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PRODUCED WATER FROM OFF-SHORE OIL AND GAS PRODUCTION, A NEW CHALLENGE IN MARINE POLLUTION MONITORING

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Produced water consists of water naturally present in the oil and gas reservoir (formation water), flood water previously injected into the formation, and/or, in the case of some gas production, condensed water. Produced water is part of the well stream together with oil and/or gas.

Oil and/or gas are separated from the produced water on the production platform. The produced water is treated to reduce the dispersed oil content to below the regulatory maximum limit of 40 mg/l, set by OSPAR, before it is discharged from the production platform. Most oil companies claim that they normally reduce the oil content to below 20 mg/l.

Produced water is the largest volume waste stream in the exploration and production process of oil and gas. Over the economic life of a producing field, the volume produced water can exceed by ten times the volume of hydrocarbon produced. During the later stages of production, produced water can account for as much as 98 % of the extracted fluids.

Typical water production rates from oil platforms are from 2 400 to 40 000 m^3/day and for gas platforms 1,6 - 30 m^3/day [1]. This amounts to an expected discharge of produced water to the North Sea in 1998 of 3,4 x 10^8 m^3.

When discharged the produced water still contains a wide range of components:
dissolved organic components, various production chemica trace metals, naturally occurring radioactive material, inorganic salts.

In addition the discharged water is almost depleted for oxygen and has an average COD or BOD value of 4 000 mg O_2/l [1].

Of the dissolved organic components carboxylic acids account for the major organic load with concentrations in the discharged produced water ranging from 30 - 930 mg/l. Other major components dissolved in the produced water are BTEX-components (Benzene, Toluene, Ethyl Benzene and Xylenes) in concen-trations from 0,5 - 14 mg/l for oil platforms and from 5 - 630 mg/l for gas platforms, phenols in concentrations between 1 - 23 mg/l and polycyclic aromatic hydrocarbons (PAHs) in concentrations ranging from 40 - 1 600 Fg/l, with naphthalene (40 - 1 600 Fg/l), phenanthrene (10 - 500 Fg/l) and dibenzo-thiophene (10 - 170 Fg/l) representing the majority [1,2,3].

In addition to the organic components trace elements as Pb, Cd, Cu, Hg, Ni, Zn, As and Cr are dissolved in the produced water in considerably greater concen-trations than in sea water.

The Naturally Occurring Radioactive Materials (NORM) in discharged water consists mainly of ^{226}Ra and ^{228}Ra representing more than 90 % of the total radioactivity in the produced water. The radium concentration in produced water can be from 100 - 1 000 times the naturally concentration of sea water.

Bicarbonate (615 mg/l), chloride (44 g/l) and sulfate (814 mg/l) are the main inorganic salts discharged.

The production chemicals consist of a wide range of products, but they are all supposed to be treated according to national and international (OSPAR) regulations.

The discharge of produced water is a continuous process and based on an expected amount of 340 million m^3 discharged in 1998 the total amount of some environmental important components can be calculated in Table I.

The figures in the Table are calculated from an assumed average concentration. But both composition and concentration change from well to well and throughout the lifetime of the production wells. As the discharge of produced water is a continuous process there will be established a certain area around the platforms where there is a more or less permanent influence of produced water. In areas with a high density of oil and gas fields the influence area of one platform overlaps the influence area of nearby platforms. Fig. 1 shows an example of a modelled influence area of produced water

TABLE I. AN ESTIMATION OF THE AMOUNT OF SOME DISSOLVED COMPONENTS AND DISPERSED OIL IN PRODUCED WATER, DISCHARGED INTO THE NORTH SEA FROM OIL AND GAS EXPLOITATION IN 1998. THE CALCULATIONS ARE BASED ON AN ESTIMATED DISHARGE OF 340 MILLION CUBIC METERS PRODUCED WATER INTO THE NORTH SEA IN 1998

Average concentration	Carboxylic acides 500 mg/l	BTEX 8 mg/l	Phenols 5 mg/l	PAHs 500 Fg/l	Hg 5 Fg/l	Cd 10 Fg/l	Dispersed oil 20 mg/l
Total input	170.000 t	2.700 t	1.720 t	172 t	1,72 t	3,4 t	6.800 t

from discharges from oil-fields in the Tampen area in the northern North Sea The crosses represents oil- and gas-fields that also are discharging produced water, but which are not included in the modelled distribution.

