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The effects of hydrocarbons on selected hydrobionts in the coastal zone of the Antarctic waters

ABSTRACT: Total toxicity of two types of mineral oil (from Zakum and Kuwait) was determined with respect to hydrobionts of the Antarctic ecosystem. Crustacean — *Euphausia superba* proved to be sensitive to hydrocarbon pollution of the sea environment ($LC_{50} \cdot 48\ h^{-1} = 7.62$ ppm). Fish — *Notothenia rossi marmorata* showed much lower sensitivity.

Key words: *Euphausia superba, Notothenia rossi marmorata*, oil bioassays

1. Introduction

The total content of oil substances in marine environment consists of oil hydrocarbons derived mainly from mineral oil transported in takers, vegetable and animal oils, fatty acids and alcohols i.e. metabolic products of plankton (Carlberg and Skarstedt 1972). There is an increasing number of data giving ample evidence of hydrocarbons injurious effect on marine organisms (North, Neushul and Clendinning 1964, Kuhl and Mann 1967, Mironov 1968, Nelson-Smith 1968, Smith 1968, Levy and Walton 1973).

Mineral oil from different geological strata differs considerably as regards its physical properties, chemical composition and toxicity. The degree of toxicity of various fractions increases successively as follows: paraffins with straight chains, naphtalene, olefine, cyclic paraffins and aromatic compounds. Within each fraction smaller hydrocarbon molecules are more toxic than the larger ones; octane and decane are more toxic while dodecane and higher paraffins are almost neutral. The degree of toxicity of hydrocarbons depends on their solubility in water and volatility. Hydrocarbons with high boiling-point have molecules too large to pass through the tissues of hydrobionts, whereas those with low boiling-point evaporate quickly before exerting any effect on living organisms.

It was found that after the penetration into the sea the chemical composition of mineral oil undergoes a quick change. The most toxic, light aromatic compounds evaporate — according to the reports by Blumer, Souza and Sass (1970).

It is why the large spillage of mineral oil from the wrecked tanker "Torrey Canyon" after spreading out to the coasts of Cornwall was almost non-toxic and caused losses mainly in avifauna sensitive to the external effects of heavy hydrocarbons.

Many authors have studied the effects of oil pollution on aquatic organisms. Their studies, however, did not refer to hydrobionts of Antarctica.

The aim of this study was a quantitative evaluation of the sensitivity of selected species of animals thickly populating the waters of Antarctica and the description of their reaction to the total effect of all the constituents of water pollution.

2. Material and methods

Two types of Arabian crude oil from Zakum and Kuwait were used in the experiments. The oil samples were obtained from The Oil Rafinery Plants in Gdańsk in sealed 100 ml containers. Chemophysical properties of oil are given in Table I. Natural sea water was used as diluent. It was sampled from Admiralty Bay, close to the Arctowski Station (King George Island, South Shetland Islands).

The analyses of the water show great chemophysical homogeneity (Table II). Isoterms and isohalines indicate high coefficients of turbulent diffusion and low stability of water-masses. Oxygen content in water is very high but never attains the state of supersaturation, so characteristic in the regions with high primary production.

Table I

Physicochemical properties of mineral oil used in experiments

Parameters		Kuwait oil	Zakum oil
Specific gravity (15.6° C)	($kg \cdot m^{-3}$)	869.0	824.5
Sulphur content	(%wt.)	2.5	0.98
Dissolved H_2S content	(% wt.)	—	—
Kinematic viscosity (21.1° C)	(c St.)	17.0	41.0
Solidification point	(° C)	−31.7	−15.6
Paraffin content (BP)	(% wt.)	5.5	8.3
Asphalt content	(% wt.)	1.4	0.08
Acidity	($mg\ KOH \cdot g^{-1}$)	0.15	0.10
Vanadium content	(ppm)	27.0	1.0
Nickel content	(ppm)	7.0	0.7
Residuum from coking (after Conradson)	(% wt.)	5.2	1.4
Distillation:			
up to 150° C	(% vol.)	16.0	21.0
up to 200° C	(% vol.)	26.0	33.0
up to 300° C	(% vol.)	44.0	57.0
Residuum after distillation	(% vol.)	56.0	43.0
Specific gravity of residuum	($kg \cdot m^{-3}$)	958.0	910.0
Water	(% vol.)	traces	traces
Water and sediments	(% vol.)	0.2	0.2

