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Assessment of heavy metals pollution level in sludge pit

I I Avdeeva[1], I I Romantsov[1], S V Romanenko[1,2] and A V Nekhorosheva[3]

[1] National Research Tomsk Polytechnic University, 30, Lenin av., Tomsk, 634050, Russia
[2] Siberian State Medical University, Moskovsky trakt 2, Tomsk, 634050, Russia
[3] Ugra State University, 60, Kievskaya st., Khanty-Mansiysk, 628007, Russia

Abstract. The spatial analysis data of the concentration fields of lead (Pb) and cadmium (Cd) is presented. The depth-areal heterogeneities of the metals distribution in the sludge pit of the well cluster within the territory of the Khanty-Mansi Autonomous Okrug-Yugra are revealed. The highest concentrations of heavy metals were observed in the places where drilling waste was discharged into a sludge pit through a sludge pipeline. The concentrations gradually decreased with distance from the discharge points.

1. Introduction

A process of drilling oil and gas wells is accompanied with the emanation of the great amount of toxic waste, which has a negative impact on the environment. The greatest danger caused to the natural environment is posed by production and technological drilling waste, which is accumulated and stored directly on the territory of the wells.

One of the most common ways of accumulating and storing drilling waste is sludge pits of different constructions [1–5]. These sludge pits must be segregated at the end of the wells construction. However, due to the imperfection of the technology of waste elimination, it is not always possible to carry out such work in a timely and high-quality manner.

The main ways of penetration of drilling waste into hydro- and lithosphere objects are filtration into soils and leaks in violation of landslides and barn walls, as well as during floods when it rains and during intense snowmelt.

As a rule, waste from field drilling of wells belongs to hazard class IV (low-hazard), and that containing oil and significant impurities of technological reagents – to hazard class III (moderately dangerous). In addition to organic compounds of petroleum origin, the composition of drilling mud includes heavy metals: cadmium, lead, zinc, copper, cobalt, arsenic, titanium, chromium, nickel, tungsten, boron and others. Their content can vary from minimal to high concentrations [6–12].

Due to the processes of adsorption on suspended particles and their subsequent sedimentation, heavy metals have an active ability to accumulate in bottom sediments, as a result of which the content of trace elements in them exceeds the concentration in water by several orders of magnitude. Also, when the pH changes, various complexing substances are present, desorption of metals occurs and their transition in the dissolved state into the water takes place, that is, bottom sediments turn into sources of secondary pollution of water objects [13, 14].

The aim of this work was to conduct analytical chemical studies of drilling sludge for the content of lead and cadmium, as well as to study of their distribution over the area and depth of the sludge pit.

The great interest in the lead is stimulated by its priority position among the main pollutants of the environment [15]. The metal is toxic to microorganisms, plants, animals and people.

Cadmium is well known as the toxic element. The main problems of the humankind are connected with Cd: the result of the technological pollution of the environment and its toxicity for living organisms even at a low concentration. Because of its chemical features, this metal keeps its mobility in the soil; as a result, it penetrates into many agricultural plants. Because of its, phytotoxicity and ability to accumulate in the plants, cadmium takes the first place among heavy metals (Cd > Cu > Zn > Pb) [15].

2. Materials and methods

A cluster of wells on the territory of a typical field of KhMAO-Yugra was chosen as the place of selection of drilling sludge. The sampling of sludge samples from the pit was carried out in the winter period. The winter period was chosen in order to be able to fully carry out sampling over the entire area of the pit from different depths [13].

The sizes of the slime are as follows: length – 90 m, width – 50 m. The full depth is 350 cm. The thickness of drilling is 280–290 cm, the width of ice is 70 cm, and the depth of slime in the time of research is 80–150 cm from one side and 80–90 cm – from the other side.

While drilling, the slime is transported on the slime transporter approximately at 3–6 meters away from the diking of the pit, at 5–7 meters high from the bottom of the pit.

