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Challenges of pre-disaster management in Iran: are organizations prepared to respond to freshwater oil spills?

Golrokh Atighechian[a], MohammadReza Maleki[a,*], Aidin Aryankhesal[a,b], Katayoun Jahangiri[c]

[a]*Department of Health Services Management, School of Health Management and Information Sciences, Iran University of Medical Sciences, Tehran, Iran, emails: atighechian_golrokh@yahoo.com (G. Atighechian), mrmaleki43@gmail.com (M.R. Maleki), aryankhesal.a@iums.ac.ir (A. Aryankhesal)*
[b]*Health Management and Economics Research Center, Iran University of Medical Sciences, Tehran, Iran*
[c]*Health in Disasters and Emergencies Department, School of Health, Safety and Environment, Shahid Beheshti University of Medical Sciences, Tehran, Iran, email: katayounjahangiri@yahoo.com*

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ABSTRACT

Oil spill in freshwater is one of the major threats to human health and environmental stability; protection of water resources based on pre-determined plans could prevent the occurrence of such a disaster. The aim of this study was to determine the challenges of pre-disaster management of oil spill incidents. This was a qualitative case study conducted in 2015 in Isfahan, Iran, on an oil spill incident and its roots based on a disaster management approach. Semi-structured interviews were conducted for data collection. Nineteen managers and staff members from among those responsible or involved in the management of the Isfahan oil spill incident were recruited to the study. Qualitative content analysis approach was employed for data analysis. Document analysis was used to collect additional information. "Weaknesses of risk reduction programs" and "weaknesses of preparedness plans" were identified as the roots of the disaster. Preparedness is a crucial aspect of timely and appropriate response to oil spill incidents.

Keywords: Oil spill; Pre-disaster management; Preparedness; Mitigation; Freshwater; Iran

1. Background

Water, being a critical natural resource upon which all socioeconomic activities and ecosystem functions depend, is an absolute necessity for production. It is essential for survival and sustainable development [1–3]. Only 2.5 percent of the earth's water is freshwater and its rivers are one of the principal freshwater sources for human use. More than half of the world's major rivers are seriously polluted, threatening the health and livelihood of the people who use their waters [4]. Chemical contamination, as one of the main threats, causes loss of animal life and damages the natural environment [5] in addition to having serious effects on human health [4].

Oil pollution is one of the most persistent and dangerous pollutions of water resources. It is a major pollution threat to both groundwater and surface water resources [6]. Nowadays, oil spills occur regularly resulting in the widespread presence of chemical

*Corresponding author.

compounds in the aquatic environment [7]. Many serious oil spill accidents from oil tankers, oil wells, tanks, and pipelines in various surface and underground sources have been reported worldwide over the recent decade [8,9], with the Deep-water Horizon oil spill in the Gulf of Mexico and the Enbridge Kalamazoo river spill ranking significantly in terms of devastating effects [9,10].

In recent years, a number of oil spill incidents have occurred in Iran in the Khuzestan, Isfahan, Kurdistan, Golestan, and Lorestan provinces [5,8]. On 14 April 2008, at 3 pm, a notable and unprecedented incident of oil spill occurred in Zayandehrood (a river in Isfahan) [5]. Due to the recklessness of a bulldozer driver working for the Road and Transportation Office, the Omidieh-Isfahan crude-oil pipeline was fractured causing the infiltration of several million liters of crude oil into the river. This central river is a main source of drinking water for its province [11]. Two-thirds of the drinking water of Isfahan city and 40 other cities of the province is obtained from Isfahan's water treatment plant. Consequently, the drinking water of these cities was completely cut off for 48 h after the incident [12]. More than 50 km of this river was polluted killing hundreds of fish and withering much plant life especially trees. Seven years after the incident, the remnants of the oil incident are still to be seen in the area (see Fig. 1).

