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Determination of drill cuttings hazard class and toxicity by means of phytotesting

Dr. Pasko OA, PhD. Posternak TS
National Research Tomsk Polytechnic University, Institute of National Resources, Department of General Geology and Land Management, Tomsk, Russia

Abstract* — With the use of test-object experimental studies were conducted for the integral assessment of toxic influence of drill cuttings on living systems. It was studied how the extracts of substrata influence upon the length of the oats germs' roots on the basis of the following structure of drill cuttings: native; drill cuttings + peat 1:1, drill cuttings + sand 1:1; drill cuttings + peat + sand 1:1:1 with the following dilutions 1:1; 1:10; 1:25; 1:50; 1:100. Both stimulating and inhibiting effects were studied. Maximum negative phytoeffect (-30%) was registered once under the influence of 100% drill cuttings extract (50-fold dilution). Addition of sand to drill cuttings decreased the inhibition; addition of peat stimulated the development of the test object (10-fold dilution). The combined effect of extracts of drill cuttings, peat and sand led to the appearance of maximum and minimum on the "Dose-effect" curve. It was confirmed to assign the 4th class of hazard to the extract of drill cuttings.

***Index Terms*—drill cuttings, technozem, biotesting, toxicity, class of hazard.**

I. INTRODUCTION

In Russian Federation the enterprises of oil-producing and oil-processing industries present the most important source of the environmental pollution. Oil, oil products, oil sludge and drill cuttings are potentially dangerous. In particular, drill cuttings due to complex mineral structure, content of oil, oil products and poisonous polymeric additives can out of control influence negatively upon agro- and biocoenosis. The issue is worsened by the increasing oil and gas extraction. Only on the territory of Western Siberia, where more than 50% of Russian oil is being extracted, more than 100 thousand tons of drill cuttings appear annually. Oil and drilling waste products remain in unliquidated earthen pits. There are 68 kilograms of polluting organics equal to 1m^3 of waste products (apart from oil and oil products and mineral pollutants). Nitrates, lead, cadmium are being found out in snow and soils at up to 2 kilometers' distance from drill sites [1]-[4].

The nature and the consequences of the pollution produced by drill cuttings on the objects of natural environment have been little studied. They can have various toxicity which forces to conduct a complex study of their influence on environment. The quality of soil as a rule is being estimated regarding the data of chemical analysis which ignores synergetic and antagonistic effects (the whole complex of pollutants used in drilling technology, peculiarities of geological structure of the territory and climate) and doesn't characterize drill cuttings toxicity for the organisms. Moreover the number of pollutants is much bigger than the number of elaborated methods of analysis [5]-[9]. It leads to the necessity to use the method of biotesting as a subsidiary tool in the assessment of soil toxicity [7]. It gives an opportunity to make an integral estimation of the degree and direction of the influence produced by the studied factor on biocoenosis [8].

The topicality of the issue, its insufficient exploration degree, theoretical and practical significance determined the choice of the theme, object and methods of investigation.

The aim of the research was to make an integral estimation of drill cuttings toxicity and determinate the class of hazard on the basis of biotesting results.
To reach the aim the following tasks were set:

1. To define the parameters of phytotoxicity;
2. To find an optimal correlation of substratum components on the basis of drill cuttings (for the further organization of recultivating works on the oil polluted territories).

II. OBJECTS, MATERIALS AND METHODS OF INVESTIGATION

Drill cuttings and the extracts of substrata on the basis of drill cuttings, having various degree of dilution was the object of research.

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The germs of cultivated oats (Avena sativa L., breed Togurchanin) were used as a traditional test-object. The germination was 95% [2].

In the first set of tests the parameters of phytotoxicity were determined by means of consecutive 2-3-fold dilution of drill cuttings. In sterile Petri dishes seeds were placed on the filter paper moistened by distiller, extract or its dilutions, 25 seeds in each Petri dish. Germination temperature was 22^0C. On the 3rd day the percentage of germinating seed was determined (germination energy); on the 7th day the maximum length of the germs' roots was estimated. The measurements were taken with the help of ruler (accuracy up to 1mm). Three-fold replication of the test. In the second set of tests the toxicity of drill cuttings and substrata in different correlations was investigated (variants: "drill cuttings", "drill cuttings + sand", "drill cuttings + peat", "drill cuttings + sand + peat"). The scheme of the experiment is presented in Table I. Three-fold replication of the test. For the statistical data manipulation software STATISTICA was used.