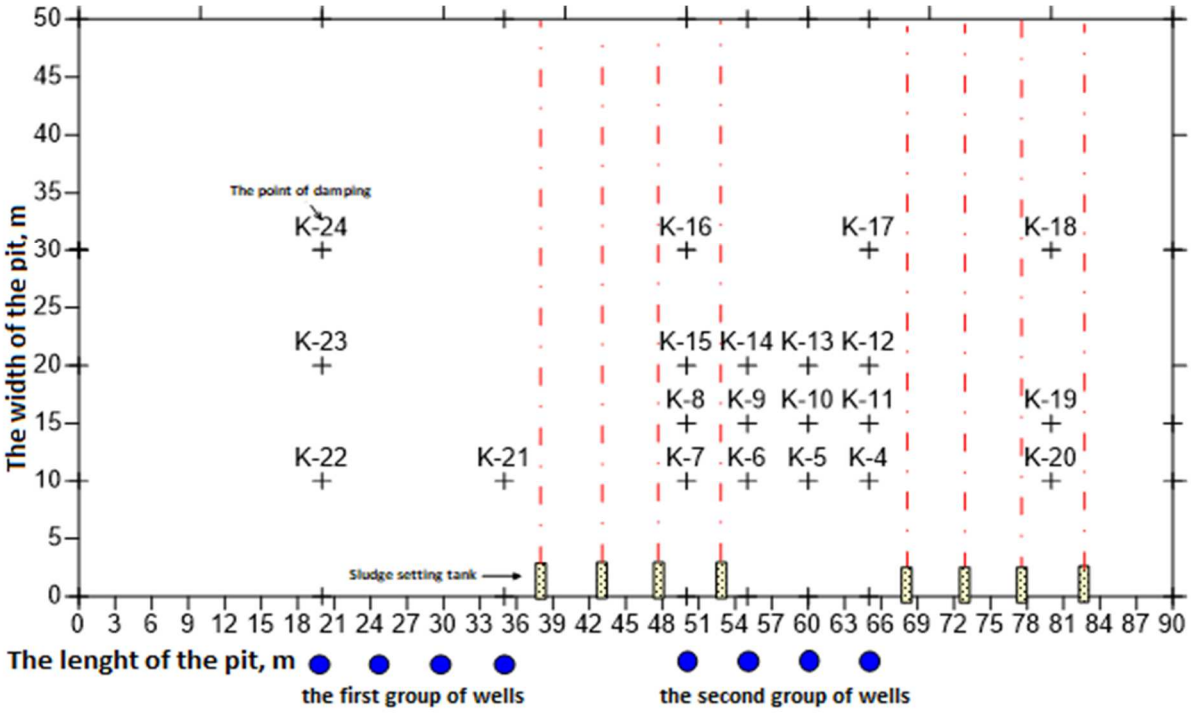

Figure 1. The scheme of the selection of the drilling slime in the first section of the pit, oil cluster No. 12

On the deposit the pit cluster consists of 3 sections. The production oil wells are drilled in groups of four wells at a distance of 5 meters between wells and 15 meters between groups. The slime transporter while drilling is moved to the right from the center of the well by about 18 meters. The storage of the slime is on the right side of the pit. The first point of disposal waste of the 1-st group is the first well being at the distance of 38 meters from the left side of the pit (Figure 1).

The slime sample was taken by the sampling apparatus of the own construction. The construction of the sampling apparatus helped to take samples and divided them according to their depths, keeping

the natural structure and its humidity. In general, in the first section of pit, we took 152 samples of the slime from the 21 points of drilling. The general scheme of taking slime samples from different depths is given in figure 2.

