



## Consequences in Norway of a hypothetical accident at Sellafield:

Potential release – transport and fallout



**Reference:**

Ytre-Eide M, Album, Standring WJF, Amundsen I, Sickel M, Liland A, Saltbones J\*, Bartnicki J\*, Haakenstad H\*, Salbu B\*\*. Consequences in Norway of a hypothetical accident at Sellafield: Potential release – transport and fallout.  
\*) *The Norwegian Meteorological Institute* \*\*) *Norwegian University of Life Sciences*

StrålevernRapport 2009:7. Østerås: Norwegian Radiation Protection Authority, 2009.  
Language: Norwegian.

**Key words:**

Consequence assessment, radioactive fallout, SNAP model, simulation, Sellafield

**Abstract:**

This report focuses on transport and fallout from “worst-case” scenarios based on a hypothetical accident at the B215 facility for storing Highly Active Liquors (HAL) at Sellafield. The scenarios involve an atmospheric release of between 0.1–10 % of the total HAL inventory; only transport and fallout of <sup>137</sup>Cs is considered in this case study. Simulations resulted in between 0.1–50 times the maximum <sup>137</sup>Cs fallout experienced in the most contaminated areas in Norway after the Chernobyl accident.

---

**Referanse:**

Ytre-Eide M, Album, Standring WJF, Amundsen I, Sickel M, Liland A.  
Saltbones J\*, Bartnicki J\*, Haakenstad H\*, Salbu B\*\*  
\*) *Meteorologisk institutt* \*\*) *Universitetet for miljø- og biovitenskap*

Rapportens tittel: Konsekvenser for Norge ved en tenkt ulykke ved Sellafieldanlegget:  
Potensielt utslipp – transport og nedfall  
StrålevernRapport 2009: nr.7 Østerås: Statens strålevern, 2009.

**Emneord:**

Konsekvensvurdering, radioaktivt nedfall, SNAP model, simulering, Sellafield.

**Resymé:**

Rapporten redegjør for nedfall over Norge fra en tenkt ulykke med atmosfærisk utslipp fra lagertankene for høyaktivt flytende radioaktivt avfall ved Sellafield-anlegget. Det er valgt å ta utgangspunkt i en utslippsmengde som svarer til 0,1 til 10 % av den totale mengden flytende radioaktivt avfall i tankene. Kun transport og nedfall av <sup>137</sup>Cs er beregnet i denne studien. Med utgangspunkt i gitte værforhold viste beregningene at nedfallet over Vestlandet vil være fra en tiendedel til 10–50 ganger nedfallet i det mest kontaminerte området i Norge etter Tsjernobyl-ulykken.

---

Head of project: Ingar Amundsen

Approved:



Per Strand, Director, Department for Emergency Preparedness and Environmental Radioactivity

---

20 pages.

Published 23-03-2009.

Electronic version only

**Orders to:**

Norwegian Radiation Protection Authority, P.O. box 55, No-1332 Østerås, Norge.

Telephone + 47 67 16 25 00, fax +47 67 14 74 07.

E-mail: [nrpa@nrpa.no](mailto:nrpa@nrpa.no)

[www.nrpa.no](http://www.nrpa.no)

ISSN 0804-4910

## Consequences in Norway of a hypothetical accident at Sellafield:

Potential release – transport and fallout

M. Album Ytre-Eide, The Norwegian Radiation Protection Authority  
W.J.F. Standring, The Norwegian Radiation Protection Authority  
I. Amundsen, The Norwegian Radiation Protection Authority  
M. Sickel, The Norwegian Radiation Protection Authority  
A. Liland, The Norwegian Radiation Protection Authority  
J. Saltbones, The Norwegian Meteorological Institute  
J. Bartnicki, The Norwegian Meteorological Institute  
H. Haakenstad, The Norwegian Meteorological Institute  
B. Salbu, Norwegian University of Life Sciences

**Statens strålevern**

Norwegian Radiation  
Protection Authority  
Østerås, 2009

# Contents

<b>Summary .....</b>	<b>5</b>
<b>1. Introduction .....</b>	<b>6</b>
<b>2. Sellafield .....</b>	<b>6</b>
<b>3. Source term.....</b>	<b>7</b>
3.1 An accident involving a tank containing highly radioactive liquid waste at Mayak Production Association, Russia, in 1957 .....	9
<b>4. Fallout in Norway after a hypothetical accident at Sellafield .....</b>	<b>10</b>
4.1 Brief description of the SNAP model .....	10
4.2 Results of model simulations .....	10
4.2.1 Model simulations of <sup>137</sup> Cs fallout.....	11
4.2.2 Model simulations of <sup>137</sup> Cs fallout dependent on particle size.....	13
4.3 Comparison to <sup>137</sup> Cs fallout in Norway after Chernobyl .....	15
4.4 Uncertainties in model simulations .....	16
<b>5. Discussion and concluding remarks.....</b>	<b>16</b>
References.....	17

---

# Summary

The Norwegian Radiation Protection Authority (NRPA) has been given an assignment by the Norwegian Ministry of the Environment to perform an impact assessment of a hypothetical accident at Sellafield, UK. It has proved difficult to find relevant information in the public domain describing possible accident scenarios reviewed by British authorities. This report focuses on transport and fallout from “worst-case” scenarios based on a hypothetical accident at the B215 facility for storing Highly Active Liquors (HAL) at Sellafield. Currently B215 contains about 1000 m<sup>3</sup> HAL divided between 21 specially designed tanks (Highly Active Storage Tanks - HASTs). The HAL is a product of reprocessing activities at facility B205 (Magnox reprocessing) and Thorp which requires continual cooling and active management.

Prevalent meteorological conditions coupled with Norway’s geographical position make the country exposed in the event of an uncontrolled release due to an accident at Sellafield; especially a large atmospheric release is expected to have serious consequences in Norway. The NRPA scenarios involve an atmospheric release of between 0.1 – 10 % of the total assumed <sup>137</sup>Cs radionuclide inventory contained in the B215 HASTs. The specific reason for the release and the course of events immediately prior to/during the release are not speculated upon in this report other than the release is assumed to be due to a combination of an explosion and fire at the facility. The scenario assumes only <sup>137</sup>Cs is present in releases; a real event inventory would include many different fission products present in the HASTs. The NRPA project partner, Norwegian Meteorological Institute (met.no), has simulated the <sup>137</sup>Cs transport from Sellafield and resultant fallout in Norway using their SNAP model (Severe Nuclear Accident Program). The meteorological data used for simulations was collected from real meteorological data observed in October 2008 and is considered by met.no as quite representative of the typical seasonal weather.