Oil spill in freshwater has been a major threat in recent years in Iran. Management of water resources was challenged by the river oil spill from a ruptured pipeline in Isfahan and the overturning of oil tankers in other places. Therefore, planning for the protection of water resources is necessary to prevent environmental disaster and oil spill incidents in freshwater resources.

The aim of this study was to determine the challenges of pre-disaster oil spill management in Iran.

2. Materials and methods

2.1. Design

This was a qualitative case study conducted in 2015.

2.2. Participants

The study population consisted of the managers and staff working in the organizations or institutions involved in the management of the incident, including the Disaster Management Office, Oil Pipeline and Telecommunications Company, Department of the Environment, Isfahan University of Medical Sciences, Water and Wastewater Organization, Regional Water Company, Fire and Safety Services organization and Red Crescent Society. Purposive sampling, and the snowball technique were employed. Initially, a group of key informants from each organization was selected; other members were then identified by

Fig. 1. Remnants of oil incident in the area after seven years (shot by corresponding author).

consulting this group. The two inclusion criteria were desire for participation in the study and experience in management of oil spill incidents. Finally, 19 managers and staff members were recruited to the study.

2.3. Data collection

The data were collected by conducting semi-structured interviews. The foci of the interview questions were framed as follows.

(1) How did this incident occur?
(2) How was your organization prepared to respond to such incidents?
(3) What skills and experiences do you have as regards response to oil spill incidents?
(4) What are the challenges of pre-disaster management related to oil spill incidents in Isfahan?

Moreover, we employed probing questions for detailed information of experience shared by the study participants. Data collection was pursued to the point of data saturation. The seventeenth interview yielded no further helpful information or insight. However, to ensure data saturation, two more interviews were conducted. Thus, nineteen interviews were conducted in total. The interviews were scheduled according to participant preference. All participants preferred to be interviewed at their workplace. Before the interview, the researcher introduced herself and explained the objectives of the study. An informed consent form was also delivered to the potential interviewees before the interview. Interview sessions lasted 15–75 min (45 min on the median). All interviews were recorded using a digital voice recorder and immediately after each session, the interview was transcribed verbatim. Also, documents, reports, and field notes were used to collect further information about the incident.

2.4. Data analysis

Data analysis was carried out concurrently with data collection. The qualitative content analysis approach was employed [13] for data analysis. Whole interviews were considered as the unit of analysis. Accordingly, each interview was read several times to procure a general understanding of its content. Then, coding the meaning units, i.e. words, sentences, or paragraphs, was initiated based on either the participants' own expressions or the constructed codes derived thereof.

Simultaneously, the codes were compared with each other and with those incoming and were categorized according to their differences and similarities. Categories were in turn compared and categorized further into a higher level overarching theme.

2.5. Rigor

The credibility of the study findings was established with the member- and peer-checking techniques [14]. Accordingly, we provided several participants with their own interview transcripts as well as our generated code and asked them to determine whether our generated codes and concepts reflected their experiences. Also the codes were revised based on proposals made by professors supervising the work.

2.6. Ethical considerations

The Institutional Review Board and the Ethics Committee of Iran University of Medical Sciences approved the study. An information sheet including the aim and the process of the study was provided to the study participants who were asked to read and sign the study's informed consent form. All invited participants gave their written informed consent for participation.

3. Results

In total, 19 staff members and managers with a mean of 30 years work experience participated in this study (Table 1). Twenty-five concepts, seven sub-categories, and two categories were developed across the transcripts, the hierarchy of which is shown in Table 2. "Weaknesses of risk reduction programs" and "weaknesses of preparedness plans" as the two main categories and the root causes of the event are explained as follows (Table 2).

3.1. Weaknesses of risk reduction programs

One of the most important challenges of managing an oil spill incident involves "weaknesses of risk reduction programs." Predicting oil spill incidents is unlikely in most cases, while the potential impact on human health and environment is high. It is important to understand all aspects of the potential risk beforehand to manage an oil spill effectively. This category comprised three subcategories including failure to identify hazards, limited plans to reduce vulnerability, and weaknesses of preventive activities.

