NATURAL DISASTERS

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Summary

Natural hazards arise unexpectedly, without any discernible regularity, and leave an indelible trace in nature, sometimes for many decades to come. At present they are appreciably complicated by anthropogenic influence, lending them an adverse and often catastrophic character. The susceptibility of a society to the impact of natural disasters is conditioned by the natural environment, and the vulnerability of the society to such phenomena is historically associated with the type of the nature management. Natural disasters can be of geological and hydrometeorological origin; the specific group of such phenomena is presented by natural disasters in mountains. Geological disasters are caused by processes running in the interior of the earth; relaxation of the accumulated tensions proceeds in the form of avalanche-like destruction which results in earthquakes, tsunamis, volcanic eruptions, and rockbursts. Earthquakes are the result of faulting in the earth's depths propagating at a speed of several kilometers per second. In the coastal regions of continents giant waves (tsunamis) constitute a threat to human life and to nature. Volcanic activity promotes the transfer of deep-seated masses and heat from the deep interior of the planet upward to its surface; volcanic eruptions are followed by huge clusters of ash, volcanic bombs, and lava flows. Rockbursts are typical for mines and underground workings if their depths exceed 200 meters below the earth's surface. Among the hydrometeorological phenomena the most dangerous are droughts, hot winds and dust-storms, hurricanes and typhoons, while events induced by solid atmospheric precipitation include hoar-frost, glaze, sleet, icing, hailstones, and snowstorms. There are also floods and high waters on rivers, forest and peatbog fires. Droughts occur upon a sharp deficit of precipitation, and cause a temporary loss of water and vegetation resources. Cyclones, hurricanes, typhoons, and tornadoes are atmospheric vortices of various dimensions, causing serious destruction. Snowstorms give rise to snowdrifts, which are the curse of roads, quarries, settlements, and airports.

Floods occur during all seasons and practically everywhere; they are caused by the spring-summer melting of snow and glaciers, rain-induced flash high waters, ice forms and ice-gorges, as well as by wind/water-pile-up inundation. In mountains, slope processes present serious problems such as landfalls, landslides, mudflows, and snow avalanches. In a number of countries there are special services for prevention of natural hazards, and special legislation regulating the actions of the state and private organizations in such circumstances, and safeguarding the interests of citizens in the event of emergencies.

1. Introduction

Natural hazards have been an integral part of nature at every stage of its evolution. They are well known throughout the history of humankind. Natural hazards arise unexpectedly, without any discernible regularity, and leave an indelible trace upon nature, sometimes for many decades to come. In the evolution of the natural environment they have always played a revolutionary role, as they transfer some of the territories or the landscape components into a new qualitative state. Furthermore, at present they are appreciably complicated by anthropogenic influence, lending them an adverse and often catastrophic character.

At the same time, people have recently become more exposed to natural hazards, and the damage inflicted by them steadily increases. This results from two causes: first, as scientific and technical progress evolves, the economic activities of people penetrate further and further into those regions (primarily mountainous and arctic) where the force and frequency of manifestation of natural hazards is on a greater scale than in the already developed territories. Second, by intruding into nature we often cause the disruption of the existing links, and the intensification of unwanted, dangerous phenomena. As a result, an unexpected paradox arises: as science and technology develop further, society becomes more and more dependent on nature, and though the death-toll in individual natural hazards decreases, the aggregate damage brought about by them increases.

It is typical for human memory to idealize the past, and to overstate the significance of present day events. Quite often we hear that the climate in our time has become much more variable, that extreme happenings characterizing the specific character of the modern epoch, and warning of serious changes in nature, are more and more frequent. If, however, we compare our time with events documented in the past, we will find that there is nothing unusual, other than the natural cyclic fluctuations in some of the natural processes. The distant past, just as the twentieth century, is memorable for similar manifestations of fearsome natural forces.