Model simulations were completed for <sup>137</sup>Cs releases present as both aerosols and as a component part incorporated in radioactive particles of different size classes. The results show that even large particles (radius up to 9 µm) reach Norway. Norway received large amounts of <sup>137</sup>Cs fallout under the scenarios (an accidental release of between 0.1 – 10 % of the total HAL inventory) of between 10 – 5000 kBq/m<sup>2</sup>, especially along the west coast. Model simulations resulted in between 0.1 – 50 times the maximum <sup>137</sup>Cs fallout experienced in Norway after the Chernobyl accident. For the chosen weather situation, fallout started to occur over Norway only 9 hours after the hypothetical release.

This project has highlighted the importance of continuing work to reduce the risks involved with storage of HAL at Sellafield. British authorities have indicated they regard this type of accident as potentially serious and that the situation is under continuous evaluation to further reduce the risks of accidents at Sellafield.

---

# 1 Introduction

The NRPA have, under the remit of the Norwegian Ministry of the Environment, started an evaluation of possible consequences to Norway of a hypothetical accident at Sellafield in the UK. This report focuses on atmospheric release of radioactivity, transport and fallout in Norway from a “worst-case” accident at Sellafield. Section 2 presents some brief background information about Sellafield. Section 3 discusses the proposed source term, while section 4 briefly describes the SNAP model and presents the preliminary fallout results from this project compared to the fallout received in Norway after Chernobyl. Section 5 presents a brief discussion and some concluding remarks.

## 2 Sellafield

Sellafield lies in Cumbria on the North West coast of England. The site was commandeered by the English authorities to produce ammunitions during the Second World War and became part of the then “Ministry of Supply” in 1945 to facilitate the UK nuclear weapons programme. Ownership has changed several times since then: to the United Kingdom Atomic Energy Authority (UKAEA) in 1954; to British Nuclear Fuels (BNFL, owned by the state) in 1971; after restructuring British Nuclear Group (BNG) became responsible for operations in 2004; and in April 2005 the current owners took over, the Nuclear Decommissioning Authority (NDA). At present, the site operations are carried out by Nuclear Management Partners for the NDA. The last change of ownership in 2005 reflects a change from commercial enterprise to decommissioning work. The site covers some 75 ha. More than 10,000 are employed at Sellafield and 95 % of the workers live within 50 km of the site. Operations at Sellafield are regulated by Her Majesty’s Nuclear Installations Inspectorate/ Health and Safety Executive (HMNII/HSE), Environment Agency (EA), Office for Civil Nuclear Security (OCNS) and local authorities. Table [2.1](#) presents some of the main facilities at Sellafield.

---

**Tabell 2.1: Some of the main facilities that have been/are operated at Sellafield [6]**

facility	brief description	operation
Windscale Piles (1 and 2)	Produced plutonium for nuclear weapons. A fire in Pile 1 in 1957 lead to both being closed. Decommissioning continues today.	1950 - 1957
Calder Hall	Four Magnox reactors, the first commercial reactors in the world, also used to produce plutonium for nuclear weapons up until 1995.	1956 - 2003
WAGR	Prototype AGR (Advanced Gas-cooled Reactor).	1962 - 1981
B204	The first reprocessing facility used for spent nuclear fuel from Windscale Piles, Magnox and light water reactors (LWR).	1952 - 1973
B205	Magnox reprocessing facility – theoretical throughput capacity about 500 ton/year.	Since 1964
THORP	Reprocessing facility for spent nuclear fuel from AGR and LWR – theoretical throughput capacity about 200 ton/year, though the facility has been shut-down for longer periods due to accidents.	Since 1994
MDF	MOX demonstration production facility - closed following “falsification” scandal.	1993 - 1999
SMP	Sellafield MOX Plant - theoretical capacity about 120 ton/year though has only produced 5.3 ton MOX during 5 years of operation.	Since 2001

---

### 3 Source term

Currently B215 contains about 1000 m<sup>3</sup> HAL divided between 21 specially designed tanks (Highly Active Storage Tanks - HASTs). The HAL generates heat, is a product of reprocessing activities (at facility B205, Magnox reprocessing and Thorp) and requires continual cooling and active management. The function of B215 is mainly to collect, condition and store HAL before it is vitrified i.e., blended as part of a solid glass matrix that is easier and safer for long-term storage.

The HAL contained in HAST tanks at Sellafield has been chosen as the potential source of radioactive materials during the hypothetical worst-case scenario. The reason for this is the tank inventory contains very large amounts of radioactivity stored in liquid form. Long-term storage of large volumes of highly active liquid waste is not regarded as a safe and robust storage scheme. Indeed the British authorities regard the HAL stored in HASTs as a primary contamination risk at Sellafield. A large component of the HAL has already been in storage for some time; this decreases the amounts of short-lived radionuclides that can be present in any accidental release compared to, for example, an accident at an operational nuclear reactor.

The total volume of HAL in the HASTs per 1.4.2007 is given as 1087.7 m<sup>3</sup> [7]. In addition, HMNII have set a maximum allowed amount of stored HAL for future compliance over the coming years [7]. For the purposes of this report, the volume of HAL is assumed to be 1000 m<sup>3</sup>.

The concentrations (TBq/m<sup>3</sup>)<sup>1</sup> of selected radionuclides present in the HAL are shown in Table 3.1. Future arisings of HAL are derived based on planned Magnox and oxide reprocessing programmes and assumed waste liquor storage concentrations. British authorities report that the concentration of radionuclides in HAL can increase in the future, even though the volume of HAL shall decrease, possibly due to reprocessing spent nuclear fuel of different characteristics compared to previous operations. Therefore, uncertainty exists in future arisings of the different radionuclide concentrations present in HAL. Cs-137 is reported to have a future multiplication factor of 1.5 compared to the concentration given for 1 April 2007. This uncertainty is accounted for when defining the source term used in the NRPA hypothetical worst-case scenario.

