The case study – Inventory of fire figthing foams in Norway

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Background

In 2004, the Norwegian Pollution Control Authority (Klif) surveyed the use of perfluorinated chemicals (PFCs) in products in Norway. This showed that the largest area of use was fire-fighting foam (fire-fighting foam). Klif developed an action plan in 2005 with the aim of reducing the use of PFCs. One of the measures listed in the action plan was to draw up an inventory of PFOS-related substances in fire-fighting foams and of emissions from this source. This was to be carried out in 2005. The aim of the inventory was to obtain an overview of stockpiles of PFOS-based foam still held by Norwegian professional users. Another aim was to obtain information on historical releases of PFOS-related substances.

Tier I: Initial assessment (6.2)
Step 1. Planning of the inventory and identification of relevant sectors and stakeholders:
The technical focal point for the Stockholm Convention in Norway Climate and Pollution agency was responsible for the inventory. The user categories were defined based on the knowledge that PFOS-based fire-fighting foams are used in facilities and installations where large quantities of flammable liquids are used or stored, including offshore installations, refineries, tank farms, tankers, ferries and ships, airports and certain industrial plants. The relevant professional users of PFOS-based fire-fighting foams were identified using phone books, web search and through telephone interviews with industrial associations and suppliers. A consultant was engaged by Klif to compile the responses, calculate and assess overall stockpiles and historical emissions.

The following user categories were identified:

- operators of fixed offshore oil and gas installations on the Norwegian continental shelf: contacted on 17 March 2005, time limit for responses 1 June 2005;
- refineries and onshore gas terminals, tank farms, airports, the Norwegian Armed Forces, relevant industrial enterprises, fire-fighting training sites, tanker companies and a selection of passenger ferries: contacted on 28 June 2005, time limit for responses 15 September 2005;
- a selection of municipal fire services: contacted on 8 July 2005, time limit for responses 15 September 2005.

Step 2. Two workshops with stakeholders:
The Pollution Control Authority held two meetings for user groups involved in the inventory, one for offshore operators and one for shipping firms and onshore users. At these meetings, information on the inventory was provided, and there was an opportunity for users to put forward their views and ask questions.

Tier II: Preliminary inventory
Step 3. Collection of data:
Klif contacted relevant users, requiring them to provide information on their stockpiles and use of PFOS-based fire-fighting foams through postal communication and e-mail. They were asked to fill out a questionnaire detailing information on their stockpiles, use and releases of PFOS-based fire-fighting foams. They were also asked to assess the possibility of replacing stockpiles of foam concentrate dating from before 2003 and to provide information on any PFOS-related substances in products for other areas of use. The following questionnaire was

used:

Questionnaire for inventory of fire-fighting foam concentrate and any other areas of use for PFOS-related substances in onshore sectors such as refineries, airports, the Norwegian Armed Forces and fire-fighting training sites, and in maritime transport (tankers and large passenger ferries).

Please provide information on foam concentrate in the table below.

There is currently no requirement to declare products containing PFOS-related substances to the Product Register, and it is therefore not possible to find information on whether or not a product contains these substances from the safety data sheet. Information on whether fire-fighting foam or other products contain PFOS-related substances can be obtained from the supplier.

Table 1: Information on quantities of fire-fighting foam concentrate

Enterprise, operating unit or other user	
Total stockpiles of foam concentrate (litres)	
When was the first time the foam tanks were filled with concentrate? (year)	
When were the foam tanks most recently filled with concentrate? (year)	
Annual consumption of foam concentrate (litres)	
Quantity of foam concentrate believed to contain PFOS-related substances (litres)	
Total quantity of PFOS-related substances held by the enterprise	
What is the PFOS concentration of the foam used today?	
Historical emissions of PFOS-related substances	
Frequency of tests of equipment using foam (number/year)	
Do not have PFOS-based foam	

We also ask enterprises to evaluate the following:

- whether it is possible to replace foam concentrate dating from before 2003;
- whether they have stockpiles of products for other areas of use containing PFOS-related substances.

Step 4. Evaluation of received information:
The number and rate of the responses were compiled in table 1. Table 1 shows the number of users contacted and the responses received in each category. There was no system of reminders to increase the response rate. The responses received were considered to be sufficient in number and quality to satisfy the purpose of the inventory. The user categories with low response rates were also those that have used very little PFOS-based fire-fighting foam and have no or very small quantities stockpiled. It was therefore decided not to send reminders, since little more information would have been obtained by doing so.