Table 1
Basic characteristics of participants

Variable	Gender		Organizations								Work experience		Level of education			
	Male *n* (%)	Female *n* (%)	DMO *n* (%)	OPTC *n* (%)	EPA *n* (%)	IUMS *n* (%)	WWO *n* (%)	RWC *n* (%)	FSSO *n* (%)	RCS *n* (%)	<20 years *n* (%)	>20 years *n* (%)	Diploma *n* (%)	B.S *n* (%)	M.S *n* (%)	Ph.D *n* (%)
Participants	17 (89.5)	2 (10.5)	2 (10.5)	2 (10.5)	2 (10.5)	2 (10.5)	5 (26.3)	4 (21)	1 (5.2)	1 (5.2)	5 (26.3)	14 (73.7)	2 (10.5)	5 (26.3)	11 (58)	1 (5.2)

Notes: DMO = Disaster Management Office; OPTC = Oil Pipeline and Telecommunications Company; EPA = Environmental Protection Agency; IUMS = Isfahan University of Medical Sciences; WWO = Water and Wastewater Organization; RWC = Regional Water Company; FSSO = Fire and Safety Services Organization; RCS = Red Crescent Society

3.1.1. Failure to identify hazards

Our participants stated that hazard identification was not complete and there was neither protection for, nor control over, the Zayandehrood river (as is the case in general in the country).

> The "Water Safety Plan" (WSP) was established just last year in Isfahan and Tabriz in order to identify hazards that threaten drinking water. With this plan we were able to control the quality of drinking water. In the plan, it was determined where water transmission lines, oil and fuel pipelines should cross or be close together. We didn't have such a plan six years ago. (Participant 5)

> There was no protection for the rivers. This meant that anyone could do practically anything as far as the rivers' water was concerned. A month ago, we had an incident where a gasoline tank was intentionally emptied into the river, and such incidents may happen again. Right now, villas and resorts near the river discharge their sewage into it. We treat this water and use it. (Participant 3)

They also noted that the locations of the pipelines were not marked and there were no danger signs in the incident area. Therefore, black spots were not identified.

> When we went to the area, we saw that the oil pipeline was at the edge of the road and bordering the river; so, the incident was likely to happen even if there were no reckless behavior from the bulldozer driver. (Participant 2)

3.1.2. Limited plans to reduce vulnerability

Most participants believed that a vulnerability assessment would help organizations understand and anticipate potential occurrences that could result in damage. Such assessment would help them to focus on vulnerable areas or on the assets such as the people, environment, or infrastructure that are the most vulnerable.

> Each organization should determine the region's vulnerability in terms of possible damage caused by potential oil spill incidents. (Participant 1)

On the other hand, ignorance of the area and lack of organizational experience in oil spill incidents lead to failure in the prediction of such incidents:

> Few staff members or managers are familiar with the black spot area, while they should have perfect knowledge in this regard. (Participant 7)

Table 2
Challenges of oil spill pre-disaster management in Iran

Category	Sub-category	Concept
Weaknesses of risk reduction programs	Failure to identify hazards	(1) Lack of protection for, and control of, river (2) Failure to identify pipelines and pipeline risks (3) Failure to predict and identify black spots
	Limited plans to reduce vulnerability	(1) Failure to identify regional vulnerability (2) Low organizational experience in oil spill incidents (3) Limited knowledge of area (4) Failure to predict incident (5) Inadequate water safety program before incident
	Weaknesses of preventive activities	(1) Incomplete plan for excavation (2) Lack of as-built plans
Weaknesses of preparedness plans	Failure to plan for response	(1) Absence of database to deal with such incidents (2) Incomplete technical guidelines for response (3) Lack of defined job descriptions in organization to respond to such incidents (4) Lack of response scenarios
	Low training	(1) Inadequate information and knowledge about response to oil spill incidents (2) Weaknesses of manager knowhow (3) Weaknesses of training before incident (4) Inadequate exercises and drills
	Poor resource management	(1) Failure to provide facilities and equipment for incident (2) Lack of basic equipment to prevent oil spill into treatment plant (3) Inadequate laboratory facilities and equipment (4) Inadequate online water quality sensors
	Failure in prediction and lack of warning systems	(1) Weaknesses of online early warning systems (2) Lack of online monitoring system to measure oil parameters in water