**Table 3.1: Concentration per 1 April 2007 of selected radionuclides present in HAL [7]**

Radionuclide	TBq/m <sup>3</sup>
Strontium-90	4610
Ruthenium-106	194
Antimony-125	102
Cesium-134	175
Cesium-137	6280
Cerium-144	140
Promethium-147	2150
Americium-241	68

Without speculating how an accident scenario occurs, it is possible to assume that a given percentage of the total HAST inventory is released to the atmosphere by an event. The UK Parliamentary Office of Science and Technology observe that earlier impact assessments concerning Sellafield facility B215 have used quite different source terms; from 0.01 % of one HAST inventory to over 10 % of all the HASTs contents [9]. Furthermore, the 10 % level is reported as reflecting worst-case prognoses involving a large explosion.

This reports focus is not to calculate the probability of a given accidental release, but rather to study how a large atmospheric release from Sellafield could affect Norway. Therefore the accidental releases (source terms) considered have fallen in a range from 0.1 – 10 % of the total volume HAL present in the HASTs.

Sr-90 and <sup>137</sup>Cs are the dominant fission products present in the HAL and will be the dominant radionuclides expected in fall out after an accidental release. However, in this preliminary study, <sup>137</sup>Cs is the only radionuclide considered. Cs-137 has previously become part of accidental releases from nuclear installations and has been well studied with respect to its effects and behaviour in the environment. It is a gamma emitter with a 30 year half-life and is chemically similar to potassium. It has therefore about the same bioavailability as potassium and is effectively assimilated by both animals and plants.

In a real event, accidental releases will include many different radionuclides, both as aerosols and particles of differing size, form, density and composition. The amount of <sup>137</sup>Cs released under the chosen scenarios varied between  $9.4 \times 10^3$  TBq and  $9.4 \times 10^5$  TBq, representing from 0.1 – 10 % of the assumed total <sup>137</sup>Cs HAST inventory (i.e. 1 – 100 m<sup>3</sup> HAL).

<sup>1</sup> One *tera* Bq (TBq) equals  $10^{12}$  Bq i.e., 1000,000,000,000 Bq.



### 3.1 An accident involving a tank containing highly radioactive liquid waste at Mayak Production Association, Russia, in 1957

Tanks containing large inventories of highly active liquid wastes also exist at the Russian reprocessing facility “Mayak PA” in South Ural. An equipment failure controlling temperature and volume in 1957 lead to the breakdown of a cooling system in one of the tanks. This in turn lead to the build up of nitrate and acetate salts at high temperature that subsequently exploded on the 29 September 1957 [5], destroying the tank structure and releasing the tanks contents, causing a cloud of radioactive contamination to spread into the atmosphere and across adjacent territory (known as the Kyshtym accident). The radioactive plume is assumed to have reached an altitude of approximately 1 km [3]. Of the approximately 740 PBq<sup>2</sup> in the tank, 90 % fell out in close proximity of the tank site. The remaining 74 PBq was transported by the wind, causing radioactive fallout covering an distance some 300 km from the tank site (see Figure 3.1), causing large consequences for local the inhabitants and environment [4, 3, 8].

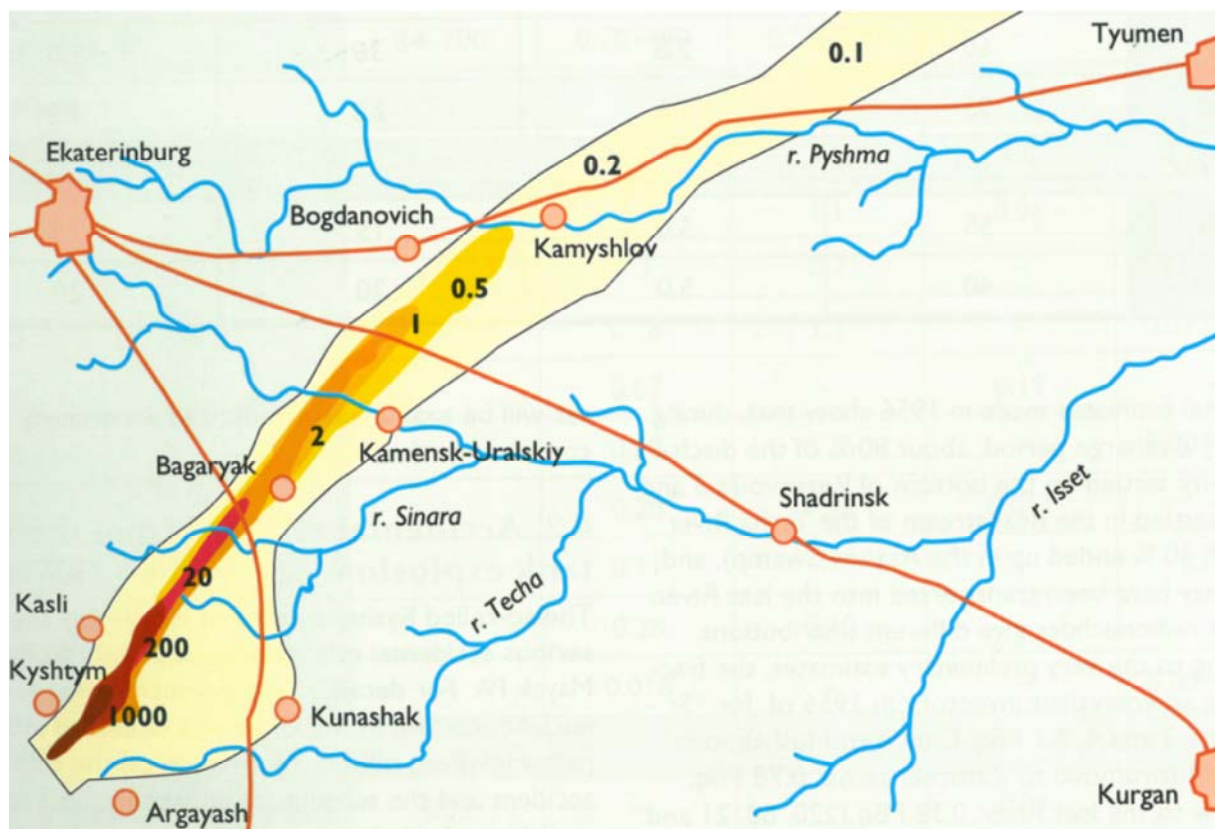


Figure 3.1: “The Eastern Ural Radioactive Trace” (EURT). Radioactive fallout of <sup>90</sup>Sr after the Kyshtym accident; Surface concentrations are given in Ci/km<sup>2</sup> (1 Ci/ km<sup>2</sup> = 3.7×10<sup>4</sup> Bq/m<sup>2</sup>).

