THE CLASSIFICATION OF HYDROLOGICAL HAZARDS. A POINT OF VIEW

V. SOROCOVSCHI[1]

ABSTRACT .- At the beginning there is given the definitions for hazard and risk concepts and a enumeration of the criteria for the hazards classification and for their purpose. Based on the utilized criteria number, there have been realized uni criterial and multicriterial classifications. The unicriterial classification of hydrological hazards used the next criteria: spatial, temporal, ways of manifestation, phenomenon nature, the generated impact, the effects perception and mitigation. In the second part of the study, based on numerous criteria, there is made a distinction between hydrological hazard from continents (extreme, hydrodynamic, stationary, of hydric interference, of physical, chemical, mechanical and mixed nature) and from the marine and oceanic environment (of dynamical, mechanical, physical and chemical nature).

Keywords: hydrological hazards, classification, criteria, continental area, marine and oceanic area.

1. Introduction

The hazard, as a component of the risk concept, represents an extreme, natural or human phenomenon, with a high risk of manifestation in a certain territory and at a certain time, high extreme consequences on the environment and on the human society. It is difficult to draw a strict limit between extreme manifestations and the normal ones. Frequently, the extreme phenomenon concept is associated with the risk phenomenon that defines a situation with a high risk for danger and a possibility for anytime occurrence, without knowing the exact time and place of manifestation, the intensity and the consequences.

When is given the definition of risk concept, it is always used a second component – vulnerability, also giving the interactions between them. So the risk expresses the probability for dangerous consequences or losses to appear after the interactions between natural or human hazards and vulnerability (UNISDR, 2003).

The classification of hazards in general and of the hydrological ones in

[1] *Babeş-Bolyai University, Faculty of Geography, 400006 Cluj - Napoca, Romania, e-mail: svictor@geografie.ubbcluj.ro*

particular, has both a theoretical and practical nature. It stands for a reference system in the studies carried on with the purpose of identifying and explaining the spatial and temporal distribution of hazards, and also for their prevention and combination.

For the classification of hazards one can consider several criteria (spatial, temporal, the nature of the phenomena and processes, way of manifestation, consequences, types of dangers that can be perceived), which allow the delimitation of types and subtypes.

An exhaustive and uniform classification of the hydrological hazards is difficult to be achieved because of the multitude of variables that have to be taken into account. In the first place it is about the varied typology of the phenomena that underlie hazards, caused by the multitude of causes that contribute to their triggering and evolution and also of the way of manifestation. In the second place one should pay attention to the fact that often several associated phenomena contribute to the occurrence and evolution of hazards. In the third place both the manifestation in space (from the local to the planetary character), time (start, duration, frequency), energy (amplitude, intensity) of hazards and the consequences induced by them are very different. Because the natural processes and phenomena interact, certain hazards can be included simultaneously in more categories.

2. The classification of hydrological hazards

According to the number of the criteria used in classifying the hydrological hazards, one can distinguish unicriterial and multicriterial classifications.

2. 1. The unicriterial classification of hydrological hazards

The majority of the classifications of hydrological hazards are based on a single criterion. This does not allow a coherent ranking of the phenomena, especially because most of them take into account the singular phenomena and not more associated phenomena as they usually occur in nature.

The use of the *spatial criterion* has great importance because it allows us to name the areas with different degrees of vulnerability to hydrological hazards. The spatial criterion takes into account the location and the size of the affected space, the environment where the hydrological hazards take place, and also the climatic zones in which these occur.

The spatial location of a phenomenon or process is essential for taking certain efficient forecasting and control actions. The location can be exact, diffuse and stochastic. The exact location is found in the case of the hydrological hazards with punctual or linear distribution (for example the coastal and fluvial floods). The hydrological phenomena and processes with areal distribution show a diffuse

location. The stochastic location is less familiar to the hydrological hazards because of their longer time of anticipation in comparison to others (for example the atmospheric ones). Flash floods are included in the category of hydrological hazards with stochastic location.

