Abstract

In addition to technical, social, and economic factors, natural hazards can also play an essential role in magnifying or triggering technological disasters. 88 percent of all natural-technological disasters or Natechs happened in Russia in 1992-2008 were caused by natural processes related to various hydrometeorological phenomena. Twelve different types of Natech events were identified and classified. The most frequent of them are accidents at power and heat supply systems, following by sudden collapses of structures, and car crashes. Global warming and climate change may increase the severity and likelihood of Natechs caused by hydrometeorological events.

Keywords: natural hazard; technological disaster; Natech events

1. Introduction

Natural and technological disasters currently remain among the most serious challenges to the world community sustainable development due to severe social, economic, and environmental losses that they cause around the world every year. More than 90 percent of disasters occurring in the Russian Federation are technological accidents and catastrophes, which account for nearly 98 percent of all the fatalities. A total of 1596 technological disasters and 161 natural ones occurred in Russia in 2008 [1]. Figure 1 shows a pattern of their number changes during the last one and a half decade. More than 80 percent of all technological disasters in Russia are fires. In 2008 15,165 people died and 12,800 were injured by fires [2]. The number of traffic fatalities came to 33,957 and 14,144 people perished from water accidents in 2005 [3]. The majority of technological disasters occurring in Russia happen in the middle and north-western part of European Russia as well as in the southern part of Siberia.

A technological/natural disaster is considered in this paper as a disturbance of the current activity of a populated region due to abrupt technological/natural impacts (catastrophes or accidents) resulting in social, economic, and/or ecological damage, which requires special management efforts for its elimination. Russian statistics regard disasters as phenomena causing four or more fatalities, and (or) injuring 10 or more people, and (or) having a large damage. The same criteria were used for this study.

The main causes of technological disasters in Russia are technical, social, and economic ones. These causes include:

- Inexpedient arrangement of potentially hazardous objects within the country from technological safety point of view;
- Poor quality of their design, building, reconstruction, and use;
- Increasing consumption of capital assets and communications up to near emergency state in some cases;
- Insufficient investment in their renewal.

The human factor (the so-called "human error") also plays a great role. The following situations can cause different tragic mistakes:

- Technological and labor indiscipline in industrial enterprises and transport;
- Poor level of employee proficiency;
- Degradation of vocational training of officials and key personnel.

![Number of disaster](image)

Fig. 1: Number of natural and technological disaster in Russia.

In addition to technical, social, economic, and human factors of technological accidents and catastrophes, natural hazards can also play an essential role in magnifying or triggering technological disasters. Almost every natural disaster is accompanied by some sort of technological one (e.g., hazardous material spills, fuel ruptures, or electrical exposure). There are many kinds of technological disasters, including sudden collapse of structures, buildings, and mines; air and car crashes; railway accidents; shipwrecks; pipeline ruptures; as well as accidents at power, water and heat supply systems, which can result from the direct destruction of given technical objects by a hazardous natural process. For
example, the destruction of an atomic power plant or chemical plant due to an earthquake, a landslide, or other hazardous event; or the destruction of communications or infrastructure systems by heavy snowfalls, strong winds, avalanches, etc. Technological disasters can also be secondary effects of natural disasters, with actual or potential threats to the environment and society, resulting from the accidental release of oils, chemicals, and other hazardous or polluting substances [4].

Such types of technological accidents triggered or magnified by natural hazards are regarded as natural-technological or "NATECH" events (Natechs). The manifestation of technical, social, and economic causes mentioned above increase a vulnerability of the technosphere to the influence of natural factors resulting in the severity and likelihood increasing of disasters. The study presented explores a spatial distribution for a wide spectrum of Natechs occurring in Russian Federation as well as a relationship between them and various natural hazards producing mechanical impacts on the technosphere at the regional level.

Fig. 2: Administrative division of the Russian Federation.

2. Research region and methods

2.1. Research region

The Russian Federation (RF) is the subject of this research. Analysis was undertaken for its main administrative units (federal regions), in order to trace regional differences. These units correspond to states in the USA, federal lands in Germany, or provinces in China. Official statistical data in Russia are usually published for these units, which represent the highest administrative level.

