Effects shown of endocrine disrupting chemicals in the marine environment

Endocrine disrupting chemicals (EDCs) have lately received a lot of attention in politics and the media, mainly related to hormone-related diseases in humans. But there is a growing concern that declines in wildlife populations and loss of species are linked to chemicals interfering with the endocrine (hormone) system.

Under current legislation, many of today’s commercial chemicals have not been tested for potential endocrine-disrupting properties. But the increasing incidences of endocrine-related diseases observed in wildlife today and the increasing number of chemicals identified to potentially have endocrine disrupting properties is a matter of concern. This concern is based on general knowledge of how hormone systems work, in combination with available knowledge about how chemicals can interfere with these systems. This knowledge has been convincingly shown in studies using experimental animals as well as in wildlife. Taken together, this gives reason for concern.

EDCs adversely interfere with hormone functions

Chemicals known or suspected to have endocrine disrupting effects, such as flame retardants, plasticisers, fragrances, preservatives and metals, are used in a wide range of industrial and consumer products. Some examples are personal care products, furniture, electronics, building materials and clothing. Pharmaceuticals, for instance contraceptives and anti-depressants, also contain EDCs.

Disruption of the endocrine system can result in various developmental, reproductive, neurological, immune and metabolic diseases. Over the past years, an increasing number of chemicals have been identified to have endocrine disrupting properties to which humans and wildlife are exposed. These include well known persistent organic pollutants (POPs) that are restricted in the western world, such as PCBs and DDT, as well as chemicals in current use, such as phthalates used in plastics and personal care products, brominated flame retardants found in textiles or electronics, and perfluorinated compounds such as PFOS used

EDCs can reach the marine environment in a number of ways, such as through the air, rivers and human activities at sea. Organisms in the marine food web are exposed to a mixture of chemicals, which can be taken up from the diet, by inhalation or by absorption through the skin or gills. Persistent and fat-soluble chemicals are taken up from the diet where they can accumulate and transfer through the marine food chain resulting in higher levels in top predators.
A perch, *Perca fluviatilis*, and its roe in the Baltic Sea. Organisms that lay their eggs in water are particularly vulnerable to EDCs since the eggs are directly exposed during the developmental stage.

Significant concentrations of EDCs found in the marine environment

EDCs can reach the marine environment in a number of ways, such as through the air, rivers and human activities at sea. Outgoing water from wastewater treatment plants are known to contain EDCs from a variety of sources such as personal care products, pharmaceuticals, and consumer goods treated with chemicals. Other sources of EDCs include discharges from industrial processes, runoff from agriculture containing pesticides, fertilisers and pharmaceuticals and urban runoff.

Considering the numerous sources of EDCs to the marine environment, organisms and top predators in the marine food web are exposed to a mixture of chemicals, which can be taken up from the diet, by inhalation or by absorption through the skin or gills. Persistent and fat-soluble chemicals are taken up from the diet where they can accumulate and transfer through the marine food chain resulting in higher levels in top predators.

Organisms that lay their eggs in water are particularly vulnerable to EDCs since the eggs are directly exposed during the developmental stage. Organisms that live in or near urban areas or wastewater treatment plants are often exposed to the highest concentrations before dilution occurs and are also continuously exposed to chemicals.

Significant concentrations of known or suspected EDCs have been measured in the marine environment. Particularly old POPs, such as PCBs and DDT, but also new emerging pollutants, such as brominated flame retardants and per-fluorinated compounds, are found in top marine predators exceeding concentrations known to cause adverse effects. Although substances that are banned show a corresponding decline in the environment, they are still of concern since they stay in the environment for a long time and accumulate in the food chain.

Brominated flame retardants like PBDEs and HBCDD, listed under the EU regulation on POPs, have been increasingly studied in the environment in the last decade. In the Baltic Sea, PBDE concentrations four times higher than levels known to cause adverse effects in American white-tailed sea eagles, have been found. High levels have also been reported in roach fishes in the Baltic Åland Sea. Measured concentrations of HBCDD in herring exceeded the threshold level in all stations measured along the Swedish coast and an increasing trend can be seen in eggs from common guillemot close to Gotland.

Of the perfluorinated compounds, PFOS is the most commonly found in animals and locations worldwide. In the Baltic Sea, the highest levels of PFOS have been measured in marine predatory birds and mammals. Although PFOS is restricted and has been phased out in many parts of the world, more than 3000 substances that are structurally similar and produced in significant quantities are currently...
The clearest example of exposure to EDCs and subsequent population changes is the masculinisation of marine snails close to marinas when exposed to TBT, a constituent in marine antifouling paint used on boats. This has been shown even at very low concentrations where the masculinisation results in sterile individuals which causes reproductive failure and subsequent population declines. The mud snail, *Peringia ulvae*, is one of the species used in the marine monitoring program in the Baltic Sea.

EDCs lead to reproductive failure for marine wildlife
Observed effects on population levels, such as reproductive failure and outbreaks of diseases, can in several cases be linked to EDC exposure in the marine environment. There are some historic cases where exposure to EDCs, such as PCB and DDT, are strongly correlated with effects seen in wildlife including reproductive impairment in seals, eggshell thinning in predatory birds, feminisation of fish and masculinisation in marine snails. Some examples include:

- Several field- and semi-experimental studies show that EDCs prone to accumulate in fatty tissue do so at levels in marine mammals that may cause adverse effects.
- Birds, exposed to new emerging EDCs, show adverse endocrine disrupting effects, which may have consequences for populations of wild birds. For example, exposure of PBDE at environmentally relevant concentrations to captive American kestrels affected among other things courtship behaviour, hatching success and eggshell thickness.
- For fish, reproductive effects including feminisation of males, masculinisation of females and reduced fertility have been reported. Feminisation in fish has been extensively investigated and is caused by oestrogenic compounds, found for instance in contraceptives, in outgoing water from wastewater treatment plants.
- The clearest example of exposure to EDCs and subsequent population changes is the masculinisation of marine snails close to marinas when exposed to TBT, a constituent in marine antifouling paint used on boats. This has been shown even at very low concentrations where the masculinisation results in sterile individuals which causes reproductive failure and subsequent population declines.
Identification and testing need to be developed
Several knowledge gaps hinder understanding of the full scale effects of EDCs in the marine environment. Even less is known about endocrine disrupting effects on marine invertebrates although they make up 95% of all known animal species and constitute large groups of the marine ecosystem that are ecologically relevant.

Many routes and sources of EDCs are unknown which makes it difficult to assess the full extent of exposure. For example, marine species living close to wastewater treatment plants’ outgoing water are likely exposed to a great number of not-yet-identified EDCs. In addition, we have insufficient knowledge of all the possible ways EDCs can interfere with the hormone system and how exposure during critical time periods of development may contribute to diseases at later life stages or be passed on to offspring. Many of the validated toxicological tests used today are not designed for detecting endocrine-disrupting effects. In general, the implication of effects seen in experiments can be difficult to translate to effects on population levels.

Identifying the cause to the effects and exposure of a single chemical is difficult as the observed effects can be a result of the interaction of several chemicals. Furthermore, monitoring of chemicals in the environment focuses to a large degree on POPs of which many are already regulated. Hence, we know little on the exposure of new emerging EDCs. Given the current knowledge on EDCs, it is likely that more resources spent on screening of chemicals for endocrine disrupting properties, monitoring of EDCs in the environment and the development of toxicological tests designed to detect EDCs will confirm the suspicion that risks with EDCs are currently underestimated.