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The Effect of Sediment Type and Toxicity of Crude Oil-Spiked Sediments to *Paramecium caudatum*

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Abstract: Results from a set of water-sediment system experiments with crude oil addition to the water-sediment system showed that the key factor influencing the distribution of oil between water and solid phases was the sorption capacity of sediments. With increasing sorption characteristics of sediments oil products redistributed toward solid phase thereby reducing water toxicity for infusoria *Paramecium caudatum*. Toxicity of silt sediment was higher than sandy one unlike water phase where toxicity was higher in sandy sediment system due to the presence of aliphatic and polycyclic fractions of hydrocarbons in water.

Key words: *Paramecium caudatum* · Toxicity · Oil Distribution · Sediments

INTRODUCTION

One of the essential mechanisms of self-purification in water ecosystem is the process of sedimentation which results in retention of contaminants in sediments. The degree of retention of toxicants depends on the sorption characteristics of sediments [1, 2]. Previous studies have reported [3-4] that contaminated sediments represent enhanced risk of effects to biota from heavy metals remobilization in sediments with lower sorption capacity. In spite of a lot of literature concerning oil polluted sediments [5-11] there is no clarity in the problem of redistribution and toxicity of oil products in the system water-sediments. Revealing the peculiarities of redistribution of different fractions of oil between water and solid phases was the aim of the paper. This problem is very important because oil products belong to priority contaminants in the rivers owing to large contribution of oil producing industry on the territory of the Republic of Tatarstan (The Middle Volga river part of Russia).

MATERIALS AND METHODS

Sediments Experiments: Two types of sediments with different sorption characteristics (sand and silt) were used in laboratory experiments with dose addition of crude oil to water-sediment system (Table 1). Crude oil was taken from the New-Suksinsky deposit of Tatarstan region (Russia). Sediments were sampled from the lake on the reserved territory and were tested preliminary according to the triad procedure [12-13]. Sandy as well as silt sediments are referred to the first class ("clean") according to chemical, biological and toxicological assessment [14]. All sediment samples were collected using a Peterson grab sampler (225-cm^2 area) from about the upper 10 cm of the sediment surface. Samples of sediment from multiple grabs were composited to obtain one liter of each sediment. Sediments were sieved to remove indigenous organisms.

Sediment division was based on the organic matter (the loss during burning, %) and sand (particles > 0.05 mm) contents [14]. The water-sediment system represented the vessels (3.0 L volume) with 150 g of sediments and 1.5 L of fresh water (ratio 1:10) in 3 replicates. After oil addition, the system vessels were shaken on rotator with a rate of 100 fluctuations in minute for 15 h and settled down during 15 h. Then samples of water and sediments were extracted with organic solvents, separated by silica/alumina column chromatography and analyzed separately for identification of different fractions of oil by following methods: fluorescence spectrophotometry (asphaltenes), UV-spectrophotometry (polycyclic hydrocarbons) and IR- (infrared) photometry (saturated hydrocarbons) [15-18].

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Table 1: Characteristics of control sediments in pot experiments (N= ±SE)

Type of sediments	Organic matter content	Content particles > 0.05 mm	Content particles < 2 mm	Oil fractions content, mg/kg		
				Aliphatic hydrocarbons	Polycyclic hydrocarbons	Asphaltens
Silty	18.3±1.8	16.5±1.5	15.5±2.3	13.32±3.9	25.90±4.66	1.08±0.32
Sandy	0.04±0.02	94.5±11.3	0	5.28±1.37	4.68±0.65	0.30±0.08

Toxicity Experiments with Infusoria *Paramecium caudatum ehrenberg*: Toxicity of overlying water and water extract of sediments (ratio 4:1) was analyzed in chronic experiments with infusoria *Paramecium caudatum Ehrenberg* with the time of exposition 24 h. Endpoints measured in the infusoria exposures included survival and number of cell divisions in comparison with control [19]. Strongly one cell of *P. caudatum* was input to 0.5 ml of overlying water or water extract of spiked sediment in plastic plate in eight replicates at 24°C. Toxicity based on inhibition of cells division was calculated according the coefficient of abundance increasing:

Where $T = (1 - \frac{Ke}{Kc}).100\%,$

Ke – coefficient of increasing of *P. caudatum* abundance in experiment; *Kc* - coefficient of increasing abundance of *P. caudatum* in control.

