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Ingestion and turnover of oil and petroleum hydrocarbons by two planctonic copepods in the Gulf of Finland

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Oil is taken up by *Acartia bifilosa* and *Eurytemora hirundoides* in the gut system when exposed to Russian crude oil for 24 hours. ^{14}C-l-naphthalene is also absorbed by *E. hirundoides* from emulsions in sea water. Oil was present in *E. hirundoides* bodies after exposure for 24 hours to 1 ml/l oil emulsion. Naphthalene elimination from *E. hirundoides* bodies after being transferred into clean sea water was studied. The half-life T_b is 6.2 days and the consumption rate is 6.3 ng naphthalene/copepod from 1 mg/l naphthalene emulsions. It is therefore assumed that copepods eating oil form a potential danger to the other components of the food chain, as part of the naphthalene accumulated in the bodies.

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1. Introduction

The accumulation and turnover of petroleum compounds by zooplankton organisms has received much attention in recent years, and a comprehensive paper summarizing recent knowledge has been prepared by Corner (1978).

The effect of oil on zooplankton was investigated by Conover (1971), who reported that oil ingested by copepods does not apparently affect the animals. Ingestion of oil by zooplankton has also been reported by Lindén et al. (1979).

Corner et al. (1976) studied the effect of naphthalene in *Calanus helgolandicus* during short-term experiments. Moreover, the sublethal effects of hydrocarbons on the copepod *Eurytemora affinis* have been studied by Berdugo et al. (1977) and Ott et al. (1978), and those of long-term exposure to low concentrations of naphthalene on *C. helgolandicus* and *E. affinis* by Harris et al. (1977a).

This study gives evidence that the copepods *Acartia bifilosa* and *Eurytemora hirundoides* ingest oil and naphthalene. The present work confirms the results of earlier studies concerning ingestion of petrochemical products by copepods.

2. Methods

Acartia bifilosa and *Eurytemora hirundoides* were caught in the sea near Helsinki and transported to the laboratory in Thermoflasks. They were allowed to acclimatize to room temperature for 24 hours, and 20 animals were used per petri dish. Oil emulsions (Russian crude oil freshly emulsified) in 6 ‰ brackish water was offered in emulsions containing 1 ml/l water. The oil was vigorously emulsified in order to facilitate ingestion by the animals.

^{14}C-l-naphthalene (1—5 mCi/mmol) was dissolved in ethanol (1 mg/l) and added to the sea water in ethanol: sea water concentrations of 1:10. This stock solution was further diluted to 1:10 by adding sea water. The animals were caught and treated as explained above. They were allowed to consume naphthalene for 24 hours, after which they were transferred to pure brackish water in order to investigate the rate of elimination of naphthalene from their bodies. The radioactivity of the animals was measured with a Geiger Müller detector (Wallac RDC-212 meter with GMS-515 detector). In order to check whether the animals actually ingested the naphthalene, autoradiographs were prepared using Kodak AR10 stripping film and the results examined after one month's incubation in a refrigator.

3. Results

Acartia bifilosa takes up oil in droplets and these are distributed through the gut system (Fig. 1, see also Conover 1971). Fig. 2 shows that radioactive naphthalene is also ingested by *Eurytemora hirundoides*.

Fig. 3 represents the rate of turnover of naphthalene in the bodies of *Eurytemora hirundoi-*

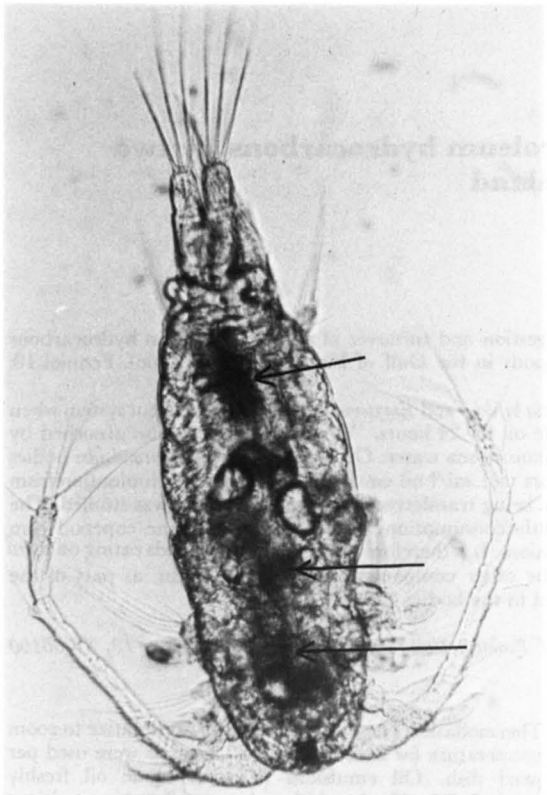

Fig. 1. Oil droplets in the intestine of *Acartia bifilosa* showing as dark spots.

