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Review

# Toxicity of seven priority hazardous and noxious substances (HNSs) to marine organisms: Current status, knowledge gaps and recommendations for future research

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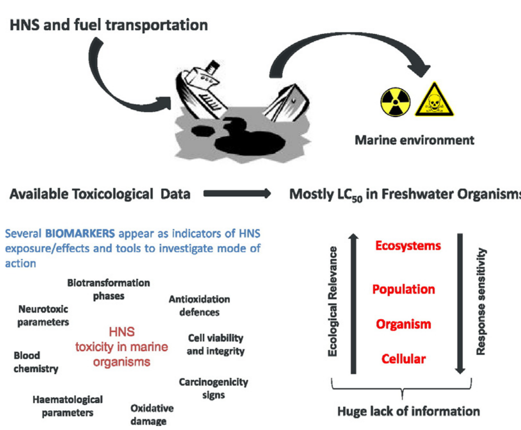
## HIGHLIGHTS

- Review of toxicological effects of seven HNS towards aquatic species
- Lack of information for marine species but HNS toxicity was found for some organisms
- Studies of long-term effects of the selected HNS in marine species are required
- Biochemical biomarkers are useful tools for studying HNS toxicity
- Using realistic HNS exposure scenarios will improve protection of marine species

## GRAPHICAL ABSTRACT

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## ABSTRACT

Shipping industry and seaborne trade have rapidly increased over the last fifty years, mainly due to the continuous increasing demand for chemicals and fuels. Consequently, despite current regulations, the occurrence of accidental spills poses an important risk. Hazardous and noxious substances (HNSs) have been raising major concern among environmental managers and scientific community for their heterogeneity, hazardous potential towards aquatic organisms and associated social-economic impacts. A literature review on ecotoxicological hazards to aquatic organisms was conducted for seven HNSs: acrylonitrile, n-butyl acrylate, cyclohexylbenzene, hexane, isononanol, trichloroethylene and xylene. Information on the mechanisms of action of the selected HNS was also reviewed. The main purpose was to identify: i) knowledge gaps in need of being addressed in future research; and ii) a set of possible biomarkers suitable for ecotoxicological assessment and monitoring in both estuarine and marine systems.

Main gaps found concern the scarcity of information available on ecotoxicological effects of HNS towards marine species and their poorly understood mode of action in wildlife. Differences were found between the sensitivity of freshwater and seawater organisms, so endpoints produced in the former may not be straightforwardly

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$LC_{50}$
NOEC

employed in evaluations for the marine environment. The relationship between sub-individual effects and higher level detrimental alterations (e.g. behavioural, morphological, reproductive effects and mortality) are not fully understood. In this context, a set of biomarkers associated to neurotoxicity, detoxification and anti-oxidant defences is suggested as potential indicators of toxic exposure/effects of HNS in marine organisms.

Overall, to support the development of contingency plans and the establishment of environmental safety thresholds, it will be necessary to undertake targeted research on HNS ecotoxicity in the marine environment. Research should address these issues under more realistic exposure scenarios reflecting the prevailing spatial and temporal variability in ecological and environmental conditions.



**Contents**



## 1. Introduction

The continuous increasing demand for chemicals and fuels, used in a variety of applications, industries, and consumer products led to a rapid growth of shipping industry and seaborne trade over the last fifty years. Maritime trade and transportation of substances are in fact one of the foundations of global economy, covering nowadays more than 90% of global trade (MKC, 2012). Despite the technological advances and increased efficiency of transportation processes, shipping is still one of the most dangerous industries to the environment (Parfomak and Frittelli, 2005). This is mainly due to leakage of hazardous substances either from routine operations (e.g. loading, discharging and bunkering) or discharges from ships and to accidental spills of goods, chemicals and fuels into the sea in consequence of shipping accidents (e.g. collisions, grounding) (MKC, 2012).

In the field of marine pollution, attention has been generally drawn to oil and fuel spills. These have great visual impact, and immediate consequences to ecosystems and economic activities. Nevertheless, the occurrence of spills of other chemical substances has increased over the last decades as a consequence of increased shipping (MKC, 2012). A good example is that of hazardous and noxious substances (HNSs) defined as "substances other than oil, which, if introduced into the marine environment, have the potential to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea" (CEDRE, 2012). HNS can be more toxic than oils and their hazardousness can be more wide reaching (ITOPF, 2011). Hence, there is a need to better understand the environmental fate and implications of these substances to support the development of strong and consistent contingency plans (MKC, 2012). However, a wide variety of chemicals exhibiting different physical and chemical properties fall into the HNS category. Thus, as a consequence of these different properties, HNS spill contingency protocols cannot be as straightforward as those adopted for oil spills since these chemicals can have an assortment of possible behaviours/interactions and of potential effects on flora, fauna and human health when released into the environment (ITOPF, 2011). There is a need to better understand the environmental fate and implications of these substances to support the pre-planning of risk management contingency protocols and regulation of HNS transport (CEFAS, 2009).

A literature review on ecotoxicological hazards to aquatic organisms was conducted for seven HNS, viz. acrylonitrile, n-butyl acrylate, cyclohexylbenzene, hexane, isononanol, trichloroethylene and xylene [the three isomers: meta- (m), para- (p) and ortho- (o)]. These target HNS were selected, from a priority list established (Neuparth et al., 2011b), for their different physico-chemical properties, toxicity for living organisms and frequency of transportation. The main purpose is to identify information and knowledge gaps in need of being addressed for hazard identification and ecological risk assessment (ERA). Information on the mechanisms of action of the selected HNS was collated to gain further understanding on their toxicity and to identify a set of possible biomarkers suitable for ecotoxicological assessment and monitoring in estuarine and coastal systems.

## 2. Material and methods

This review is based on studies identified from 1990 onward on the seven selected HNSs. The aim was to obtain information on toxicity of selected HNS, as well as on statistical endpoints, i.e., median lethal concentration ($LC_{50}$), effective concentration at x% ($EC_x$), concentration causing x% inhibition of the response observed ($IC_x$), as well as no observed effect concentration (NOEC) and lowest observed effect concentration (LOEC)). Searches were conducted in various information sources: i) Scopus (http://www.scopus.com/); ii) ISI Web of Knowledge (WoK, http://wokinfo.com/) databases; iii) ECOTOXicology database from Environmental Protection Agency (EPA); iv), datasheets from European Union reports; v) documentation from the Organisation for Economic Co-operation and Development (OECD); vi) documentation from the Agency for Toxic Substances and Disease Registry (ATSDR); and vii) documentation from the International Agency for Research on Cancer (IARC). Scopus and WoK provided most of the significant literature. Several keywords and combinations of search terms were used: "name of HNS of interest" or "chemical synonym" (acrylonitrile, n-butyl acrylate, cyclohexylbenzene, hexane, isononanol, trichloroethylene and xylene) in combination with one or more of the following