DOI https://doi.org/10.36719/XXXX-XXXX/3/25-32

Emil Mammadli
Azerbaijan State Oil and Industry University
https://orcid.org/0009-0008-4257-0462
emilmammadli54@gmail.com

Development of Research on Groundwater Pollution and Economic Protection During Well Construction

Abstract

The polluting properties of the drilling mud are determined by the mineralogical composition of the drilled rock and the remaining drilling mud residues. Analysis of the phase, fraction and component composition of the mud, as well as its physicochemical properties, shows that due to the adsorption of chemical reagents used to clean the drilling mud on the surface of the mud particles, it exhibits obvious polluting properties. Thus, its composition includes a significant amount of oil and oil products, organic substances hazardous to the natural environment, and soluble mineral salts toxic to soil and vegetation. Thus, it can be concluded that drilling waste is dangerous for the natural environment, since it contains a large number of pollutants. In this regard, it is impossible to give a completely unambiguous description of the processes occurring in the natural environment associated with its pollution during well drilling and to assess the consequences of this negative impact.

This pollution leads to not only ecological, but also economic consequences. Modern technologies and protective measures applied to prevent pollution during well drilling also require efficiency from an economic point of view. It is important to develop innovative methods to reduce and manage groundwater pollution, as well as to assess the economic efficiency of these methods. Compliance with environmental restrictions, waste reduction and effective resource management in the oil and gas sector affect production costs. In addition, economic analysis of pollution risks and development of appropriate compensation mechanisms allow for the preservation of environmental and economic balance in this area.

Keywords: *drilling mud, environmental impact, economic efficiency, protection measures, environmental and economic balance, innovative methods*

Introduction

The assessment of damage caused by emergencies should be achieved using approaches and methods (techniques) agreed upon and permitted for use by management bodies at various levels of the national economy (state, territorial, sectoral). At the same time, it is possible to improve and refine industrial methods for assessing damage, develop more substantiated methods for assessing damage, taking into account new economic conditions, the impact of damaging factors of emergencies, changes in the regulatory and legal framework, and a number of other factors. It should be borne in mind that both the approaches and methods used in practice and new ones allow us to obtain an assessment of damage, which is a more or less reasonable approximation to its actual value. In practice, damage is often considered justified when all interested parties agree on its amount (and, accordingly, the calculation method). In this regard, the reliability of the damage assessment method can be considered a subjective concept. If all interested parties agree with the assessment obtained on its basis, then this method is not considered reliable, its reliability must be confirmed by law.

The assessment of damage caused by an emergency should be formulated in such a way as to reflect the entire composition of cause-and-effect relationships from the moment of the emergency to the damage caused to economic entities and individuals. This can be expressed as the following chain: “the scale of the emergency taking into account its source” - “the nature and strength of its impact on the socio-economic system” - “the scale of disruption (degradation) of the socio-economic system” - “the impact of the damaging factors of the emergency on the economic object” and the size of the natural factors resulting from the natural losses of the economic object of the emergency” - “economic assessment of damage". In general, the entire complex of approaches and methods for assessing economic damage from emergencies, implementing them, is divided into two main groups: direct calculation methods and indirect assessment methods (Imanbekov, Bozov, Ordobaev, Abdykeeva, 2013, pp. 65-95).

Damage (loss) is determined not by the content of the emergency itself, but by its consequences. The same emergency can lead to the same result as a result of different emergencies, but can lead to different specific consequences.

To assess the damage caused by an emergency, an expert approach can be used to determine the value of damage for various categories of economic facilities based on the requirements of relevant regulatory legal documents, direct inspection of the facility by an expert, as well as the collection and generalization of market data on the value of similar economic facilities.

The final value of the damage caused as a result of an emergency, indicated in the damage assessment act, drawn up on the basis of the Methodology and in accordance with the procedure, may be considered recommended for the purposes of carrying out legal actions (transactions) with the object of assessment, if no more than 6 months have passed from the date of drawing up the assessment act to the date of assessment of the object (submission of the legal act) or to the date of submission.

