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TECHNICAL ASPECTS ASSOCIATED WITH THE RELEASE OF RADIOACTIVE MATERIAL INTO THE ATMOSPHERE AND THE IMPACTS ON IN-FLIGHT EXPOSURE

- A Prelimary Look -

(Submitted by Canada)

Summary and purpose of document

The purpose of the paper is to present a preliminary “order-of-magnitude” analysis of the impacts on the health and safety of crew and passengers due to in-flight exposure to airborne radioactivity following an episodic release of radioactive material into the atmosphere (e.g. nuclear facility accident) in light of the recent adoption of ICAO Amendment 72. This paper has been presented at the ICAO VAW Study Group meeting held in Brisbane in May 2000.

Action proposed

The meeting is invited to consider the proposals presented in this document and to make recommendations.

1. Introduction

We are constantly surrounded by background radiation. Typical surface background dose values range between 10 and 100 nSv1/hr in the Northern Hemisphere. In villages surrounding Chernobyl, typical values currently range between 300-500 nSv/hr. As you move further up in the atmosphere, the exposure to cosmic rays increases. At typical flying altitude (FL320), the radiation dose reaches 2000-3000 nSv/hr. The higher you fly, the larger the dose that is experienced by passengers and crew. Figure 12 shows the dose equivalent rate that a passenger would experience on a flight between Tbilisi and Vienna. A few facts should also be considered:

- Commercial pilots often receive doses (5-15 mSv/year) comparable to the limit set for radiation workers (which is 20 mSv/year);
- Commercial aircrafts provide a fair shelter to radioactive particulates, since outside air has to go through filters thus limiting/preventing the accumulation of internal radiation doses through ingestion and breathing;
- Filters are useless for screening radioactive noble gases (for example ^{133}Xe and ^{135}Xe, ^{85}Kr, etc);
- In a typical reactor accident, the evacuation zone determined strictly on the excedance of health thresholds will generally be limited to 3-5 kilometers downwind of the site. The evacuation zone will likely exceed this value to manage public perceptions and fears associated with radioactivity;
- Once in the atmosphere, the plume dilutes very rapidly through advection, convection, diffusion and, in the case of particulates, is reduced through other atmospheric removal mechanisms.

Even though there might not be a problem from a health and safety point of view (except within a certain radius around the nuclear power plant and for some distance downwind), the public perception is such that some mitigative procedures need to be put in place.

2. A simple experiment: Dose rate calculations based on a CANERM simulation of the Chernobyl accident

On 26 April 1986 the World's worst nuclear power accident occurred at Chernobyl in the former USSR (now Ukraine). The Chernobyl nuclear power plant, located 150 kilometers north of Kiev, had 4 reactors and while testing reactor number 4 numerous safety procedures were disregarded. At 01:23 local time the chain reaction in the reactor became out of control creating explosions and a fireball which blew off the reactor's heavy steel and concrete lid. The Chernobyl accident killed more than 30 people immediately, and as a result of the high radiation levels in the surrounding 35-kilometer radius, 135,000 people had to be evacuated.

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1 The Sievert (Sv) is the International System unit of measurements of the equivalent dose or radiation received by a tissue, an organ or an organism. It expresses the biological effect of a particular absorbed dose. The Sievert replaces the Rem (Roentgen equivalent man).

2 Malcolm Crick IAEA ERU, personal communication.

This event has been extensively studied[3] and the long range transport and dispersion of radionuclides in the atmosphere is no exception. An evaluation of the performance of transport and dispersion models has been done by the Commission of the European Communities in association with the World Meteorological Organization and the International Atomic Energy Agency[4].

For the purpose of this experiment, we have looked at vertically integrated concentrations of ^{137}Cs in the layers FL000-200, FL200-350 and FL350-600 using one of the CANERM simulation of the Chernobyl accident. The version of the CANERM model used for Chernobyl simulations has a horizontal resolution of 30 km and uses 21 levels in the vertical in σ coordinates. The source term considered a release of $25\bullet10^{+17}$ Bq of ^{137}Cs at the surface and a maximum plume height above the release site of 1100 meters. Integration was done for 240 hours using 3600 seconds time steps, and the results are presented in Figure 2. Note that the outputs are presented using the same format as the VAAC's advisory ash chart.