According to the size of the affected area the hydrological hazards can have a local (flash-floods, urban floods, avalanches), regional (costal floods, the floods of the large rivers Huang He, Amazon, Mississippi, etc), zonal (subequatorial hydrologic drought) or a planetary character (the oscillation of the level of the Planetary Ocean).

According to the environment where they occur and manifest, the hydrological hazards are specific to the terrestrial (fluvial, lacustrine, glacial) and underground aquatic environment, to the marine and oceanic environment, and also to that situated at the interference of the terrestrial and marine and oceanic environment (coastal). According to this criterion the hydrological hazards can be classified into several main types (continental, oceanic and coastal) with various sub-types.

Because there is a close relationship between the zonal extreme atmospheric phenomena and the hydrological ones it is used a classification according to the climates in which the hydrological hazards take place. So, within the warm climate the floods are specific to the areas with an equatorial and subequatorial climate (periodical character), while the droughts are specific to the areas with a dry tropical (permanent character) and subequatorial climate (periodical character). The flash-floods are specific to the dry tropical areas. The hydrological hazards found in the warm climate are among the most destructive because of an extra energy intake from this area. Instead, the financially evaluated damages have a relative small value because of a poor infrastructure. But there are a great number of casualties.

In the temperate climate the hydrological hazards are very varied from the extreme ones (floods, droughts) to the freezing phenomena to those who cause excessive humidity. Their frequency and intensity is very much reduced in comparison to those from the warm climate, but under a high population density and some fragile transition environments (the Mediterranean area), the damages they cause are very important. Specific to these areas are the Mediterranean and temperate-continental flash-floods in summer, the summery Mediterranean hydrological drought, the intensity of the erosion in the channels and on the slopes in the subtropical climate, the floods during the winter in the subtropical and marine west-coast climates.

In the cold climate prevail the risks induced by the freezing and thaw processes (floods, excessive moisture, melting of the glaciers, avalanches).

The temporal criterion takes into account several aspects. One of these is that that considers the trigger of the phenomena, which may be slow (drought),

progressive (the erosion of river channels and shores, the silting of the lakes, the raising of the Planetary Ocean), sudden (flash-floods, avalanches). Another temporal criterion is the duration of the hazards, which may be short (flash-floods, avalanches), mean (river-floods), long (the droughts in the warm climate) and very long (the raising of the Planetary Ocean). The duration of a phenomenon is closely related to the time span when there is an energetic potential able to maintain it.

Another temporal criterion used in the classification of the hydrological hazards is the time of the year when they take place. This depends on the climate we have in mind. For example in the temperate climate in the cold period of the year are very frequent freezing processes, avalanches and floods in the subtropical and west coast climate. In the warm period o the year droughts and flash floods are very frequent. According to this criterion one can distinguish scheduled phenomena which take place with a remarkable periodicity (floods caused by the tropical and temperate monsoons) and irregular or random phenomena (flash-floods, tsunami).

The rhythm is a temporal criterion which allows to underline the cyclic character of the hydrological phenomena and processes, meaning their regulate sequence in time, or in other words the regulate repetition of a phenomenon in certain time spans. So one can distinguish phenomena and processes with daily (tides), seasonal (floods in the subequatorial and humid tropical climate), annual (freezing on rivers) and multiannual rhythmicity (El Niño).

Reversibility means the characteristic of a phenomenon or process to happen again after a certain period of time having the same or different quantitative and energetic attributes. The reversing period of the phenomenon may have a cyclic or random character.The frequency shows how many times a periodic phenomenon takes place in a unity of time. The frequency of occurrence of a phenomenon can be low, moderate or high.

The manner of manifestation of phenomena and processes is a complex criterion because it takes into account several already mentioned aspects (in time and space) and also some aspects that we are to mention below (shape, amplitude, magnitude). The manifestation of a certain hydrological phenomenon or process has very different shapes: punctual (the emergence of springs), linear (floods) or areal (excessive moisture).