Personal risk – the risk (frequency of occurrence) of certain types of harmful effects arising from the implementation of certain hazards at a certain point in space (where a person can be located). It characterizes the distribution of risk. For emergencies – the probability of a certain type of damage (fatal outcome, disability, severe injuries without loss of working capacity, moderate injuries and minor injuries) arising from the implementation of certain hazards at a certain point in space. The quantitative value of individual risk is equal to the probability (frequency) of a certain type of harmful effects.

Indirect economic damage includes unavoidable expenses, losses, damages resulting from secondary effects (actions or inactions resulting from the main actions) of a natural, technogenic or social nature. Indirect damage, unlike direct damage, can manifest itself long after the moment of the initial action; does not have a clearly defined territorial affiliation and in most cases has the so-called cascade effect, i.e. secondary actions (inactions) lead to a series of subsequent actions (inactions) and, accordingly, indirect damage.

Indirect damage from emergency situations – damage resulting from an emergency situation, but not included in direct damage. Indirect damage consists of the following components:

• damage associated with disruption of the activities of economic facilities – damage associated with the suspension (stoppage) of the activities of the facility or the injured person (including damage associated with lost profits);

• damage to "third parties" – indirect damage caused to subjects as a result of an emergency;

• costs associated with the elimination of emergencies.

A specific feature of the assessment of indirect economic damage is that its components, as a rule, cannot be documented. They are determined using appropriate methods or are assessed, including by experts. In addition, due to the systemic nature of economic damage from emergencies and cascading factors, controversial provisions inevitably arise regarding the inclusion or exclusion of individual components in the composition of indirect economic damage. In this regard, calculations and/or assessments of indirect economic damage, especially those that claim to fully take into account all components of the "emergency factor", objectively have a sufficiently high degree of uncertainty and insufficient reliability.

Direct calculation methods, as a rule, reflect all elements of the chain of causal relationships that cause economic damage to economic entities. They include the assessment of the effects arising between all links of this chain and the calculation of various components of the losses of the economic entity, expressed in value. Approaches to the assessment of damage caused by emergencies based on the use of direct calculation methods are quite widely used in the assessment of losses of objects as a result of technogenic accidents and natural disasters, terrorist attacks. This is due to the fact that objects (territorial and natural complexes, enterprises, residential areas) damaged by such events are usually characterized by a fairly clear structure, the value of its elements can be estimated more or less accurately. In this case, the loss of elements can usually be associated with the power of the event (the power of the earthquake, the power of the explosion, the duration of the fire). To obtain reasonable and objective estimates of damage caused by emergencies (taking into account the causes and factors of damage occurrence), a direct calculation method is used, which predetermines the high accuracy of the damage assessment based on them. However, these methods are quite labor - intensive and difficult and require a large amount of initial information. As a result, their application in practice is not always possible.

Indirect assessment methods are less labor - intensive. They are based on the principle of transferring general patterns of action of harmful factors to a specific economic object. This principle is implemented using a number of standard indicators that convert the type and magnitude of the impact of the damaging factor into economic damage to the economic entity.

At the same time, the emergency factor should be taken into account at all levels of data collection, its generalization and generalization, analysis and forecasting of indicators of socio-economic development of organizations (enterprises), territorial entities and the Russian Federation as a whole. It is appropriate to distinguish three main levels of formation of information on economic damage from emergencies: lower, middle and upper (macroeconomic).

The lower level is the level of the “primary link” (organization (enterprise), municipality).

This is the main level of collection of primary data on the emergency factor - economic damage caused as a result of an emergency, since accounting and planning and economic services in organizations (enterprises) keep records of the state of property of organizations (enterprises), its disposal for various reasons, including as a result of an emergency. The task is to provide this information for use by state statistical bodies and, on this basis, to use it for its further processing, analysis and generalization at the middle and upper (macroeconomic) levels.

At the level of municipalities, initial data on economic damage caused by emergencies in the social sphere, including non-accounting data, should be obtained.

Proposals for forms and indicators - basic data on damage caused by emergencies - are presented below.

The intermediate level is the level of federal subjects and industries (ministries and departments).