In order to compute dose from concentration values, we used the following set of assumptions:

- Aircraft filters have 100% efficiency into blocking all particulates from entering the cockpit
- Only gamma radiation from cloudshine is considered
- Infinite 'cloud' is considered
- Cloudshine coefficient factor for ^{137}Cs is $9.28 \bullet 10^{-17}$ $Sv\bullet s^{-1}\bullet Bq^{-1}\bullet m^{-3}$
- Flying time through the area where maximum concentration occurs last for one hour
- Calculations are made using the maximum vertically integrated concentrations plotted for each of the layers on Figure 2 at 72 hours

Based on the concentration values of Figure 2, a summary of the dose calculations is provided in the following Table:

Layers	Maximum concentration $Bq\bullet m^{-3}$	Dose equivalent rate $nSv\bullet hr^{-1}$
FL 000 - 200	46.23	$1.5\bullet10^{-2}$
FL 200 - 350	2.73	$9.1\bullet10^{-4}$
FL 350 - 600	0.05	$1.7\bullet10^{-5}$

Not losing sight that these calculations are based on modelling data rather than on observed data, these values are extremely small. This is especially true when the dose values obtained through modelling are compared with the observed values during the flight Tbilisi-Vienna shown in Figure 1 which reached 3000 nSv/hr. These values need also to be compared with generally accepted 'health' threshold (Canadian Standards Association on an annual basis):

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[3] Details can be found at the following web page: http://www.iaea.org/worldatom/inforesource/bulletin/bull383/gonzalez.html on the IAEA web site.

[4] Klug, W., G. Graziani, G. Grippa, D. Pierce, and C. Tassone, 1992: Evaluation of long range atmospheric transport models using environmental radioactivity data from the Chernobyl accident - The ATMES Report. Elsevier Applied Science, New York, 366p.

public dose 1 mSv
occupational dose (radiation workers) 20 mSv
increased risk of cancer (chromosome damages) 100 mSv
radiation sickness 1000 mSv
100% death rate 10000 mSv

3. Conclusions and possible future work

Health physics is a complex field of expertise. Based on this simplistic experiment, the dose values we estimated are extremely low. In fact they are much lower than the dose received by the exposure to cosmic rays at typical cruising altitudes. It should be recognized that landing and takeoff within a few tens of kilometers around the reactor and a few hundred kilometers downwind of the reactor following a nuclear accident with radiation released to the atmosphere could result in exposure many orders of magnitude above the values we have estimated. In this instance, there is no argument that local safety and contingency measures need to be put in place and activated to avoid and eliminate any possibility of such potentially elevated exposure of passengers and crew and contamination of the aircraft.

On the other hand, outside this ‘hot zone’, the negative perception and fears may well be the primary issue, and as such specific mitigation measures will need to be taken by the aviation authorities, and indeed similar measures are likely already managed within the national authorities for public safety in the event of a nuclear accident. It should be recognized that the risk associated with any mitigative measure (such as re-routing aircraft in-flight) should be in suitable balance with the real risks associated with the exposure to the estimated radiation levels.

The Expert Group needs a better assessment, better than this order-of-magnitude examination, of the various levels of exposures/doses and risks implicated for in-flight passengers and crew. To achieve this, we recommend that further work be done with the IAEA member and the Secretariat.

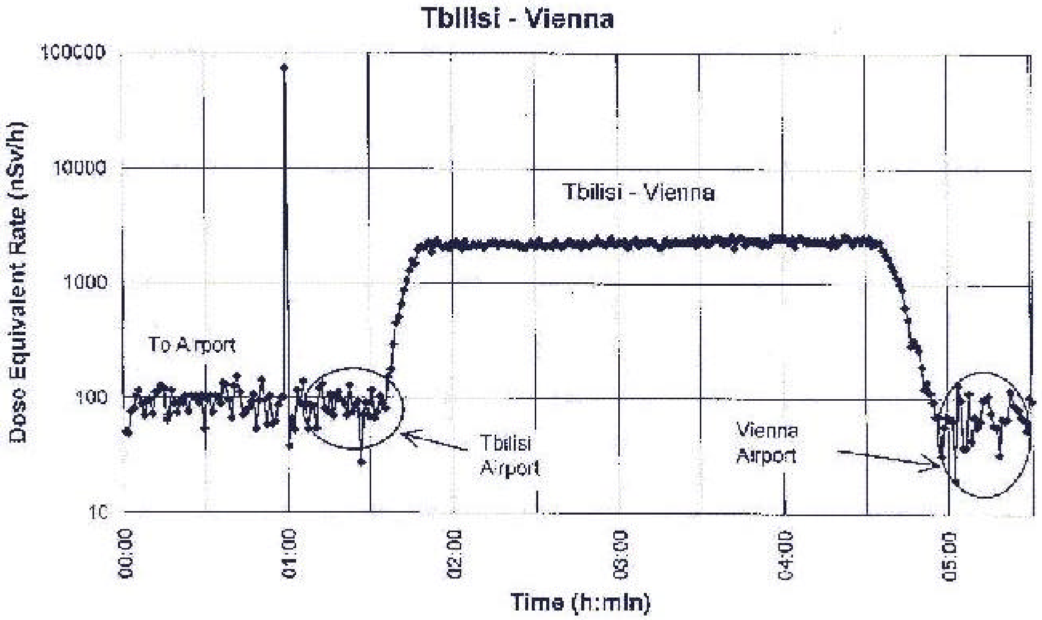

Figure 1. Equivalent dose rate experienced by a traveler on a flight from Tbilisi to Vienna. The spike displayed at time 01:00 corresponds to the passage of the dosimeter through the x-ray device. Figure provided by Malcolm Crick, IAEA ERC.

