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ON ONE NUMERICAL 3D MODEL OF SOIL POLLUTION BY OIL UNDER HIGH PRESSURE

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At present there exist the following routes of oil and gas transportation via the territory of Georgia: Baku-Supsa (BS) pipeline; Western Export Pipeline (WEP); Baku-Tbilisi-Ceyhan (BTC) oil pipeline (BTC, transporting up to 50 million tons of row oil from the expanded Sangachal terminal near Baku through Georgia to Turkey), Vladikavkaz-Erevan (VE) gas pipeline. New pipeline system - South Caucasus pipeline (SCP) - is under construction and will convey 7.3 billion cubic meters of gas per year from Sangachal to Turkey via Georgia [1-3].

According to data of European transit countries besides of great political and economical benefits the transit of strategic materials causes great losses to the ecological situation in these countries. Besides of the ordinary pollution of environment, there can arise non-ordinary situations as well - accidents on pipes, depositories, which are followed by sharp deterioration of the ecological situation in the neighboring regions [3,4].

As foreign practice of pipeline exploitation shows, the main reason of crashes and spillages (and fires as a consequence) is destruction of pipes as a result of corrosion, defects of welding, natural phenomena and so on (including terrorist attacks and sabotage).

The probability of crashes for pipeline transport rises with the age of oil pipelines in service, and with the extent of their network. For example, in the table 1 there is represented some data for US and West Europe pipeline networks. Table 1.

The probability of crashes for pipeline network

Place	Length of pipeline network	Occurred ruptures	Date
The USA	250.000 km	250	Every year in 1973-1983
West Europe	16.000 km	10-15	Every year

As it can be seen from the Tab. 1, on the US pipeline network with a total length of about 250,000 km occurred 250 ruptures, which are accompanied by spillage of the transferred products, every year in 1973 - 1983. In West Europe it has been found, that 10 - 15 leakages occur every year in a pipeline network of around 16,000 km length resulting in loss of 0.001% of transferred products.

Now we will try to present a short review on environmental baseline for the territory of Georgia as an example of WEP pipeline and BTC pipeline route.

Western Export Pipeline Route

As known, the WEP fulfils a transportation of oil by pipeline from the expanded Sangachal terminal near Baku in Azerbaijan, through Georgia to Supsa terminal, which is located between Poti and Batumi. From 1991 to 1993 the WEP pipeline was almost destroyed on the territory of Georgia (caused by terrorism and sabotage). Almost the whole transported oil (pipeline's diameter was 580 mm) was spilled on the ground and into the rivers.

Baku-Tbilisi-Ceyhan Pipeline Route

Pipeline trenches will be excavated to a nominal depth of 2.2m. This will vary according to the severity of the terrain and local topography in order to ensure, that the pipeline is buried with a minimum depth of cover of 1m in soil and 0.6m in rock. Deeper installation will be required at river, road, rail and other crossings.

The proposed pipeline route crosses a multitude of rivers and surface water flows. Namely, six major rivers cross the route on the territory of Georgia. It is necessary to carry out additional protective measures for the places, where the oil-pipeline crosses the rivers. Namely, under the rivers, BTC pipeline will be buried deeper in the soil (3-4 meters instead of nominal 2,2 meters) [1,2]. However, mountain rivers are characterized by the periodical floods. In Georgia there are frequent cases, when flooded river undermines bridges and bases. So eventually can take place erosion of the soil, decrease of the protective layer of the soil to the minimum, damage of the protective coverage of the pipeline by the broken stones, development of the corrosion processes and leakage of the oil. In addition, if we take into account that Georgia is placed in the seismically active zone, it increases the possibility of getting of the spilled oil in the rivers.

Ground water along the route is also abundant and generally of high quality. The eastern part of the proposed route is characterized by a shallow water table and by localized poor quality, owing to either high salinity, biological and chemical contamination. The central part of the route is characterized by drinking water used by the local population as the main source of water supply. The western part of the route crosses the famous therapeutic water associated with the Borjomi springs. So that it is necessary: to design a new high-quality river pollution models; to develop new algorithms and means of the control and detection of emergency places on pipelines according to polluted rivers crossing the way of these pipelines; to develop an automated monitoring system of pollution of the river in area of the pipeline and identify a source of its pollution.