Table I. The scheme of the experiment on the determination of drill cuttings and substrata toxicity

Extract of substrata*				Dilution
Drill cuttings (DC)	DC + sand 50:50	DC + peat 50:50	DC + sand + peat 34:33:33	
				1:1
				1:10
				1:25
				1:50
				1:100

*Note. Control – distiller

The phytotoxic effect was estimated by means of comparison of the test-function ($L_{a)}$ results of control seeds and experiment seeds according to the equation (1):

$$La = \frac{SUM\, L_i}{n} \quad (1)$$

Where

L_i – length of maximum root of each seed, mm;
n – Total number of seeds in a test.
Braking effect was determined according to the equation (2):

$$E_{br} = \frac{L_c - L_t}{L_c} \times 100\ \% \quad (2)$$

Where

E_{br} – braking effect, %;
L_e – average root length of experiment seed, mm;
L_c – average root length of control seed, mm.

Based on the comparison of the results of braking effect in the development of test-objects was made a conclusion about toxicity of samples. Phytotoxic influence was considered proved if the braking (ET) is 20% and more [2].

To determine the class of hazard the quantity ER50 (the dilution of the extract provoking phytoeffect (ET = 50%) was calculated according to the criteria presented in Table II. It was taken into account that waste products are automatically of the 4th class of hazard if toxic effect is registered only under the influence of native extract, morphophysiological reaction of the seeds on the dilution is absent.

Table II. Criteria of waste products hazard according to phytotoxic influence

Classes	1	2	3	4
Hazard	Extremely hazardous	High hazardous	Moderately	Little hazardous

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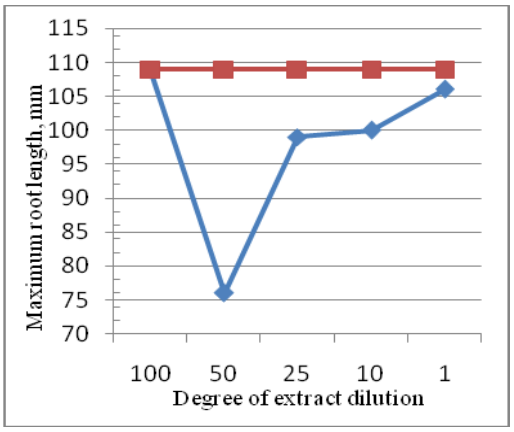
categories			hazardous	
Quantity ER_{50}	$>10^2$	$>10-10^2$	>1-10	≥1

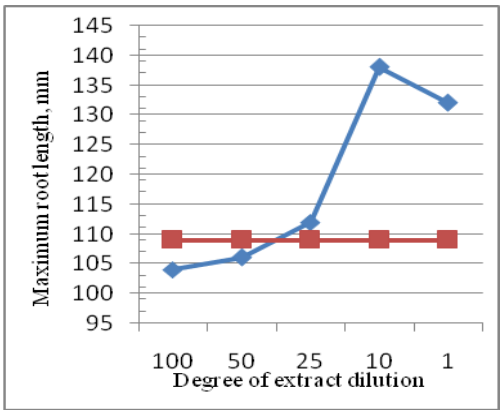
III. RESULTS AND DISCUSSION

The conducted experiments did not reveal reliable differences in the dynamics of seeds germination in different variants. The indices of germination energy which is determined by the percentage of seeds germination on the 3rd day were practically on the same level. Faster germination of the seeds was registered in the variant with peat extract. Moreover the germs visually were thicker. The percentage of the germinated seeds was the following: native extract (variant "drill cuttings") – 93% regarding control seeds, "drill cuttings + sand" – 107%, "drill cuttings + peat" – 106%, "drill cuttings + sand + peat" – 97%. Reliable oppressive influence of technozem extracts on the initial stage of germination was not registered.

