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MUDFLOW RISK MANAGEMENT (AN EXAMPLE OF SOUTHEASTERN KAZAKHSTAN)

Annotation. The complex approach to the definition of erosion and mudflow zones in conditions of intensive economic development is considered for the mountain areas. The goals and objectives of the quantitative assessment of mudflow risk are defined for decision making and effective management of mudflow risk. The area of acceptable risk and the extent of possible direct socio-economic damage are justified on the territory of the subjects of the Almaty region. The identification of the most vulnerable areas in terms of the degree of mudflow hazard will allow timely organization of preventive measures and effective protection against catastrophic mudflows, which minimizes damage in urban areas.

Keywords: volume of mudflow, hazard, mudflow risk, management, damage.

Introduction. Mudflow (mudslide) is a rapid stream of water and fragmental rocks. Mudflow is characterised by a sudden rise in the level of flow, oscillatory (undulatory) movement, short duration (usually 1-3 hours) and by a significant denudation effect. Mudslides are formed (basic traits - abruptness and incidence) and move within the mudflow basin. The area of a mudflow basin can be from 1-2 to 100-200 km^2. Mudflow basins are divided into 3 cartographic zones - initiation, transit and accumulation of the mudslide. An average incline of the mudflow channel changes within an interval of 100-300‰. Hard material takes up 10 to 75% of the volume of the mudflow during the movement. Density of the mudflow mass can change from 1100 to 2500 kg/m^3.

Mudflow Hazard is the risk of losing people's lives and tangibles due to the impact of the mudflow. The danger of the mudflow (to population) is linked to its high speed (2-10 m/sec), powerful applied shock (mudflow can reach a speed of 1000 to 10000 m^3/sec), channel erosion, accumulation of the mudflow deposits (up to 10^7 m^3 in the accumulation zone).

For creation of safe activity conditions (sustainable social and economic development) in the region, it is necessary to carry out a scientific assessment of mudflow risk based on a complex information system (monitoring, forecast) and to develop recommendations for effective protection of the population.

The development of monitoring basics and methodologies, the forecast of hazard occurrences and early emergency population warning, induced from mudflows, is the urgent direction of the research having great scientific and applied relevance on support of sustainable development of the southeast region of Kazakhstan. Emergency is such a situation which is developed or can be developed under the influence of the unfavorable factors representing threat for life of people and their normal activity.

Exploration technology. Heavy rains, flooding, significant accumulation of the landwaste in the area of occurrence and in the mudflow channel are the characteristic forecast signs of the rain mudflow formation. Certain success is achieved by drawing up the automated forecasts of triggering conditions based on the daily sums of rainfalls with the forecast interval of up to seven days. Application of a method of calculation of the amount of precipitation based on parameterization of microphysical processes in global spectral model of the atmosphere (T85L31) has allowed to increase the forecast quality of rainfall areas for the entire period of advance time (24–72 h) at the individual stations located in Russia's european part of the territory.

The method is focused on the forecast of light and moderate precipitation (with an assessment of intensity in mm/h). For example, in May 2002, the accuracy of liquid precipitation occurrence prediction has increased from 27 to 65%. Attempts to adapt numerical methods values of the meteorological fields forecast to the stochastic weather model SWM [1-2] are being made. Construction of such a model is an important stage on the path of the creation of an innovative hydrological calculations methods system of a new generation.

The mudflow risk is a combination of the mudflow occurrence frequency (or probability), certain characteristics (maximum flow speed, volume and density of the mudflow) and consequences from these dangerous events. Quantitative index of the mudflow risk can be derived from the risk assessment or from the expected loss value. This characteristic gives us the information about the average damage which an object (economic activity) will incur (in case of the constant behavior strategy) during a certain period of time (average annual, average monthly). An object often selects the behavior strategy (protection against the consequences of adverse developments) based on the most acceptable damage value and the probability of its occurrence.