User category	No. contacted	No. of responses	Response %
Operators of offshore installations	12	12	100
Mobile rigs	10	8	80
Refineries and onshore gas terminals	5	5	100
Petrochemical and other relevant industry	10	9	90
Tank farm operators	5	3	60
Airports[1]	13	10	78
Norwegian Armed Forces	3	3	100
Fire-fighting training sites	22	7	32
Tanker companies	37	13	35
Passenger ferry companies	5	3	60
Fire and rescue brigades	23	16	70

Table 1: Number of requests for information and responses received in different user categories

[1] All airports owned by Avinor are treated together.

Tier III: In-depth inventory
Step 5. Further investigations
The data were evaluated according to reliability and variability. The industrial associations or larger stakeholders were contacted to discuss the data received. Results:

Fixed offshore installations: The information on stockpiles held on fixed offshore installations is based on registration of volumes in tanks, purchase lists and analyses, and is considered to be reliable. The information on historical emissions is more uncertain, but the total quantity is considered to be of the right order of magnitude. Annual consumption varies widely from one installation to another, with figures ranging from 20 litres to more than 20 000 litres. This is partly related to the frequency of training exercises and how they are organised. The equipment on some installations is tested without using foam, and therefore without releasing any foam. This also contributes to the wide variation in remaining stockpiles of PFOS-based foam.

Mobile riggs: The information on stockpiles on mobile rigs is considered to be reliable. However, two of the companies did not answer the request for information. The total

stockpiles are therefore assessed as somewhat higher than those reported in connection with the inventory.

Ships and ferries: Although the response rate from this group of enterprises was low (35 %), there is no reason to believe that there has been large-scale use of PFOS-based foam on board ships. Annual consumption of foam concentrate by the respondents is in the range 0–20 litres.

Two of the three ferry companies that responded do have stockpiles of PFOS-based foam on their ferries. The quantities involved are relatively small. Two of the companies did not respond. Total stockpiles are therefore assessed as somewhat higher than those reported. Annual consumption of fire-fighting foam is low (10–20 litres per vessel) and it is therefore unlikely that there have been any substantial historical emissions.

Refineries and onshore gas terminals: Responses were received for all the installations, and the information is considered to be reliable. Little information is available on historical emissions of PFOS-related substances. Emissions were calculated on the basis of information on annual consumption of foam and the number of years of operation. The level of uncertainty in these calculations is relatively high.

Petrochemical and other relevant industries: One enterprise did not respond, but otherwise the information received is considered to be reliable. Little information is available on historical emissions of PFOS-related substances. Most respondents reported low consumption of fire-fighting foam, and very few training exercises involving the use of PFOS-based foam. It is therefore assumed that historical emissions have been limited.

Tank farms: The information received is considered to be reliable. However, responses were only received from three of the five companies that were contacted, and total stockpiles of PFOS-based foam are therefore assessed as somewhat higher than those reported. Little information is available on historical emissions of PFOS-related substances. The frequency of training exercises and annual consumption of fire-fighting foam vary from one tank farm to another, but are generally low. It is therefore assumed that historical emissions have been limited.

Air ports: Even though some airports did not respond, the information received is considered to be reliable. Fire-fighting foam is used only in fire engines, which carry very limited amounts of foam. Very little information is available on historical emissions of PFOS-related substances. It is likely that PFOS-based foam has previously been used at many of the airports, but it is not possible to make a quantitative estimate of emissions.

The Norwegian Armed Forces: The Armed Forces indicated that the figures they have provided are uncertain. Very little information is available on historical emissions of PFOS-related substances, and it is not possible to make a quantitative estimate of emissions.

Fire-training sites: None of the respondents use PFOS-based foams today. The response rate for this category was very low (32 %), but the respondents are considered to be representative of this group as a whole. It was therefore decided not to send reminders in an attempt to increase the response rate. Remaining quantities of PFOS-based foams at fire-fighting training sites are assessed as very small. Very little information is available on historical emissions of

PFOS-related substances. It is likely that PFOS-based foam has previously been used at a number of fire-fighting training sites, but it is not possible to make a quantitative estimate of emissions.