The most important feature of the elemental processes is the lack of periodicity of their manifestations, their emergence after unequal and, as a rule, indeterminate time intervals, namely, several times a year (snow and rock avalanches, unexpected high water), once in several years (floods, mudflows), and once in many years (glacier surges, earthquakes, volcanic eruptions). It is their lack of discernible periodicity that makes us regard them as natural disasters, unexpected and fearsome.

Natural hazards in their essence are not catastrophic, they become such upon coming into contact with humans and their property. The definition “catastrophic” always has a social and economic undertone, and, thus, cannot describe an elemental process by itself. Studies of natural hazards have their specific aims, the main one being to predict the time and scale of a process. But to do that we need to know the mechanism and the causes of its onset, the distribution over the territory, and the impact on the other components and elemental processes.

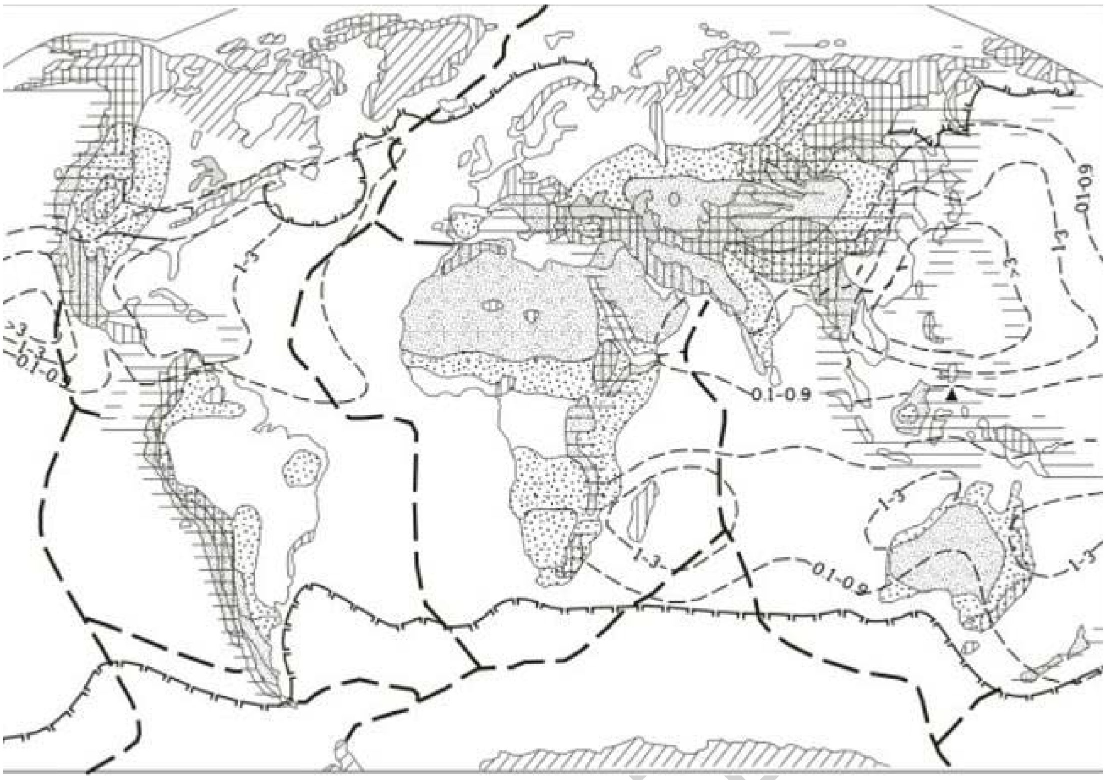
2. The Role of Hazards in the Life of Nature and Society

2.1. Natural Hazards and Their Gravity

Adverse natural processes and phenomena include all those that deflect the state of the natural environment from the range optimal for the life and activities of man. The number and variety of natural hazards increase as industry becomes more and more complex, and man intrudes into the regions with unfamiliar natural environments. Table 1 contains a tentative list of the known kinds of unfavorable natural phenomena, and Figure 1 shows the distribution of the main natural factors and several kinds of such phenomena over the earth.