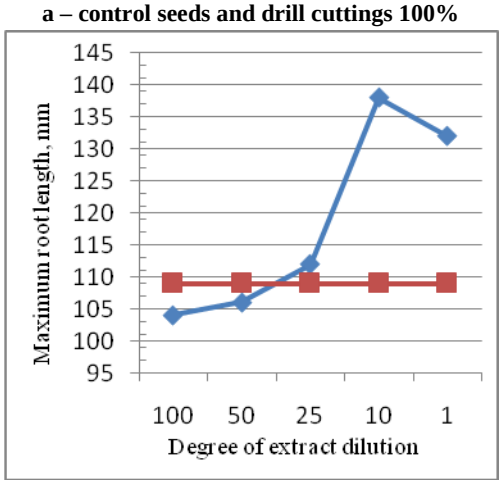
Later on were registered both stimulating and inhibiting effects of technozem extracts and their dilutions on test-object development (Fig). Maximum effect (-30%) was registered once under the influence of 100% drill cuttings extract (50-fold dilution) (Table III). Addition of sand to drill cuttings decreased the inhibition to 13% and shifted the extremum of diagram in the direction of weaker dilution of the extract (10-fold dilution). Addition of peat to drill cuttings stimulated the development of test-object (+28%) the maximum was registered with 10-fold dilution. Combined influence of extracts of drill cuttings, peat and sand led to the appearance of both maximum and minimum on the "Dose-effect" curve. 10% decrease of morphological performance happened with the use of 50-fold dilution (similar to native drill cuttings) stimulation happened with 25-fold dilution.



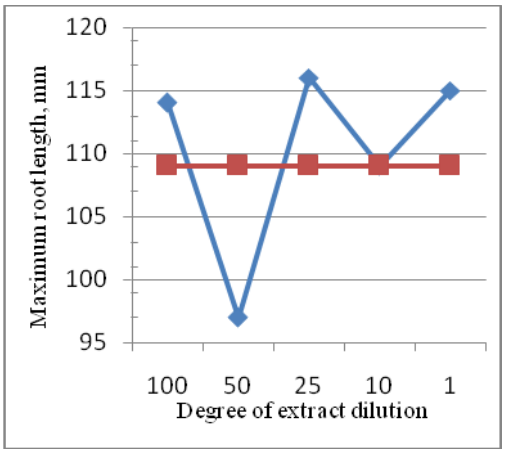
a – control seeds and drill cuttings 100%



b – control seeds and "drill cuttings + peat"



c – control seeds and "drill cuttings + sand



d – control seeds and "drill cuttings + peat + sand"

Fig 1. The influence of various extracts on the basis of drill cuttings on root length of the oat seeds

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Table III. Description of influence produced by 100% drill cuttings extract on the oat seeds

Extract dilution	Average root length,	Average root length,	Phytoeffect,	Test-reaction
Control seeds	109	100	0	Norm
100	109	100	0	Norm
50	76	70	30	Braking effect
25	99	91	9	Norm
10	100	92	8	Norm
1	106	97	3	Norm

The results are explained by various morphophysiological reaction of test-object on used substratum [6], [7]. Peat having acid reaction on the one hand neutralized alkaline medium of drill cuttings, on the other hand it stimulated roots' growth by means of bioactive materials like humates. Sand being chemically neutral could ease negative influence of drill cuttings extract improving filtering properties of the solution.

As far as "Braking effect" was registered only under the influence of native extract of drill cuttings and the seeds were indifferent to various dilutions, composite sample of drill cuttings was given the 4^{th} class of hazard.

IV. CONCLUSION

Drill cuttings of certain dilution have phytotoxicity. Addition of sand and/or peat to drill cuttings changes the nature, force and direction of their influence on bioobjects. Composite sample of drill cuttings DC-1 can be attributed to the 4^{th} class of hazard.

It is necessary to conduct extra research, receive oats seeds from the sprouts cultivated on technozem and determine percentage of their germination to find the most effective mix of technozem on the basis of drill cuttings with the purpose of use on oil polluted lands.

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