HISTORY OF TECHNOLOGICAL HAZARDS, DISASTERS AND ACCIDENTS

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Keywords: History, Technological Hazards, Disasters, Catastrophes, Accidents, Risk, Environment.

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Summary

Although some technological risks can be traced back to the ancient times, it was between the nineteenth and the beginning of the twentieth century that technical advancement and the process of industrialization posed the question of the management of the technologies and of their possible disastrous consequences. During these years there was an important change in approaching these issues: from the inevitability of disasters to the adoption of policies of prevention and risk management.

This important change had as a consequence an increasing role of public institutions (national governments, agencies and authorities) in the control, prevention and emergency management of technological disasters. According to this new approach, *scientists*, the *experts* and the *technicians* that were required to "predict" using their special knowledge technological disasters, became central figures.

The first post-war period represents an important turning point because this new and modern attitude towards technological hazards reached its full maturity. The spreading of new technologies also facilitated by the process of industrialization and the emergence of the era of mass consumptions, influenced a new discipline that, from different approaches, tried to address and resolve the various aspects of technological threats.

Born in the postwar period, the disastrology and in general policies to ensure safety, found a systematic application after the Second World War. The increasing complexity of certain technologies used in industry, in the production of energy, in the transport sector and especially the potentially catastrophic consequences of technological accidents, imposed an additional effort in the field of regulation, prevention and management of emergencies. In some cases, such as the atomic energy for civilian use,

an increasing role was played by national and international agencies that were created during this period.

Since the 1970s but especially in the following decade, several major accidents (Three Mile Island, Seveso, Bhopal, Chernobyl, the environmental disasters caused by oil tankers) put forward the need for a standardization of rules and a greater international co-operation. The globalization of technological hazards at the time of the so-called “risk society” has fostered a more interdisciplinary approach to the issues of technological disasters.

Moreover, the increased number of new hazardous substances and materials and the opportunities for human error inherent their use has determined an escalation of technological accidents. All this factors and the more and more unstable boundaries between natural disasters and man-made disasters has necessarily imposed growing efforts for harmonization policies at a national and an international level to ensure collective security, public health and environmental protection.

1. Introduction

There is not a universal definition of technological hazards and accidents. Even though some studies emphasize the complexity of the issue of individual responsibility in technological disasters, literature has commonly accepted a distinction between natural hazards (*acts of god*) and man-made (*acts of man*) hazards. According to some classifications natural hazards are threats determined by uncontrollable events, while man-made hazards are threats determined by artificial (technological) factors.

Natural hazards can be defined as “those elements of the physical environment, harmful to man and caused by forces extraneous to him”. The term “natural hazards” refers to all atmospheric, hydrologic, geologic (especially seismic and volcanic), and wildfire phenomena, while the term “man-made hazards” refers to “artificial” phenomena caused by human action, inaction, negligence or error. These phenomena are also defined as technological hazards when determined by a technology (i.e. industrial, engineering, transportation) and as sociological hazards when they have a direct human motivation (i.e. crime, riots, conflicts).

As threat and potential danger, hazards are strictly connected to concepts of *risk*, *disaster* and *catastrophe*. The term *risk* (from the ancient Italian *risicare*) indicates the possibility of suffering a harmful event or loss or danger. While a risk involves uncertainty, a *disaster* (from the Italian *disastro*, literally “unfavorable to one’s stars”) is an unexpected natural or man-made event with harmful but temporary consequences. Disasters can be defined as the result of an extreme event that significantly disrupts the workings of a community.

A disaster is “a tragic situations over which persons, groups, or communities have no control-situations which are imposed by an outside force too great to resist”. This kind of events may have as a consequence deaths, material destructions and severe economic damages but can also determine situations of collective stress in a community and bring to the test the level of vulnerability of a society. Some interpretations consider a disaster a consequence of peculiar social conditions, some others, consider man-made disasters mainly as *socio-technical problems*, as the product of a failure of foresight and a combination of technical, social and even institutional and administrative factors. The *Normal Accident Theory* argues that the combination of high complexity and tight coupling must lead to failures. According to this theory, that has been integrated, empirically tested and verified, technological accidents are "inevitable and happen all of the time; serious ones are inevitable but infrequent; catastrophes are inevitable but extremely rare".