The RF consists now of 83 federal regions (Figure 2), including 21 republics (such as Karelia Republic, Komi Republic, the Republic of Dagestan, etc.), nine krais or territories (such as Krasnodar Krai/Territory, Krasnoiarsk Krai/Territory, etc.), 46 oblasts or regions (such as Moskovskaia Oblast’ or the Moscow Region, Leningradskaya Oblast’, etc.), one autonomous oblast’/autonomous region (Evreyskaya AO), and four autonomous okrugs/autonomous districts (such as Khanti-Mansisk AO and Chukotskii AO). The two largest Russian cities, Moscow and Saint Petersburg, are separate federal regions too. According to their geographical locations, all the main administrative units of the RF are usually grouped at the State level into seven federal okrugs/areas for the administrative purposes. The Russian Ministry of Emergency also uses federal okrugs/areas for statistical data in its annual State Reports.

2.2. Methods

A data base of technological disasters, including Natech events that occurred in the Russian Federation since 1992, has been created first. Official daily reports of the Russian Ministry of Emergency and mass media reports about technological accidents occurring in Russia were taken as initial sources of information collected. About 11,000 events are listed in the data base. New information is constantly being added to it. Occurrence time and location, a type of disaster, a number of people killed and affected, economic and ecological losses as well as a probable cause of every disaster are registered; its short description is also included.

Using collected data a contribution of various natural hazards to occurrence of technological disasters (Natech events) at the regional level was assessed. The following steps were taken in the evaluation process:

- The most frequently occurring types of technological disasters for each Russian federal region were identified and classified.
- Probable causes and triggers of every disaster type were analyzed; the technological disasters produced by natural factors (Natechs) were found and investigated.
- Natural hazards affecting technological disasters were examined and divided into groups according to their genesis and their impact on increasing technological risk.
- The different types of Natechs were finally identified as a result of three previous steps. The pattern of Natechs occurrence frequency since 1992 was investigated for Russian federal regions; the maps of their distribution were additionally created.

3. Results

Natural hazards that play an essential role in magnifying or triggering technological disasters in Russia were found.

Geological, meteorological, hydrological, biological, and other natural hazardous processes have direct dangerous impacts on communities, industrial and power plants, transportation, agriculture, lines of communications, power, heat and water supply systems, and local environment. Causing destroying or disturbing impacts on the technosphere they thus become triggers for various Natech events. These
natural hazards include earthquakes, volcanic eruptions, hurricanes, typhoons, cyclones, tornadoes, and heavy windstorms, landslides, snow avalanches, hailstones, thunderstorms, snow and ice storms, temperature extremes (such as heat waves and hard frost conditions), wild fires, floods, drought, etc. The physical manifestations of these natural hazards vary greatly by their spatial scale and geographical location. For example, according to the University of Colorado studies, earthquakes are the most common cause of Natechs in the USA (73 percent). Hurricanes create 8 percent of Natechs, floods 5 percent, lightning, winds, storms, wild fires, landslides, fogs, and others comprise the remainder [5].

88 percent of all Natechs happened in Russia in the period of 1992-2008 were caused by natural processes related to various hydrometeorological phenomena. The majority of them were produced by windstorms and hurricanes (37 percent), snowfalls and snowstorms (27 percent), rainfalls (16 percent), hard frost and icy conditions of roads (12 percent), and thunderstorms (nearly 4 percent).

Twelve types of technological disasters, which can result from direct destroying or disturbing impacts of various natural hazards, were found for Russian federal regions (Table 1). These disasters are listed in the lines of the Table 1. Natural hazards affecting technological disasters were also divided into twelve groups according to their genesis. The column headings of the table show these groups. The relationship between technological disasters and corresponding natural hazards is marked with "plus".

