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Oil spill response in the Arctic: Norwegian experiences and future perspectives

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ABSTRACT

With the northwards expansion of offshore petroleum activity in Arctic states, there is a concern of the adequacy of emergency response systems. Petroleum activity in these areas is challenging due to harsh weather conditions, darkness, ice, large distances and lack of infrastructure. The politically controversial nature of Arctic oil and gas exploitation makes improvements in oil spill response a necessary condition to receive a license to operate for the oil industry. This paper analyzes the characteristics and development of the Norwegian oil spill response systems in the light of the northwards expansion of the petroleum industry. It addresses the Norwegian case from a pan-Arctic perspective, and looks at the different scales at which emergency response networks are organized. The preparedness theme turns out to be a meeting point for environmental and business interests and provides opportunities for innovation and economic development. Despite ongoing developments and improvements, the paper discusses the challenges ahead in Arctic oil spill preparedness. These should be addressed from a local, state and international level simultaneously, involving public institutions, private companies, and public–private constellations. While implementation takes place at the national and local level, the Arctic Council has a potentially important role in harmonizing standards and regulations across Arctic countries.

1. Introduction

The future of petroleum development in the Arctic is a widely discussed theme (e.g. [1–4]). With the focus on increasing petroleum activity in the Arctic, there is a growing concern about the effectiveness of the systems for oil spill emergency preparedness [5]. Petroleum activity in these areas is particularly challenging due to harsh weather conditions, darkness, ice, icing, and large distances. In many Arctic regions, the existing infrastructure is insufficient to permit an adequate response to acute pollution of petroleum activity. The Arctic is considered to be specifically vulnerable to oil spills: low temperatures usually mean longer persistence of hydrocarbons in the environment and slow recovery in highly seasonal ecosystems [1]. Special environmental and ecological conditions thus demand adapted and strict emergency technologies and protocols, which cannot simply be copied from the systems that are developed further south.

All Arctic states with established petroleum activity have more or less developed systems for emergency preparedness in place, with divided tasks and responsibilities among a diverse set of actors. The Arctic Council has developed guidelines for offshore oil and gas activities in the Arctic, which includes a section on how to handle emergencies [6]. However, the growing accessibility of the Arctic puts emergency preparedness in focus. Moreover, the Deepwater Horizon disaster in the Gulf of Mexico in 2010 provided a reminder of the risks that petroleum operations are associated with. It is not enough to reduce the risk of oil spills through safety requirements and preventive measures. It is also necessary to have an effective and credible oil spill response network and infrastructure available that can be mobilized immediately after an accident occurs.

Oil spill response (OSR) is therefore an essential aspect of offshore petroleum activity in the Arctic. Without a good emergency response system in place it will not be politically acceptable to engage in exploration and production of oil and gas in the Arctic. While it is important to recognize that risks cannot be eliminated, contingency planning can mitigate the potential harmful effects of adverse events. OSR consists of two phases: prevention and combating. Here, the focus is not on preventive measures, but rather on emergency response; i.e. combating the negative effects if an accident should occur.

This paper analyzes the adequacy of the Norwegian oil spill emergency response systems in the light of the northwards

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expansion of the petroleum industry in this country. Norway has a relatively well-developed emergency response system to deal with acute pollution along the Norwegian coast and on the Norwegian Continental Shelf. Different roles are defined for private, municipal and state actors. There is however a renewed attention for the adequacy of the Norwegian emergency response system as the oil and gas exploration and exploitation are gradually extended from the North Sea and the Norwegian Sea and into the Barents Sea. Various organizations have argued that infrastructure and technologies are underdeveloped in order to deal with the consequences of acute pollution. The likely vicinity of future petroleum activity to small-scale fisheries is another concern that needs to be taken into account in such governance systems. Hence, the paper looks into the development and the overall capabilities of the emergency response system. So far, the focus on oil spill preparedness has mainly been directed towards technological and natural scientific questions, while the socio-economic and organizational aspects have received little attention. These aspects will be highlighted.