The Kyshtym accident at Mayak is the largest known accident where a tank containing highly active liquid waste has exploded and spread radioactive materials over a considerable area. Even though some parallels can be drawn between the Mayak tanks and the HASTs present at Sellafield, there are

<sup>2</sup> One *peta* Bq (PBq) equals 10<sup>15</sup> Bq i.e., 1000,000,000,000,000 Bq.

---

several important differences; e.g., the contents, construction and safety systems of the HASTs are different compared to the Russian tanks. However, the Kyshtym accident shows that accidents causing the release of highly active liquid waste stored in tanks can cause considerable impacts. A similar accident, with lesser consequences, also occurred near Tomsk, Russia in 1993. Here, accidental releases were smaller than the Kyshtym accident and under different weather conditions: lower wind velocity and light snowfall.

## **4 Fallout in Norway after a hypothetical accident at Sellafield**

After the Chernobyl accident in 1986 computer models were created to model atmospheric transport and fallout of radionuclides after nuclear accidents. These transport models were designed to calculate the extent and level of impacts after an accident, to aid decision making for emergency response. The risk of accidents and, after 11 September 2001, terrorist attacks at nuclear facilities is still relevant today. The Norwegian Metrological Institute has developed and manages such a transport model (SNAP - Severe Nuclear Accident Program) which is used by NRPA [2]. The current version of this model also incorporates the possibility of modelling transport of radioactive particles of different size and density [1], developed through collaboration between met.no and the Norwegian University of Life Sciences (UMB), referred to as SNAP2 in this report.

### **4.1 Brief description of the SNAP model**

The SNAP model simulates transport and deposition of radioactivity from an atmospheric plume of radioactive contaminants. The model can also describe transport of such a plume during shorter periods in the past. The input meteorological data is taken from the met.no High Resolution Limited Area Model (HIRLAM).

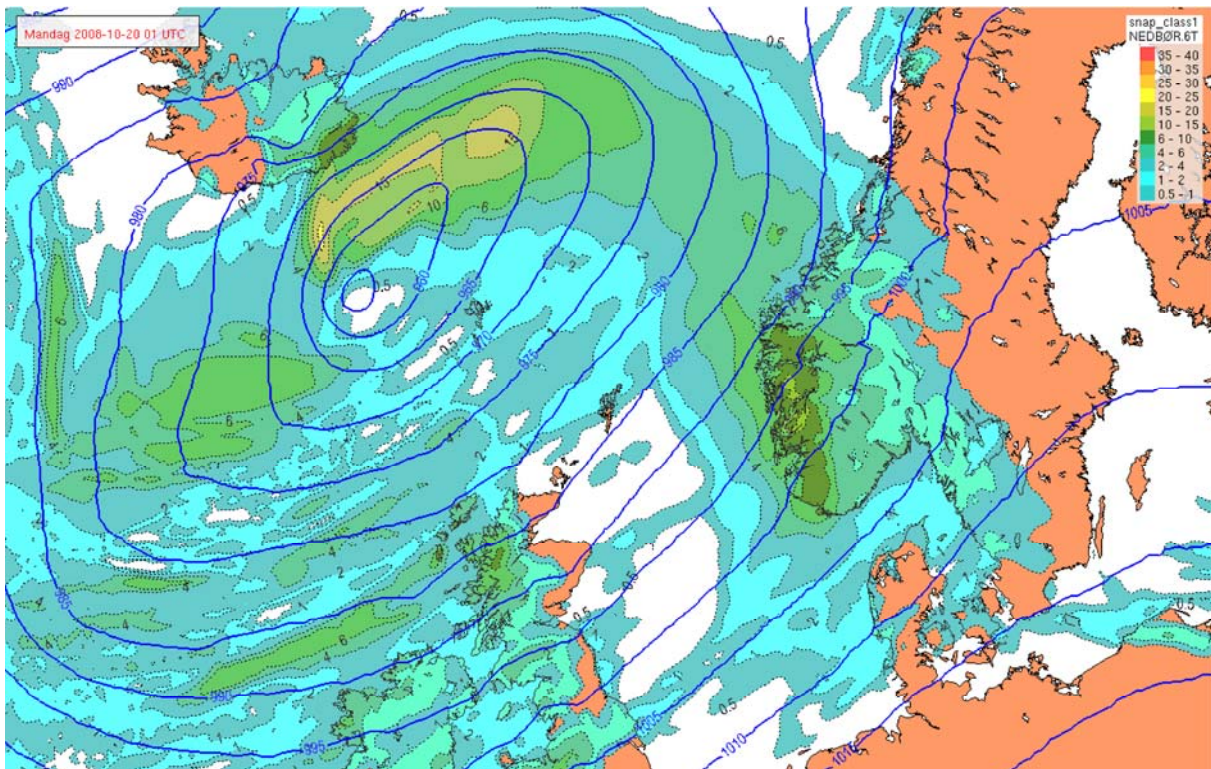
In the SNAP model, the release is simulated by a large number of particles (aerosols) which are transported in the prevailing air masses. The particle has no size dimensions and cannot be divided into smaller parts. However, the mass of the particle can be divided and the particle can thereby lose mass during transport due to fallout and radioactive decay [2].

The lower part of the atmosphere is represented in the model as a mixing layer of relatively turbulent air (also known as the atmospheric boundary layer, ABL) of differing depth dependent on the weather conditions. The ABL depth generally ranges from 300 – 2500 m. The SNAP model assumes complete and instant mixing within the ABL i.e., the probability distribution of a particle within this vertical layer is homogenous.

### **4.2 Results of model simulations**

The worst case scenario starts 19 October 2009 at 13:00. The weather situation used during the NRPA scenarios was one dominated by a low pressure system located southeast of Iceland, causing southwest winds from the UK across the North Sea towards Scandinavia giving quite extensive precipitation, especially in south Norway and on the western coast. This weather type is considered quite typical by meteorologists for the studied time period and geographical region.