Types of adverse natural processes by the character of the affected area	
Possible everywhere	**Limited in area**
Climatic and hydrological phenomena	
Hurricanes, typhoons, whirlwinds, squalls Thunderstorms, hail hits, sea storms Extreme air temperatures Cold spells in the vegetation period Extreme rain and snow showers Rime, glaze, icing Snowstorm, blizzard Droughts, dry hot winds Soil deflation, dust storms Extreme fluctuations of the river runoff	Floods Ice mounds on rivers and slopes Flooding and dehydration of the shores Permafrost deformations of the ground Thermokarst (cave-in) Changes in the water table of ground waters Underflooding Abrasion of sea and reservoir coasts Ice in rivers
Geological and geomorphological phenomena	
Earthquakes Soil erosion Turbidity flows and slumping on the sea bottom	Tsunami Flows of volcanic lava and ashes Landfalls, rockfalls, landslides Mudflows, water-snow flows Snow avalanches Glacier surges Ravine erosion Readjustment of river and channel beds Silting of water reservoirs

Table 1. Adverse and dangerous natural processes and phenomena



Source: S. M. Myagkov.

Figure 1. Distribution of the main factors and kinds of adverse natural phenomena
Notes: 1 – areas of earthquakes or volcanicity (volcanism) or volcanic activity; 2 – axes of mid-oceanic ridges, i.e. zones of seaquakes (submarine earthquakes) and/or volcanicity; 3 – maximal registered (recorded or observed) height of tsunami waves; 4 – mountain regions with typical (for them) combinations of adverse natural phenomena; 5 – isolines (isometric lines) of average annual occurence of typhoons (hurricanes); 6 – permanently arid (dry) regions; 7 – areas with high occurrence of droughts; 8 – plain areas of permafrost or ice sheets of Greenland and Antartica; 9–11 – closest to the equator boundaries of: stable snow cover (9), rare snowfalls (10), and spreading of sea ices and icebergs (11).

It should be stressed that the categorization of dangerous phenomena is a relative one. A natural phenomenon, bringing inconvenience and danger in some cases, may even be beneficial under a different set of circumstances. For example, snow cover presents inconvenience on the roads, whereas on fields with winter crops it is a definite benefit. The boundary between inconvenience and danger is again very blurred, and depends on the degree of social and economic adaptation to the natural conditions. People tend to adapt empirically to frequent impacts of some natural calamity, even though these may be intense in their manifestation, and in the optimal case the adaptation is so good that these impacts are perceived only as inconveniences. For example a frost of –40 °C in the far north is an inconvenience, and in a temperate climate it is a calamity, whereas in India a frost of –5 °C would be a disaster.

Since the 1950s the damage caused by natural hazards has been growing faster than the gross world product (GWP). If this ratio is maintained, in a few decades the augmentation of damages from natural hazards will overtake the increase of the GWP, and, therefore, less and less of the GWP will remain for the needs of humankind.

Over several past decades most countries have been maintaining direct statistical records of emergencies of natural, technogenic and ecological origin, including natural hazards. The lower limit of a natural hazard is conventionally taken to be a certain minimal number of dead or injured people, and a direct economic damage, such as, for example, 10 dead, 1,000 injured, 10 million dollars of damage. The practical significance of quantitative estimates of losses is evident, though it does not cover all the existing concepts of natural hazards. These days the term "emergency" is used to designate disasters of various provenance.