The paper first explores the need for international agreements on oil spill response from an Arctic perspective. Then, with the focus on north Norway, it outlines the existing division of tasks and responsibilities of the Norwegian OSR system. The section that follows analyzes the conditions for OSR in the Norwegian Arctic region. What are the requirements for effective response systems and the conditions to get these in place? Since organizational and technological innovations are central to establishing well working systems, the paper also explores how such innovations are stimulated in relation to petroleum activity in the Norwegian context. Finally, the (potential) role of local and regional actors, including fisheries, will be discussed. Based on these insights lessons are drawn that are applicable to the wider Arctic.

2. International regulations and cooperation on oil spill response

The risk of blow-outs and pollution from offshore petroleum drilling, production and transportation are widely recognized. Internationally, a number of agreements have been signed regarding emergency response regulations and procedures with particular reference to oil and gas activities (see [7]). Norway is party to several such agreements. To consider the case of Norway in an international or pan-Arctic perspective, it is relevant to provide a brief overview of the already existing bilateral and multilateral arrangements and forms of cooperation. Future regulations on emergency response procedures will have to be fitted into this patchwork. The focus on bilateral, multilateral and (future) pan-Arctic agreements is particularly relevant in the light of expanding petroleum activity in boundary regions, where a potential oil spill might mobilize the emergency response networks of more than one country.

The OSPAR Convention on the protection of the marine environment of the northeast Atlantic was implemented in 1992 and includes an annex on the prevention and elimination of pollution from offshore sources. The objective of OSPAR's Offshore Oil and Gas Industry Strategy is “to prevent and eliminate pollution from offshore sources and to protect the OSPAR maritime area against the adverse effects of offshore activities so as to safeguard human health and conserve the marine ecosystems” [8]. The Bonn Agreement (an international agreement between North Sea states) includes a Counter Pollution Manual that contains information needed for counter-pollution measures, as well as general material about pollution control strategies [9]. Within the Bonn agreement, there is a joint contingency plan between Norway and the United Kingdom—the NorBrit agreement. The 1971 Copenhagen Agreement (revised in 1993) between Denmark, Finland, Iceland, Norway and Sweden, also addresses marine oil pollution [9]. The parties agree to cooperate on surveillance, investigations, reporting, securing of evidence, combatting and assistance in combatting, as well as general exchange of information to protect the marine environment from pollution by oil or other hazardous substances.

With respect to oil and gas activities in the border area of the Barents Sea between Russia and Norway, a bilateral OSR Agreement was put into force in 1994, which includes a joint contingency plan, joint training exercises and a joint planning procedure [10].

On a pan-Arctic scale, the Arctic Council is the central organ that is concerned with the overall challenges that relate to oil and gas activities and their potential consequences. Since its establishment in 1996, it has been the Arctic Council's main objective to promote coordination and interaction among the Arctic states, in particular relating to issues of sustainable development and environmental protection in the Arctic.

The Arctic Council has six scientific working groups, among which EPPR, AMAP and PAME are the most relevant to mention in this paper. The Emergency Prevention, Preparedness and Response Working Group (EPPR) addresses different aspects of prevention, preparedness and response to environmental emergencies in the Arctic. It was established by the declaration on the protection of the Arctic environment, which was signed June 14, 1991 in Rovaniemi, Finland. The aim was to establish a network for information on Arctic accidents and for facilitating co-operation among the Arctic states around emergency prevention, preparedness and response [11].

PAME (Protection of the Arctic Marine Environment) has the key responsibility for the Council's activities related to the protection and sustainable use of the Arctic marine environment. In 1997, PAME published its first report on Arctic offshore oil and gas guidelines. This was updated in 2002 and 2009.