Municipal and intermunicipal fire and rescue services: Most fire and rescue services reported that they had no stockpiles of PFOS-based foams, while a few had small quantities. The inventory did not include all Norway's fire and rescue services, but the information received is believed to be representative of this category as a whole. The largest and most relevant users were selected, and it is unlikely that other users have larger stockpiles. The total remaining stockpiles of PFOS-based foams held this sector are therefore assessed as small. Very little information is available on historical emissions of PFOS-related substances. It is likely that PFOS-based foam has previously been more widely used, but it is not possible to make a quantitative estimate of emissions.

Step 6 and 7. Compilation and estimation of quantities:
The reported quantities of PFOS-based fire-fighting foams were compiled in table 2. Table 2 shows the results of the inventory (stockpiles of PFOS-based foam (litres), content of PFOS-related substances in the foam (in kg) and historical emissions of PFOS-related substances (in kg)). Quantities are given for each user category, as well as the total for all users that provided responses. For some user categories, there is so little information on historical emissions that it is not possible to calculate or estimate a total, and this is indicated by "n.e." (no estimate) in the table. This means that it has not been possible to estimate or calculate the total quantity of PFOS-related substances in historical emissions. Total historical emissions from the enterprises that have reported quantifiable emissions come to 57 160 kg.

To estimate the quantity of PFOS and related substances in fire-fighting foam, conversion factors of 0.017 kg/l and 0.037 kg/l have been used for 3 % and 1 % fire-fighting foam concentrate respectively. One of the offshore operating companies has analysed potassium levels in old and new foam at its installations. The conversion factors for 3 % and 1 % fire-fighting foam were calculated on the basis of the potassium content and the ratio between the atomic weight of potassium and the molecular weight of the potassium salt of PFOS. According to a Dutch report from 2002 /2/, monomeric perfluorinated salts were used in fire-fighting foams, mainly the potassium salt of PFOS.

User category	**Stockpiles of PFOS-based foam, litres**	**Quantity PFOS-related substances in stockpiles, kg**	**Historical emissions of PFOS-related substances, kg**
Offshore installations	1 025 000	15 600	54 000
Mobile rigs	12 500	330	500
Ships and ferries	23 000	300	100
Refineries and onshore gas terminals	221 800	2 260	2 300
Petrochemical and other relevant industry	31 000	530	< 100
Tank farms	24 000	400	160

Airports	2 000	34	n.e.
Armed forces	90 000	1 500	n.e.
Fire-fighting training sites	0	0	n.e.
Fire and rescue brigades	1 000	13	n.e.
Total	1 430 300	20 967	min. 57 160

Table 2: Information received on stockpiles and historical emissions from PFOS-based fire-fighting foams.

n.e. = no estimate (not quantifiable because information was incomplete)

Step 8. Reporting:
The reporting format in table 3 was used. Table 3 lists estimated total quantities of PFOS-related substances in stockpiles of fire-fighting foams and estimated historical emissions. The estimates are based on the results of the inventory, and also take into account the possibility that stockpiles in certain branches may have been underreported because the response rate was low.

User category	**Quantity PFOS-related substances in foam stockpiles, kg**	**Historical emissions of PFOS-related substances, kg**
Offshore installations	15 600	54 000
Mobile rigs	400	700
Ships and ferries	400	200
Refineries and onshore gas terminals	2 260	2 300
Petrochemical and other relevant industry	530	< 200
Tank farms	600	< 200
Airports	< 50	n.e.
Armed forces	1 500	n.e.
Fire-fighting training sites	< 50	n.e.
Fire and rescue brigades	< 50	n.e.
Total	ca. 21 500	min. 57 600

Table 3: Estimated total quantities of PFOS-related substances in stockpiles of fire-fighting foam and historical emissions

n.e. = no estimate (not quantifiable because too little information is available)

The inventory report:
The data were presented in an inventory report. The report assessed the results, described the situation on use, practical limitations, such as space, drilling frequency etc., explained variation in the data and the reliability in the data for the different user categories.

Summary:
Norway's total stockpiles of PFOS-based foam are estimated at 1.4 million litres. The largest quantities are to be found on offshore installations and at refineries and onshore gas terminals. The Norwegian Armed Forces also have considerable remaining stocks of PFOS-based foam. It is estimated that the total content of PFOS-related substances in foam stockpiles in all branches is approximately 22 tonnes.

The estimates of historical emissions are more uncertain. The figures for fixed offshore installations and mobile rigs are considered to be most reliable. Total historical emissions from the branches that have provided the most reliable information are estimated at 57 600 kg, expressed as PFOS-related substances.