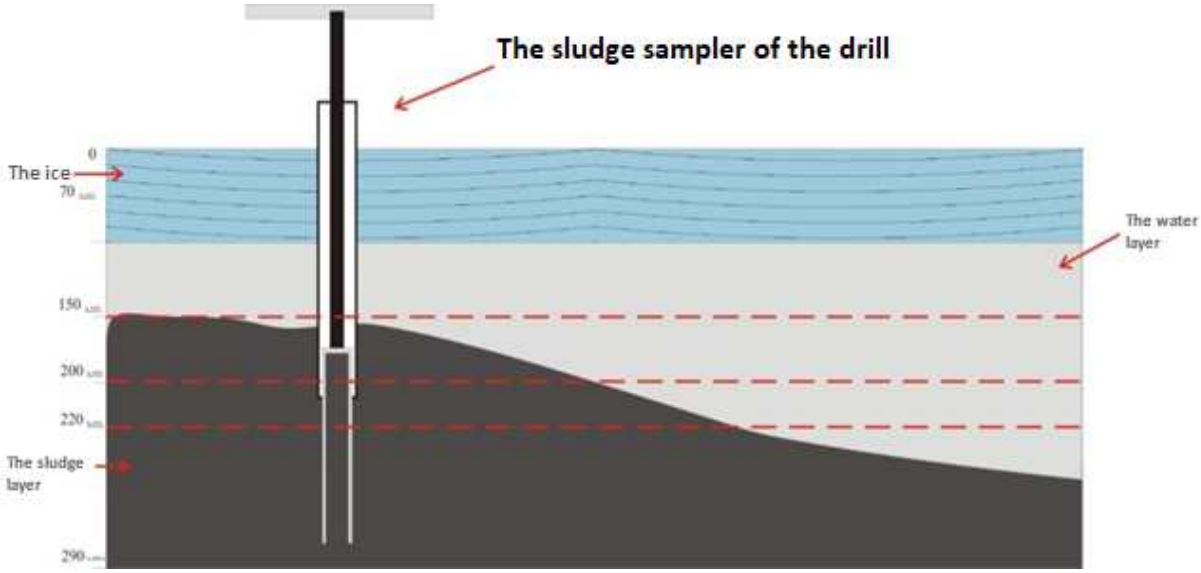

Figure 2. The scheme of taking sludge samples from different depths of the pit.

The determination of Pb and Cd in the testing samplers was done using the atomic-emission spectrometer with inductive connected plasma by means of the Optima 2000 DV (Perkin Elmer Instruments, USA).

3. Results and discussion

The results of the quantitative chemical analysis of the Cd, Pb in the slime samplers are given in table 1, and they present the concentration difference in metal distribution both throughout the square of the pit and the depth.

The main amount of Pb is concentrated in the upper and middle layers in the places of the slime dumping into the pit. It is presented in figure 3 in the fields of the concentration in these layers, which is 14–20 times.

The mentioned research showed practically uniformity in containing Cd, so in the upper 2 layers, the difference in the concentration throughout the total square of the pit is less than two times, in the lower – a little bit more than 2 times (figure 4).

The pH solubility depends on the pH and decreases in the alkaline solutions. The higher ability to the complex formation and the absorption on the hydroxide metals and clay particles is typical for Pb [15].

The low-power ability to the complex formation and the sorption on the weighted particles lead to the migration of the bigger Cd part in the dissolution condition, but, while pH increases, the bigger amount of free ion form complexes is absorbed on the weighted particles.

For further analysis, some weighted mean elements concentration in the layers was taken on average from the verticals shown in table 2, where average means about the pit were taken for their comparison in MPC and APC, according to HS 2.1.7.2041-06 and HS 2.1.7.2042-06 in general. The MPC means prevailed according to the table.

Table 1. The concentration of Cd and Pb in slime samplers.

The code of the point	Interval from the surface, cm	Pb, mg/kg	Cd, mg/kg
K-4	150–200	14.3	0.8
K-4	200–250	14.6	0.72
K-4	250–290	16.6	0.58
K-7	150–200	19.2	0.89
K-7	200–250	136.4	1.19
K-7	250–290	42	0.55
K-8	150–200	158.7	1.04
K-8	200–250	123.1	1.22
K-8	250–290	20.5	0.47
K-12	150–200	61.7	0.96
K-12	200–250	75.6	1.03
K-12	250–290	43.8	0.67
K-15	200–250	58.5	0.94
K-15	250–290	37.2	1.06
K-16	200–250	28.6	0.82
K-16	250–290	40.4	0.92
K-17	150–200	47.7	0.98
K-17	200–250	49.8	0.99
K-17	250–290	34.2	1.05
K-18	150–200	36.8	1.04
K-18	200–250	43.4	1.19
K-18	250–290	16.2	0.94
K-20	150–200	189.1	1
K-20	200–250	20.6	0.92
K-20	250–290	23.4	0.77
K-22	250–290	39.8	0.52
K-23	200–250	45.8	0.83
K-23	250–290	31	0.65
K-24	200–250	20.3	0.85
K-24	250–290	24.2	0.58

Table 2. The comparison of the Cd, Pb proportion in MPC and APC.