Another important document resulting from the Arctic Council's work on these issues is the Arctic Monitoring and Assessment Program (AMAP) Working Group's Arctic Oil and Gas 2007 assessment [1], in which the PAME and EPPR working groups participated. The objective was to present a holistic assessment of the environmental, social, economic and human health impacts of current oil and gas activities, and to evaluate the likely course of development of Arctic oil and gas activities and their potential impacts in the near future (see also [12]). The report included some key findings related to emergency response in the Arctic. Generally, responding to major oil spills remains a challenge in remote, icy environments. One of the conclusions of the AMAP report was that there are no effective means of containing and cleaning up oil spills in broken sea ice. This is particularly difficult during the winter season. Further work is needed on response techniques, particularly for oil under ice and in broken ice. The development of technology and regulations can partly help reducing the negative impacts [1].

At the ministerial meeting in Nuuk in 2011, the Arctic Council signed its first legally binding agreement on Search and Rescue (SAR) operations in the Arctic. Although this agreement is specifically directed at shipping activities, it was an important milestone in the Arctic Council's work in the development of a regulatory framework for activities in the north. Its success has without doubt influenced the second binding agreement, which the eight Arctic states signed in the latest Arctic Council meeting in Kiruna, May 2013. The objective of this agreement is to “strengthen cooperation, coordination and mutual assistance among the Parties on oil pollution preparedness and response in the Arctic in order to protect the marine environment from pollution by oil” (for the agreement text, see [13]). The parties

state that each state shall maintain a national system for promptly responding to oil pollution, taking into account the particular activities and locations that most likely give rise to acute pollution. In addition, these systems should anticipate the risks in areas of special ecological significance. The agreement is specifically relevant if an oil spill takes place in international waters, or in case of a spill with a size that extends national maritime boundaries. The next sections explore how Norway is developing and strengthening its oil spill response in the north, as well as the challenges that remain.

3. Organization of emergency response in Arctic Norway

It is argued above that it is important to explore how international agreements and guidelines are developed on a pan-Arctic scale. However, in order to study their potential modes of implementation, more knowledge is needed about the characteristics of the individual countries emergency response networks. Therefore, the Arctic areas of Norway are taken as an example. First, the developments in the region and the growing need for adequate emergency preparedness will be described. Consequently, an overview of the existing rules, regulations and responsibilities of actors in this Norwegian system is provided.

3.1. Background: A growing need for emergency preparedness in north Norway

While the oil and gas industry has been established in the south of Norway for more than four decades, the oil economy has only recently started its inroad into northern Norway [14]. The Barents Sea region has attracted attention as a region with prospective petroleum resources. Several studies have been undertaken to foresee how unproven resources can be developed and what economic benefits this might provide (e.g. [15–18]). However, cold climate, darkness, ice and icing, long distances, low population density and complicated logistics entail that the operating conditions are different from those in the North Sea. The concern for fisheries and a vulnerable environment has also made oil drilling off the coast of north Norway far more controversial than further south [19,20].

The circumpolar offshore areas of Norway can roughly be defined as the Barents Sea-Lofoten area, which includes a part of the Norwegian Sea. In this paper the focus is on the area that is geographically delimited in the management plan for the Barents Sea—Lofoten area [21]. Today, there is one field in production (the Snøhvit gas field) and one under development (the Goliat oil field) in this area. The Goliat oil field is the development closest to the Norwegian shore. It is situated about 85 km northwest off the coast of Hammerfest in Finnmark, Norways northermost county. The field operator is Eni Norway, which shares ownership with Statoil. The Goliat field is also the world's northernmost offshore oil field.