Table II

Physicochemical properties of sea water from Admiralty Bay, 2 Jan. — 31 May 1978

Parameters		mean	max.	min.
Temperature	(° C)	0.70	1.40	0.00
Salinity	(°/₀₀)	33.80	34.00	33.40
Oxygen	($cm^3 \cdot dcm^{-3}$)	7.20	8.42	6.23
Silicates	($\mu gat \cdot dcm^{-3}$)	82.00	92.00	72.00
Nitrates	„	26.00	30.00	23.00
Nitrites	„	0.17	0.22	0.11
Phosphates	„	2.38	2.68	2.26

The animals used in the experiments were caught in Admiralty Bay, in the area close to the Arctowski Station. In the selection of bioassays top priority was given to the species characteristic for the waters in this region, i.e. Antarctic krill (*Euphausia superba* Dana) and Antarctic fish — *Notothenia rossi marmorata* Fisher. The selected crustacean and fish species are very abundant locally and show a wide range of occurrence, are easy to collect and adapt promptly to laboratory conditions.

Reactivity test was determined in adult specimens of *Euphausia superba*. The age-structure of experimental fishes was within the range of 4—5 years (immature individuals, before spawning time). Acclimatization and feeding procedures and preparation of bioassays for experiments were conducted in accordance with biological test methods described in the "Standard Methods" (1965). Further methodical procedures were carried out after modifications by La Roche, Eisler and Tarzwell (1970) described in the "Bioassays procedures for oil and dispersant toxicity evaluation".

3. Results and discussion

The preliminary studies on *Euphausia superba* aimed at determination of the symptoms of its reaction to water pollution.

The components of crude oil in a total dosage within the range of 7—60 ppm cause at first hyperkinesis. The animals move in sudden jerks or swim very swiftly around the vessel. Simultaneously with the state of hyperkinesis brief moments of immobility are observed and then movements become slower. The animals come up to the water surface and turn over to one side, abdominal appendages accelerate locomotor movements, whereas the movements of thoracal appendages are incoordinated and do not rest firmly on the bottom of the vessel. The again single impetuous leaps occur followed by a whole series of jumps. These symptoms in the early stage of the shock are criterions of a light stroke of paralysis.

Further effects of the poison cause animals to move in a sideways position around the walls of the crystallization vessel and to fall off from the wall at the end. The abdomen falls into a state of tonic spasm and curves. The animals sway from one side to another trying hard to get back to the normal position. The limbs keep on moving slowly. These symptoms are called partial paralysis.

Later on, under the continuous effect of the poison the animals drop to the bottom of the vessel in the upside-down position and the ends of their limbs start twitching. These convulsions are of different duration. Before long the whole body is paralysed. Next, sharp changes in pigmentation (red-green colouring) appeared with sharp contours of uropodia with fans turned up to the inside sideways. The pigmentation of the eye fades, tarnishes, and a gelatinous rim appears around the eye. Later on, pigmentation vanishes, movements are slower and slower and at last cease completely with a full contraction of uropodia. This is the end-stage of complete paralysis. After this, in the following few hours gradual wasting away is observed ending in decomposition of the tissues and cells.

Notothenia rossi marmorata shows sensitivity to mineral oil pollution in the range of 1748—3846 ppm (Table III). The above concentrations

Table III

Sensitivity of selected hydrobionts to oil pollution ($LC_{50} \cdot 48\ h^{-1}$)

Species	Type of oil	(ppm)
Euphausia superba	Zakum	7.62
Euphausia superba	Kuwait	12.57
Notothenia rossi marmorata	Zakum	1748.30
Notothenia rossi marmorata	Kuwait	3846.20

of hydrocarbons are much higher than those practically recorded in the sea environment, therefore, further studies were carried on another species, the sensitivity of which to oil pollution is in the range useful for the experiments. Tables IV and V show median tolerance limits R_{50} and LC_{50} calculated on the basis of three repeats of mineral oil bioassays (on 990 specimens of *Euphausia superba*) and average deviations from these values. The R_{50} and LC_{50} values obtained for *Euphausia superba* (Tables IV and V) served as basis for tracing the curves of the increasing reaction (Fig. 1).

The comparison of the total toxicity of the two types of mineral oil expressed by the R_{50} and LC_{50} values showed that in sea water crude oil from Zakum has a higher degree of taxicity than that from Kuwait (Tables IV and V, Fig. 1).

Mineral oil as any poison shows in the bioassay analysis its own specific growth rate of the bioassay reaction and its durabity. The formulas for the calculation of thies coefficients of growth rate and reversibility of the bioassay reaction and the obtained data are given Table VI according too key of toxodynamic coefficients, by Kamiński (1964). In this case the values of the coefficients of reversibility are less which indicates a considerable weakening of reaction in *Euphausia superba* and a relative casiness of excretion of toxic substances from the organism after the transfer into unpolluted water.