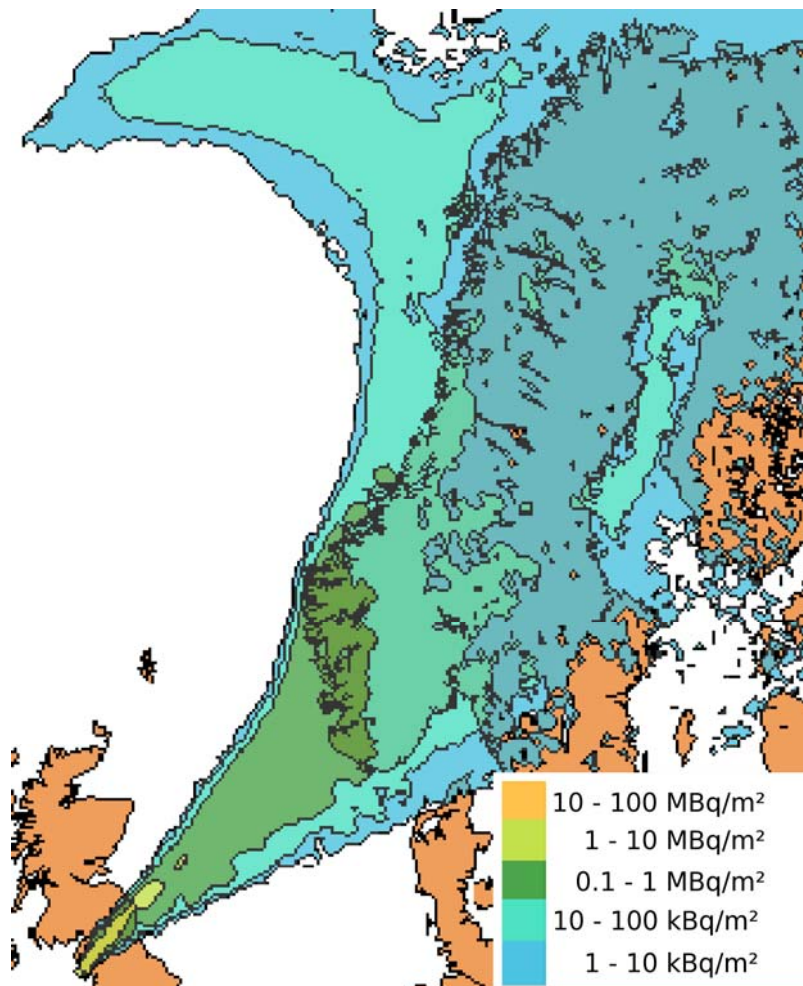
The total precipitation for the period 6 – 12 hours after the scenario start is indicated in Figure 4.1. The radioactive plume reaches the Norwegian coast during this period causing large amounts of fallout. The coastal and southern areas of Norway receive relatively large amounts of rainfall. October 2008 was a wet month; Bergen (coastal city lying approximately in the middle of Norway's south west coast) received 182 % of its average monthly precipitation during this period. Recorded precipitation in Bergen was 20, 15 and 30 mm for the dates 19, 20 and 21 October, respectively.



**Figur 4.1: The total precipitation for the period 6 – 12 hours after the scenario start of the worst case scenario (mm).**

#### 4.2.1 4.2.1 Model simulations of $^{137}\text{Cs}$ fallout

The total  $^{137}\text{Cs}$  fallout 48 hours after the scenario start is presented in Figure 4.2. This figure indicates the fallout simulated from an accidental release of 1 % of the total HASTs inventory of  $^{137}\text{Cs}$  into the atmosphere.



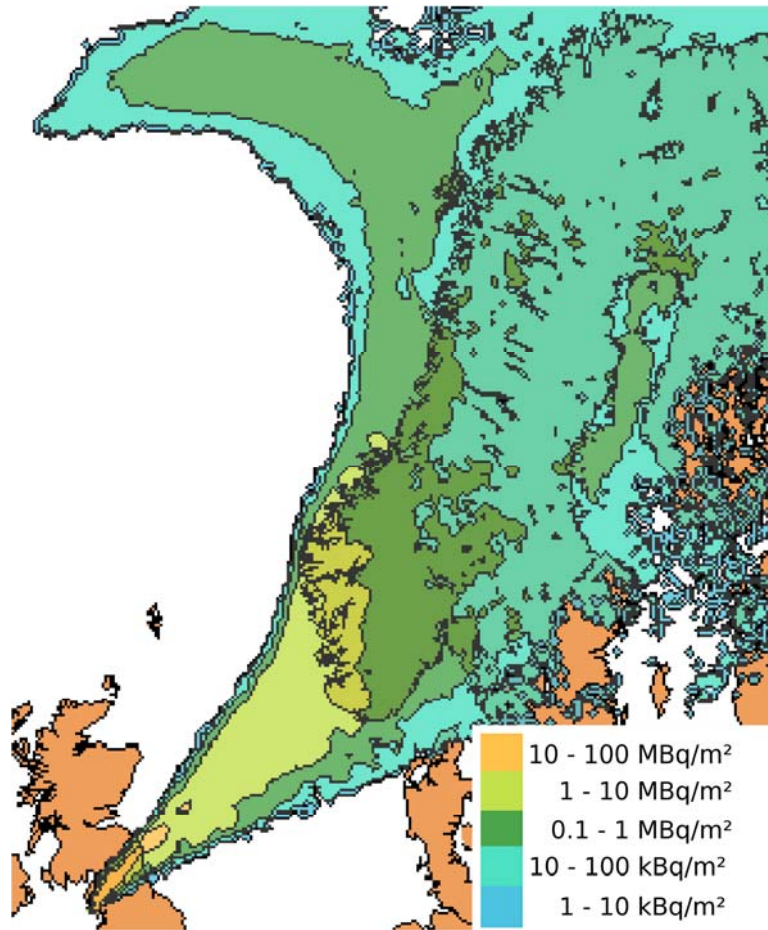
**Figure 4.2: Fallout of  $^{137}\text{Cs}$  ( $\text{Bq}/\text{m}^2$ ) 48 hours after a worst case accident releasing 1 % of the assumed total  $^{137}\text{Cs}$  inventory from the HASTs at Sellafield<sup>3</sup>.**

Figure 4.2 shows that, for the 1 % release scenario, the west coast of Norway receives fallout giving a  $^{137}\text{Cs}$  deposition of over  $100 \text{ kBq}/\text{m}^2$  (in the range  $100 - 500 \text{ kBq}/\text{m}^2$ ) after 48 hours. A large area of south and mid-Norway received fallout depositions of over  $10 \text{ kBq}/\text{m}^2$ .