Numerous assessments of the consequences of petroleum activity in the Norwegian Sea and the Barents Sea have been carried out since the 1970s [14]. The first White Paper that dealt with the potentials for opening areas north of 62° north was presented in 1976 [22]. It contained considerable scepticism to oil and gas developments due to fisheries and environmental concerns. It was argued that oil spill response systems were underdeveloped. The large Ekofisk Bravo accident in 1977 led to another postponement of exploration activities in the north. However, in 1979, the majority of the Parliament gave green light to start exploration activities in a few selected areas that the authorities considered both appropriate and mature for commercial exploration ([23]: 64). As a result, in January 1980 the first blocks north of 62° north were allocated. It was the government's long-term intention for the northern areas to provide the resource basis for continued activity beyond what the North Sea alone could sustain ([23]: 65).

In 2001, the Norwegian government decided on a moratorium on all oil and gas activity in the Barents Sea—Lofoten area. Before reopening, it required a consequence assessment of year-round oil and gas activities. Furthermore, an ecosystem-based, integrated management plan had to be developed (see [24]). It was assumed that such a plan could offer the right tools and methods to manage the petroleum industry in relation to environmental and fisheries concerns. It was established that normal petroleum operations should take place under stricter conditions than further south, for example through the implementation of a zero discharge regime [25][2]. The plan, however, puts relatively little focus on the adequacy of the established emergency preparedness systems [21].

Today, there is a great optimism among petroleum interests resulting from the discovery of new fields (for example the Johan Castberg field) and the opening of new areas. The formerly disputed area between Russia and Norway in the southeastern Barents Sea is argued to contain several promising prospects. After agreement between the two countries on the maritime delimitation in 2010 (with its ratification in 2011), the Norwegian Parliament has set in motion a process towards opening this area for petroleum activity, which led to a recommendation for its opening in June 2013. These developments and the specific conditions and vulnerability of the Arctic area emphasized the importance of the conditions for emergency preparedness (for the assessment reports (in Norwegian) see [26,27]).

3.2. Regulations, roles and responsibilities

There are many actors involved in oil spill preparedness in Norway. The Ministry of Petroleum and Energy has the overall responsibility for all petroleum activity on the Norwegian Continental Shelf. The Pollution Control Act of 1981 is the legal basis that sets the preconditions for oil spill emergency preparedness in Norway, and which describes demands and obligations to different parties. In accordance with the Pollution Control Act, a system has been established that works at three levels.

First, oil companies have the primary responsibility for dealing with acute pollution closest to the source. Offshore oil and gas projects as well as larger industrial facilities on land need to have oil spill preparedness systems in place. The operator companies on the Norwegian Continental Shelf have organized themselves into the Norwegian Clean Seas Association for Operating Companies (NOFO), which manages emergency response systems, develops contingency plans and supports research and development of oil spill response equipment. In case of an accident, the use of mechanical equipment is the primary strategy and the companies are required to have response equipment in place for each individual project.

Second, coastal municipalities have an important operational responsibility. They are obliged to take care of the necessary equipment to deal with smaller, acute spills and should be able to provide crews and equipment. Norway is divided into 34 emergency-regions, each with an inter-municipal committee for acute pollution. The Coastal Administration considers these committees as the core of the total Norwegian preparedness network [28].

[2] However, the waste management regime was harmonized with the regime that applies to the rest of the Norwegian Continental Shelf with the revision of the management plan in 2011.

Third, the state is responsible for emergency response in case of major incidents of acute pollution when spill response cannot be covered by private and municipal preparedness. The state shall prevent acute pollution and ensure that the responsible polluter or municipality takes appropriate measures when acute pollution occurs. The overall responsibility for oil spill preparedness in Norway lies with the Ministry of Transport and Communications, with the Coastal Administration as advisory, planning, controlling, and executive body. Apart from the Coastal Administration, other governmental agencies have important roles. The Petroleum Directorate (subject to the Ministry of Petroleum and Energy) and the Petroleum Safety Authority (subject to the Ministry of Labor and Social Affairs) (see [29]) have monitoring and reporting responsibilities. The responsibility for follow-up lies with the Norwegian Environment Agency[3] (subject to the Ministry of Climate and Environment), which plays an important role in establishing environmental regulations for petroleum activities. It sets the environmental requirements for preparedness systems and monitors compliance with the environmental regulations. With respect to the environmental effects of oil and gas activities, the Ministry of Climate and Environment has overall responsibility.