Damage caused to the state from emergencies - a comprehensive assessment of the socio-economic consequences of emergencies in monetary terms.

DAMAGE TO INDIVIDUALS - includes injuries and damage to the health of individuals.

ACTUAL DAMAGE FROM EMERGENCY SITUATIONS - damage from the emergency that has occurred.

ACTUAL ECONOMIC DAMAGE - losses that have occurred as a result of the damaging factors of the emergency and are estimated in monetary terms. For practical purposes, actual economic damage is usually calculated on an annual basis and expressed in prices (rates) of the previous year. This “delay” is explained by the features of statistical reporting. In economic calculations, an annual delay is considered normal and is taken as a basis.

VALUE – property (money), intangible assets, as well as their properties and relationships.

ECONOMIC DAMAGE – material losses and expenses associated with damage (destruction) of production and non-production objects of the economy, its infrastructure and disruption of production and cooperation relations. When determining economic damage:

• firstly, the transition (recalculation) of physical damage indicators to cost (money) units is carried out;

• secondly, the economic processes of the activities of economic and social infrastructure objects are directly or indirectly reproduced (modeled).

The average damage from an emergency can be determined using statistical data. The average damage for rare events can be estimated using data calculated for various scenarios of the onset and development of man-made, natural or terrorist emergencies and subsequent average calculations taking into account the scenarios.

When justifying measures to prevent accidents and disasters and mitigate their consequences, risk is usually considered as an integral indicator that includes both the probability of an undesirable event occurring within a year and the damage associated with it.

Depending on the nature of the damage under consideration, the type of risk is determined - economic, social, environmental, etc.

Depending on the tasks to be solved, risk is presented in the following forms:

• the mathematical expectation of a certain type of loss each year;

• the probability of an adverse event occurring within a year.

In the first case, the risk is determined by the formula:

$$R = pЧg ,$$

Here, p – probability of occurrence of an emergency (frequency of accidents, disasters) per year; g – potential damage from an emergency.

The risk dimension is consistent with the nature of the damage and has the form: damage/year. In the second case, the risk is determined from the ratio:

$$R = pЧs ,$$

Here, p – probability of an emergency occurring in a year; s – probability of an adverse event occurring given the occurrence of an emergency.

In the second case, the risk measure, taking into account the dimensionlessness of the parameter s, has the form: 1/year.

Taking into account the main task - the protection of the population, it is usually considered a negative event as a degree of danger to human life.

The probability of an emergency situation occurring p (the frequency of an accident or disaster) is determined using hazard zone maps or statistical data.

The potential damage from an emergency situation is determined taking into account the probabilistic nature of the processes, such as the mathematical expectation of damage M(U).

Given the occurrence of an emergency situation, the probability of an unpleasant event P can be determined using the mathematical expectation of damage to elements of a settlement or population:

$$P=MVU; P = M_N N ,$$

M(U) – mathematical expectation of damage to elements of a populated area; V – number of elements in a populated area (buildings, structures, utilities, etc.); M(N) – mathematical expectation of population losses; N – total population.

Total damage is the sum of direct and indirect damage. Total damage is determined at a certain point in time and is intermediate compared to total damage that will be quantified over a long period of time. The need to take into account the time-distributed or remote manifestations of damage is especially important for emergencies associated with the impact on environmental components or exposure to radioactive materials. Thus, the duration of the manifestation of damage from an accident at a nuclear power plant can reach 100 years.

The total economic damage accompanying an emergency, based on the above, can be determined as the sum of direct economic damage and indirect economic damage.

The calculated dependencies are presented by the formula:

$$U = U^p + AU^k,$$

Here, A – coefficient of reduction of costs at different times (discount coefficient);

U – economic damage from emergencies; U^p – direct economic damage; $U^к$ – indirect economic damage.

Anthropogenic impact on groundwater in the areas of development and exploitation of oil and gas fields has become especially noticeable in recent times due to the intensive technogenic impact of drilling and exploitation processes. At the same time, the most negative impact on groundwater and subsurface waters is associated with the well construction processes. The main reasons for the penetration of pollutants are the low quality of the waterproofing of slag pits and the discrepancy between their volumes and the volumes of waste generated, mainly liquid waste, due to their high accumulation capacity and mobility. It should be noted that fresh groundwater used for drinking, domestic and technical purposes and relatively shallow water under pressure are more susceptible to pollution.