Table IV

Number of the specimens of *Euphausia superba* reacting to Zakum oil in sea water

Mineral oil		Exposure (h)					
Dilution	Concentration (ppm)	1	2	3	4	24	48
1.00	61.13	10	10	10	10	10	10
1.30	47.02	9	10	10	10	10	10
1.69	36.17	8	10	10	10	10	10
2.20	27.82	6	8	10	10	10	10
2.86	21.40	3	5	8	10	10	10
3.72	16.46	0	3	5	7	10	10
4.84	12.66	0	2	3	5	10	10
6.29	8.97	0	0	1	3	6	6
8.18	6.90	0	0	0	0	5	5
10.63	5.31	0	0	0	0	3	3
Control		0	0	0	0	0	0
Extreme dilution $R_{50} \cdot t^{-1}$		2.40	3.34	4.19	5.13	8.50	8.50
Arithmetic mean		1.94	2.90	3.77	4.71	8.54	8.54
Standard Deviation		0.31	0.54	0.54	0.56	0.28	0.28
Extreme concentration $LC_{50} \cdot t^{-1}$		25.47	18.30	14.49	11.92	7.19	7.19
Arithmetic mean		32.34	22.13	16.63	13.22	7.17	7.17
Standard Deviation		4.58	4.84	2.68	1.72	0.61	0.61

Table V

Number of the specimens of *Euphausia superba* reacting to Kuwait oil in sea water

Mineral oil		Exposure (h)					
Dilution	Concentration (ppm)	1	2	3	4	24	48
1.00	61.13	10	10	10	10	10	10
1.30	47.02	8	10	10	10	10	10
1.69	36.17	6	8	10	10	10	10
2.20	27.82	2	5	7	9	10	10
2.86	21.40	0	3	5	7	10	10
3.72	16.46	0	0	2	6	10	10
4.84	12.66	0	0	0	4	7	7
6.29	8.97	0	0	0	2	4	4
8.18	6.90	0	0	0	0	3	3
10.63	5.31	0	0	0	0	0	0
Control		0	0	0	0	0	0
Extreme dilution $R_{50} \cdot t^{-1}$		1.82	3.28	3.93	4.45	6.50	6.50
Arithmetic mean		1.67	2.09	2.56	3.44	5.12	5.12
Standard Deviation		0.11	0.20	0.25	0.67	0.93	0.93
Extreme concentration $LC_{50} \cdot t^{-1}$		33.59	25.68	20.86	13.74	9.40	9.40
Arithmetic mean		36.89	29.62	25.81	18.58	12.57	12.57
Standard Deviation		2.63	2.63	2.33	3.23	2.55	2.55

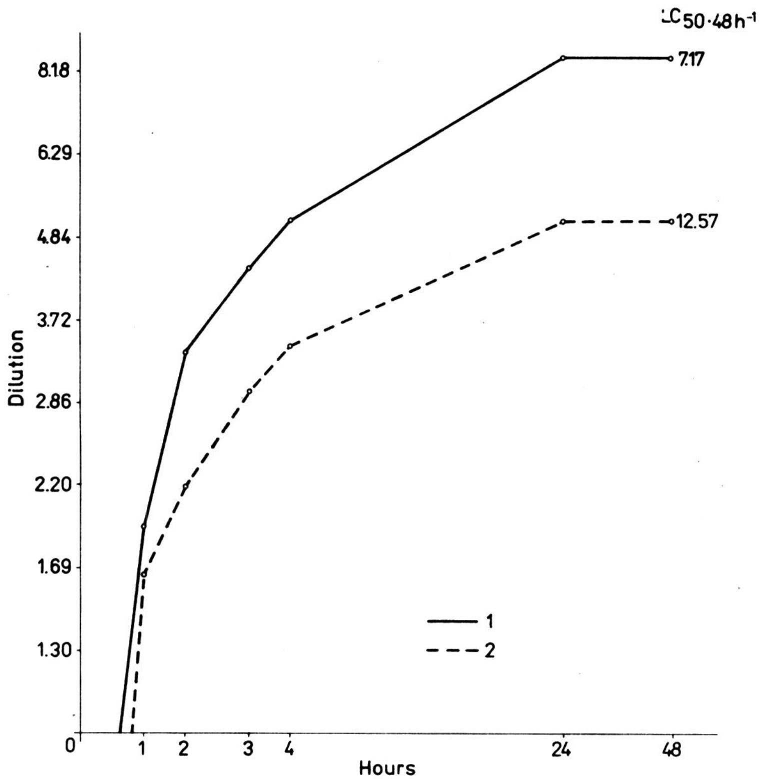

Fig. 1. Oil bioassay in *Euphausia superba*
Results expressed as median tolerance limits LC_{50}. Concentrations of water-soluble fractions as ppm of total oil-hydrocarbons in aqueous phase.
1 — Zakum crude oil, 2 — Kuwait crude oil

