Perfluorinated compounds in offshore fire-fighting foams – a source for marine contamination?

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Introduction

Per- and polyfluorinated compounds (PFCs) are synthetic chemicals with a variety of applications as surface treatments, paper protectors and performance chemicals [1]. PFCs have the unique ability to repel both oil and water making them ideal candidates for surface protection of e.g. textiles or paper [2]. Their applications also include their use as speciality surfactants, for example, in cosmetics and electronics, as well as their use in Aqueous Film Forming Foamers (AFFF) [2,3].

Since the early 2000s, increasing evidence has been published that PFCs and, particularly, the historically used perfluorooctane sulphonate (PFOS), are persistent in the environment and can fulfil the Stockholm Convention criteria for bioaccumulative and toxic, leading to the listing of PFOS as persistent organic pollutant (POP) under the Stockholm Convention in 2010 [4]. The restriction of PFOS was successfully implemented, however, replacement PFCs were quickly introduced and have since been increasing in production and use [5].

A variety of potential sources have been investigated as potential emission pathways for PFOS and its replacement PFCs to the marine environment. Potential sources include releases during manufacturing and application processes [6], leaching from products and long-range atmospheric transport [7].

However, there has, so far, been limited research regarding the potential impact of direct discharge of PFC containing products into the marine environment; through e.g. the use of fire-fighting foams on offshore platforms.

Materials and methods

In this study, we used use and discharge data of offshore fire-fighting foams published by the Norwegian Pollution Control Authority (Klif) [8] to estimate potential release and accumulative effects from the discharge of fire-fighting foams from offshore oil and gas platforms in UK and Netherlands waters. Based on differences in incident, testing and training frequency, Klif reported an annual discharge of PFC-containing firefighting foams of between 20 L and 20000 L per platform [8].

Based on these discharge volumes, the environmental release and potential risk were estimated using the Dose-related Risk and Effects Assessment Model (DREAM) of the Marine Environmental Modelling Workbench (MEMW) suite [9]. DREAM is a dispersion model that calculates the Predicted Environmental Concentration (PEC) of a discharge and relates this to a pre-defined Predicted No-Effect Concentration (PNEC). The resulting predictions provide information regarding the expected concentrations in the water-column, sediments, surface and shore-line, as well as associated environmental risks based on a PEC/PNEC ratio [9].

The evaluated scenarios included a "worst-case" incident scenario, based on the maximum 20000 L reported annual discharge of fire-fighting foams [8], a "best-case" minimal testing scenario (single platform) using the 20L minimum reported amount and a multi-platform scenario to estimate the combined effects of "best case" discharge from 5 platforms using a foam containing 3% PFOS as example.

The water framework directive quality limit of 0.65 ng/L for surface water was chosen as the limit value for the model predictions [10].

Results and discussion

The worst-case scenario for the single and multiple platforms indicated a significant risk from the discharge of PFOS containing fire-fighting foams will pose a significant environmental risk (PEC/PNEC > 1) in an area of several kilometers around the release site (Figure 1, left).

