Pollution in the urban environment under earthquake conditions

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Abstract: Typically**,** Earthquake engineering refers to the construction of seismically resistant structures within the man-made environment. Records of pollutants in cities are kept routinely, and pollution is generally under control. Environmental pollution is often associated with faults in technological processes which are linked to particular pollutants. Impact on such an environment may ensue from earthquakes which cannot be felt by sensual perception. For example, underground sources for water supply to cities, have periodically and inexplicably been found to contain prohibited materials, such as pesticides. The search for an explanation of such an occurrence suggests the role of earthquakes should be considered, even though there is no sensual perception for them within the source area. Therefore, in the future, the seismic hazard meant for environmental requirements should be prepared separately by taking into consideration its specific features.

Résumé: L`ingeneering de tremblement de terre se réfère principalement à la construction résistante au tremblement de terre du milieu existant. Dans les villes est faite une évidence des pollutions potentielles qui sont mises sous contrôle. La pollution du milieu urbain est liée aux déséquilibres dans le processus technologique qui apparaissent dans les industries polluantes répertoriées. L`influence sur la pollution du milieu urbain peut être provoquée par les tremblements de terre qui ne se manifestent pas sur l`espace nommé. Les sources souterraines d`approvisionnement, ont périodiquement l`apparence non explicable de matières interdites (par exemple les pesticides). La recherche de l`explication de cette apparence nous apprend qu`il ne faut pas oublier les tremblements de terre qui ne sont pas ressentis au droit des sources. De cela, dans l`avenir, le risque des tremblements de terre pour les besoins du milieu urbain doit être spécialement élaboré en considérant la spécificité qui le caractérise.

Key words: pollution, fluids, earthquake, urban, geologic environment.

INTRODUCTION

At a series of springs, one very often ascertains higher concentration of a particular pollutant compared to its allowed value, or even a new pollutant may appear. The interpretation of causes pertaining to the appearance of such sudden occurrences is not providing satisfactory answers, and usually these occurrences are considered as excessive ones. The justification for classifying such occurrences as excessive, can be found in the fact that they last for a short time, and then disappear suddenly. Yet, it is well known, if excessive occurrences have extensive negative consequences, they cease to be considered as excessive, and the real reason of their appearance is sought. Authors of this paper have tried to give a modest contribution to the explanation of pollution in urban environments with excessive attribute.

Practically, the environment represents the tightly linked system made of geologic environment, man-made environment, air, and social environment. The appearance of earthquake in the geologic environment either in its preparation stage, or during its action, or even to certain extent in its "calming stage" within the framework of the geological environment, brings about vast disturbances compared to the conditions when there are no earthquakes whatsoever. In addition to the earthquake appearance being considered within the scope of engineering geology as endogenous phenomenon, the appearance of pollutants can be influenced by exogenous occurrences, such as large infiltration of surface waters in rainy periods. Under such conditions during the investigations for mineral raw materials it was ascertained that there appears an increased presence of mineral halo effects, and even frequently those hidden, which are not present in dry periods. The geologic environment is a complex system containing fluids, either in liquid, or gaseous state, which are prone to migrate through permeable lithologies.

ANALYSIS OF SOME OCCURRENCES AS REGARDS THE FLUIDS WITHIN THE GEOLOGIC ENVIRONMENT

The occurrences as regards the fluids have been analyzed for earthquakes being treated as the act of impulse tectonics. Within these earthquakes one can single out as follows: a zone of direct rock mass rupture and creation of arterial fault with associated secondary (minor) faults, a zone of plastic deformations and a zone of elastic deformation from where the volumetric seismic waves originate prior to transmission to the earth's surface. Earthquake energy is much higher than the aforementioned seismic one and it arises from much wider area than one which belongs to the hearth. There are series of models meant to elaborate the appearance of an earthquake and often the model of progressive rupture within unstable fissured rock mass along with the appearance of arterial fault is utilized (developed in Russia), in addition there is the dilatation-diffusion model, and the model linked to the elastic energy relieving (developed in the USA).