Fresh groundwater is concentrated mainly in the upper part of the earth's crust (in the pedosphere), in the zone of active water exchange at a depth of up to 150-200 m, rarely deeper; below, in the zone of slow groundwater flow, there are waters of increased mineralization.

Many natural and technogenic factors affect the change in the natural chemical composition of fresh groundwater, the main of which are the physicochemical properties and composition of polluted wastewater and its movement from the feeding zones to the discharge areas or its physicochemical interaction with host rocks of various composition and structure during the subsidence of the aquifer. The penetration of pollutants into aquifers occurs as a result of the process of leaching of wastewater through low-permeability layers and lithological windows, the attraction of river flows, irrigation systems, etc. In addition, the nature of pollution depends on climatic conditions, the nature of soil cover and vegetation, its relief, density, and the hydrographic network.

The entry of pollutants contained in wastewater into groundwater, first of all, leads to a change in the oxidation-reduction state in the infiltration area; this leads, in particular, to an increase in the concentration of iron, calcium, and magnesium sulfates in water as a result of the oxidation of finely dispersed pyrite contained in the rocks.

In peaty and swampy areas, along with the decrease in groundwater levels, organic matter in rocks decomposes, which, as a result of the enrichment of water with organic matter and carbon dioxide, leads to an increase in the amount of nitrogen-containing substances extracted from rocks and iron in water (Gabibov, Gabibova, 2015, pp. 91-94).

Various organic substances that leach into aquifers from waste stimulate the intensive growth and activity of microorganisms in the aquifer, which leads to a further deterioration in water quality.

Local and regional groundwater pollution differs in terms of the scale of impact on aquifers.

Under the local source of pollution (sludge pits), a groundwater contamination area is formed, which is very diverse in terms of shape and size in plan, as well as in terms of penetration into the aquifer and depends, firstly, on the intensity and nature of the ingress of the pollutant (permanent, periodic), on its chemical composition, density of the polluted water and its secondary filtration, secondly, on the hydrorheological conditions of the area from the pollutants - the lithological structure, the hydrogeological parameters of the aeration zone and the aquifer, the direction and speed of movement of groundwater; thirdly, on the nature of the manifestation of the processes of physicochemical interaction between the polluting components and groundwater and rocks. With the multicomponent composition of filtered polluted wastewater (drilling wastewater), a complex contamination area is formed.

The aggregate acquires a regional character under the influence of numerous local sources, which determine the territorial nature of pollution. Such pollution is characteristic of large oil and gas fields, especially for intensive drilling networks. The main source of groundwater pollution is industrial and technological drilling waste and sludge pits, which are products of well development. The cause of pollution should be considered, first of all, the poor waterproofing of the bottom and walls of the pits, especially those built in permeable rocks. Studies have shown that pollutants penetrate the soil with a soil filtration coefficient of more than 105 cm/s. Groundwater, in general, is better protected from pollution than surface waters, since the aquifer is covered with a more or less thick layer of soil and rock. However, if the cover layer is permeable and has a small thickness, then polluted water seeping from the surface quickly penetrates the aquifer and pollutes it. Only when impermeable rocks are above the aquifer can it be protected from pollution (Kurchenko, 2007, pp. 138-145).

Groundwater not covered by impermeable rocks is usually less protected than the main horizons of confined groundwater and usually receives the main part of the pollutants that seep from the surface. Pollutants then penetrate from groundwater at low pressure into deeper confined and unconfined horizons - through lithological windows in aquifers, during flow from separate horizons with low permeability, through the annular gap of wells due to poor-quality cementing, etc (Gabibov, Amrakhov, Odzhagov, 2011, pp. 39-43).