Figure 4.3 presents the simulated  $^{137}\text{Cs}$  fallout 48 hours after the scenario start for a source term of 10 % of the assumed total  $^{137}\text{Cs}$  inventory in HASTs. Here, the west coast of Norway receives  $1000 - 5000 \text{ kBq}/\text{m}^2$   $^{137}\text{Cs}$ .

The SNAP model has a linear relationship between the source term released and fallout; the fallout patterns presented in Figures 4.2 and 4.3 which are the simulation results for source term releases of 1 and 10 % of the total  $^{137}\text{Cs}$  inventory from the HASTs at Sellafield, respectively, compare favourably. Therefore, a release of 0.1 % of the assumed total  $^{137}\text{Cs}$  inventory in HASTs is expected to result in 10 times less  $^{137}\text{Cs}$  fallout compared to the results presented in Figure 4.2.

<sup>3</sup> One *mega* Bq (MBq) equals  $10^6$  Bq i.e., 1000 000 Bq; one *kilo* Bq (kBq) equals  $10^3$  Bq i.e., 1000 Bq.



**Figur 4.3:** Fallout of  $^{137}\text{Cs}$  ( $\text{Bq}/\text{m}^2$ ) after a worst case accident releasing 10 % of the total assumed  $^{137}\text{Cs}$  inventory from the HASTs at Sellafield.

#### 4.2.2 Model simulations of $^{137}\text{Cs}$ fallout dependent on particle size

Simulations have also been carried out for a 10 % release source term using the SNAP2 model with the same input metrological data. This was done in an attempt to qualify the effects of a particulate release containing  $^{137}\text{Cs}$  as opposed to a release of aerosols. According to the IAEA, serious accidents at nuclear installations are expected to cause the release of radioactive particles [10]. The composition of such particles will be source dependent, while the particle forms and densities will depend on the accident characteristics. It is reasonable to assume that a serious accident involving the HASTs will cause the release of radioactive particles and a large share of released  $^{137}\text{Cs}$  will be associated with particles of differing size and structure.

Figure 4.4 presents differing fallout patterns simulated for different particle sizes. Here, the fallout patterns are shown for particle radii of  $2.2\ \mu\text{m}$  and  $8.6\ \mu\text{m}$ , respectively. The particle radius of  $2.2\ \mu\text{m}$  represents an aerosol and is, as such, very similar to the SNAP simulations as can be seen by comparing Figures 4.4 and 4.3. Norway received slightly less  $^{137}\text{Cs}$  fallout when the particle radius was set as  $8.6\ \mu\text{m}$  compared to  $2.2\ \mu\text{m}$ . However, fallout concentrations were still over  $100\ \text{kBq}/\text{m}^2$  along the west coast. Figure 4.4 shows the model results are affected by the assumed release-particle size; a four-fold increase in particle size resulted in a slight reduction in fallout, though still lead to high level contamination in Norway.