There is thus a range of private, state and regional actors involved in oil spill emergency preparedness in Norway. In addition, there are several other actors, such as NGOs (e.g. WWF) and (regional) public–private constellations that play key roles. The aforementioned state, regional and private actors have partly overlapping responsibilities, where for example the Coastal Administration may take over if private or municipal preparedness system does not function adequately. The Coastal Administration thus plays a key role, described by other authors as "a hub […] that mobilizes and coordinates the other key national actors" ([30]: 63).

Oil spill contingency planning in Norway is divided into four barriers. Table 1 shows the specifics of each barrier, as well as the measures and equipment that are in place to combat an oil spill. Some of the measures and equipment mentioned in the table are based on the experiences with the Goliat field and are the result of recent innovations, which will be discussed in the next section. Important to note, of course, is that OSR starts with procedures on and close to the platform to prevent spills, fire, or explosions with the use of sensors, alarm equipment, mechanical valves and duplicated barriers at the seabed and on the platform (sometimes called "barrier 0") (see [31]).

Equipment depots are managed by the Norwegian Coastal Administration, NOFO, and private companies. The Coastal Administration manages 16 main depots, and ten supplementary depots. It has six oil recovery vessels, and has contracted five emergency towing vessels as well as a surveillance aircraft. In addition, the Coastal Administration has ten coast guard vessels with oil booms, skimmers and pumping systems. Together, it has 45 000 m of oil boom available (pers. comm.). In addition to these state depots, there are 29 inter-municipal depots that are part of the public response equipment, with about 70 000 m of lightweight booms and 300 skimmers [32].

NOFO also has bases spread along the Norwegian coastline and manages an Emergency Response Centre. It has standby personnel available (approx. 60 persons) and manages special task forces. It owns 61 vessels for ocean-going oil spill response and 63 vessels for coastal response (as of March 2013) and has OSR equipment for all barriers available (booms, skimmers, etc.). In addition, it has stocks of oil dispersants as well as remote sensing equipment [33].

[3] The Norwegian Environment Agency was established in July 2013, resulting from a merger between the Climate and Pollution Agency (formerly known as Norwegian Pollution Control Authority) and the Directorate for Nature Management. Both were directorates under the Ministry of the Environment.

NOFO has made agreements with the inter-municipal committees and the Coastal Administration regarding assistance in oil spill response. Where necessary, the parties may use each other's material and personnel.

Despite the available resources, many question the adequacy of the current Norwegian OSR system. Are the responsibilities for each actor well enough defined in crisis situations? Will there be sufficient personnel available? Are the available material resources really satisfying? These questions are particularly pressing with the northwards development of the Norwegian petroleum sector.

4. Developing the north: New partnerships and innovative technologies

To strengthen the oil spill response system for Arctic conditions, new initiatives, partnerships and technologies are introduced—or need to be introduced. Even though it could be argued that formal roles are relatively well-defined [34], the expected increase in petroleum activity has spurred the establishment of new partnerships in the north, leading to an even more complex constellation of involved actors than sketched above. The structure that is outlined above is still valid in the context of Arctic drilling in Norway, but it is relevant to explore how activities in the Arctic trigger the establishment of new relationships and the development of innovative technologies.

4.1. The involvement of fishermen

With the increasing petroleum activities in the Barents Sea a structure has been implemented in which fishermen receive responsibilities in the field of emergency response. This is a direct outcome of the development of the Goliat field off the coast of Hammerfest. Eni Norway, the operator company, has together with Statoil and NOFO established a cooperation with Fiskarlaget Nord (the national Fishermen's Association's division in the north) to develop procedures that involve local fishermen in the emergency response system, whereby the oil company formally contracts fishermen. The fishermen maintain their normal fishing practices, while their contribution to emergency preparedness comes as an additional activity. This includes regular courses, exercises and potential real action. The fishermen are obliged to maintain their vessels in prescribed necessary conditions and to have equipment on board. They also have to report their accessibility and location.