3.1.3. Weaknesses of preventive activities

A number of participants suggested two important preventive activities. The first was an excavation plan. The Roads and Urban Development Organization must develop a work plan for each excavation and identify all pipelines under the ground. Secondly, as-built plans are necessary. These plans are the official record drawings that document what is constructed. Participants pointed out that in many cases such plans do not exist.

> As-built plans are very important … these plans show underground facilities such as oil pipelines … but we don't have as-built plans; and those of our organizations which have underground facilities don't have adequate knowledge about those facilities. (Participant 16)

3.2. Weaknesses of preparedness plans

Most participants believed that overcoming inadequate preparedness for an oil spill incident is an important challenge to pre-disaster management. Failure of planning for timely and effective response, low training, poor resource management, and lack of warning systems are obstacles hindering the preparedness phase.

3.2.1. Failure of planning for response

Planning for an oil spill incident can help minimize potential risk to human health and environmental stability by ensuring a timely and coordinated response. Participants believed that responder agencies should have a database to deal with such incidents. The database may include technical response guidelines, job descriptions, and response scenarios.

> We don't have any guidelines for oil spill incidents (Participant 10). We have guidelines for disaster in general (applicable to earthquakes and floods for example), but not specific guidelines for oil spill incidents (Participant 1). We don't have a scenario for responding to such incidents. In fact, I have not seen anything. (Participant 8)

3.2.2. Low training

Almost all participants highlighted the fact that training and exercise sessions, drills and regular review of oil spill response plans are necessary precautions in preparing for possible incidents. It was also mentioned that all staff members and all teams should have an identified response role and be given effective training based on specific needs.

> Because the job description of responder organizations includes no specific task for oil spill incidents, there are no training cources for the staff and concequently response team knowledge is very little … not only knowledge, but also skills and capabilities are lacking. (Participant 4)

3.2.3. Poor resource management

The failure to provide, and the lack of, adequate laboratory facilities and equipment for possible incidents are important requirements mentioned by all the participants. When an oil spill occurs in freshwater, it is vital to contain the spill as soon as possible in order to minimize risk and potential impact on people, environment, and property. Containment facilities and equipment are used to limit the deployment of oil and to allow for its recovery, elimination, or dispersal. Managers believe that lack of financial resources and procurement of equipment before the incident lead to poor management at the time of the incident.

> From my personal perspective, responder organizations must have more equipment and facilities to contain oil spills. At present, organizations have some equipment that isn't professional. (Participant 10)

On the other hand, professional laboratory equipment for measuring oil parameters is not available in the public sector.

> We have measured the Total Organic Carbon (TOC) here, but specialized tests about oil have yet to be conducted because oil compounds are very complex. (Participant 8)

3.2.4. Failure of prediction and lack of warning systems

Participants said that spill prevention and reduction through remote early detection promotes early action limiting impact on people and environment. They emphasized that online early warning systems did not exist. Early warning systems were "person-based."

> In the Isfahan oil spill incident, one of the technical assistants was from the Chaharmahal Bakhtiari province. On the way while retruning from Chaharmahal Bakhtiari to Isfahan, he happened to see the oil spill incident accdently and informed his organization quickly. One of the local farmers had already seen and announced the incident beforehand. (Participant 18)

While the oil company did have a warning system working based on the pressure in the pipeline, according to the participants, it was not reliable.