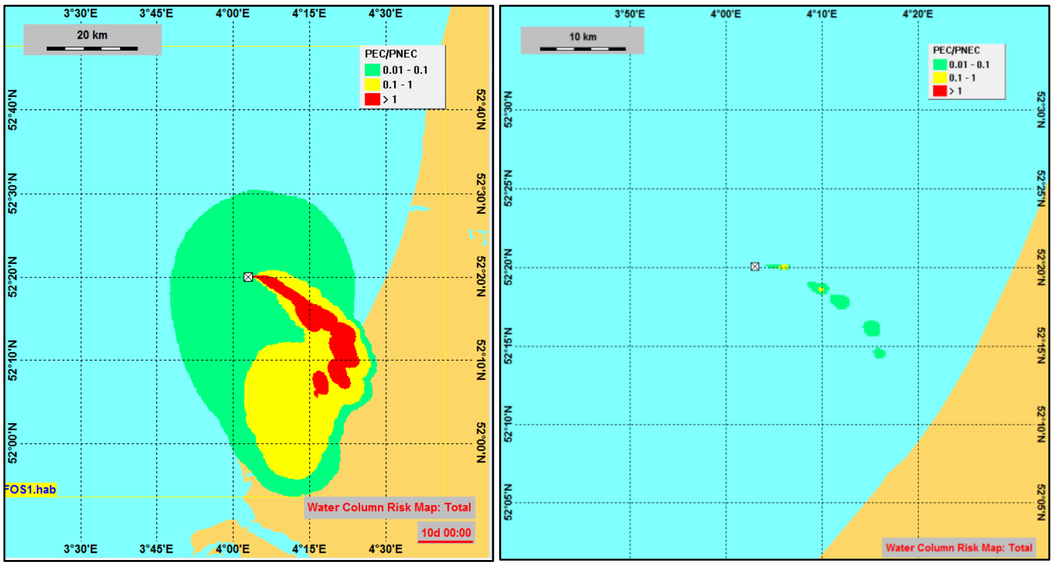

Figure 1: Maximum environmental risk (PEC/PNEC) over ten days for the water column, following a discharge of 20000 L (left) and 20 L (right) fire-fighting foam containing 3% PFOS.

Unexpectedly, even in the "best-case scenario" an environmental risk from the discharge was predicted within the first day after a release (Figure 1, right). The predicted risk reached a PEC/PNEC of close to 1 only in direct vicinity of the platform. However, since the results were based on an unrealistic "best case" scenario with practically no testing of the equipment, a predicted risk of close to PEC/PNEC = 1 is concerning. Furthermore, the predicted environmental risk in DREAM is based on acute release and toxicity, meaning that chronic or sub-lethal effects are not considered in the risk evaluation. Considering the persistence and potential for bioaccumulation of many PFCs, chronic and sub-lethal effects should be included in further evaluations of the environmental impact of discharged fire-fighting foams from offshore installations.

It could be shown that the discharge of fire-fighting foams during incidents and testing have the potential to cause a significant environmental risk to areas in vicinity of the platform or, in case of the "worst case" release, even in more than 20 Km distance to the release point.

This study, highlights the relevance of fire-fighting foams discharged from offshore oil and gas platforms as potential sources of PFCs in the marine environment. However, more research is needed regarding the typical discharge volumes and compositions of fire-fighting foams used offshore during incidents and regular testing, as well as regarding chronic and sub-lethal effects of a discharge.

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References

1. Kannan K., Hansen K.J., Wade T.L. and Giesy J.P. (2002b). Perfluorooctane sulphonate in oysters, Crassostrea virginica, from the Gulf of Mexico and the Chesapeake Bay, USA. Archives of Environmental Contamination and Toxicology 42: 313-318.
2. Hekster F.M., Laane R.W.P.M. and de Voogt P. (2003). Environmental and toxicity effects of perfluoroalkylated substances. Reviews of Environmental Contamination and Toxicology 179: 99-121.
3. So M.K., Taniyasu S., Yamashita N., Giesy J.P., Zheng J., Fang Z., Im S.H. and Lam P.K.S. (2004). Perfluorinated compounds in coastal waters of Hong Kong, South China, and Korea. Environmental Science and Technology 38 (15): 4056-4063.
4. Stockholm Convention (2010). Governments unite to step-up reduction on global DDT reliance and add nine new chemicals under international treaty. Geneva: Stockholm Convention Secretariat.
5. Allsopp, M., Santillo, D., Walters, A. & Johnston, P. (2005). Perfluorinated Chemicals: an emerging concern. Greenpeace Research Laboratories, Department of Biological Sciences, University of Exeter, Technical Note: 04/2005.
6. Stock N.L., Lau F.K., Ellis D.A., Martin J.W., Muir D.C.G. and Mabury S.A. (2004). Polyfluorinated telomer alcohols and sulfonamides in the North American troposphere. Environmental Science and Technology 38 (4): 991-996.
7. Shoeib M., Harner T., Wilford B., Jones K and Zhu J. (2004). A survey of perfluoroalkyl sulfonamides in indoor and outdoor air using passive air samplers. Organohalogen Compounds 66: 3999-4003.
8. Klif 2012. Inventory of PFOS and PFOS-related substances in fire-fighting foams in Norway. Authors: COWI A/S Norway. Klif report, TA-nummer 2961/2012.
9. SINTEF 2013. MEMW 6.5 User Guide: SINTEF Marine Environmental Technology. MEMW 6.5 User's manual. Retrieved from: www.sintef.no
10. Moermond CTA, Verbruggen EMJ, Smit CE (2010). Environmental risk limits for PFOS: A proposal for water quality standards in accordance with the Water Framework Directive. Rijksinstituut voor Volksgezondheid en Milieu RIVM. RIVM rapport 601714013.