Management of risk – process by means of what decisions are made and operations are performed to eliminate or reduce influences of the identified dangers. Process of mudflow risk management can be subdivided into two independent components [3, 7]:

a) *Risk regulation* – is a process of supervision and danger source control; observation of a condition of the environment surrounding the person, its changes under the influence of economic and other activities, timely identification of tendencies of its change; the inspection of implementation of plans and actions for conservation, rational use of natural resources, observance of requirements of the nature protection legislation and standards of quality of the environment;

b) *Protection costs optimization* – is a process of the mudflow risk reduction for the purpose of it achieving such a level that is reasonable (accepted) from the point of view of practical experience. It is necessary to be guided by the principle of ensuring activity that demands a low risk level, which can only be achieved in real ecological, economic and social conditions.

Risk management process includes procedures of risk analysis and administrative decision making in the form of recommendations on risk reduction. Measures for the reduction of the torrential risk can have a technical or an organizational character. The general assessment of effectiveness of measures, which influence the risk, has a crucial importance in the choice of the types of actions. Mudflow risk management is generally based on the expenses comparison principle in preventive actions and the benefits received at the same time from reducing the risk.

The task of ensuring a certain safety level of social and economic system in mountainous areas is directly connected with the task of management of the mudflow risk for mudflow danger zones.

Development of the following technologies of forecasting, prevention and elimination of the emergency situations caused by the mud streams is promising:

– zoning of the territory based on the size of the combined risk from the emergencies of natural (mudflow risk) and anthropogenic type;

– mitigation of social and economic consequences and reduction of economic damage from the mudflow phenomena;

– assessment and certification of buildings and constructions engineering safety (real stability and durability residual resource);

– information support of decision-making on potentially dangerous objects in case of a powerful mudflow influence;

– management of city and civic complexes (various buildings) during the emergency prevention and elimination;

– monitoring of mudflow basins (potentially dangerous mudflow sites) which are under the potential danger and early mudflow warning;

– complex risk assessment of an individual mudflow site.

Research results and discussion. Definition of the value of acceptable risk criteria for a mudflow zone is at a discussion stage. Risk is a conscious danger (threat) of approach in any system of a negative event with the consequences defined in time and space. For each object located in a mudflow zone, the upper bound of the acceptable risk is rather individual. As a rule, it is defined by the size of unforeseen admissible expenses of its functioning (for industrial and economic facilities). For natural complexes, object stability degree in relation to force of anthropogenous influence is considered. Eventually, it is defined by a ratio of the expenses and benefits connected with decrease in mudflow risk. For each mudflow area which is in a zone of admissible values excess of risk it is necessary to make social importance estimates of risk for the population in terms of total economic damage from death, traumatizing people and material losses as a result of an emergency.

Erosion type of occurrence is typical for the rain and human-induced mudflows.

Traditionally, the range of the intensity fluctuation of the potential erosion (t/ga) is divided into 5

classes: up to 0,5 t/ga (1 class); 0,5 ÷ 2 (2 class); 1 ÷ 5 (3 class), 5 ÷ 10 (4 class); 10 ÷ 50 and higher (5 class) [3]. Potential mudflow hazard is defined by the level of the mudflow activity. Parameters of the recurrence and the volume of the mud flow are used for evaluation of the mudflow activity in time within a single mudflow basin. All of the mudflow basins are sometimes divided into 4 or 5 danger categories, based on the mudflow activity (duration of the cycle equal to 100 years): volume of the debris mudflows (density of the flow equal to 2100-2500 kg/m^3) is over 10^6 m^3 (I category); within the range of $10^5 \div 10^6$ m^3 (II category); $10^4 \div 10^5$ m^3 (III category); $< 10^4$ m^3 (IV category). Suspended mudflows (1100-1600 kg/m^3) are characterised by the maximum flow speeds of: over 250 m^3/sec (I category), 100-250 m^3/sec (II), 10-100 m^3/sec (III), < 10 m^3/sec (IV). The fifth category characterises a mud flood, which is defined by a low debris saturation (density of less than 1100 kg/m^3). We are proposing a single scale of the destructive power of the erosive and mudflow processes, which includes the volume of the soil loss and mud flow (m^3), based on the following gradations: over 10^6 (10 category); within the range of $10^5 \div 10^6$ (9); $10^4 \div 10^5$ (8); $10^3 \div 10^4$ (7), $10^2 \div 10^3$ (6), $10^1 \div 10^2$ (5), 5÷ 10 (4), 1÷ 5 (3), 0,5÷ 1 (2 category) [4]. Dependency of the destructive force of the natural disaster parameter (J_c) on the characteristic, describing and intensity of the destructive factor, has been detected. Parameter (J_c changes from 0 to 1) characterises what fraction (from the maximum possible amount of loss lgE = 8 J_c within a year) the destructive power has within the zone of the mudflow influence. Noticeable disruptions of the economic objects' functioning start with the volume of the mud and debris flow equal to 1000 m^3 (zero-order level of destruction corresponds to the gradation 6), while a full destruction of a concrete dam (gradation 10) occurs when 10^6 m^3 is exceeded.