> Now, an oil alert system exists. If the pipeline is ruptured, it causes pressure changes and the pipline staff detects such an incident by monitoring it. However it does not work automatically and when an incident occurs, the valves must be closed manually (Participant 11). A helicopter must fly viewing the pipelines and identify the exact location of the incident. (Participant 12)

4. Discussion

The participants' descriptive analysis showed that lack of risk reduction programs and lack of preparedness plans are among the main challenges of pre-disaster management of oil spill incidents. They also believed that readiness is crucial to timely and appropriate response to oil-spill incidents.

4.1. Risk reduction programs

4.1.1. Identifying hazards

According to a US National Academy of Sciences publication; "Nearly 8 percent of the petroleum that enters North American ocean waters comes from tanker or pipeline spills" [15]. Based on the findings,

the ability to predict pipeline faults would play a significant role in risk reduction. In particular, such risk assessment identifies the risk of crude oil and delivered water spills during pipeline operations. In this context, Assilzadeh stated that many cases of oil spill are predictable; prediction of such incidents needs management that involves comprehensive resources, equipment, manpower, and skills from various organizations plus efficient coordination [16]. Also, the participants mentioned that in oil spill incidents, the primary focus and priority should be reducing risk by preventing incidents that may potentially lead to oil spill. However, additional risk reduction can be achieved by ensuring effective response in case of incident through the establishment of source control and oil spill preparedness measures. In this regard, according to the International Petroleum Industry Environmental Conservation Association in London, the hazard identification process should be as comprehensive as it is reasonably practicable; events which are identified as hazardous will form the basis for subsequent analyses and the selection of oil spill scenarios [17]. This is consistent with the experience of participants in the present study as regards river protection and control, and black spot prediction and identification.

4.1.2. Reducing vulnerability

The Environmental Protection Agency has stated that vulnerability analysis provides information about resources and communities that could be harmed in the event of a spill. This information helps organizations involved in cleaning up a spill make reasonable, well-informed choices about protecting public health and the environment [18]. Therefore, Andradea writes in a study that vulnerability studies are essential as one of the first steps in the management of oil spill incidents in coastal zones [19]. In this context, Nelsona developed a spatial vulnerability approach and example assessment to support future spill prevention and improve future response readiness. Ultimately, this approach can be used further to assess a range of conditions and scenarios to better understand potential risks and improve informed decision-making for operators, responders, and stakeholders to support spill prevention as well as response readiness [20]. The participants of the present study believed that regional vulnerability identification would have been one of the most important factors in the management the Isfahan oil-spill incident. This consists of human, environmental, and organizational vulnerability.

4.1.3. Preventive activities

The Environmental Protection Agency has expressed that preventing oil spills is the best strategy in avoiding potential damage to human health and environment. However, once a spill occurs, the best approach for containing and controlling it is to respond quickly and in a well-organized manner [18]. Also, the present study showed that in executive projects such as road construction, drilling, excavation, and fuel supply, as-built plans should be available and all possible cases likely to cause oil pollution in water resources should be identified.

Finally, Chitongo stated that mitigation efforts attempt to prevent hazards from developing into disasters altogether, or reduce the effects of disasters when they occur [21]. In addition, in studies conducted in other countries, great emphasis has been placed on mitigation efforts. The present study confirmed that the mitigation phase differs from other phases because it focuses on long-term measures for risk elimination or reduction. The Water Safety Plan is one of the most important national mitigation programs that has been provided by the Ministry of Health in Iran. In addition, water oil pollution and all organizations and institutions responsible for oil spill management are the subjects that appear in this program.

4.2. Preparedness plans

4.2.1. Response plan

The no-response method is completely effective or at least risk-free. Decision processes that evaluate options and response strategies are critical to an effective response [22]. Preparedness is a continuous cycle and refers to all the activities taken in the context of threats that cannot otherwise be controlled. It helps avoid threats by applying preventive measures and building capacity and improving knowledge and skill to facilitate an effective response [23]. It includes planning, organizing, training, equipping, exercising, evaluating, and implementing improvement activities to ensure effective coordination and increased ability [24]. Lamine et al. noted that providing an appropriate response lies in the ability and expertise of people to solve the problems and understand the issues surrounding oil spills and in the preparation of equipment [25]. This study showed that, in Iran, few agencies are involved in preparedness activities or are familiar with oil spill response processes.