Category of emergencies	**Losses replenishment**		**Character of consequences**
	degree of replenishment	**normal terms of replenishment**	
1. Very slight	complete	up to 3 days	Mostly disruption of functioning of transport communications, loss of some means of transportation, without great number of victims. Other losses are insignificant.
2. Slight	complete	up to 1 year	Damage of transport communications, centers of population, enterprises, losses of crops, without significant social or ecological damage.
3. Medium	complete	up to 5–7 years	Damage and destruction of the centers of population, enterprises, loss of crops, with possible big losses of life, but without serious environmental damage.
4. Grave	incomplete	over 5–7 years	Various damages, with considerable loss of life and ecological damage, entailing significant drop in the production volume and changes in the mode of the nature management and exploitation.
5. Wipe-out	in the economically foreseeable time frame the losses cannot be replenished		Various damages, the most serous part of which is the almost complete loss of the natural environment, resulting in cessation of any economic activity here.

Table 2. Types of emergencies according to the gravity of their consequences

The gravity of emergencies should be logically assessed not in the absolute values of losses, but in the values characterizing the ability of the society to make up for incurred losses, and retain its viability. Accordingly, an element of the society should designate an economically independent unit occupying a certain location. For example, in subsistence farming, with its manual labor and simplest of technologies, the elementary cell is a village with its farmed land; in irrigation farming it is a group of settlements stretching along the irrigation system and governed from one center; in the industrial commodity exchange economy it is a state with its foreign outlets and resource donors. The practical assessment of natural hazards is performed by administrative independent units of the state.

Emergencies differ in the gravity of their consequences (Table 2). The term 5–7 years separating categories 3 and 4 was determined by the rate of a capital investment return; in category 3, a simple reconstruction of the destroyed facilities is enough, whereas in category 4 a profound upgrading of the industry is called for.

The main share of emergencies falls on the industrially developed countries and the most densely populated agricultural regions. In the latter, the maximum one-time death-toll in the twentieth century amounted to from 10 to 100 thousand persons in category 3 disasters, and more, by an order of magnitude, in category 4 disasters. The two last categories in Table 2, if they cover a sufficiently large part of the population, cause its degeneration or even complete ruin, in other words, an ethnocultural or "humanitarian" catastrophe. The known social ecological disasters of distant times – such as the downfall of the Ubadia culture in Lower Mesopotamia during the Deluge, the death of a series of Saharan cultures, leaving behind the "Tassili murals;" and a changeover of civilizations in the Middle East due to several episodes of salinization of irrigated lands – belong to these two categories. These days such a disaster is possible, for example, as a result of a grave radioactive (emergency, military) contamination of the environment, anthropogenic desertification of vast territories, or depletion of non-renewable natural resources.

2.2. Factors Initiating Natural Hazards

The natural hazards risk is a function of, first, susceptibility of a certain object to the impact of natural forces, second, its sensibility to these impacts, and, third, its vulnerability to them. The latter depends on the experience and knowledge of the natural hazards and measures of damage reduction, as well as on the economic policy pursued by the state. The experience, knowledge, and policy are directly connected with the ethnic culture. These factors are changing with time, as the society and the economy become more and more complex.

The susceptibility of a society to the impact of natural hazards is determined by the natural environment (seismicity of the territory, probability of hurricane winds, etc.), while the sensibility of the society to such phenomena is historically associated with the type of the nature management. More involved technologies used in the economy lead to the strengthening of both factors, namely, to a greater number of elemental processes and phenomena becoming dangerous, and to the occupation of the territories fraught with greater natural hazards. For hunter/gatherers the number of natural calamities was small. It increased with the appearance and development of agriculture, seafaring, transport, and industry. The development of industrial manufacturing and technologies has been accompanied by especially rapid growth in a number of natural hazards. Out of approximately seventy currently known natural hazards, about half have come into this category only in the twentieth century, and many of the previously known adverse natural phenomena have acquired anthropogenic analogs (ground subsidence, underflooding, landslides, deviations in river runoff, etc.).