Specific tasks of a fisherman would be to drag oil booms with his vessel to the emergency location, to monitor oil slicks, and to block off coastal sounds and inlets. In return he will get a general financial reimbursement and specific compensations for days spent on training, courses, or real action. One of the central arguments that have been used in favor of this partnership with fishermen is that fishermen possess relevant local knowledge about sea currents, influence of weather, and local geography. Furthermore, a large advantage of the involvement of fishermen is that they can be mobilized within a short time frame.

Despite the often conflicting discussion about petroleum versus fisheries activity, the organization of oil spill response shows an area where this conflict is less polarized. Here, fisheries and oil companies have found common ground. Fishermen have demonstrated their interest in participating in preparedness systems: owners of more than 140 fishing vessels have registered their interest in the coastal response around Goliat in the western part of Finnmark, of which 110 are from the region. In the first instance, Eni Norway articulated a need of 30–40 fishing vessels to be part of this cooperation in the Goliat case.

Regulations to enable the formalization of such cooperation between oil companies and fishermen were implemented in 2011.

Table 1
Barriers in Norwegian oil spill preparedness (see also www.oljevern.no).

Barrier	What/where	Measures/equipment
Barrier 1	In case of a spill, the contingency plans on board and in the vicinity of the platform will come into operation	Standby vessels with booms and skimmer equipment, helicopters
Barrier 2	Recovering oil in the open sea before it reaches land	Infrared cameras and oil-detecting radar systems; buoys that transmit signals to satellites; booms and skimmers
Barrier 3	Coastal contingency	Equipment depots; contingency training for inter-municipal groups; booms and skimmers
Barrier 4	Coastal and beach zone contingency	Depots for shore zone contingency equipment; special task forces; contingency schemes with local fishermen

Before this, fishing vessels could not legally be used in oil spill contingency operations [35]. This form of cooperation can be regarded as a new kind of value creation for fisheries and the regional economy in the north. Finnmark is first out with this development in Norway, but other regions along the north Norwegian coast might follow.

The involvement of fishermen with relatively small vessels demands not only an extended regulatory framework, but also adapted oil spill response technology. NOFI, a state-of-the-art company that specializes in emergency technology, is one of the larger players in the market for response equipment. The company, originally specialized in the production of fishing gear, has responded to the current demand by developing oil beams that can be towed by smaller boats like fishing vessels, which are stored in the offshore supply base in Hammerfest. New roles and partnerships in the context of oil spill preparedness are enabled and stimulated by technological developments. Simultaneously, these new constellations also stimulate technological development.

4.2. Organizational and material innovation triggered by field development

Apart from the involvement of fishermen, the development of the Goliat field has triggered several other forms of organizational and material innovation. One example is the establishment of a so-called coastal task force (*Innsatsgruppe kyst*) [36], consisting of about 40 persons that are recruited from Finnmark. This coastal task force comes into action within 48 h in case acute pollution occurs, and is specifically directed at cleaning up the shoreline. The coastal task force can, if required, be mobilized along the entire Norwegian coastline [35]. The concept was developed by Eni Norway and Statoil, in cooperation with the Norwegian Clean Seas Association for Operating Companies (NOFO), while the establishment of the group resulted out of cooperation between NOFO and Arctic Protection AS, a local company in northern Norway. The latter is responsible for the establishment and operation of the group.

