The effect of experimental drill fluid on the vital activities of the bivalve mollusk *Mytilus edulis* L.

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Abstract. The effect of two drill fluids on the survival rate and linear growth rate of bivalve mollusks *Mytilus edulis* has been studied. The standard water-based drill fluid includes barite and carboxymethyl cellulose, which are highly toxic substances. The main components of an experimental presumably biodegradable solution are the ground brown alga *Saccharina latissima*, inhabiting the coast of the Barents Sea, and ferrochrome lignosulfonate, which also applies to toxic components. The minimal concentration of a standard drill fluid led to the 100% death after 9 days of exposure; the experimental drill fluid did not affect the mortality of mussels at all. The mollusks exposed to the concentration of 5 and 10 g/L of experimental drill fluid have been characterized by a high relative linear growth. An experimental drill fluid that does not contain barite and carboxymethyl cellulose may be considered safe for marine bivalves; and its components seems to be easily degradable, since some of them may be used as a food source by some detritus-feeding invertebrates

1. Introduction
Currently, the oil and gas industry is faced with technological and environmental problems when operating on the Arctic shelf. The hydrocarbon-based drill fluids containing surfactants, or clay-bentonite fluids, where barite (anhydrous barium sulfate) is used as the main component, are widely used nowadays during the process of drilling, and especially when pumping the wells, but the forming drilling mud is highly toxic for the most of marine organisms [1, 2, 3]. The development of new environmentally friendly substances based on biodegradable components with improved quality characteristics may become a solution. It is known that AMC Company is developing a wide range of drill fluids, including non-toxic, biodegradable components that affect the environment the least [4], similar drill fluids are being developed in Russia [5, 6]. However, the data on the toxicity of such drill fluids, both of Russian origin and from other countries, are scarce, namely, nearly nothing is known about how these substances will manifest in the Arctic.

An experimental drill fluid has been developed at the Murmansk State Technical University, where brown alga *Saccharina latissima* (C. E. Lane, C. Mayes, Druehl & G. W. Saunders) [7], widespread along the Murman Coast of the Barents Sea, was used as biodegradable material. This drill fluid is characterized by a decrease in water loss, an increase in viscosity, as well as a shift in the shear stress upward [7]. Thus, the quality of the experimental drill fluid is higher than that of the standard drill fluids used for drilling on the Arctic shelf. However, it is still necessary to investigate the possible toxic effects of the resulting drill fluid on the aquatic organisms.
The study aims to assess the toxic effect(s) of experimental drill fluid on the survival rate and some other vital characteristics of *Mytilus edulis* in comparison to the standard drill fluid.

2. Materials and Methods

Blue mussels *Mytilus edulis* L. have been used as a convenient model object, since they are active filter-feeding animals, occupying a dominant position on the intertidal and upper sublittoral zones of the Barents Sea and characterized by a significant tolerance range [8]. For the experiment, 128 mussels from the lower littoral zone of the Kola Bay, the Barents Sea (Cape Mishukov, 69.042253, 33.032533) were acclimatized for 2 days at a water temperature of 10 °C and salinity of 30 psu. The shell length, shell width, total weight, and age of each animal have been measured. The age of the mollusk was determined by counting the annual rings on the shell surface. The mollusks were then placed in 1-L containers with different concentrations (1 g/L, 5 g/L, 10 g/L) of a standard and experimental drill fluid in two replicates, eight mollusks per container. In the experiment, mollusks aged 3+ and 4+ were used, because the mussels of these age groups are physiologically fully formed, having a high growth rate at the same time [8]. The control group were 16 mussels in two 1-L containers (8 each) without the drill fluid. The experiment lasted for 31 day. Each day, the viability of each mollusk was noted according to the work of the contactor muscle using a dissecting needle. Dead animals were removed from the containers and re-measured.

At the end of the experiment, the relative growth rate was determined in all animals:

\[ RGR_L = (\ln L_\Delta) \Delta t \]  

where \( L \) is the mollusk shell length; \( t \), the duration of experiment, days; RGR is the relative linear growth rate of the mollusk, tracked by the increase of the shell length (%).