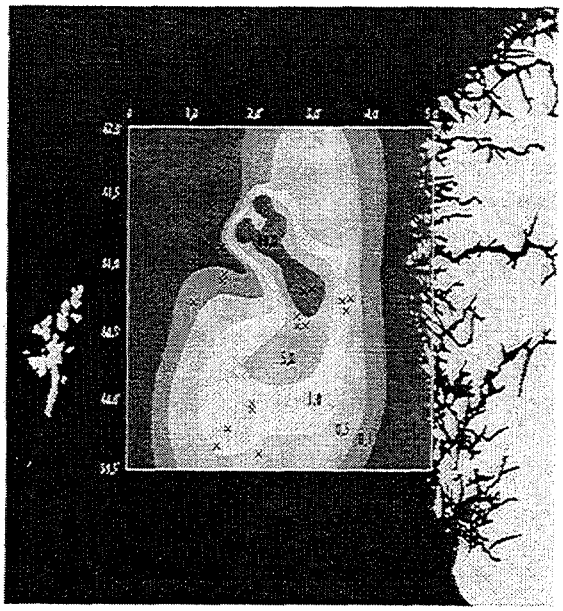

FIG 1. Modelled horizontal distribution of concentration fields in percent of produced water in 0 - 25 m, in a summer situation of discharges from oil platforms within the Tampen area, in the northern North Sea [2]. X indicates nearby oil and gas platforms which also discharge produced water, but which are not included in the modelled distribution.

Most of the discharge points for the produced water are located at some depths beneath the sea surface. Fig. 2 shows the modelled vertical distribution of the produced water from the oil-fields in the Tampen area in a summer and winter situation. As can be seen in Fig. 2, the plume of produced water occurs between depths of 25 and 50 meters and this is the part of the water column where most planktonic organisms are found.

Oil companies claim that the discharges from their activities only influence a very limited area around the platforms, and that at a distance of some few km from the discharge point the dilution has reduced the contamination to a non detectable level. They also claim that evaporation and biological degradation are important factors for reducing the degree of contamination. Evaporation may certainly be an important factor for the lighter component like the BTEX and phenols provided that they are found in the surface, but if the modelled vertical distributions demonstrated in Fig. 2 represent the normal behavior of the produced water, evaporation can hardly be of specially grate importance.

Carboxylic acids may act as a growth medium for bacteria and therefor such bacterial growth may change the abundance and the composition of the marine bacteria communities and thereby change the basis for organisms at a higher level in the food chains, feeding on bacteria. The problem of monitoring and assessing the impact of produced water have recently been raised within the Working Group of Environmental Assessment and Monitoring Strategies (WGEAMS) of the International Council for the Exploration of the Sea (ICES). WGEAMS pointed to a range of studies

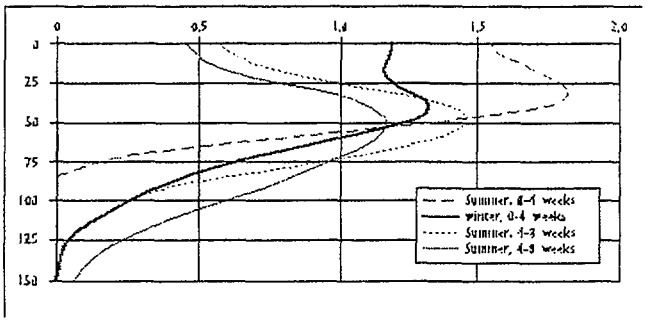

FIG. 2. Modelled vertical distribution (depth in meters) of produced water, discharged in 8 week periods during summer and winter months. The distributions are given as percent share per depth meter [2]

and activities needed to be undertaken should the possible problems created by the increasing discharge of produced water be properly assessed. WGEAMS mentioned among others the need for development of new tests for chronic effects on fish eggs/larvae, the need for regional studies to investigate effects on pelagic communities from bacteria through phytoplankton to zooplankton and modelling results should be verified by field surveys [4].

As the oil exploration moves northwards to colder waters along the Norwegian coast and in to the Barents Sea, into areas where most of the important fish resources of the Northeast Atlantic have their spawning and breeding areas we fear that the chronic exposure from produced water can affect the development of strong year classes of important fish stocks. It is therefor necessary to find practical methods for monitoring the fate of produced water both for the sake of reducing the existing suspicion of effects not yet detected or for documenting effects that can be used in the political decisions that have to be taken prior to further oil- and gas- field developments.

For the polluter, the oil companies, there is an urgent need to develop methods for continuous measurement of all dissolved components in the produced water. To day only the dispersed oil content are monitored regularly. For the purpose of assessing the impact of produced water the oil companies must be required to provide data on the composition and the amounts of discharged components.

So far, no acute toxic effects of produced water have been reported. The huge and increasing amount of produced water discharged to the sea, without any regulations from national or international regulatory bodies, seems nowever, to be an important threat to the marine environment and its living resources. The lack of knowledge is frightening, and the possibility that there is a sneaking ecosystem change that will not be detected before it may be to late is unfortunately evident. Both national and international authorities should give high priority to these problems at least in a precautionary context.

References

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