In addition, with the development of Goliat, new equipment depots have been established in Finnmark. The development of Goliat goes hand in hand with technology development in order to address specific climate challenges, such as darkness. Operations on the seabed are monitored with sensors in a remotely controlled mini-submarine. The companies have developed infrared technology for the early discovery of spills, both underwater and on the ocean surface, including infrared technology on a helicopter, an aircraft, and on a preparedness vessel that was optimized to deal with cold weather [37]. The infrared technology is developed to see the oil spill in darkness. Sensors in mini-buoys will monitor the direction of an oil slick. In this way, the Goliat preparedness illustrates the modernization of Norwegian oil spill preparedness to address specific Arctic challenges.

This modernization process is not driven by market supply and demand alone. Rather, it is the political controversial nature of Arctic oil and gas exploitation that makes improvements in the oil spill response a necessary condition for the oil industry to get a license to operate in these areas. The preparedness theme is a meeting point for both environmental interests and business interests. Oil spill response thus turns out to be a field that provides opportunities for innovation, economic development and increased employment in the region. This extends far beyond innovation within oil companies. Interestingly, while northern Norway is a latecomer in petroleum development and generally lacks a strong oil and gas supplying industry, two of the leading Norwegian companies in oil response technologies (Norlense and NOFI) are established in this region.

5. Discussion: Challenges ahead

Although new partnerships and networks are formed in the north, and technology is under continuous development, there are many challenges ahead for a well-functioning emergency preparedness network in the north. The term preparedness network refers to everything that together constitutes emergency preparedness, including the institutions involved, the equipment and material infrastructures that need to be in place, regulatory arrangements, and the necessary trained personnel if an accident may occur.

The issue of available crew and personnel is critical. Some argue that mobile preparedness teams need to be established in order to catch up for the lack of available people in the remote Arctic areas if an emergency takes place. In a worst-case accident, thousands of people working on ocean, coastal and beach zone cleaning operations will be needed. In the Mexican Gulf accident in 2010, BP claims that at its peak the cleanup of the spill involved 48 000 people, 6500 vessels and 125 aircraft [38]. While the BP spill is not comparable to a worst-case scenario in the Barents Sea[4], these numbers provide an illustration of the potential size of cleanup operations. This is an enormous challenge in planning such operations in peripheral Arctic regions. In the Barents region, experiences from Barents Rescue – a large biannual cross-sectoral and transnational rescue exercise involving Russia, Finland, Sweden and Norway – will be highly relevant in case an accident may occur.

The lack of infrastructure along the Arctic coastlines is another potential problem. If an oil spill would reach the coastline, there are many locations that cannot be reached with cleaning equipment from land. Vessels have been developed that are very shallow and can reach very close to the shore, but it is unclear

[4] The potential magnitude of a spill is not only dependent on spill response, but also on uncontrollable factors such as the pressure of the well (which is relatively low in the Barents Sea, compared to e.g. the Mexican Gulf), the type and viscosity of the oil and weather circumstances.

what their capacity will be. In a recent assessment, Det Norske Veritas analyzed oil spill response systems for the northeastern Norwegian Sea [39]; an area that is still closed for petroleum activity due to fisheries and environmental concerns. The two institutions that later merged into the Norwegian Environment Agency have been critical about this assessment in a public hearing process. The Climate and Pollution Agency pointed at the limited possibilities to reach the coast. Infrastructure is developed to a small extent and they question whether this can be developed to a satisfactory degree at all [40]. The Directorate for Nature Management stated that the "the oil spill response analysis describes very challenging conditions and large limitations related to the possibilities to establish adequate coastal and beach zone preparedness" [40]. These limitations in available infrastructure, and the question whether an adequate level of infrastructure is at all feasible, are pressing issues in most Arctic regions.

A central issue that should be mentioned here is the limited capacity of response equipment and techniques to clean up the spilt oil. International experience shows that only in exceptional cases, more than 10–20% of the oil can be cleaned up mechanically. This is also confirmed by the recent assessment of oil spill response in the Arctic that was developed by the Pew Charitable Trusts [5]. In the case of the Deepwater Horizon oil spill in the Mexican Gulf, less than 3% of the oil was recovered with the use of mechanical equipment [5]. This also calls for a stronger focus on the *prevention* of spills in dealing with oil spill preparedness.