In order to study transformation, filtration and diffraction of spilled oil to soil we investigated a problem when a big amount of oil is spilled in the ground. As BTC pipeline trenches are excavated to a normal depth of 2,2m (minimum depth is 1m in soil and 0,6m in rock), we suppose that leakages occur through damage of the pipeline in the ground under high pressure. In this case we consider the following types of leakage: a) point source; b) line source; c) area source.

Remark: We have studied the above-mentioned problem for different kinds of oil and oil products. The calculations have been performed for four main types of soil.

According to [5-13] the process of oil-products spreading in soil can be described by the following equation:

$$\frac{\partial W}{\partial t} = \frac{\partial}{\partial x}\left(\frac{K(W)}{\gamma}\frac{\partial P}{\partial W}\frac{\partial W}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{K(W)}{\gamma}\frac{\partial P}{\partial W}\frac{\partial W}{\partial y}\right)$$

$$+\frac{\partial}{\partial z}\left(\frac{K(W)}{\gamma}\frac{\partial P}{\partial W}\frac{\partial W}{\partial z}\right)+\frac{\partial K(W)}{\partial z}+Q, \qquad (1)$$

where t- is time; an axis Ox is directed along the earth surface; an axis Oz is directed vertically down; W is a saturation of the soil; $K(W)$ is a coefficient of filtration; P is a pressure; $\gamma = g\rho$ is a unit weight of liquid. ρ is density; g is gravitational acceleration; Q is external source of oil.

It is known that generally filtration of the liquid to soil has the following form [14]:

$$\Omega = f(R) \qquad or \qquad R = \varphi(\Omega) \qquad (2)$$

where $R = \frac{W\rho\sqrt{k}}{\mu}$ is number of Reinolds; $\Omega = \frac{\rho k^{\frac{3}{2}}}{\mu^2}\frac{P}{h}$-is number of filtration.

For turbulence environment we have:

$$\sigma = \frac{1}{B_1}R^{-1} \qquad or \qquad \Omega = B_1 R^2, \qquad (3)$$

where $\sigma = \frac{R}{\Omega}$ is a derivative number of filtration.

In the presence of high pressure in soils it is necessary to take into account the change of porosity by compression of soil applying the following expression:

$$m = m_0 + \beta p(P - P_0), \qquad (4)$$

where P is pressure, m is porosity of soil under high pressure, m_0 and P_0 are porosity and pressure, respectively, under normal conditions. $\beta p = \beta_0/P$, β_0 is a constant and its value is $\beta_0 = 1.5 * 10^{-5}$.

Equation of continuity with (4) will take the following form:

$$\beta_0\frac{\partial P}{\partial t} = \frac{\partial}{\partial x}\left(\frac{K(m)}{\mu}\frac{\partial P}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{K(m)}{\gamma}\frac{\partial P}{\partial y}\right)$$

$$+\frac{\partial}{\partial z}\left(\frac{K(m)}{\gamma}\left(\frac{\partial P}{\partial z}-\rho g\right)\right)-\frac{\partial K(m)}{\partial z}+Q. \qquad (5)$$

We have investigated the following types of leakage of oil under high pressure: a) point source; b) line source; c) area source. For the sake of brevity we are only discussing results of numerical calculations obtained for a point source. The solutions show a complex behavior. Calculations have shown that. The vertical distribution of oil usually exhibits a single maximum of concentration, but there are also cases where two or several maximal of the concentration are found. In particular, this happens after leaking from the point source has been stopped.

Also numerical calculations have shown that the characteristics of oil infiltration into soils under high pressure are qualitatively similar for the all considered soils. Absorption of oil in the soil is much more intensive than penetration of oil to deeper layers and lateral spreading. Oil infiltration into BBP soils was found to be most intensive, whereas it was least intensive in GBS soils.

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