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Original Research

Assessment of the Toxicological Effects of Dispersant on Fresh and Brackish Water Shrimp

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Abstract

The toxic stress of a commonly used dispersant (Caamol lubri-clean) on freshwater shrimp, *Desmoscaris trispinosa,* and brackish water shrimp, *Palaemonetes africanus,* was tested. The mean percentage mortality obtained for the 10-day experiment duration was 20, 60, 80, 100, 100% (freshwater test) and 20, 40, 63, 83, 100% (brackish water test). The 10 d median lethal concentration (LC_{50}) was estimated using the Finney Probit method of analysis and was found to be 53.33±3.52 mg/kg and 78.24±6.11 mg/kg for the fresh and brackish water acute toxicity tests, respectively. The release of dispersants into aquatic systems may affect bottom dwelling organisms inhabiting such environments due to the toxic nature of the surfactant component in the dispersant.

Keywords: dispersant, sediment toxicity, *Desmoscaris trispinosa*, *Palaemonetes africanus*, shrimp, LAS

Introduction

There are different types of chemical treatment agents that can be applied to an oil spill to assist in controlling, cleaning up, or removing the oil. These include dispersants, surface washing agents, bioremediation agents, and miscellaneous oil spill control agents. Dispersants are the most commonly used chemical treatment agent.

Linear alkylbenzene sulphonates (LAS) are the most widely used group of anionic surfactants [1, 2]. Surfactant hydrophobicity is derived from saturated hydrocarbon chains of various length and linkages to the hydrophilic group. Several authors have shown that surfactant is toxic to aquatic organisms [2-4]. LAS could potentially harm organisms by denaturing proteins and depolarizing cell membranes [5]. It is rapidly aerobically degraded, but only very slowly and not at all degraded under anaerobic conditions [6, 7]. Due to their widespread use, surfactants have become common constituents of municipal effluent and river water [2, 8]. Surfactants in surface water have become an environmental concern and, as a consequence, toxicity data on their effects on freshwater and marine life have been gathered since the early 1950s [9].

Chemical dispersants are designed to break up surface oil slicks and disperse the oil as fine droplets into the water column so that natural mixing action will dilute the subsurface oil concentration. This action transfers the oil from the water surface into the water column. Spraying dispersant may be the only means of removing oil from the sea surface, particularly when mechanical recovery is not possible. Their use is intended to minimize the damage caused by floating oil, for example to bird or sensitive shorelines [10]. The use of dispersants has in the past tended to provoke controversy since their application can be seen as a deliberate introduction into the sea of an additional pollutant in

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Table 1. Acute toxicity profile of fresh and brackish water shrimp to Caamol lubri-clean exposure.

	10-Day LC_{50}±SD (mg/kg)	95% CL	Probit line equation	Slope±SD
Freshwater	53.33±3.52	29.32-80.88	Y= -0. 82+2.42 × Log (conc.)	2.57±0.10
Brackish water	78.24±6.11	45.12-125.25	Y= 0.98+2.13 × Log (conc.)	2.93±0.18

LC_{50} – Median lethal concentration causing 50% death of organisms exposed to chemical, CL – confidence limit, Y – probit, SD – standard deviation

addition to the short-term increase in hydrocarbon concentration in the water. When applied before spills reach the coastline, dispersants will potentially decrease exposure for surface dwelling organisms (e.g. seabirds) and intertidal species (e.g. mangroves, salt marshes), while increasing it for water-column (e.g. fish) and benthic species (e.g. shrimp, corals, oysters) [11]. Decisions should be made regarding the impact to the ecosystem as a whole, and this often represents a trade-off among different habitats and species that would be dictated by a full range of ecological, social, and economic values associated with the potentially affected resources. Toxicity tests are one of the primary tools that are used to assess these impacts [12].

The objective of this study was to determine the lethal effect of the dispersant (Caamol lubri-clean) to benthic fauna using fresh and brackish water shrimp as bioindicators. The test organisms were chosen because they are sensitive, readily available year-round and of great economic importance in the Nigerian Niger Delta environment [13, 27]. The assessment was necessitated due to the toxic stress of dispersants on aquatic fresh and brackish water shrimp that dominate the Niger Delta region of Nigeria, where this chemical is commonly used in cases of oil spills from petroleum exploration and production activities.

Experimental Procedures

Our test chemical (Caamol lubri-clean) was provided courtesy of the Nigerian Petroleum Development Company Limited. The chemical was manufactured by Manuex Nigeria limited. Information as contained in the materials safety data sheet (MSDS) indicates that the chemical contained linear alkyl benzene sulphonate (30%) as a major constituent with a specific gravity of 1.06, pH of 11.3 and 99.9% purity.

The test organisms; *Desmoscaris trispinosa* and *Palaemonetes africanus* were collected from farms at Kpakiama and Abua in Delta and River states, respectively. The average weight of the test shrimp were 0.166±0.06g (fresh) and 0.172±0.05g (brackish). The test organisms were held in large aquaria measuring 100 cm × 100 cm × 100 cm to get them acclimated to laboratory conditions for a period of seven days. The test organisms were checked for disease and general fitness after collection and before starting the experiment.