Amplitude means the scale of manifestation in time of o phenomenon. It is calculated as the difference between the highest and the lowest value of a phenomenon or process during its periodic or non-periodic evolution. The values of the amplitude of a phenomenon can be characterized as low, moderate and high.

The energy of a hydrological risk phenomenon or process is highlighted by means of magnitude, which can be low, moderate and high.

The nature of phenomena and processes is a frequently used criterion in the classification of hydrological hazards. The physical phenomena and processes

that induce risks are determined by the water's temperature and freezing regime. These are obvious both in the domain of continental waters by the occurrence of various ice formations in rivers and lakes and in that of marine (total or partial freezing of the water near the shore) and oceanic waters (El Nño).

The chemical phenomena and processes that can induce risks are the interferences between the fresh and the salt waters which occur both on the coastline and inside the continents.

The dynamic phenomena and processes, which show the movement of different water resources are very diversified. In this category one can include: liquid maximum and minimum flow, solid flow, waves, tides, streams, sea-level rise, the oscillation of the piezometric level. For solid water one can mention avalanches and icebergs.

The stationary hydrological processes can induce risks by maintaining water in excess on the plain lands, generating a moisture excess.

In the category of mechanic processes one can include the erosion exercised by the continental waters (on the slopes, in the river channels and on the lake shores) and by the marine ones (on the coastlines), the silting of lakes and of the aquifers, land settlement.

The impact of the hydrological phenomena and processes is another classification criterion. The impact can be of human, economic, socio-cultural and environmental nature. No matter in what environment it occurs the impact can be weak, moderate or strong. This criterion allows only to assess the damages.

The perception of hydrological phenomena and processes is a criterion that takes into account both the degree of perception (weak, moderate, strong) and the degree of evaluation of the phenomena and their consequences (under-evaluation, real evaluation and over-evaluation). Slope erosion is the least perceived while floods and tsunamis show high degrees of perception.

Forecasting and prevention of hydrological phenomena and processes is a criterion that takes into account several cases in which the two non-structural measures are: possible, partially possible or impossible.

2. 2. The multi criteria classification of hydrological hazards

The multi-criteria classification of hydrological phenomena and processes was elaborated on basis of a hierarchy of the descriptors presented in the previous chapter and putting in order the variables that define them. For geographers the spatial criterion is the most important, reason why for establishing the main types of hydrological hazards it was taken into account the environment where the hydrological phenomena and processes take place. The coastline hazards represent a special type because they occur at the interface of the two environments (land and sea). For establishing the subtypes were taken into account variables that belong to one or more descriptors.

2. 2. 1. Hydrological hazards from the continental area

This category includes the hazards induced by the surface and underground waters. These differ in their temporal, dynamic and energetic attributes. The nature of the phenomena and processes, the dynamics, the way of manifestation and the effects they cause are the criteria used for establishing the types of hazards induced by the continental waters.

Extreme hydrological hazards. This subtype includes the floods and the hydrological droughts, the most frequent hydrological hazards. The extreme hydrological hazards are a part of continuous series, having different forms as compared to the normal ones and may appear periodically or at random. The magnitude and frequency of extreme events can be expressed and estimated. Another important feature of the extreme hydrological events is their duration.

There are several reasons why it is necessary to estimate the magnitude, frequency and duration of the extreme hydrological hazards that are possible to occur in a certain period, the most important being the measures that need to be taken in order to protect and prevent the disasters they can produce.

According to their origin floods can be natural and accidental. Natural floods were classified according to their way of manifestation (slow, quick, torrential), location (rivers, sea-shores, urban spaces) and genesis (pluvial, nival, mixed, caused by the rising of the level of ground-waters, by landslides). Accidental floods are caused by the breaking of dams and dykes or by the wrong handling of the installations.