So far, the geographical focus on oil spill response has been on ice-free regions. Oil spill response equipment depots in most of the Arctic are equipped with material that is not developed for combating spills in ice-covered waters [1]. When moving further towards the north, the issue of oil in ice becomes a more central research and governance challenge. In icy conditions, only 1–5% removal is feasible [5]. How can a potential spill be cleaned up in broken ice, and what technologies can be used if a blowout occurs under the ice? These are central questions in current natural scientific research on Arctic petroleum exploration [41,42], in which oil companies also are involved (see for example [43,44]). However, the issue of oil-in-ice has so far not been a governance issue in Norway, as no areas have been opened with seasonal ice coverage. Generally, the Arctic Council has argued that consideration should be given to whether Arctic areas should be opened for oil and gas activities where the methods of dealing with a spill are lacking [1].

Finally, a large challenge lies in the adequacy and consistency of cross-border emergency preparedness, in case an oil spill takes place that affects several countries. This is an area where the work of the Arctic Council can potentially be very relevant. In the future, the Arctic Council could achieve a more central role in developing guidelines that each country must live up to. Developing shared knowledge and common guidelines can hopefully contribute to and strengthen existing bilateral or multilateral forms of cooperation, such as today's cooperation between Norway and Russia in the Barents region. This is also emphasized in the 2007 Oil and Gas assessment by AMAP as a specific recommendation, where it is stated that it is important to recognize the trans-boundary context of oil pollution hazards associated with certain oil and gas activities. It is written that "the Arctic Council should support improvements in bilateral (and multilateral) cooperation among the Arctic countries to institute or improve coordination of preparedness and response measures across the circumpolar region, in particular cooperation in the Barents, Chukchi and Bering Seas" [1]. In developing these forms of cooperation, experiences from technological and organizational innovation at the regional and national level can serve as a central starting point.

6. Conclusion

This paper focuses on the characteristics of oil spill emergency preparedness networks in the Arctic. With expanding oil and gas activities in the north and increasing activity in border regions, it is important that adequate preparedness systems are in place with common standards. What is adequate, however, is a question that cannot be answered objectively. Acceptability is strongly related to the level of risk that each actor is willing to take. There exists no consensus about the level of risk that is acceptable in the Arctic. But controversy, opposition, and critique on petroleum activity in the Arctic is perhaps the best guarantee for technology development and improved preparedness systems. This has already led to progress in the organization and technology of oil spill response in the Arctic, as illustrated with the case study of northern Norway. However, this paper has argued that there are some large challenges ahead.

Concerns about oil spill response are addressed at the various levels at which oil spill response is organized: at the local and regional (inter-municipal) level, the state level, and at the international level. The insights from the Norwegian case study have shown that these concerns cannot solely be addressed at one of these levels. In individual nation states, it is important that the local, regional and state level work closely together on developing oil spill response, in cooperation with private companies, NGOs and public–private constellations. With respect to cross-boundary issues, the Arctic Council is an important forum for international cooperation on oil spill response in the Arctic, with a particularly relevant role to developing adequate networks with common guidelines and standards across borders. The work of the Arctic Council is also relevant in producing knowledge about the gaps and necessities in Arctic oil spill response. While the nation states are responsible for their individual operational organization, it is also important that national examples of innovations in technology and organizational solutions are shared and discussed on an international level. This could lead to mutual learning among countries and could promote common cross-border solutions.

However, harmonization across borders is an extremely challenging task as all countries operate with their own regimes. International oil companies might also play a leading role towards further harmonization across borders and thereby stimulate the lifting of international standards of preparedness systems. These private actors have a great interest in continuous improvements, as the acceptance and legitimacy of their activities are fully dependent on adequate and effective OSR networks.

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