The Progressive rupture model is dealing with four phases of earthquake development. In the first phase, within the spatial volume part wherein the earthquake originates, the fractures appear with erratic distribution, yet along the entire volume. In the second phase, the fractures initiate the orientation towards a certain direction and in this process some of them begin to merge and grow. In the third phase, in certain directions fractures initiate with intense concentration within the zone of a future arterial fault. When the critical density of fractures is attained in this zone of concentration, unstable conditions are created, leading to the progressive merging of these fractures, and consequently to the cracking of rock mass and finally an earthquake.

In contrast, the dilatation-diffusion model takes account of the fluids, such as ground water as regards the earthquake appearance. In such a way, according to this model in its first phase, i.e. in the zone of future earthquake hearth there appears the concentrated increase of stress notation, which in the second phase leads to the appearance of dilatation fractures and ground water pressing out from the volume of future hearth. In the third phase the fractures are filled up with ground water thus causing the loss of strength within the volume under study, and consequently in the fourth phase the rock mass rip is occurring along with the arterial fault.

Elastic energy relieving model has also four phases, yet it includes the presence of a fault. In the first phase there are no deformations in the flanks of a fault. The second phase refers to the time prior to earthquake, when the deformations in the flanks of a fault are appearing. The rock mass rupture begins in the third phase along with the relieving of gathered potential energy and creation of fault's active part, and it attains its full scale in the fourth phase.

Earthquake strength also influences the mobility of fluids. The issue of assessing the earthquake strength in the hearth, until nowadays still remains open. The magnitude indicates for how many times the recorded earthquake is bigger than an arbitrarily selected one, so called "zero" earthquake. Since it is defined on the basis of comparing the waves of mentioned earthquakes, practically it represents the measure/rate for seismic energy assessment. In cases, when the hearth "comes out" on surface, the occurrence of seismic-tectonic deformations ensues. In the zone of their appearance there is an area of rupture and plastic deformations and due to this there are no elastic waves, and in this case also all necessary prerequisites have not been fulfilled for magnitude assessment based on the records. Seismic moment which is also utilized for the assessment of earthquake strength is somewhat linked to the physics within the earthquake hearth, yet the defect lies in the fact that rock mass "creep" has also high moment but not followed by an earthquake.

Every single earthquake phase has its own repercussions on the fluids. In the professional reference literature, numerous examples are quoted when prior to earthquake appearance the changes in fluids have been ascertained. For illustration purpose, we are referring to an example from professional reference literature regarding an oil field in Russia. This field, during the tremor found itself within the zone of 6th degree on the seismic scale, while in epicenter this tremor recorded 9 degrees. The field itself was at the distance of 70 - 80 km from the earthquake epicenter. At about 15 - 20 days, before the earthquake occurrence, an increased yield of naphtha and water was ascertained on a series of boreholes. Immediately prior to the earthquake occurrence, i.e. 1-3 days, the yield was distinctly decreased, yet on the very day of the earthquake it increased again. The yield of fluids gradually decreased along with the lowering of seismic activity. Periodical changes in the yield from the boreholes was ascertained during several months. Monitoring investigations indicate, that before the occurrence of future strong earthquake there appeared the changes in the yield of fluids in boreholes, and not only at those located in epicentric zones, but also those located at distances of 100 - 300 km from the epicentric zone (this was ascertained on naphtha boreholes). In other words, within seismically active areas, in the phase of strong earthquake preparatory indication, there is a mobility of fluids on extensive distances from the epicenter of future earthquakes. This mobility can allow the entry of pollutants into geologic environments, which until then fulfilled assigned design - operational requirements.