Since the mid-1980s, starting with an approach opposite to that of the *Normal Accident Theory*, some researchers developed the *High Reliability Theory*, which says that is possible to create highly reliable systems capable of ensuring almost absolute security levels.

The science that deals with the study and prevention of disasters is called *disastrology*. Born at the beginning of the twentieth century but developed especially from the second post-war period, this discipline relies on the contribution of different specialists: physicists, geologists, geographers, planners, engineers, sociologists, psychologists, historians. In the 1980s it was developed a sort of new branch of this discipline, the *kindunology* (from the Greek *kindunos* that means "hazard"). This science is focused on the study of methods and means to know, understand, assess, classify and represent different aspects of hazards and disasters.

A *catastrophe* (from the Latin *catàstrofa* and the ancient Greek *katastrophē*, "to overturn") is a large harmful event with great and irreversible consequences. According to some classifications the principal catastrophic risks can be divided into four homogeneous classes. The first class catastrophic risks consist of natural catastrophes (such as pandemics and asteroids) that are not directly determined by technology or human labor.

The second class consists of scientific risks as "laboratory or other scientific accidents involving particle accelerators, nanotechnology […] and artificial intelligence". Instead of the first class risks these catastrophic risks are directly caused by technology. The third class consists of unintentional man-made catastrophes that determine phenomena such as "exhaustion of natural resources", "global warming" or "loss of biodiversity". Finally, the fourth class of catastrophic risks consists of intentional or "deliberately, perpetrated" catastrophes such as "nuclear winter, bioweaponry, cyberterrorism and digital means of surveillance and encryption". Even though they are determined by the use of technology, these are *warfare risks* that can be considered *intentional* acts of violence and not accidental.

According to the International Society for Environmental Protection classification, *hazards* are physical or chemical agents capable of causing harm to persons, property, animals, plants or other natural resources. Technological accidents are the potential consequence of one of that events and are caused by technical, social, organizational or operational failures ranging from minor accidents (i.e. single toxic agents) to major accident (industrial, chemical or nuclear accidents). Some other observers consider technological accidents in a more strict sense as "accidental failures of design or management relating to large-scale structures, transport systems or industrial processes that may cause the loss of life, injury, property or environmental damage on a community scale". When these events have long-run effects they are considered *chronic technological disaster*.

Some studies identify seven major classes of technological hazards ordered on a three-fold scale of severity. According to this classification, the most severe technological hazards are the *multiple extreme hazards* (i.e. nuclear war, recombinant DNA, pesticides).

In the second level of the scale there are the *extreme hazards*, respectively caused by intentional biocides (chain saws, antibiotics, vaccines), persistent teratogens (i.e. uranium mining, rubber manufacture), rare catastrophes (i.e. LNG explosions, commercial aviation crashes), common killers (i.e. auto crashes, coal-mining diseases such as black lung), diffuse global threats (i.e. fossil fuel and CO_2 release, ozone depletion). In the third and lower level there are the so-called *simple technological hazards*.

In late 1990s, trying to provide "technical and organizational tools for the prevention, mitigation and the relief of disasters an International Working group appointed by United Nations drafted an indicative list with different type of actions which can constitute technological hazards (IDNDR, 1997):

- Release of chemicals to the atmosphere by explosion, fire
- Release of chemicals into water (groundwater, rivers etc.) by tank rupture, pipeline rupture, chemical dissolved in water (fire)
- Oil spills in marine environment
- Satellite crash (radionuclides)
- Radioactive sources in metallurgical processes
- Other sources of releases of radionuclides to the environment
- Contamination by waste management activities
- Soil contamination
- Accidents with groundwater contamination (road, rail)
- Groundwater contamination by waste dumps (slowly moving contamination)
- Aircraft accidents
- Releases and contaminations as consequence of military actions (e.g. depleted uranium) or destruction of facilities
- Releases as consequence of the industrial use of biological material (e.g. viruses, bacteria, fungi)

2. From The Nineteenth To The Early Twentieth Century

Natural hazards and disasters are phenomena with which human societies has always been accustomed to live since antiquity. But even man-made threats, technological hazards and disasters cannot be considered a prerogative of modern societies. Therefore, there is no doubt that the rise of industrial society, the modernization process and the spread of technology determined, after the First and the Second Industrial Revolution, a dramatic increase of harmful events. Hazard management in developed societies has consequently shifted from risks associated with natural harmful events to those arising from technological development and application.