Among the characteristics of droughts the most important are the temporal ones (beginning, duration, end, persistency, frequency, returning period), the spatial ones (development area) and the energetic ones (intensity). The characteristics of droughts differ according to the climate of the areas where they occur and to the water usage.

Hydrological drought is a phase in the evolution of the water quantities from the water cycle, defined by deficiencies in surface and sub-surface water supplies. It can be classified according to: the phases of evolution of the phenomenon, duration (episodic, almost permanent or permanent), the time of the year they occur, the affected area (local, regional), the effects they induce.

Hydrodynamic hazards. These phenomena are specific both to the surface waters (waves, streams, seiches and even tides for certain rivers) and to underground waters (hydrostatic level oscillation). This category also includes avalanches which are a movement of the water in solid state.

The most destructive effects are produced by avalanches and river streams, which during flash floods cause important changes of the river channels and intense erosion of the riversides. No matter the category they are included in (dry, wet, surface, deep, small, medium, large) avalanches cause casualties, damages and

destroy the equilibrium of certain components of the environment (soil, forests, etc).The most destructive are the dry (speed between 100 and 300 km/h), the wet and the deep avalanches.

Tides, besides their positive effects, as the penetration of the waters through the estuaries long inside the land, favoring the circulation of the large ships (Amazon, Chang Jiang, Gange, Brahmaputra, the Thames, Saint Lawrence) also have negative effects. The tide that enters the rivers at the flux can destroy smaller boats. The phenomenon is known under different names (pororoca, mascaret, bore), sometimes indicating its destructive character (pororoca on the Amazon means in the local language "the boat destroyer"). The areas with high turbidity also have negative effects (mud cork), as well as the spots with still water, "mud cream"-like, usually located in the central part of the estuary, which can disturb the navigation and need dredging.

Seiches, encountered on the great lakes, act as a unique wave which may remain for a long time at the shore level, causing the flooding of the low coastlines areas.

The fluctuations of the hydrostatic level of the ground waters are determined by natural or anthropic causes. Over-usage of the ground-waters causes a continuous lowering of the piezometric levels. The piezometric levels go down very quickly in many regions of the world where there is a high density of population or intensive agriculture (the SW of the USA, the south of the Great Plains in USA, a great part of Northern Africa and Middle-East, the greatest part of India, China).

In the case of ground-waters the dynamics of the hydrostatic level can cause processes with negative effects for the environment. The rising of the hydrostatic level causes the moistening of the land surface which can lead to the apparition of marshlands, while the lowering of the hydrostatic level, causes, together with other factors, land settlement.

Stationary hydrological hazards. These processes and phenomena can cause human and material damages as an effect of maintaining the water in liquid state on or under the surface of the land for an undetermined period of time. Some of the induced hazards belong to the hydrological ones (the moisture excess), while others belong to the geomorphic ones (mudflows, landslides).

The water excess is specific in those territories where the relief by morphology, lithology and structure favors water stagnation and the apparition of water-spots, marshlands and bogs, namely the wet lands, which are transition areas between land and water. The wet land may accompany springs, running waters and the lake and sea-shores. The extension of the wet lands reduces the cultivated surfaces or may lead in time, to the deterioration of the human goods. The water from the lakes causes pressure upon the near-by regions and may lead to local earthquakes.

Hydrological interference hazards. These are of physical or chemical nature, and occur both in the case of surface and ground waters, and also at the contact between the continental and the marine environment. The hydrological interferences mean the penetration of foreign substances in natural waters, which makes them either inappropriate for using, or changes their chemical properties.

The negative hydrological interferences are induced not only by human activity by means of different pollution sources, but also by natural ways. The negative hydrological interferences caused by natural processes can occur in various conditions. The leaching of the soluble rocks containing sulphates, radioactive minerals, etc, or of salt massifs situated close to the earth's surface may cause the contamination of surface or ground waters.