A standard drill fluid solution was 400 mL of sea water, 20 g of barite, 20 g of modified clay powder, 20 g of carboxymethyl cellulose.

The experimental drill fluid solution was 500 mL of sea water, 100 g of clay powder, 1 g of diluent of modified ferrochrome lignosulfonate (FHLS-M), 2 g of the ground algae *Saccharina latissima*.

3. Results

The mortality was 62.5 and 75% in the mussels exposed to the standard drill fluid at the concentrations of 5 and 10 g/L on the fourth day of the experiment, on the fifth day, 94 and 100%, respectively. The mortality of mussels at a standard drill fluid concentration of 1 g/L exceeded 50% at the fifth day, then increased gradually over the next four days. By the ninth day of the experiment, all the mollusks exposed to various concentrations of standard drill fluid were dead (Fig. 1).

![Figure 1. Mussel mortality rate (%) at different concentrations of a standard drill fluid.](image-url)
There were no dead specimens in the mussels both exposed to the experimental drill fluid and of the control group throughout the experiment. The relative linear growth rate (\( RGR_L \)) in the specimens exposed to the concentrations of 5 and 10 g/L of the experimental drill fluid was two times higher than that in the mollusks of the control group (Fig. 2).

![Figure 2. The relative growth rate of the mussel shell in the mollusks exposed to the experimental drill fluid. The vertical lines indicate the confidence interval of \( p = 0.05 \).](image)

4. Discussion
The obtained results show that even small concentrations of a standard water-based drill fluid have a lethal effect on Mytilus edulis. Barite is the main toxic component of this solution. It is believed that barite is a slightly toxic substance, and it does not affect aquatic organisms [9]. Earlier, it has been reported that the barite concentration of 0.5 g/L in sea water did not cause toxic effects, including those on bivalve mollusks [10]. However, some experimental data show that even its low concentration affects the filtration rate and damages the gill apparatus of mollusks. The mollusks of Mytilidae family are the most resistant to drill fluid components, including barite, than the representatives of other families of bivalves, for example, of Veneridae and Pectinidae. The most pronounced toxic effect is manifested at chronic pollution [11, 12, 13].

Carboxymethyl cellulose is another component of a standard drill fluid that negatively affects the mollusks, this compound is used to maintain a constant density of the fluid. This reagent evidently reduces the physiological reaction rate of many hydrobionts [14, 15], and the presence of barite enhances the negative effect of carboxymethyl cellulose [11].

In our experiment, the barite content in water ranged from 0.05 g/L up to 0.5 g/L, which is lower or corresponds to the MPC; however, all the mollusks exposed to the standard drill fluid have died after 9 days.

In the experimental drill fluid, the toxic component was ferrochrome lignosulfonate. Its maximum permissible concentration is 0.002 g/L [16], which correlates with the content of 1 g/L of drill fluid in the experiment. The excess of ferrochrome lignosulfonate in seawater reduces the production of phytoplankton and the survival rate of fish embryos, as well as impedes the development of many organs and tissues in fish larvae [17]. In the experiment, we used adult animals, and the MPC excess by 5 and 10 times did not manifest itself; generally, the effect of ferrochrome lignosulfonate on the invertebrates is poorly studied up to date.

The growth rate of mussels increased at high concentrations of the experimental drill fluid in water; this was due to an increase in the concentration of mannitol and salts of alginic acid in water, since this type of drill fluid contains the ground algae. We suggest that the salts of alginic acid and mannitol not
only increase the physicochemical properties of the solution itself [7], but also provide the mollusks with natural organics. Saccharina latissima inhabiting the coasts of the Barents Sea is characterized by high content of salts of alginic acid (12--35% dry weight) and mannitol (20--22% dry weight) [18].

5. Conclusions
The experimental drill fluid that does not contain barite and carboxymethyl cellulose can be considered safe for marine bivalves, as its components will be easily degradable, since some of them may be used as a food source for detritus-feeding invertebrates. Exceeding the maximum permissible concentration of ferrochrome lignosulfonate by 5 and 10 times in the experimental drill fluid did not manifest itself on the survival rate of Mytilus edulis.

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