In the historical past, the susceptibility of a society to the impact of elemental forces varied depending on natural changes in the climate, thus accounting for many instances of the rise and fall of agricultural civilizations in Asia and Africa. In the foreseeable future, all the said factors of the susceptibility of the society to the impact of natural hazards will increase. In order to mine economic minerals we will promote the appearance of mining enterprises and communications in the most harsh highland and Arctic regions, as well as on the marine shelf. The tendency to move industrial facilities into the developing countries with their cheap labor will continue. The processes of further sophistication of technologies will not be curbed, creating more and more situations fraught with potential emergencies, natural in their “trigger mechanism,” and technogenic in their main casualty effect. They will bring harm by failures in the workings of transport and controlling systems, or through hazardous pollution of the environment. Finally, anthropogenic activation of natural processes will continue, ranging from forest fires in the actively populated recreational zones to floods in the growing cities.

Global climate change will become a special factor in natural hazards, if it really happens, as expected, as a result of anthropogenic emission of greenhouse gases into the atmosphere. It will be manifested in the increased intensity and spread of droughts, tropical cyclones, storm rainfalls, extreme air temperatures, water erosion processes, mudflows, snow avalanches, blizzards, etc., as well as in the retreat of glaciers, upwelling of the world ocean level, and thawing of permafrost accompanied by destabilization of buildings and structures built on such ground. There will be possible changes in the features of droughts, extreme precipitation, and cold in the temperate latitudes of the northern hemisphere; possible increase in the power of the tropical cyclones in southeast Asia, amplification of hurricanes (typhoons), and, accordingly, rainfall floods and erosion processes; as well as possible changes in the water balance in river basins over many territories, activation of mudflows, disintegration of permafrost in Siberia and Canada, and increased abrasion of sea coasts because of the rise in ocean level.

While analyzing the vulnerability to – or the degree of protection from – natural hazards we should take into account not only the level of scientific knowledge in this field, but also the psychology of the human attitude to the hazards conditioned by the ethno-cultural specifics of nature management and exploitation. The latter is collaborated by statistical data on the damage inflicted by natural hazards. It is agreed that the data from industrially developed countries for 1960–90 is complete and equally accurate. Let us compare the data for Japan, western Europe (Great Britain, France, Germany) and the United States, countries commensurable in their population, technologies, and the effectiveness of their national economies, and also countries bound by fierce competition among themselves on the world market with its unifying rates of return. If the economies of these countries were governed only by the standard market rules, we could expect to find there the same level of vulnerability of their people and national economy to natural hazards, that is to say, the same specific quantities of damage. Actually these attributes differ considerably from one country to another. If we take the attributes of Japan as 1, we receive for the other countries the following result: the number of natural hazards per unit of area in western Europe equals 0.55 and in the United States 0.27. Still taking the Japan statistical values as 1, the gross national product per unit of area in western Europe turns out to be 0.39, in the United States 0.07; the density of population in western Europe is 0.52, in the United States 0.08.

It is known that the susceptibility of the population and economics to the natural hazards in Japan is much higher than in other countries. Thus, other things being equal, we should expect to find here a higher specific damage from natural hazards. It is, on the contrary, much lower. The economic damage in Japan per unit of gross national product is lower than in western Europe by a factor of 4.1, and 8 times lower than in the United States, the death-toll per 1 million of population is lower by factors of 1.7 and 7.7 respectively. Individual natural hazards cause the Japanese population fewer losses (by an order of magnitude) than in western Europe, and 350 times fewer than in the United States.

Each natural hazard inflicts on the national economy of Japan smaller damage than in western Europe (20 times) and the United States (420 times). Some part of these differences may be accounted for by the regional specifics of natural hazards, but even this factor weighs in favor of Japan, being far more frequently exposed to such serious elemental processes as earthquakes, tsunami, and typhoons. What is more, the density of population in Japan is so high that they are forced to occupy even the territories with a high level of natural hazards, in contrast to western Europe and the United States.