The greater risks are possible as a result of mixing the marine waters with the fresh ones found in the highly populated coastline regions. In the same time the penetration of the marine waters in the main rivers causes the phenomenon known as "salt cone" or "salt feather", influencing the sedimentation process and the fresh waters from the dunes nearby the river.

In this category we can also include the chemical changes in the surface waters caused by the acid deposits, which affect the structure and functionality of the aquatic ecosystems.

Among the physical interferences affecting the plants and animals in the rivers one can mention the discharge of great quantities of hot water coming from thermo centrals.

Hydrological hazards of physical and mechanical nature. Being of physical and mechanical nature, the freezing and thaw processes may cause human and material damages and also affect the environment where they take place by diminishing the quantity of water from rivers and lakes and by causing floods as a result of blocking the channel with ice or of the thaw (Siberian rivers). They various ice formations cause the degradation of the river banks and of the vegetation from nearby the river. In northern Siberia the spring floods maintain the surfaces with water excess.

Silting is a physical process that consists in the sedimentation of the solid particles both in the surface and underground waters. The most reservoirs on the Earth are strongly silted as a result of the massive deforestations done lately in their hydrographical basins. The silting degree depends on the dimension of the lake, on the volume of water, on the position of the reservoir inside the basin, the equilibrium profile of the territory between two reservoirs.

The silting of the lakes brings a series of negative effects such as them being invaded by vegetation in the parts where the sediments are close to the surface, which leads to the reduction of the water surface with all its consequences. The most important negative effect of silting is the deterioration of the quality of the water in the lake.

In the case of the aquifers the very fine silting material may pervade, especially during flash floods and floods, to great depths (a few tens of meters). The infestation of the water tables is felt at the level of the major channel. As a result, the water of the wells from these territories gets a yellow color and for a while becomes inappropriate for drinking. The danger is greater when the silting material is infested with various chemical substances.

Another negative consequence of the silting of the aquifers is the decreasing of the porosity coefficient, which diminishes its storage capacity.

The degradation and the aggradation processes of the river bed are included in the hydrological hazards of mechanical nature. The hydromorphological changes are a consequence of the denudation and accumulation processes, which are more intense during floods. The negative effects consist in the degradation of the banks, the deterioration and even destruction of certain hydrotechnical frameworks (dykes, groins, dams, etc). The changes of the directions of certain water courses on hundreds or even thousands of kilometers are spectacular (Huang He). Besides destroying people's goods the denudation exercised by the running waters has as a negative effect the reduction of the surfaces proper for agriculture.

Lateral denudation does not greatly affect the channels of the rivers where stabilization works were done. The average denudation rate for the rivers with non-cohesive banks in the temperate climate can reach 10 m/ year, while in the tropical areas it reached 200-400 m/year on Brahmaputra between 1975 and 1981. It is obvious that in the assessment of the risk induced by the lateral denudation we must take into account the frequency of the occurrence of this process.

The aggradation of river bed has a negative effect the floods frequency increase due to the bed's over rising. This phenomenon is typical for the Huang He River, China. In Romania, this phenomenon occurs in the Western Plain Rivers.

2. 2. 2. Hydrological hazards in the marine and oceanic domain

The most risk processes and phenomena occur in the coastline area, where there is a high population density (65 cities with over 2.5 million of inhabitants), and the migration phenomenon towards these regions is significant. In present approximately 60% of the world population lives in the coastline areas, at less than 60 km from the coast, and it is expected that in the next three decades the proportion to reach 75 %. The coastline areas are dynamic environments, where the continental and oceanic processes act together in order to create rapid changing landscapes.

Hazards generated by the dynamics of sea and ocean water. There is a series of dynamic forms of the water (waves, streams, tides), caused by atmospheric factors, by the difference of density between the water layers, by geomorphological, geological and cosmic factors.

