ABSTRACT

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The aim of this thesis, which is based on five papers [I-V], was to assess the hazard associated with dumped ammunition in the marine environment, with special focus on the explosive compound 2,4,6-trinitrotoluene (TNT). The release and effect of TNT from a solid state [I, II, IV], or in the form of cleaved artillery shells [III, V], were studied in fish [I-III, V], blue mussels [III], and in bioassays with crustaceans [III-V].

In laboratory studies, TNT-treated rainbow trout (*Oncorhynchus mykiss*) showed increased levels of methemoglobin and glutathione, and enhanced activities of glutathione dependent enzymes, indicating that TNT oxidizes macromolecules and activates antioxidant defense systems [I, II]. TNT and its aminated metabolites, 2-ADNT and 4-ADNT, were detected in bile of TNT-treated fish, and these were suggested as direct biomarkers of exposure to TNT [II].

However, no exposure and effect biomarkers responded in flounder (*Platichthys flesus*) exposed to shells for 8 weeks in the field [III], probably due to rapid dilution of TNT in the overlying water mass, limited bioconcentration and/or strong binding of TNT and its transformation products to the sediment [III, V]. However, flounders that were exposed to shells in basins with static sea water died already after one day of exposure [V]. The water phase also became highly toxic to the crustaceans *Nitocra spinipes* and *Hyalella azteca* [V]. A toxicity identification evaluation (TIE) study with *N. spinipes* identified TNT as the causative toxicant in the leakage water from the shells [V]. Hence, the release of TNT to acutely toxic concentrations can be relatively rapid if the ammunition is not covered with sediment, and if the dilution in the water is limited [IV, V].

In contrast, the leakage of TNT was effectively inhibited by sediment burial [IV, V]. No leakage of TNT to seawater, and no acute water phase or sediment toxicity, was found during 21 weeks with shells buried within the sediment [V]. However, a three years' study on sediment toxicity close to shells in the field, resulted in a reduced survival of *N. spinipes*, while no acute effects were found on *H. azteca* and *Daphnia magna* [III]. Leakage of TNT was more rapid through sandy sediment than fine-grained sediment [IV]. However, at sites with sandy sediment (erosion and transport bottoms) the leaking of TNT will probably be diluted at rates that will prevent acute toxicity [IV, V]. At sites with fine-grained sediments (accumulation bottoms), the leakage of TNT to the water phase will be slowed down [IV]. The retention of TNT in sediment will protect pelagic organisms like fish form acute exposure, but may lead to an increased exposure to benthic organisms [III-V]. In conclusion, the present thesis suggests that adverse acute effects of dumped ammunition are unlikely to occur in fish, but may occur in sensitive benthic invertebrates (e.g. *N. spinipes*).

Keywords: 2,4,6-trinitrotoluene, TNT, ADNT, dumped ammunition, toxicity, bioassays, biomarkers, fish, crustaceans, TIE, *Nitocra spinipes*, *Platichthys flesus*