Besides, certain dependence in the change of gas content was also ascertained, depending on the distance of the observation station from the epicenter, as well as the earthquake energy and other factors. There are examples of ground water monitoring in the spas located in the vicinity of epicentric zone, and thus radon was ascertained as the most frequent informative parameter, and to a lesser extent, carbon monoxide, chlorine, calcium, while there were also changes in temperatures and concentrations. The changes in the chemical composition were also ascertained at local earthquakes $M \approx 1$, while the radius of geochemical anomaly halo effect itself is defined by the earthquake strength. In this sense hydrochemical anomalies precede the tremor from 2 to 10 days depending on the strength of future tremor.

The examples, above, indicate that in the earthquake preparation phase, fluids change in the subsurface even at large distances from the epicenter of the future earthquake, and these fluids are not in a hydraulic link at various distances.

The professional reference literature quotes cases where abandoned boreholes became productive again in the four years, following a strong earthquake.

The impact on fluids exerted by earthquake seismic waves is of particular interest. The professional literature refers to the strong Lisbon earthquake in 1755, when at the distance of approximately 2000 km from the epicenter, the mineral water had become turbid at Karlsbad, along with the disturbances in the regime of ground water springs in Bohemia and France. In these areas the oscillations carried out by seismic waves had not been felt by sensual perception. In the areas where the oscillations, carried by seismic waves, were felt by sensual perception, the impact on fluids is much higher, whereas in the zone of failure "in the proximity of epicentral zone" there are numerous occurrences of groundwater being expelled on to the ground surface.

The alteration of fluid yield practically represents the hydro-dynamic effects, which are taking place during plastic deformations (ascertained before the earthquake occurrence and during the passage of waves which are causing the earthquake). Size of deformation ensuing from high tide and ebb tide influenced by the sun and the moon is in the rank of 10^{-8}, so one can say, that they are encompassed permanently by hydro-dynamic effects, yet the degree and mode of their contribution can be dealt with and evaluated. The field of plastic deformations starts when the waves passing through the environment cause the deformations in the environment thereof in the rank of 10^{-4}. Deformations caused by the passage of seismic waves within a given environment exert the influence onto the porosity of such a environment, and thereby on the mobility of fluids within its framework.

Seismic check-points record numerous earthquakes being far away from them and which are not felt by sensual perception. With very distant tremors of magnitude higher than 7, oscillations of soil ensuing from incoming waves may last 45 minutes and even longer. All this time, the changes in porosity are taking place in the environment, through which the waves with considerable length are passing and spreading over large complexes in the environment thereof, so that the barriers for pollutants which operate under static conditions, are no longer effective under dynamic conditions.

RESULTS OF ANALYSIS

Presented data show that terrain seismic features should be taken into consideration since they exert influence on the mobility of fluids in a geologic environment. Namely, barriers to pollutants which are operate when there is no impact of earthquakes and accompanying waves, can be disrupted and lost during the earthquake impact. Potential earthquake impact, we designate as seismic hazard and the same is indicated on seismic maps. In addition to seismic hazard on maps, one should also take into consideration the impacts of seismic waves which do not share the intensity shown on the aforementioned maps, and originate from strong earthquakes recorded far away from the area under study and are not felt by sensual perception. It means that the ecology in urban areas should consider the potentials as regards the migration of fluids in a geologic environment, thus to assess the potential for pollutants to infiltrate protected zones.

It should be noted, that nowadays the inventory of pollutants on a given urban area has become a standard, and the accidents are under control, since they are connected with known pollutants. Yet, under the conditions of strong tremors we can face massive vulnerability to potential pollutants, which are the integral part of the man-made environment along with their mutual interaction, and therefore this phenomenon should be awarded significant attention.

CONCLUSION

This analysis indicates there is a room in urban ecology assessments to consider the migration of fluids under earthquake conditions and to suggest steps to prevent accidental situations from causing major consequences. In the broader sense, one of the steps to be undertaken is the project preparation for future investigations with instrument devices on a series of selected locations, whereby one would obtain an objective tool for assessing the potentials as regards the migration of fluids and their role in urban pollution.

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