The following twelve types of Natechs were identified and classified as result of this relationship assessment:

1. The most frequent of them are accidents at power and heat supply systems caused by windstorms, cyclones, and hurricanes, snowfalls and sleet, hard frost, earthquakes, rainfalls, hailstones, icing, avalanches, or thunderstorms (more than 50 percent of all Natechs registered in the data base).
2. Sudden collapses of structures caused by windstorms, snowfalls, rainfalls, hard frost, subsidence of rock, or floods come to 12 percent.
3. Car crashes caused by snowfalls and snowstorms, icy conditions of roads, rainfalls, fogs, mist, or avalanches, making 10 percent of all Natechs, are responsible for the most part of fatalities and injured people number.
4. Shipwrecks caused by storms, cyclones, typhoons, or other weather effects come to 9 percent.
5. About 3 percent comprise accidents at water supply systems caused by hard frost, rainfalls, or subsidence of rock.
6. The most severe effects for environment have pipeline ruptures caused by windstorms, subsidence of rock, or landslides.
7. Very dangerous for people and environment are also accidents with toxic emissions and releases caused by floods, landslides or other geological or hydrometeorological hazards.

<table>
<thead>
<tr>
<th>Natural Hazards</th>
<th>Accidents at power supply systems</th>
<th>Accidents at heat supply systems</th>
<th>Accidents at water supply systems</th>
<th>Car crashes</th>
<th>Railway accidents</th>
<th>Air crashes</th>
<th>Shipwrecks</th>
<th>Fires, explosions</th>
<th>Agricultural accidents</th>
<th>Pipeline ruptures</th>
<th>Sudden collapse of structures</th>
<th>Accidents with toxic emissions</th>
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<td>Hurricanes, cyclones, windstorms, squalls</td>
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Table 1. Technological accidents triggered by natural hazards.

Severe social and economic losses produce also the following types of disasters:
8. Air crashes caused by windstorms, snowfalls, icing, or fogs;
9. Railway accidents caused by snowfalls and snowstorms, rainfalls, landslides, or avalanches;
The most part of all Natechs happened in Russia in 1992-2008 were caused by natural processes related to various hydrometeorological events and phenomena. It is to be expected that global warming and climate change can increase their intensity and frequency to the end of this century and in the next one. This may in turn increase the severity and likelihood of Natech events. For example, increasing of precipitation (especially in liquid form) in cold seasons and alternation of thaw periods and cold spells may trigger such accidents as abrupt transmission facilities and other lines of communication, sudden collapse of structures and roofs, as well as increasing in number of transport accidents. Permafrost area comes to 63 percent in total area of Russia. Potential permafrost thawing will produce risk of roads, railways, and pipelines disruption, destruction of dangerous waste storages, and sudden collapse of buildings and other structures.

The problem of relationships between natural hazards and technological disasters is very complicated one and needs further investigation, especially from the point of view of climate change expected.

4. Discussion and perspectives

The data base of technological disasters including Natechs that occurred in Russia since 1992 has been created for the first time. Occurrence time and location, a type of disaster, the number of people killed and affected, economic and ecological losses, a probable cause of every disaster as well as its short description have been registered there. Using collected data it is possible to examine temporal distribution of technological disasters as well as their proportions and a specific pattern of natural hazards contributing to their occurrence at the regional level.

The analysis of the data base permitted us to identify the most significant types of technological disasters for Russian federal regions and to find out natural hazards affecting them. Twelve types of technological disasters, which can be results from direct mechanical impacts of various natural hazards, have been found for Russian federal regions. Natural disasters causing technological disasters have been also divided into twelve groups according to their genesis and their impact pattern on the technosphere. The investigation of relationships between technological disasters and natural hazards at the regional level revealed twelve types of Natech events. The maps of Natechs triggered by hydrometeorological events in Russian federal regions have been created for the first time.

Fig. 3: Frequency of Natechs triggered by snowfalls, snowstorms, hard frost, and icing (average annual number of events): 1 – less than 0.1; 2 – 0.1-0.3; 3 – 0.4-0.6; 4 – more than 0.6.

5. References