Waves are undulatory motions caused by wind's friction (eolian), by tides, by earthquakes, underwater volcanic eruptions and massive landslides, by meteorites (tsunamis). The most exposed are the coastline territories, the gulfs, the river mouths, the deltas.

The hazards based on hydrodynamic phenomena and processes can cause besides casualties, material losses, changes of the coastline and the complete or partial destruction of the offshore bars and coral reefs, which protect the coastline areas.

Waves are one of the main denudating and coastline destructing agents. The most destructive are the tsunamis, which had a rather high frequency (24 of high intensity and over 200 moderate) and caused a great number of human losses (1 050 000 confirmed). The most of the tsunamis 65% occurred along the Pacific coast (the Pacific fire circle) and were caused by the seismic activity (86%). By the energy they have the tsunamis can cause huge damages.

The eolian waves are dangerous both in the coastline areas and in the open ocean because they can reach in certain favorable conditions, maximum heights of 34 m and speeds of 102 km/h. The dimension of the wind waves depends on the speed and duration of the wind and also on the distance the wind blows along the water surface ("fetch"). From the types of waves caused by wind, the strong waves called "rogue waves" can be extremely dangerous because of their energy and the heights they can reach (30m). This type of wave can appear in the open ocean, too. In the open sea the waves generated by storms are called swell.

Internal waves can embarrass navigation, diminishing the speed of the large ships.The raising of the sea level is one of the hydrodynamic processes with possible disastrous effects because over half of the world population lives in the coastline areas.

The sea level is permanently changing because of a series of factors which act at a local, regional and global level. So the relative sea level is influenced by the tectonic and water movements. The global level of the Planetary Ocean called eustatic level is controlled by the processes that affect the total volume of water in the ocean and by the shape of its basin.

A rising of the sea level would have the most disastrous effects upon the low coastline areas (estuaries, deltas, plains, offshore bars, polders) and low islands. The estimated values of the annual raising rates of the sea level until 2100 differ from one author to another: between 4,8 – 29,7 mm (Hoffman, 1984) , respectively 2,8 – 10 mm (Warrick, Oerlemans, 1990).

ENSO one of the most complex global phenomena of interaction between the atmosphere and the hydrosphere occurs in the tropical area of the Pacific Ocean and is known as El Nino. The negative effect induced by this phenomenon results in abnormal climate changes on the whole planet, and especially in the tropical areas, where are recorded droughts and violent storms accompanied by floods and

cyclones and by the diminution of the fish crop along the South American Pacific coasts.

The La Niña phenomenon intensifies o series of intense meteorological phenomena as such: heavy monsoonal rainfalls in India, heavy rainfalls and typhoons in Australia, violent hurricanes in the Atlantic Ocean.

Hazards induced by the abrasion process. Abrasion is widely spread in the world. It is estimated that 95% of the coasts are being eroded in various rhythms. It has been found that 70% of the world's sandy beaches are being eroded with an average rate of 0,5 – 1 m / year.

The hazards induced by the erosion exercised by the sea water affects both the goods made by man (different categories of buildings) as well as the coastline environment. The swash zone is the most exposed to the erosion exercised by waves and different types of streams. The basis of the capes is also exposed to abrasion.

Hazards induced by the ice in seas and oceans. The ice in seas and oceans comes from the freezing of the sea water, from the breaking of fragments from the ice cap or from the continental glaciers. From the four ice categories existing in the marine and oceanic environment the most dangerous are icebergs and ice banks. Approximately 90% of the icebergs in the northern hemisphere move southwards in the Labrador Stream and endanger navigation as they frequently intersect the routes of the ships. On the other side the iceberg production is the most prolific in the north of the Atlantic Ocean. In the southern hemisphere icebergs are not so threatening for navigation because they do not intersect so often the routes of the ships. The negative effect of the ice bank's dislocation and breaking during spring resides in the destruction of the coast structure or of certain installations found on the bottom of the sea (oil installations and pipes).

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