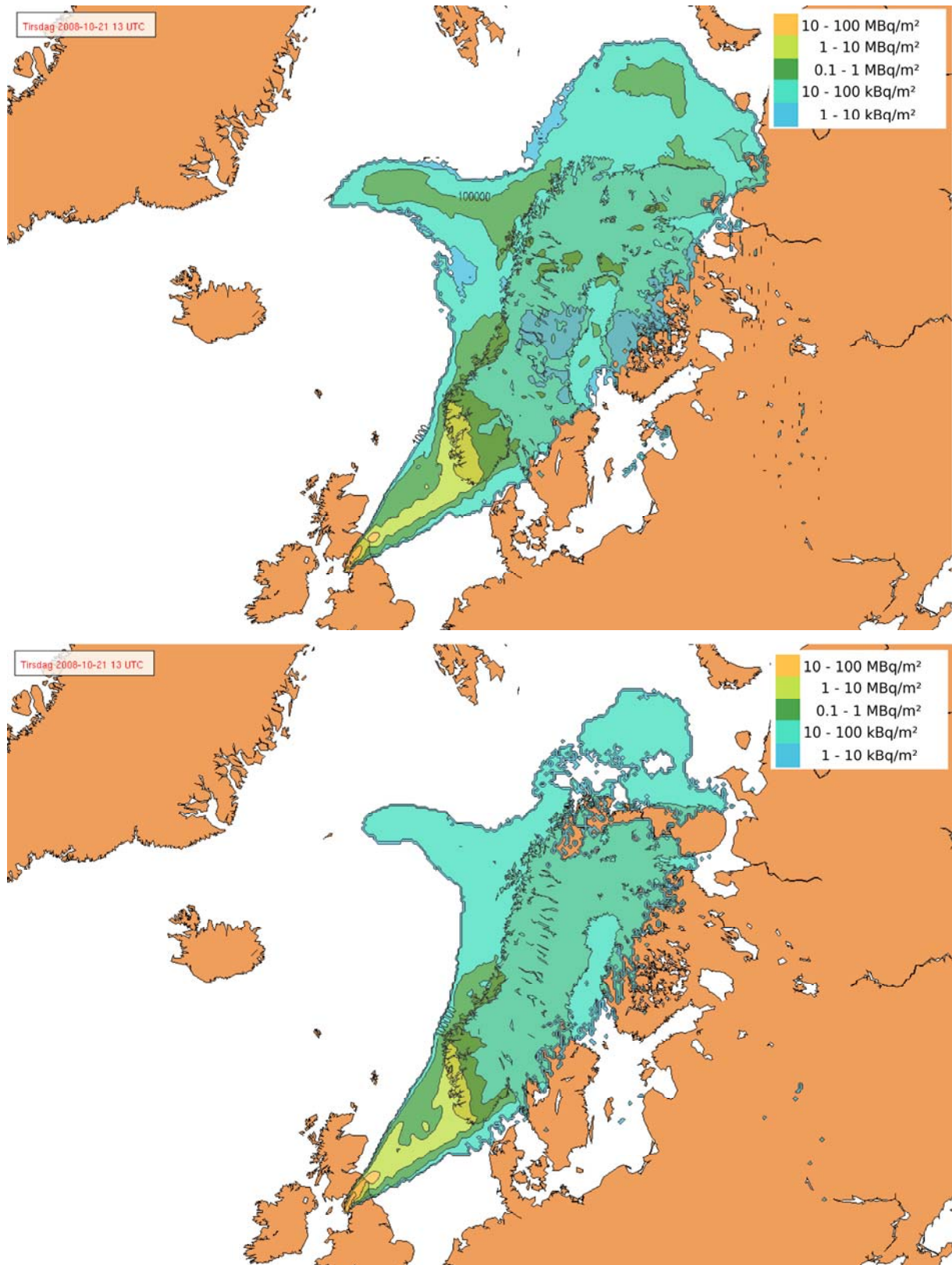
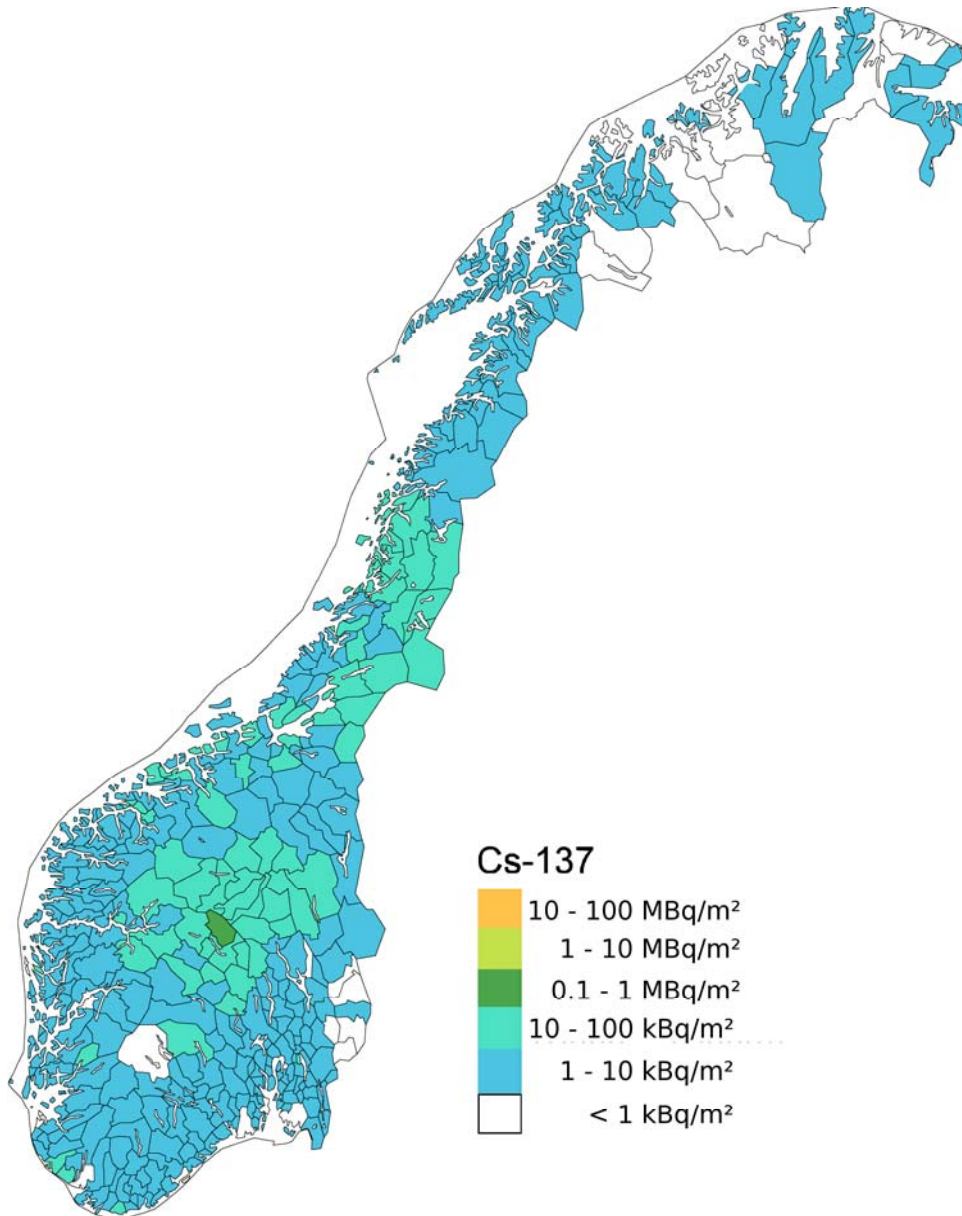


Figure 4.4: Fallout of  $^{137}\text{Cs}$  (Bq/m<sup>2</sup>) after a worst case accident releasing 10 % of the total assumed  $^{137}\text{Cs}$  inventory from the HASTs at Sellafield. Particle radii were set as 2.2 µm (upper figure) and 8.6 µm (lower figure), respectively.

Particulate fallout will occur in a non-homogenous manner such that hot spots can occur with markedly higher radioactive contamination. Singular particles can also contain very large amounts of radioactivity and become point internal sources if inhaled/ingested by humans or animals [10].

### 4.3 Comparison to $^{137}\text{Cs}$ fallout in Norway after Chernobyl

Figure 4.5 indicates the  $^{137}\text{Cs}$  fallout experienced in Norway after the Chernobyl accident in 1986.



Figur 4.5:  $^{137}\text{Cs}$  fallout experienced in Norway after the Chernobyl accident

The highest  $^{137}\text{Cs}$  fallout concentrations in Norway after the Chernobyl accident are found in selected mountain areas in southern Norway, which received contamination densities of approximately 100 kBq/m<sup>2</sup>. The corresponding levels for the west coast of Norway were approximately 5 kBq/m<sup>2</sup>. By

---

comparison, under the model simulations completed in this report for the hypothetical worst case accident at Sellafield (with source terms ranging from 0,1 – 10 % of the total assumed  $^{137}\text{Cs}$  inventory in HASTs), this area received fallout densities of between 10 kBq/m<sup>2</sup> to 1 MBq/m<sup>2</sup>.

It is also important to qualify that many different radionuclides would be expected to be transported to Norway during a real event, and this would cause further consequences and impacts in Norway.