Justification is given for the range (area) of the acceptable risk for geoecosystems, which is within $2{,}0\times10^{-6}$ – $5{,}0\times10^{-6}$, respectively, under anthropogenous and favorable conditions in the south of Kazakhstan [4].

The Almaty region can be classified in three categories - weak, average and severely eroded territories. In percentage terms they make up 4%, 20% and 10% of the Almaty region's territory respectively, which belongs to the hazard category 3–5 [4, 5]. Potential erosion-hazardous territories and mudflow fans (category 7), as well as the area of mudflow sites (category 8) occupy 0.88% and 1.65% of the whole region respectively. In Karasay district, most of the territory (80%) is located in the mountainous area, with 204 mudflow sites, which have the total area of 314 km^2 [5]. Moreover, 17% of the mudflow basin area is a direct source of mudflow hazard. In Enbekshikazakh and Jambyl districts the similar situation is observed (15–17% of the territory is subjected to exogenous processes). In the desert zone of Ile district the mudflow center is human-induced. It is impossible to exclude a possibility of the development of the erosive process on the low-inclined underlying surface under the irrigation conditions and active land development (watering, underflooding).

During 1955-2004 on a northern slope Ile Alatau the mudflow sites' area has increased by 3,3 times at the expense of a new moraines area increment as a result of glaciers degradation. Further, (until 2075) the tendency will remain, though with much smaller intensity of the mudflow sites' area increment [6]. According to monitoring of the mudflow phenomena in mountains of Ile Alatau for the last 30 years, an increase in the number of rain mudflows cases is noted, that averages 1 time in 2,2 years. Whereas in the fifties of last century they recurred each 4,5 years and at the beginning of the century after 7 years have passed. Glacial mudflows, according to observations, occur more rarely than a similar phenomena of the rain origin.

A linear dependence between the volume of washed-out soils (up to 20 thousand tons) and the costs of restoring their fertility (within the limits of 0.1-30 million tenge) is established. In the event of a mudflow disaster formation, the specific values of parameters, which are seen as a measure of the degree of destruction of the economic system infrastructure and the negative impact on the population, have a nonlinear appearance [3, 4]. The estimated cost of soil disturbance, resulting from the erosion-hazardous process on the territory of South-Eastern Kazakhstan, expressed by the direct material damage size, depending on the volume of the displaced mud mass (5000 tg / m^3 [4, 5]) is determined.

The upper limit of the catastrophic rainfall frequency decreased from 59 to 35 years. At the same time, in the mudflow foci, the upper limit for the volume of mudflow decreased from 100,000 m^3 to 72,000 m^3 [5]. In the alpine zone, where the main mudflow foci are concentrated, in the case of rainfall under the conditions of climate aridization, the mudflows with the largest volumes up to 120,000 m^3 (their occurrence probability is 1%) can be formed, whereas in the mudflow canal up to the outlet from the mountains, these volumes can reach more than 500,000 m^3 [6]. It is commonly believed that the frequency

of outstanding rainstorms, surface runoffs and mudflow phenomena corresponds to an average of one time per 100 years. However, not only the atmospheric precipitation, which is scarce in the layer, is able to form a mudflow, but also ordinary rains can cause the "emergence" of powerful debris and water-rock flows.