Table VI
Coefficients of an increase of bioassay reaction and its reversibility in *Euphausia superba*

Type of mineral oil	$C_{50} \cdot 24\ h^{-1}$ (ppm)	Increase coefficient $Wp \cdot h^{-1} = \frac{C_{50} \cdot h^{-1}}{-C_{50} \cdot 24\ h^{-1}}$			Reversibility coefficient $Wo \cdot h^{-1} = \frac{C_{50} \cdot h^{-1}}{C_{50} \cdot h^{-1}}$		
		Exposure (h)			Exposure (h)		
		1	2	3	1	2	3
Zakum	7.17	4.51	3.09	2.32	0.62	0.51	0.43
Kuwait	12.57	2.93	2.36	2.05	0.84	0.73	0.62

The values of two types of mineral oil total toxicity for *Euphausia superba* ($LC_{50} \cdot 48\ h^{-1} = 7.62$ ppm for Zakum oil and 12.57 for Kuwait oil indicate high sensitivity of the test material. This may be utilized in testing toxicity of the components of oil determining its toxicity. According to Kuhl and Mann (1967) the lowest limit of the injurious effect of mineral oil substances on adult fishes is at the concentration of 16 ppm and on the fish larvae at 1.2 ppm. The respective threshold concentration is for zoobenthos — 1.4 ppm and for plankton — 0.1 ppm. However, already at the concentration of 0.5 ppm fish may have an offensive smell.

Mineral oil concentrations within the range of 0.01—0.001 ppm, after 3—4 days of testing, cause death of the nauplii of copepod *Acartia* sp. on which sprat and herring feed (Mironov 1968). Mature forms of copepod die after a longer stay in water polluted with oil at 1 ppm concentration. According to Nelson-Smith (1968) mollusc *Cardium* edule die in a short time in 0.5 ppm concentration of Kuwait oil at an intensive aeration and emulsification of that oil. Crustacean *Crangon crangon* survive in 1 ppm concentration of Iranian oil.

4. Summary

Tolerance limits of lethal concentrations in different period of resorption of Zakum and Kuwait mineral oil were determined in two animal species characteristic for the waters of the South Shetlands. Taking into account the R_{50} and LC_{50} values for the two types of oil samples in sea water mineral oil from Zakum showed higher toxicity than that from Kuwait (Tables IV and V, Fig. 1). Some toxodynamic indices of mineral oil were also determined. Antarctic krill — *Euphausia superba* proved to be very sensitive to the hydrocarbon effects and therefore it is a suitable material for further ecotoxicological studies. Antarctic fish — *Notothenia rossi marmorata* shows a markedly high resistance to mineral oil pollution of water (Table III).

5. Резюме

На двух видах зверей характерных для аквена Южных Шетландов обозначено предельные концентрации смертельнопаралижующие тестовные объекты в разных периодах ресорпции нефти Закум и Кувайт. Принимая во внимание величины R_{50} и LC_{50} для обоих образцов в морской воде, констатировано, что большую токсичность проявляла нефть Закум, чем Кувайт (таблица IV и V, рис. 1). Определено также некоторые токсидинамические указатели нефти. Антарктический крыль *Euphausia superba* оказался очень чувствительным к углеродам и годится к дальнейшим экотоксилогическим исследованиям. Рыба *Notothenia rossi marmorata* отличалась большой стойкостью к заражению нефтью (таблица III).

6. Streszczenie

Oznaczono stężenia graniczne porażające śmiertelnie obiekty testowe w różnych okresach resorpcji dla ropy naftowej Zakum i Kuwait na dwóch gatunkach zwierząt charakterystycznych dla akwenu Południowych Szetlandów. Biorąc pod uwagę wartości R_{50} i LC_{50} dla obu próbek w wodzie morskiej, większą toksyczność przejawia ropa naftowa Zakum niż Kuwait (tabela IV i V, rys. 1). Określono również niektóre wskaźniki toksykodynamiczne ropy naftowej. Kryl antarktyczny — *Euphausia superba* okazał się bardzo wrażliwy na węglowodory i nadaje się do dalszych badań ekotoksykologicznych. Ryba *Notothenia rossi marmorata* odznacza się dużą odpornością na skażenie ropą naftową (tabela III).

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