## 4.4 Uncertainties in model simulations

The largest uncertainties here are concerning the chosen source terms and accident scenario assumptions. The source term has been chosen based on the available information. However the type of accident/incident required to cause such a release is not elaborated upon. The probability of such an accident is also uncertain and not considered here. The transport models used contain less uncertainty, though the likelihood of the specific weather conditions used in model simulations occurring is open to debate. Different weather conditions would cause different fallout patterns, possibly affecting other areas of Norway compared to those presented in this report. It is reasonable to assume that a portion of releases due to a serious accident involving the HASTs will be in particulate form. However, the particles size and density distributions are more difficult to predict. Particulate fallout is expected to be non-homogonously distributed though uncertainty remains as to how high localised levels of contamination will be.

## 5 Discussion and concluding remarks

This report focuses on transport and fallout of radioactivity in Norway caused by “worst-case” scenarios based on a hypothetical accident at the B215 facility for storing Highly Active Liquors (HAL) at Sellafield. It does not focus on the cause or probability of such an accident. It is difficult to predict the volume and corresponding radioactivity of a release of HAL to the atmosphere caused by an accident/terrorist attack at Sellafield. Relevant information required to assess this is not readily available in the public domain due to security considerations. Therefore, the worst case assumption made in this report is based around a range of possible releases from 0.1 – 10 % of the assumed total HAL volume stored at B215.

Model simulations indicate that an accidental release of radioactivity to the atmosphere under typical weather conditions following a major accident at Sellafield can reach Norway in nine hours. High  $^{137}\text{Cs}$  contamination densities were simulated, especially along the south west coast of Norway. Calculations show that increased precipitation effectively fell out  $^{137}\text{Cs}$  causing elevated deposition in areas that experienced high rainfall during the scenario. This was also observed after the Chernobyl accident. Model simulations reported here only study  $^{137}\text{Cs}$  as a case radionuclide; Sellafield HASTs contain many different radionuclides which, in the event of a real accident, would increase the impacts to Norway.

Model simulations were completed for  $^{137}\text{Cs}$  releases present as both aerosols and as a component part incorporated in radioactive particles of different size classes. The results show that even large particles (radius up to 9  $\mu\text{m}$ ) reach Norway. Norway received large amounts of  $^{137}\text{Cs}$  fallout under the scenarios (an accidental release of between 0.1 – 10 % of the total HAL inventory) of between 10 – 5000 kBq/m<sup>2</sup>, especially along the west coast. Model simulations resulted in between 0.1 – 50 times the maximum  $^{137}\text{Cs}$  fallout experienced in Norway after the Chernobyl accident. For the chosen weather situation, fallout started to occur over Norway only 9 hours after the hypothetical release.



---

If such a worst case accident should occur, the consequences for Norway would be equal or worse than those experienced after Chernobyl. This will include consequences affecting society, agriculture and the environment for decades requiring mitigation measures to be adopted

This impact assessment has, despite the obvious uncertainties, indicated that a worst case accident at B215 in Sellafield could entail considerable fallout and impacts to Norway. From an emergency preparedness and response perspective, it is important for Norway to assess the different possible sources of radioactive contamination that could affect Norway. The Norwegian emergency response structure is designed to cope with such an accident at Sellafield.

This study has shown the importance of reducing the risks of an accident occurring at the B215 facility. Security and safety procedures should be in continual focus and subject to periodical evaluation. It is also important to reduce the amounts of HAL stored at B215 via vitrification, as soon as possible, to enable storing the radioactivity in a safer form. British authorities have assured Norwegian authorities that they regard these issues as very important. The Norwegian authorities would welcome increased bilateral emergency response collaboration with the UK, especially concerning the timely and effective reporting of all incidents at British nuclear installations as well as increased information exchange regarding risk assessments for British nuclear installations, especially Sellafield.

## References

- [1] Jerzy Bartnicki and Jørgen Saltbones. Modelling atmospheric dispersion of radioactive debris released in case of nuclear explosion using the norwegian snap model. *Croatian Meteorological Journal* 43, pages 111–115, 2008.
- [2] Jørgen Saltbones, Anstein Foss, and Jerzy Bartnicki. Severe nuclear accident program (SNAP). A real time dispersion model. In *International aspects of Emergency Management and Environmental Technology*, 1995.
- [3] JNREG. *Sources contributing to radioactive contamination of the Techa River and the areas surrounding the "Mayak" production association, Urals, Russia: Programme on investigations of possible impacts of the "Mayak" activities on radioactive contamination of the Barents and Kara Seas*. Norwegian Radiation Protection Authority, NRPA., 1997.
- [4] JNREG. *Impacts on man and the environment in northern areas from hypothetical accidents at "Mayak" PA, Urals, Russia*. Number ISBN 82-996531-2-6. Norwegian Radiation Protection Authority, NRPA., 2004.
- [5] S. A. Kabakchi, A. V. Putilov, and E. R. Nazin. Analysis of data and physiochemical modelling of the radiation accident in the southern urals in 1957. *Atomaya Energiya*, 78(1):46–50, 1995.
- [6] Forwood M. The legacy of reprocessing in the United Kingdom. *International Panel on Fissile Materials Research Report*, <http://www.ipfmlibrary.org/rr05.pdf>, 2008.
- [7] NDA/DEFRA. The 2007 UK radioactive waste inventory. Nuclear Decommissioning Authority and Department for Environment, Food and Rural Affairs. *NDA, Cumbria.*, 2008.
- [8] NRPA. Bulletin 8, 2008. [www.nrpa.no](http://www.nrpa.no)
- [9] Parliamentary Office of Science and Technology. Terrorist attacks on Nuclear Facilities POST report Number 222, 2004. <http://www.parliament.uk/documents/upload/POSTpr222.pdf>
- [10] IAEA Coordinated Research Program (CRP) on the “Radiochemical, Chemical and Physical Characterization of Radioactive Particles in the Environment” TECDOC series (in press).







Statens strålevern  
Norwegian Radiation Protection Authority

**StrålevernRapport 2009:1**

Virksomhetsplan 2009

**StrålevernRapport 2009:2**

Røntgendiagnostikk blant norske tannleger

**StrålevernRapport 2009:3**

Analyse av variasjon i representative doser ved CT-undersøkelser

**StrålevernRapport 2009:4**

Årsrapport fra persondosimetritjenesten ved Statens strålevern 2007

**StrålevernRapport 2009:5**

Teknisk kvalitetskontroll - konstanskontroller for digitale mammografisystemer

**StrålevernRapport 2009:6**

Konsekvenser for Norge ved en mulig ulykke ved Sellafield-anlegget

**StrålevernRapport 2009:7**

Consequences in Norway of a hypothetical accident at Sellafield