The most informative criteria are the public health indicators of population, which together characterize population's reproductive, social and economic activity. Second-order indicators are per capita parameters of GDP, comfort of the natural and social environment, all of the service sector. In the region, the index of potential losses essentially depends on the population density (the correlation coefficient is 0.81) and the economic factor (r = 0.44) plays an important role. In the Almaty region, the number of deaths per catastrophe can reach an average of 6.7 thousand people per year. For Kazakhstan, this figure reaches 7.9 thousand people (2003) [4]. At the same time, the correlation coefficient (r = 0.16) characterizes the weak connection with the catastrophe indicators (mostly random). In the Karasai district, on the erosion-hazardous territories (within an area of 50 km^2), the amount of direct socioeconomic damage can on average reach 8.6 million tenge (with the recurrence of violent mudflow phenomena of 1 time in 45 years and less often) [4, 5]. In this situation, with the existing infrastructure and population density, the maximum damage can reach 27 million KZT (90% of all losses). Studies on the identification of the impact of climate warming in the region on the trigger of mudflow processes have shown that their frequency will increase. Consequently, powerful mudflows (with a mudflow volume of 1 million m^3 or more) will recur more often (once in 15 years) [5, 6]. Consequently, in the future, the risks of losses from exogenous processes will increase and they should be taken into account when designing and developing urbanized areas.

Conclusions. Based on the results of the analysis, it is possible to concretize tasks on the topic of the scientific and applied research "Integrated management of mudflow risks in the mountainous regions of South-Eastern Kazakhstan" (on the example of the city of Almaty).

A) Establish a time scale of severe mudflow phenomena (2-3 hours), impact area (10-25 km^2).

B) Construct the loss (damage) functions from powerful mudflows for the western and eastern parts of Almaty, taking into account the existing anti-mudflow protection.

C) Justify the crisis scenarios from possible powerful mudflows and develop measures for the timely warning and effective protection of the population of Almaty.

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СЕЛ ТАСҚЫНЫ ҚАТЕРІН БАСҚАРУ (ОҢТҮСТІК – ШЫҒЫС ҚАЗАҚСТАН БОЙЫНША)

Аннотация. Таулы аудандарының қарқынды шаруашылық игеру жағдайындағы эрозионды және сел қаупі бар аймақтарды анықтаудың кешенді тәсілдемесі қарастырылды. Шешім қабылдау және сел қатерін эффективті басқару мақсатында сел қаупін бағалаудың мақсаттары мен міндеттері айқындалды. Алматы облысы субъектерінің территориясындағы қолайлы қауіптер аймағы мен ықтималды тікелей әлеуметтік-экономикалық залалдың көлемі дәлелденді. Сел қатерінің дәрежесі бойынша осал аймақтарды анықтау урбанизацияланған территорияларындағы залалдарды ықшамдайтын апатты селдерден превентивті шараларды және эффективті қорғанысты уақытында ұйымдастыруға жол ашады.

Түйінді сөздер: сел көлемі, қауіп, сел қатері, басқару, залал.

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УПРАВЛЕНИЕ СЕЛЕВЫМ РИСКОМ (НА ПРИМЕРЕ ЮГО-ВОСТОЧНОГО КАЗАХСТАНА)

Аннотация. Рассмотрен комплексный подход определения эрозионных и селеопасных зон в условиях интенсивного хозяйственного освоения горных районов. Определены цели и задачи количественной оценки селевой опасности для принятия решений и эффективного управления селевым риском. Обоснована область приемлемого риска и размеры возможного прямого социально-экономического ущерба на территории субъектов Алматинской области. Выявление наиболее уязвимых участков по степени селевой опасности позволит своевременно организовать превентивные мероприятия и эффективную защиту от катастрофических селей, что минимизирует ущербы на урбанизированных территориях.

Ключевые слова: объем селя, опасность, селевой риск, управление, ущерб.