Planning for oil spills must not only look at the immediate tactical response and the managing of an immediate aftermath, but must also be prepared to

cater for a much lengthier tactical response and have a more strategic view with regard to an aftermath that may extend for years [26]. One type of plan for such incidents are contingency plans that contain descriptive files of incident prevention and the control system and its operational mechanism [27,28]. Al Malek and Mohamed have stated that the increased size of oil tankers and enlargement of petroleum production operations strongly necessitates advanced planning to prevent and control oil spill incidents and to develop defensive measures in the event that accidents do occur [29]. Based on research findings, it must be said that oil spill planning is not the sole responsibility of one agency. Organizations and communities need to plan and prepare in conjunction to minimize the consequences and impacts of an oil spill incident. However, in Iran, investment in planning to respond to oil spill is very low.

4.2.2. Training

Participants believed that a specific training program should be provided. The competencies and skills that are necessary for personnel and teams to function competently with a specific goal-oriented perspective must be taught. Coordinate training is necessary for responders and supporting agencies in order to provide them with the required knowledge, skill, and ability needed to prepare for and respond to an oil spill incident. Training curriculums are based on assessments, strategies, improvement plans, and ongoing evaluation efforts. Training should be based on specific needs identified by relevant organizations and agencies.

4.2.3. Resource management

Our participants believed that providing facilities and equipment for an incident is essential for appropriate response. They stated that the office in charge of disaster management should provide the necessary equipment and have it deployed in the critical points.

4.2.4. Warning systems

One of the most important pre-disaster management measures is implementing an appropriate early-warning system. Unlike most emergencies and disasters that occur with little warning and are over in a relatively short period of time, an oil spill incident may occur with little warning but extend for weeks, months, or even years [26]. An early-warning system serves as a key component of disaster preparedness [30]. It is acknowledged that a warning system is essential so that people may receive the maximum benefit from pre-disaster planning, or, for example, receive timely warning of attack [31]. Zaboli stated that early-warning systems need functional improvements in the domains of risk knowledge, monitoring/warning, dissemination/communication, and response capacity. Based on his findings, the most frequent routes for early warning in the system in Iran are the coordinating and disaster management centers, and the most frequent communication tools are mobile telephones, landline telephones, and pagers [32]. The participants pointed out that in the Isfahan oil-spill incident there existed no integrated early-warning system. They believed that the Pipelines and Telecommunications agency, Water and Wastewater Organization, and EPA should have their own early-warning systems and measure oil parameters.

5. Conclusion

Obviously, one of the most important measures which must be taken in any disaster is to be prepared. Very few countries assess the overall capability of oil-spill preparedness [33]. However, most oil-spill incidents are unexpected, so no one can know beforehand when, where, or how they will occur. This study shows that, in an oil spill incident, strategies for decision-making and response are critical to keep oil away from freshwater and to minimize impact on people, wildlife, and environment. In addition, planning for the prevention of an oil-spill incident helps minimize potential danger to human health and the environment by ensuring a timely and coordinated response. Well-designed local, regional, and national contingency plans can assist response personnel in their efforts to contain and clean up oil spill by providing information that they will need before, during, and after spills occur. Developing and exercising such plans provides opportunities for the response community to work together as a team and develop the interpersonal relationships that can mean so much to the smooth functioning of a response. Because the approach and methods for responding to oil spills are constantly evolving and each oil spill provides an opportunity to learn how to better prepare for future incidents, contingency plans must also be constantly evolving and improving—ensuring increased protection of people and environment from these incidents. According to the findings, all staff and managers responsible for responding to oil-spill incidents, must receive certain basic and technical skills, to be able to

effectively act during a disaster. Finally, the findings of the present study can serve as a guide for pre-disaster management, in terms of preparing for oil-spill incidents and can also be a basis for further studies on training programs in this regard.

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