Since early nineteenth century, but especially after the second half of the century, industrial accidents, maritime disasters, railway and public transportation wrecks became unavoidable aspects of most advanced societies. According to some studies major disasters occurred in this period can be classified into three main categories that can also be applied to some contemporary technological accidents. These main categories are respectively: *large scale engineered structures* (public buildings, bridges, dams), *industry* (manufacturing, storage and transport of hazardous materials, power production) and *public transports* (sea, rail, air).

Fire can be considered one of the most relevant agents in large scale structures disasters. From the Great Fire of London of 1666 (13 200 houses burned down) to the Great Chicago Fire of 1871 (18 000 houses burned down, about 300 victims) and from the Vienna Theatre Fire of 1881 (850 dead) to the Iroquois Theatre incident (571 dead) these kind of disasters were extremely common in late nineteenth century and early twentieth century industrial societies. According to some of the first "disaster specialists", at the turn of the century the death toll resulting from theatre fires in the nineteenth century England was nearly thousand people.

Between other major large scale structures disasters occurred in these years there are the collapse of Tay Bridge in Scotland in 1879 (75 dead) and the failure of South Fork Dam in Pennsylvania in 1889 (more than 2000 victims). For the engineering elite, these calamities represented a sort of shock that eventually led to a more precise codification of building regulations.

Another important consequence of these events was in the approach. "Scientific speech and the rhetoric of risk" supplanted "the didactic language of the pulpit": "instead of waiting for bridges to collapse or people to be burned alive in opera houses, structural engineers and social psychologists were employed to *predict* the effectiveness of design and the psychology of the crowds in danger".

Steam-boiler explosions, fires and other industrial accidents determined new kinds of threats and damages and putted at risk not only safety of the workers but also life and properties of communities close to factories and industrial plants. Even disasters in minefields were particularly frequent during the nineteenth century: in United Kingdom, particularly in Wales coalfields, there were recorded several accidents such as the gas explosions at the Albion Colliery in 1894 (almost 300 deaths) and at the Universal Colliery in 1913 (439 victims).

In the United States the number of documented mine accidents with five or more deaths through 1876 to 1921 was 497. Many accidents occurred also in main European minefields especially in Belgium, Germany, Poland and Russia. One of the most deadly mine accident of the early twentieth century was the Courrières mine disaster occurred in 1906 (more than 1000 victims, some of them children) near the French city of Lens.

Besides the accidents directly caused by technical malfunctions or human negligence in using machinery or during production or extraction processes, should also be considered those disasters and emergencies caused by environmental events indirectly influenced by human actions. During the nineteenth century the poor land management and the urbanization process of major industrial cities in some cases multiplied the disruptive effects of floods and landslides causing damages and casualties.

The severe impact of the great urban and industrial agglomerations on river basins and the lack of modern hygiene and health legislations were other factors that determined some environmental emergencies such as the *Great Stink* of London occurred during the summer of 1858, when the river Thames became a sort of huge sewer. This episode posed the question of the urban pollution and of the management and channeling of drinking water and wastewater to insure safety of the population and prevent the repeated outbreaks of cholera.

Directly related to the process of industrialization can also be considered phenomena such as air pollution episodes which occurred and had so much popular echo during nineteenth century. The pollutants emitted from the chimneys as a result of the different stages of the production process, mixed with the fumes produced by the coal for civilian uses, repeatedly caused huge emergencies that in some cases had dramatic consequences on public health.

These events were registered especially in some great cities of the United Kingdom, in some areas of central and Western Europe, but also in more industrialized areas of the United States (Chicago, Pittsburgh, St. Louis, Cincinnati). One of the most serious episodes of nineteenth century was recorded in London between 1879 and 1880. Despite legislation on emission of smoke (introduced since the 1960s, following the studies of Robert Angus Smith on the effects of acid rains), a heavy cloak of fog mixed with smoke remained for months on the city.