Where $Ke = \frac{N_t}{N_0},$

N_t – abundance of cells after 24 h of exposition in the testing sample; N_0 – the initial abundance in testing sample.

$$Kc = \frac{N_t}{N_0}$$

Where N_t – abundance of cells after 24 h of exposition in control; N_0 – the initial abundance in control.

For assessment of sorption ability of different types of sediments the partition coefficient *Kd* was calculated according to the following equation [20]:

Where $Kd = \frac{P_s}{P_w},$

Ps – the contaminant concentration in the sediment (mg/kg), *Pw* – the contaminant concentration in water (mg/L).

Statistical Analysis: Comparisons of contaminant concentration, mean survival and coefficient of abundance were made using a one-way analysis of variance (ANOVA) with mean separation by Fisher's protected least significant difference test (at $\alpha < 0.05$) [21]. A sample was designated as toxic when mean abundance was significantly reduced in the sediments relative to the control sediment.

Relationship between toxicity and content of hydrocarbons was spent using regression analysis with quality estimation of regression equations by Pearson's coefficient.

RESULTS AND DISCUSSION

Spiking sediments by crude oil was made at concentrations 15; 30; 45 mg/L which were chosen after preliminary experiments with oil addition to water-sediment system in different concentrations. Beyond oil concentrations 0.1 g/L both types of sediments lost their capacity to bind oil which was transferred to water phase with forming of oil film on the surface of water.

Results of the experiment with oil addition showed that all fractions of hydrocarbons in the test system with sand were increasing in water phase with increasing oil addition (Figure 1). At the same time hydrocarbons content in water did not increase significantly in the system with silt sediments due to the higher sorption capacity of this type of sediments. It was observed that all fractions of hydrocarbons were increasing with oil concentrations in silt sediments in contrast to sandy one.

Overall the partition coefficient *Kd* was calculated and demonstrated so great difference between sorption ability of sandy (*Kd*=26.3±20.6) and silt (*Kd*=154.7±74.0) sediments. So large value of error of partition coefficient *Kd* in sandy modification experiment was connected with difference sorption ability to aliphatic and polycyclic hydrocarbons, where *Kd*=49.3±12.9 and *Kd*=9.3±1.6 accordingly. Unstable value of partition coefficient *Kd* was obtained for asphaltens in water-sandy sediments system (20.4±19.8).

Such redistribution of oil products in systems with different sediments was reflected by toxicity of water and solid phases. Hydrophobic molecules that did not go to the dissolved phase, they could become a substantial

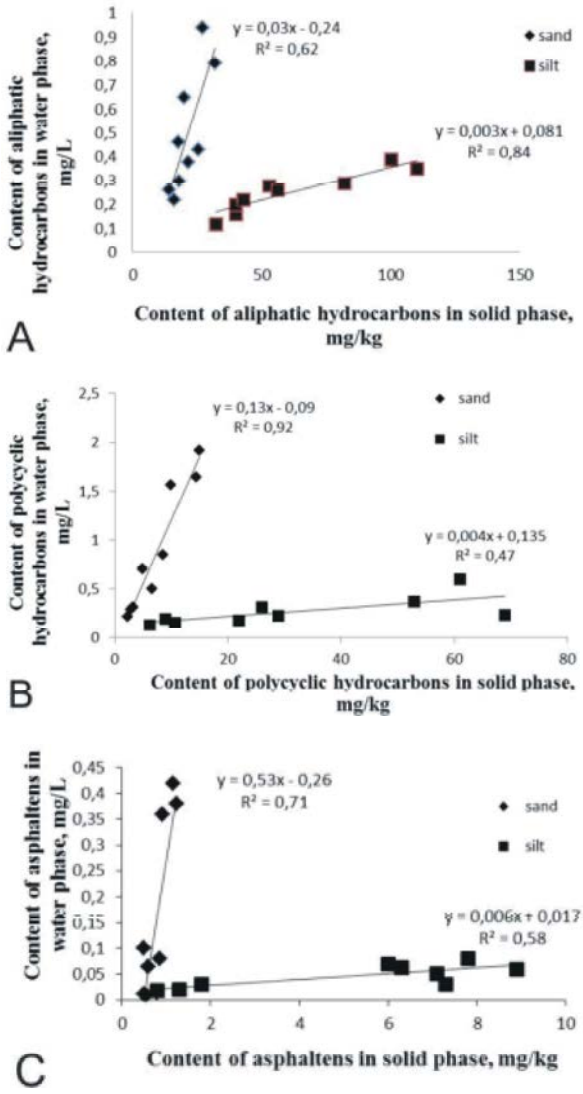

Fig. 1: Content of different fractions of hydrocarbons in water and solid phases in system with sandy and silty sediments (A - aliphatic hydrocarbons, B - polycyclic hydrocarbons, C - asphaltens)