The code of the point	K-4	K-7	K-8	K-12	K-15	K-16	K-17	K-18	K-20	K-22	K-23	K-24	Average	MPC of the mobile form, mg/kg	APC of the general content
Pb, mg/kg	15.2	16.9	100.8	60.4	47.9	34.5	43.9	32.1	77.7	39.8	38.4	22.3	50.5	6.0	130.0
Cd, mg/kg	0.7	0.9	0.9	0.9	1.0	0.9	1.0	1.1	0.9	0.5	0.7	0.7	0.9		2.0

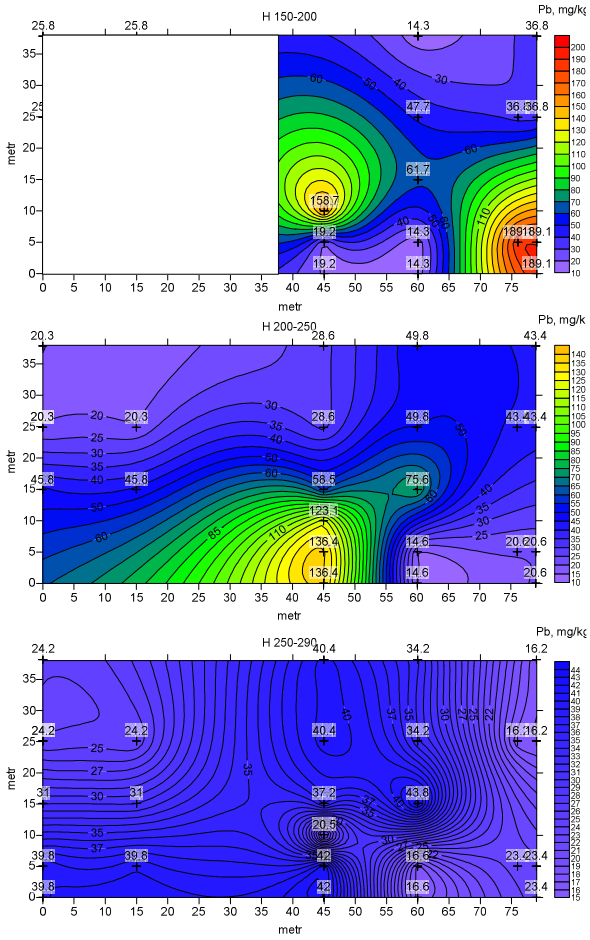

Figure 3. The field layers of the Pb concentration in the pit under research.

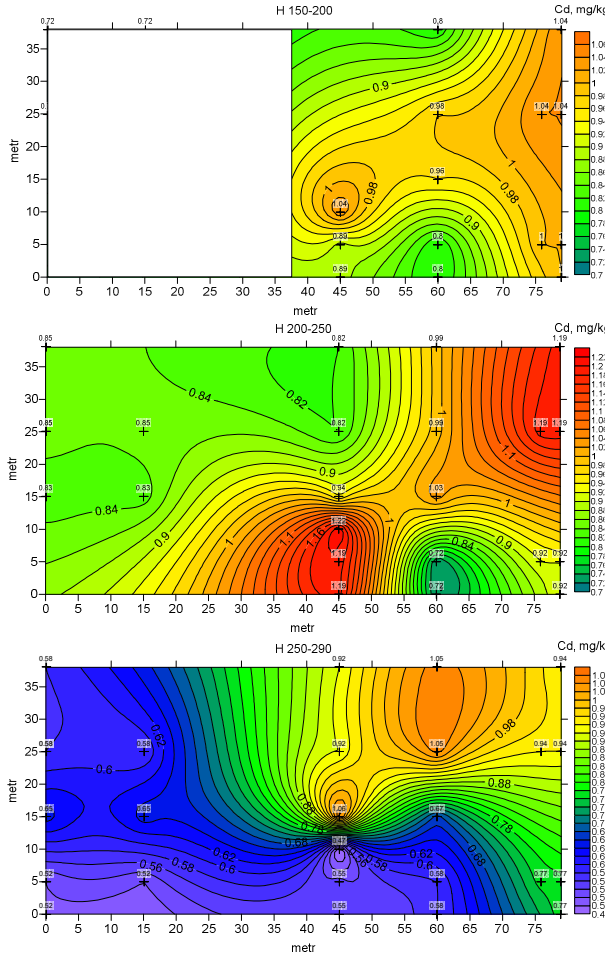

Figure 4. The field layers of the Cd concentration in the pit under research.

4. Conclusion

The comparative assessment of the measured data of the metals in the pit was done according to HS 2.1.7.2041-06 and HS 2.1.7.2042-06

On the basis of the research we made a preliminary conclusion about the level of contamination of sludge pits with heavy metals and other compounds. Their distribution throughout the territories of the barn was also studied. The maximum concentration was observed in the field of drilling waste discharges into a sludge pit with a gradual decrease in concentrations in remote locations from the discharge point.

This information can be used for the overall assessment and exploitation of the most productive and optimal methods in the conservation and detoxication of sludge pits.

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