For airports, fire-fighting training sites, fire and rescue brigades and the armed forces, the information reported does not provide a basis for estimating historical emissions. This is indicated by "n.e." (no estimate) in Table 3.

Annual consumption figures for these user categories are relatively low, generally under 100 kg foam concentrate. It is likely that historical emissions from these user categories were considerably lower than those from offshore installations and refineries and onshore gas terminals.

Most enterprises that still have stockpiles of PFOS-based foam responded to the question of whether these could be replaced. They all considered this to be technically possible.

The enterprises that have the largest remaining stockpiles pointed out that complete replacement of PFOS-based foam will take time and require considerable financial resources. This applies particularly to some offshore installations and refineries and onshore gas terminals. One oil company estimated that complete replacement of PFOS-based foam would cost NOK 20 million.

The inventory report/1/ can be found at www.klif.no.

Later evaluations

a. Inventories of contaminated sites:

PFOS-based fire-fighting foams were banned in Norway in 2007. In 2007 a survey was conducted to investigate whether PFOS-containing fire-fighting foam had contaminated soil around areas where test for fire-fighting were performed/3/. The Climate and Pollution Agency surveyed four selected fire training facilities in Norway, 2 in close proximity to airports, an oil refinery, and a producer of fire-fighting foam. The main focus of this investigation was on influence on the terrestrial environment. The concentrations of PFOS found in the vicinity of the four fire training facilities show that soils in these areas are severely contaminated. Rough estimations of the total amounts of PFCs in soils around two of the investigated facilities show that 10-40% of PFOS used in aqueous film forming foams

may still be present in the soil (these figures are uncertain). The survey has been followed up with remediation where needed.

Avinor is responsible for 46 airports in Norway. In 2011 they initiated a project where they aimed to investigate all test fields for fire-fighting in terms of PFC-contamination. The survey includes soil, ground and surface water reserves in addition to biota sampling. The preliminary results show that PFOS-contamination is found in the soil at almost all test fields for fire-fighting as well as in runoffs distant from the contaminated test field/4/. The permeability of the soil is critical for the spreading of PFOS. The few existing data indicate that in ground and surface water PFOS-contamination could be a significant problem at some sites. The investigations will be followed up with risk assessments and remediation where needed.

b. Follow up of the first inventory of fire-fighting foam:

In preparations for the Norwegian implementation plan the inventory was followed up in 2012. The aim was to see if the obligation of phasing out of fire-fighting foams had been fulfilled, and to identify alternatives. The same list of stakeholders was then contacted as in 2005 and a questionnaire was developed. In 2011 it was discovered that one of the stakeholders had not been aware of the list of PFOS related substances and still had stockpiles with PFOS-based fire-fighting foams after the ban in 2007. The leakage from the stockpiles had led to contamination of a local site. The questionnaire was therefor sent out together with the OECD list of PFOS related substances. In addition Klif asked for contact details to the suppliers/producers. In the validation of the information received the suppliers and producers were contacted. No remaining stockpiles were now identified. All stakeholders had identified alternatives to PFOS-based fire-fighting foams. The result of the inventory in 2012 is described in /5/.

Below you find the questionnaire used in the follow up:

Questionnaire

1. Name and address of fire-fighting agency or factory/entity using fire-fighting foams:

Name	Address

2. Name of producer/supplier of currently used fire fighting foams

Name	Address

3. What type of fire-fighting foam is used? (Please attach safety data sheet if available)

	Name of currently used fire fighting foams	Content of chemicals	CAS number.	Content of PFOS or PFOS related substances (%, or mg/L, or mg/kg)
1				
2				
3				
4				
5				
6				
7				
8				

4. What is your experience with substitution to fire-fighting foams without PFOS or PFOS related substances?

Cost	
Technical feasibility and efficacy	
Other matters	

5. Additional information

6. Addresser

Name:		Title:	
Phone:		Unit:	
E-mail:		Date:	

References

/1/ 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.

/2/ Hekster F.M. and P. de Vogt: Perfluoroalkylated substances. Aquatic environmental assessment. Report RIKZ/2002.043, 1 July 2002. http://edepot.wur.nl/174379

/3/ Screening of polyfluorinated organic compounds at four fire training facilities in Norway, Klif TA-2444/2008

/4/ Miljøtekniske grunnundersøkelser ved Avinors lufthavner, Avinor report 168180-1/2011.

/5/UNEP 2012. Assessment of alternatives to perfluorooctane sulfonic acid in open applications. UNEP/POPS/POPRC.8/10