The degree of natural protection of groundwater from surface pollution depends on factors that determine the possibility, speed and time of seepage of pollutants from the surface into the aquifer. Such factors include: thickness, permeability and active porosity of the overlying rocks;

the value of the difference in levels (pressures) between the contaminated and groundwater of the aquifer in question, taking into account the decrease in water level during the operation of the water intake facility; type and chemical composition of pollutants, intensity and nature of their penetration into groundwater, physicochemical, especially sorption, properties of overlying rocks and pollutants, determining the possibility of complete or partial absorption of pollutants of a certain composition or their transformation into a harmless state.

When assessing the protective capacity of clay and clayey rocks located above the used aquifer, it should be taken into account that in the aeration zone, clays often have vertical macroporosity and increased water permeability due to the presence of cracks and drying macropores formed as a result of the development of plant roots and shrinkage during alternating wetting and drying. As the depth of formation of clayey rocks increases, their porosity and water permeability decrease. At great depths, in calm tectonic conditions, clayey rocks are characterized by a very low filtration coefficient (<10-8 m/day) and are therefore practically water-resistant.

The diversity of geological and hydrogeological conditions, the composition and structure of overlying rocks, as well as the characteristics of individual types of pollution (microbiological, chemical) determine large differences in the natural protection levels of groundwater (Guignet, Walsh, & Northcutt, 2016, pp. 10-25).

When it comes to the issues of protecting groundwater from pollution during well drilling, it is necessary to assess the degree of their natural protection.

Protected waters include pressurized and non-pressurized interlayer waters that have a continuous impermeable roof covering in the area under consideration and that have not been recharged here either in natural or disturbed conditions, and are recharged from groundwater, rivers and reservoirs through separating layers or hydrogeological windows.

Insufficiently protected groundwater includes groundwater recharged in the distribution zone, as well as pressurized and non-pressurized interlayer waters that are recharged from upper groundwater, rivers and reservoirs with direct hydraulic connection through separating layers or hydrogeological windows.

The most negative pollutants of groundwater and groundwater are oil and oil products. Oil and most oil products are immiscible with water, their solubility is relatively low. For example, for liquid paraffins and naphthenic hydrocarbons, it is 40-150 mg/l, which is many times higher than the MAC. The solubility of aromatic hydrocarbons is higher and reaches 500 mg/l for toluene and 1800 mg/l for benzene (Morris, Lawrence, & Chilton, 2013, pp. 62-85).

With a small amount of dispersed petroleum products, they remain in the aeration zone, cover the surface of grains and cracks in the rock, and when they reach the capillary fringes, they spread horizontally to a certain distance. In this case, groundwater contamination with dissolved hydrocarbons occurs as a result of washing out the rocks of the aeration zone by atmospheric precipitation. Seasonal fluctuations in the surface of groundwater slightly change the height of petroleum products concentrated in the capillary fringe, which increases the size of the contaminated part of the rocks in the aeration zone. The movement of petroleum products through the aeration zone is accompanied by their partial stratification, adsorption on rocks, biochemical decomposition and evaporation. With a large number of penetrated petroleum products, during vertical infiltration, they fill the entire aeration zone, capillary fringes and spread to the surface of groundwater in the form of a layer of various thicknesses.

Emulsified and dissolved hydrocarbons migrate in the aquifer with groundwater flow in the direction of groundwater flow. Lenses of petroleum products can also move, the speed of their spread is usually lower than the speed of groundwater flow and depends on the physical properties of petroleum products (viscosity, density, surface tension) and water-borne samples (granulometric composition, fracture, permeability, water content). At high flow rates, the formation of aggregates from asphaltene particles occurs as a result of turbulent diffusion and turbulent transport. These structures are unstable and can break up into individual particles as a result of the fragmentation of aggregates under the influence of shear flow, and as the shear rate increases, the equilibrium shifts towards the formation of individual particles. At high flow rates, the formation of aggregates from asphaltene particles occurs as a result of turbulent diffusion and turbulent transport. These structures are unstable and can break up into individual particles as a result of the fragmentation of aggregates under the influence of shear flow, and as the shear rate increases, the equilibrium shifts towards the formation of individual particles (Kelbaliyev, Rzayev, Rasulov, Suleimanov, Guseynova, pp. 246-250).

