 2021).
17. Canadian Energy Regulator. Canada's Ports and Energy Imports and Exports: International Comparisons. 2020. Available online: https://www.canadianenergycentre.ca/wp-content/uploads/2020/09/CEC-FS-17-Canadas-Ports-FINAL.pdf (accessed on 12 May 2021).
18. CBC; Radio-Canada. Oil vessel off the Newfoundland coast spills 250,000 litres of crude. *CBC News*, 17 November 2018.
19. Transport Canada. Marine Transportation. 2020. Available online: https://tc.canada.ca/en/corporate-services/policies/marine-transportation (accessed on 20 July 2021).
20. WebEcoist. Sick Slicks: Counting Down the 13 Worst Oil Spills. 2010. Available online: https://webecoist.momtastic.com/2010/05/04/sick-slicks-counting-down-the-13-worst-oil-spills/ (accessed on 20 July 2021).
21. Clear Seas Organization. Oil Tankers in Canadian Waters. 2020. Available online: https://clearseas.org/en/tankers/ (accessed on 10 February 2021).
22. Clear Seas Organization. Responding to Oil Spills in Canadian Waters. 2020. Available online: https://clearseas.org/en/responding-to-oil-spills/ (accessed on 14 May 2021).
23. ITOPF. Norway. 2018. Available online: https://www.itopf.org/knowledge-resources/countries-territories-regions/countries/norway/ (accessed on 20 July 2021).
24. Transportation Safety Board of Canada. 2018. Available online: https://www.tsb.gc.ca/eng/surveillance-watchlist/2018.html (accessed on 23 March 2021).
25. Transportation Safety Board of Canada. 2019. Available online: https://www.tsb.gc.ca/eng/publications/priorites-priorities/2019/2019.html (accessed on 20 July 2021).
26. IMO. International Convention on Oil Pollution Preparedness, Response and Co-Operation (OPRC). 2020. Available online: http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-on-Oil-Pollution-Preparedness,-Response-and-Co-operation-(OPRC).aspx (accessed on 20 May 2021).
27. OPRC. Article 6 of the International Convention on Oil Pollution Preparedness, Response and Co-Operation (OPRC). 1995. Available online: https://treaties.un.org/doc/publication/unts/volume%201891/volume-1891-i-32194-english.pdf (accessed on 20 July 2021).
28. Kiran, R.; Krishna, B. Liability and Compensation for Oil Pollution Damage: An Examination of Imo Conventions. *NUJS Law Rev.* **2010**, *3*, 399.

29. CCG. Canadian Coast Guard-United States Coast Guard Joint Marine Pollution Contingency Plan. 2013. Available online: https://www.canada.ca/en/environment-climate-change/corporate/international-affairs/partnerships-countries-regions/north-america/canada-united-states-marine-pollution-contingency.html (accessed on 20 January 2021).
30. CCG. Marine Spill Contingency Plan—National Chapter. 2018. Available online: https://www.ccg-gcc.gc.ca/publications/environmental-environnementale/marine-pollution-deversements-en-mer/toc-tdm-eng.html (accessed on 20 July 2021).
31. Agreement for Cooperation Relating to the Marine Environment. 1983. Available online: https://www.treaty-accord.gc.ca/text-texte.aspx?id=101887 (accessed on 21 May 2021).
32. Transport Canada. Marine Oil Spill Preparedness and Response Regime. 2014. Available online: https://tc.canada.ca/sites/default/files/migrated/tp14539e.pdf (accessed on 20 July 2021).
33. Transport Canada. A Review of Canada's Ship-Source Oil Spill Preparedness and Response Regime. 2013. Available online: https://www.tc.gc.ca/media/documents/mosprr/transport_canada_tanker_report_accessible_eng.pdf (accessed on 20 June 2021).
34. Department of Fisheries and Oceans. Departmental Plan 2019–2020. 2019. Available online: https://www.dfo-mpo.gc.ca/rpp/2019-20/dp-eng.html (accessed on 20 April 2021).
35. Transport Canada. Canada's Marine Safety and Security System. 2018. Available online: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjb3oPLk5j6AhWdqVYBHaEPDzwQFnoECCQQAQ&url=https%3A%2F%2Fwww.ceaa.gc.ca%2F050%2Fdocuments%2Fp80054%2F125568E.pdf&usg=AOvVaw1S75McfwFQFA1NUFzpfsTi (accessed on 20 May 2021).
36. Transport Canada. Regulatory Framework. 2010. Available online: https://www.tc.gc.ca/eng/marinesafety/oep-ers-framework-1469.htm (accessed on 20 February 2021).
37. Government of Canada. Regulatory Framework. 2010. Available online: https://tc.canada.ca/en/marine-transportation/marine-safety/regulatory-framework-0 (accessed on 20 June 2021).
38. IMO. Port State Control. 2019. Available online: https://www.imo.org/en/OurWork/MSAS/Pages/PortStateControl.aspx (accessed on 20 May 2021).
39. Government of Canada. Canadian Environmental Protection Act. 2018. Available online: https://laws-lois.justice.gc.ca/eng/acts/c-15.31/page-20.html#docCont (accessed on 20 July 2021).
40. Government of Canada. Canada's Preparedness and Response for Hazardous and Noxious Substances Released from Ships: Discussion Paper. 2018. Available online: https://tc.canada.ca/en/marine/canada-s-preparedness-response-hazardous-noxious-substances-released-ships-discussion-paper (accessed on 20 May 2021).
41. United States Environmental Protection Agency. Oil Spills Prevention and Preparedness Regulations. 2020. Available online: https://www.epa.gov/oil-spills-prevention-and-preparedness-regulations (accessed on 20 January 2021).
42. Mohr, K.S. An overview of US and international regulations regarding hydrocarbons in water effluents. In Proceedings of the Water Environment Federation, Anaheim, CA, USA, 14–18 October 2000; pp. 158–166, The European Marine Safety Agency (EMSA). 2022. Available online: https://www.emsa.europa.eu/ (accessed on 20 March 2021).
43. EMSA. European Maritime Safety Agency-Pollution Preparedness and Response Activity. 2010. Available online: https://emsa.europa.eu/csn-menu/csn-background/items.html?cid=14&id=230 (accessed on 20 July 2021).
44. EMSA. Marine Intervention in Chemical Emergencies Network. 2010. Available online: http://www.emsa.europa.eu/we-do/sustainability/pollution-response-services/chemical-spill-response.html (accessed on 20 March 2021).
45. NOFO. Our Operation. NOFO. 2018. Available online: https://www.nofo.no/en/our-operation/ (accessed on 20 April 2021).
46. Norwegian Environment Agency. Norwegian Pollution Regulations. March 2012. Available online: http://www.miljodirektoratet.no/en/Legislation1/Regulations/Pollution-Regulations/ (accessed on 20 January 2021).