That being the case, the above differences may be explained only by ethno-cultural specific attitude to the hazards, and motivation of economic and social activities. The Japanese ethnic culture is marked by the highest degree of collectivism and a propensity to avoid ambiguities, namely, to act on the basis of traditions absorbing many centuries of ethnic experience. The American culture, on the contrary, is distinguished by individualism and a humble role of traditions in people’s behavior. In western European cultures these attributes occupy a middle position. The combination of collectivism and traditional lines of behavior means the least inclination to risk, and vice versa. In Russia the collectivism is higher than in western Europe (though lower than in Japan), and by their disposition to non-traditional behavior and, thus, propensity for risk, Russian people in the group under examination rank second only to the Americans.

The experience of nature management and exploitation, including experience in protection against natural hazards, is inherent in practically every culture; it is accumulated throughout many centuries and helps to bring down the losses inflicted by such phenomena. Earthquake-resistant building and construction appeared practically as soon as large cities appeared about 5,500 years ago, and comprehensive geotechnical assessment of territories for construction purposes, no less than 2,500 years ago. Up to quite recent times there were wizards in the Tien Shan predicting the weather and richness of the highland pastures a season ahead, and in Amazonia there was a tribe of hunter/gatherers who could anticipate a flood more accurately than the hydrometeorological service. As late as the nineteenth century Australian aborigines had stored in their memory information about earthquakes, tsunami, and volcanic eruptions witnessed by their ancestors on their way from Southeast Asia about 20,000 years previously. Thus, the ethno-cultural experience of nature management and exploitation provides both the motivation for man's behavior aimed at lowering the risk from natural calamities, and the necessary knowledge.

Cultures adapt to their natural environment by trial and error methods and, as a rule, avoid grave natural situations thereafter. Deviation from the ethnic culture of nature management and exploitation in the course of economic modernization, on the other hand, disrupts the previous experience of protection from natural calamities (Japan is an example of a fortunate exception). Scientific knowledge of adverse natural phenomena and protective measures is undoubtedly being accumulated very rapidly in the twentieth century. Increasing even more rapidly, however, are the motivations of human behavior impelling humankind toward risk and disregard of the scientific recommendations. A number of scientists opine that the losses from natural hazards in industrial countries increase mostly because property-owners make less and less use of permanent protection measures against natural hazards, preferring to take out insurance on their property instead.

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Biographical Sketch

Vladimir M. Kotlyakov (born in 1931) is a member of the Russian Academy of Sciences (elected in 1991). He is Director of the Institute of Geography, Russian Academy of Sciences. With a particular interest in glaciology and physical geography in polar and mountain regions, he directed the twenty-year project which resulted in the *World Atlas of Snow and Ice Resources*, published in 1997.

V. M. Kotlyakov has participated in many expeditions, and has worked and wintered in the Arctic, Antarctica, on the slopes of Europe's highest summit, the Elbrus, and headed the high mountain glaciological expeditions to the Pamirs.

The main theoretical results of his work consist of elucidation of the laws of snow and ice accumulation of the Antarctic ice sheet, as well as ice sheets in general (1961), the snowiness of the earth and its fluctuations within time and space (1968), the tasks and abilities of space glaciology (1973), the application of isotope and geochemical methods to the study of the environment and its evolution (1982), and the study of the past for four glacial–interglacial cycles (1985 and onwards). In recent years he has dealt with global changes of the environment, geographical aspects of global and regional ecological problems, and the problems of interaction between nature and society.

V. M. Kotlyakov is Vice-president of the Russian Geographical Society and President of the Glaciological Association. In 1983–7, he was elected President of the International Commission of Snow and Ice, in 1987–93, he was a member of the Special, and later Scientific, ICSU Committee of the International Geosphere–Biosphere Program, and, in 1988–96, became Vice-president of the International Geographical Union. Currently a member of the Earth Council, he has also been elected a member of the Academia Europaea and the Academy of Sciences of Georgia, and is an honorary member of the American, Mexican, Italian, Georgian, and Estonian Geographical Societies.