The visibility was nearly zero: people that went out of the house to walk, was forced, to not get lost, to proceed along the walls of buildings. This phenomenon had also serious consequences on public health. According to some sources the London smoke of 1879-1880 increased the mortality rate of 220%. The peculiar “London Pea Soup Fog” described in some novels by Charles Dickens or painted by Claude Monet, by 1905 was called with a new term: *smog* (smoke plus fog).

Besides the industrial hazards, the public transport hazards and disasters were probably the most relevant threats to public safety during nineteenth and early twentieth century. The development of modern mass transport systems influenced a relevant debate on the question of the safety of the passengers of the traditional means of transport (e.g. ships) and of the new ones: from train lines of urban transport, to the automobiles and other motor vehicles for transporting people and goods.

Even excluding war-time disasters and only considering those accidents occurred between late nineteenth century and the beginning of the 1900s, the list of maritime disasters is impressive: from the incident that involved the *Princess Alice*, a Thames river paddle steamer which sank after a collision in 1878 (about 700 victims) and the

French passenger steamer *La Bourgogne* that was sunk after a collision on July 1898 (about 550 victims) to the Danish steamship *Norge*, sank near Rockall Island in 1904 (more than 600 victims).

But the real *annus horribilis* for maritime disasters was 1912. In that year, in fact, occurred not only probably the most famous naval incident in the history of maritime civil transportation, the sinking of the *Titanic* (1517 deaths), but also the sinking of the Spanish steamship *Príncipe de Asturias* (about 500 victims) and the disaster of the Japanese ship *Kirchemaru* (1000 deaths).

The list of rail disasters is equally long. Apart from early accidents that involved the early steam trains (in many cases because of the explosion of boilers), other disasters were caused by clashes, derailment of trains or the collapse of bridges. To this list must be added those disasters occurred on subway lines (e.g. the Paris Metro disaster of 1903, 84 victims). From 1833 to 1918, at least 8803 deaths are attributed to railroad crashes, about 35.7% of total amount of accidents registered from 1833 to 1975.

All these disasters contributed to place the question of the adoption of safety standards to prevent further accidents and insure the safety of persons. The protection of workers and new legislative measures against industrial risks were also strongly demanded by trade union organizations and left-wing parties. This process involved both private and public subjects and generated a debate on technical and insurance matters that had a great influence on national governments and promoted the adoption of laws on prevention and safety, thus accentuating the role of the State in these areas.

The discussions on security and prevention and emergency management sanitation related to the production process were relevant aspects of the debate around the so called “unhealthy industries” that led to the first public health legislations: from the *British Public Health Act* of 1875 to the public health provisions contained in the legislation adopted by the Italian government of Francesco Crispi in 1888, which was in turn inspired by French legislation.

Another important indirect consequence of the industrial accidents was the development of the occupational medicine, that had a growing importance in prevention of occupational diseases starting to investigate on the relations between some diseases and certain manufacturing processes. For example, the link between the exposure to asbestos dust and some serious lung affections was emphasized and confirmed in observations of doctors and experts in occupational diseases since early twentieth century up to the *Merewether and Price Report* of 1930.

In most cases, however, until the second post-war years the health and the safety of the workers during the processes of production, were still considered some marginal issues. This was primarily because of the relationship between the workplace and certain diseases even when had dramatic connotations - e.g. the thousands workers that died from *ancylostomiasis* during the work of the St. Gotthard tunnel in 1888 - was considered as inevitable.

With the result that safety and health of the workers on the job was monetized or simply considered as a technical matter. This approach was partly due to the difficulties (in some cases to the impossibility) of making in the public domain the documentation of many of the environmental disasters which occurred in that period.

In general, the emergence of increasingly sophisticated techniques of "civil protection", generally applied in case of natural disasters, was further facilitated by technological and scientific progress, but also from a revision of knowledge and approach to professionalism and skills that, since mid nineteenth century, brought to the affirmation of the concept of *expertise* and of the figure of the expert, a professional with special knowledge and skill, specifically prepared and formed to solve technical questions, prevent and manage disasters.

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