component of the solid fraction in the water column, being bioavailable to specific organisms [22, 23]. As far as the level of toxicity is determined by the presence of dissolved hydrocarbons (including aliphatic and polycyclic fractions) toxicity of water was higher in system with sand than in system with silt sediments (Figure 2). There was no observed mortality of infusoria in all modifications of experiment. So toxicity was calculated on the data of inhibition of cells division of *P. caudatum* in comparison with control and showed the maximum value T=30±8 (T=N±SE) for water in sandy modification. There was no significant difference from

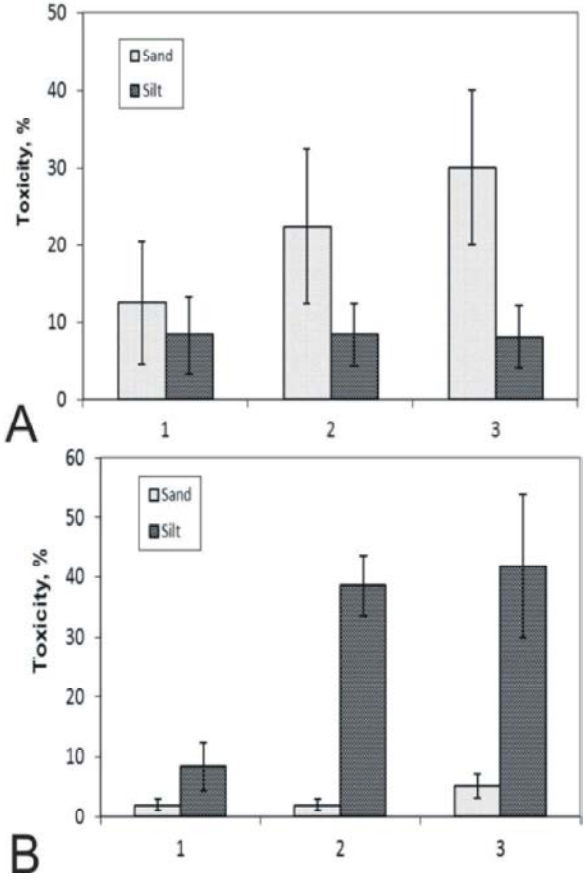

Fig. 2: Toxicity (N±SE) of water (A) and solid phase (B) in system with sandy and silt sediments in different modifications of experiment (1 - oil addition in 15 mg/L; 2 - 30 mg/L and 3 - 45 mg/L)

control in toxicity of water in silt modification. Maximum toxicity in modification with silt was observed for sediment (T=42±12) and the absence of toxicity for water. There is information in literature [24] about natural sediments with concentrations of total PAHs about 52 mg/kg which were not toxic to invertebrates (Hyalella azteca toxicity test). Results of present research demonstrated that the maximum value of toxicity 54% to *P. caudatum* was observed in content of polycyclic hydrocarbons on the level 69 mg/kg.

Relationship between aliphatic, polycyclic hydrocarbons contents in water phase and toxicity to infusoria *P. caudatum* was described by equation of regression. Toxicity to *P. caudatum* depended from aliphatic and polycyclic hydrocarbons content for water phase in sandy modification experiment and expressed by equations $\log T=1.769+1.639\log C_{Aliph}$ ($R^2=0.58$) and $\log T=1.426+0.930\log C_{Polyñ}$ ($R^2=0.80$) accordingly.

In contrast to sandy sediments toxicity of silty one was higher and mainly identified by the presence of polycyclic hydrocarbons $T=4.784+0.071C_{Polyñ}$ ($R^2=0.79$).

Toxicity of silt sediment was higher than sandy one unlike water phase where toxicity was higher in sandy sediment system due to the presence of aliphatic and polycyclic fractions of hydrocarbons in water. So, it could be proposed that water system with sandy sediments may represent potential hazard of toxicity increasing to biota by oil entry in case of an emergency.

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