During anaerobic biochemical reactions in the aquifer, oxidation of petroleum products occurs, which is accompanied by the development of a sharply expressed reducing environment. Under these conditions, dissolved oxygen and nitrates disappear from the water and the amount of sulfates decreases, but ammonium, hydrogen sulfide appears, the amount of iron, manganese and free carbon dioxide increases (Guignet, Walsh, & Northcutt, 2016, pp. 10-25).

The ingress of organic substances into wastewater used in the technological stages of well construction also causes pollution of groundwater and subsurface waters. Such pollutants undergo biodegradation with the formation of harmless substances under the influence of the microbiological factor of the soil environment. However, with a large influx of organic substances, the biological activity of microorganisms is so enhanced that this leads to a change in the oxidation-reduction conditions, composition and quality of groundwater and subsurface waters.

References

1. Blanke, J., Strzepek, M., & Vargas, E. (2022). *The economics of groundwater in times of climate change*.
2. Burlaka, V. A., Burlaka, N. V., & Ishchenko, E. P. (2016). *Method of processing oil sludge and cleaning oil-contaminated soils* (Patent No. 2602179). Russian Federation.
3. Christian von Hirschhausen, Holz, F., & Kemfert, C. (2022). *The economics of groundwater in times of climate change*.
4. Gabibov, F. G., Amrakhov, A. T., Odzhagov, G. O., & Bayat, H. R. (2011). Expert methods for assessing the probabilities of rare negative events in complex geotechnical and engineering-geoecological objects. In *Geotechnical problems of new construction and reconstruction* (pp. 39–43). Novosibirsk: NGASU (Sibstrin).
5. Gabibov, F. G., & Gabibova, L. F. (2015). On the use of oil refining waste and oil products in construction. In *Prospects for the Development of Construction Materials Production in Azerbaijan* (pp. 91–94). Baku: Azerbaijan University of Architecture and Civil Engineering.
6. Guignet, D., Walsh, P. J., & Northcutt, R. (2016). Impacts of ground water contamination on property values: Agricultural run-off and private wells.
7. Hardisty, P. E. (2010). *The economics of groundwater remediation and protection*.
8. Imanbekov, S. T., Bozov, K. D., Ordobaev, B. S., & Abdykeeva, Sh. S. (2013). *Assessment of economic damage from the extreme situations* (pp. 65–95). Moscow.
9. Kelbaliyev, G. I., Rzayev, A. G., Rasulov, S. R., Suleimanov, G. Z., & Guseynova, L. V. (2015). Processes of aggregation and coagulation of asphaltene particles in oil and oil emulsion (pp. 246–250).
10. Kurchenko, A. B. (2007). *Method of cleaning swampy bogs and marshy areas from oil and oil products* (Patent No. 2310038). Russian Federation.
11. Lobacheva, G. K., Pavlichenko, N. V., Kurin, A. A., Klopova, T. Yu., Chadov, O. P., Vartanov, R. R., Karpov, A. V., & Filippova, A. I. (2014). *Composition for cleaning and reclamation of soil from oil pollution* (Patent No. 2556062). Russian Federation.
12. Morris, B. L., Lawrence, A. R., & Chilton, P. J. (2013). *Groundwater and its susceptibility to degradation: A global assessment of the problem and options for management*. UNEP.

13. Orellana-Macías, J. M., & Perles Roselló, M. J. (2022). Assessment of risk and social impact on groundwater pollution by nitrates: Implementation in the Gallocanta Groundwater Body (NE Spain).
14. Orellana-Macías, J. M., & Perles Roselló, M. J. (2022). Assessment of risk and social impact on groundwater pollution by nitrates: Implementation in the Gallocanta Groundwater Body.
15. Stephen, F., Chilton, P., Moench, M., Cardy, F., & Schiffler, M. (2010). *Groundwater quality protection: A guide for water utilities, municipal authorities, and environment agencies*.
16. United Nations Environment Programme (UNEP). (2010). *Protecting groundwater for health: Managing the quality of drinking-water sources*.

Received: 06.02.2025
Accepted: 20.05.2025