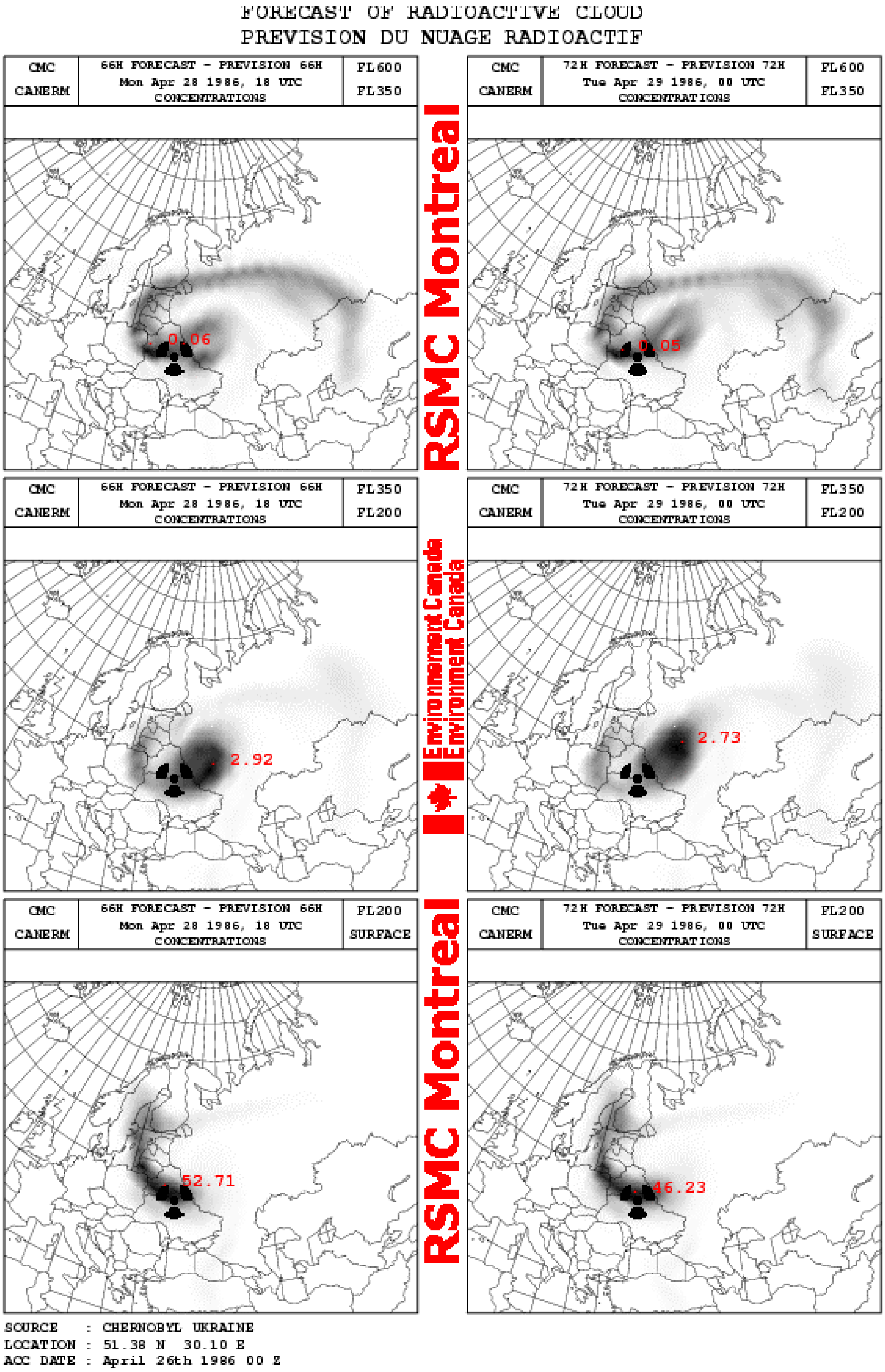

Figure 2. Adaptation of a standard VAAC model output to the nuclear context. The example shown is a CANERM simulation of the Chernobyl accident for the period 66-72 hours after the release which happened on 26 April 1986. Integrated concentration for ^{137}Cs are displayed and maximum values in Bq•m^{-3} are plotted. Contours were left out for clarity.