Sediment samples collected from fresh and brackish water environments using a van Veen grab were sieved with a 500 μm mesh sieve to remove interfering organisms and substances [14-16]. The sediment was then allowed to settle overnight and the supernatant was decanted. The sieved sediment was kept in the dark at 4ºC and allowed to get to laboratory temperature at least 24 h before starting the experiment.

The experimental procedure was carried out using OECD #218 [22] bioassay protocol for sediment toxicity, starting with a 24 h range-finding test using three concentrations (10, 100, 1000 mg/kg), to determine the concentrations to be used for the definitive test. Stock solution (1000 mg/kg) of the test chemical was prepared from which serial dilutions of 400, 200, 100, 50, and 25 mg/kg was obtained. The sediment was weighed in triplicate and placed into amber-coloured treatment glass tanks of 5 litres. It was then spiked with 2000 ml of the prepared test concentrations. The test solutions and the sediment contents in the containers were allowed to settle for 2 to 3 h before the test organisms were introduced. Each glass vessel containing the test chemicals had ten (10) shrimp; the control experiment had dilution water (water from the organism's habitat) and the test organisms with no test chemical. The experimental system was gently aerated using oil-free low whisper aerators for the 10-day duration. Daily observation of the test was made and symptoms of chemical toxicity, behavioural, and morphological changes recorded include irritability, broken appendages, erratic movement, and mortality. Dead organisms were removed immediately on detection. The criterion for establishing test organism mortality is the point at which no movement could be detected on gentle prodding [17, 18].

The physico-chemical characteristics of the test solutions were determined at the beginning and end of the experiment. Some of the parameters tested include temperature, dissolved oxygen (DO), salinity, and hydrogen ion concentration (pH). The mean temperature and dissolved oxygen concentration for the test were 27±2ºC and 6.40±0.5 mg/l, respectively. The pH was 7.01±0.31 (freshwater) and 7.27±0.24 (brackish water), while salinity was 0.07±0.007 ppt (freshwater test) and 3.98±0.59 ppt (brackish water test).

Results

The results of acute toxicity of the test chemical (Caamol lubri-clean) to fresh and brackish water shrimp using the OECD 10-day sediment toxicity test are presented in Table 1. Mean percentage mortality obtained at day 10 for the five concentrations were 20, 60, 80, 100, and 100%

(freshwater test) and 20, 40, 63, 83, and 100% (brackish water test). There was no mortality in the control experiment for the test duration, which indicated that the test conditions were appropriate and thus mortality recorded in the test solutions could be attributed to the effect of the dispersant.

At the end of the 10-day freshwater bioassay, the median LC_{50} concentration obtained from the probit analysis was 53.33±3.52 mg/kg with a 95% confidence limit of 29.32 to 80.88 mg/kg [19]. In the brackish water test, a 10-day LC_{50} of 78.24±6.11 mg/kg with a 95% confidence limit of 45.12 to 125.25 mg/kg was reported (Table 1). Mean percentage mortality in the fresh and brackish environments were significantly different at levels of $F(10,22)=641$, $p<0.05$. The test chemical, Caamol lubri-clean, could be classified as slightly toxic in the fresh and brackish water tests with reference to GESAMP rating [20].

There was variation between the fresh and brackish water species as observed in the aforementioned 10-day median LC_{50} values. Buikema et al. [21] observed that the higher the median LC_{50}, the lower the toxicity or sensitivity to test organisms and vice visa. There was a progression of effect from low mortality to high mortality rates with increases in toxicant concentrations in both environments.

Discussion of Results

Applying the OECD [22] rating for chemical concentrations in sediment, the data obtained from the Probit analysis for 10-day median LC_{50} acute toxicity test indicate that the dispersant was slightly toxic to bottom dwelling organisms in both the fresh and brackish water environments. However, the freshwater test organisms were more sensitive to the dispersant than the brackish water test organisms [4]. Wilde et al. [23] observed that the toxicity of a chemical to aquatic organisms is dependent on the type of chemical, exposure duration, test organism, and environment. In the sequence of dispersant toxicity, gill damage is the most obvious acute toxic effect; the immediate cause of death may be asphyxiation, but detergents may also be toxic internally. The interactions between detergents and proteins, and their influence on membrane permeability, could be the basis for the biological action of detergents [2].

Furthermore, due to the physiology of freshwater organisms, which have a greater body fluid concentration (about one-third), they are constantly taking in water by diffusion through their gills and skin for osmotic balance [24]. Thus in a situation where there is damage to the skin and other tissues as is the case in exposure to high concentrations of dispersant, there is an influx not only of water but also of the dispersant leading to a higher toxicity of the chemical and death rate in the freshwater organisms [25]. The difference in response between the fresh and brackish water shrimp may be related to the relative activity levels of the species tolerance in the brackish environment and the toxicant's mode of action [25]. Surfactants would dissolve most chemical compounds entering the environment and can cause severe harm or damage to aquatic organisms, especially bottom dwelling organisms, since the sediment is a repository of most of these substances [26].

With the findings from this study, appropriate safety measures such as adherence to standard operating procedures should be applied before the use and disposal of surfactant-containing chemicals since the test chemical was slightly toxic in both environments. This would ensure that the biotic components of the Nigerian Niger Delta ecosystem are prudently protected.

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