Fig. 2. Incorporation of ^{14}C-l-naphthalene in the gut system of *Eurytemora hirundoides*, indicated by an arrow. The dark areas are developed by autoradiography. The large dark area at the base of the legs of the animal is an artefact.

des. The main portion of naphthalene has been shown to be taken into the copepod body by consumption, and surface absorption of the hydrocarbon was only a minor factor influencing its net uptake by the copepods (Lee 1975, Harris et al. 1977b). From the naphthalene elimination graph it is also possible to calculate the biological half-life T_b as 6.2 days, and accordingly also the ingestion of the animals from the formula:

$$I = kQ$$

where: I = ingestion, Q = the ^{14}C in the animal's body and k = the elimination coefficient, which is $\ln 2/T_b$.

The consumption rate is 6.3 ng naphthalene/copepod/day.

4. Discussion

Conover (1971) expressed the view that copepods are able to ingest oil in small droplets. These had no apparent effect on the organism and a large fraction of the ingested oil sedimented as zooplankton faeces. Certain fractions of oil, e.g. naphthalene, can also be accumulated directly from emulsion in sea water (e.g. Lee 1975). Corner et al. (1976) showed that depuration of this fraction was rapid when taken from an emulsion in sea water, whereas its depuration was much slower when taken from food sources such as particulate matter. No such comparison has been made in this investigation. It appears that animals ingesting oil and its fractions become carriers, transporting the oil and its fractions to higher levels in the food chain.

Corner (1978) states that zooplankton are

capable of biosynthesizing hydrocarbons. Some hydrocarbons are actually of biogenic origin in the organisms. One of these is pristane, which is present in the zooplankton, but which is also a constituent of various crude oils (Blumer et al. 1964). Blumer et al. (1970) traced a single polyunsaturated hydrocarbon (3,6,9,12,15,18-heneicosahexane) in marine organisms. They stated that e.g. *Calanus* could be biochemically predestined to become carriers of hydrocarbons. The actual biosynthesis of hydrocarbons in marine zooplankton has received little attention (Corner 1978). Pristane is presumably synthesized from phytol (Corner et al. 1976).

When using naphthalene as a hydrocarbon indicator in zooplankton, the main problem is its rapid loss by evaporation. Therefore only one-day experiments were performed with naphthalene emulsions, after which the animals were transferred to fresh brackish water solutions. As Harris et al. (1977a) have shown, the loss of naphthalene was 86 % in *Calanus helgonandicus* after 24 hours, but only 50 % in *Eurytemora affinis* after one day in clean sea water. This finding is in good agreement with the present results, which show that 48 % of the radioactive naphthalene is depurated in 24 hours by *Eurytemora hirundoides* (Fig. 3). However, Harris et al. (1977a) made only three measurements of the release of radioactivity for *E. affinis* whereas this study gives six measurements (with 4 replicates).

If the naphthalene is offered continuously, Lee (1975) showed that there is a linear increase in the net uptake during the first three days, but no further increase after the third day. Also Harris et al. (1977b), using low concentrations of naphthalene found that the radioactivity would eventually level off with increasing exposure time. Corner et al. (1976) also showed that the net uptake of ^{14}C-l-naphthalene from emulsions in sea water varied with the concentration of the hydrocarbons used.

Corner (1978) stated that the total lipid content of zooplankton is a good indicator of the potential net uptake of an aromatic hydrocarbon by copepods. This fact had been verified earlier (Lee 1975) and the size of lipid droplets in *E. hirundoides* and *Cyclops oithonoides* was used as an indicator of emulsifier uptake (Gyllenberg & Lundqvist 1976).

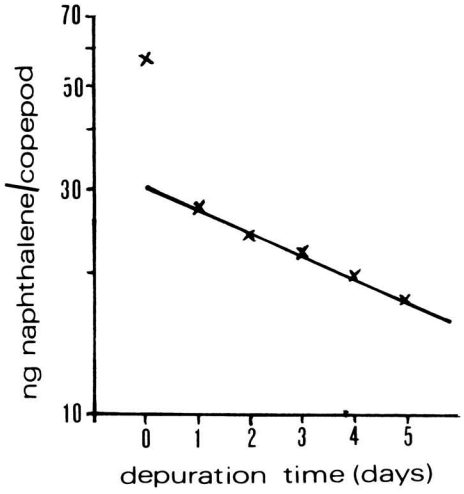

Fig. 3. *Eurytemora hirundoides*. Release of radioactivity by copepods that had accumulated ^{14}C-l-naphthalene during one-day exposure. The values were measured as cpm and changed to weight units by taking the corresponding weight units for a definite naphthalene radioactivity. The values are means of 4 experiments (95 % confidence intervals within 25 %).

Lee (1975) found that most of the metabolites of aromatic hydrocarbons were retained by the animals and therefore available for transfer to a higher trophic level, but Corner et al. (1976) observed that the major fraction was rapidly excreted. The proportion of metabolites remaining in *Calanus helgolandicus* and still capable of being detected as naphthalene was, however, as high as 84—100 % after a 24-hour depuration period (from Corner 1978). The metabolic pathways of naphthalene in marine animals lead to dihydrodiol and premercaptonic acid (Corner 1978), and the presumably also holds true for copepods. However, attempts to detect specific water-soluble metabolities using thin-layer chromatography were unsuccessful both in this study and in studies carried out by Harris et al. (1977a) owing to the limited amount of material available for analysis.

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