DOMESTIC SMOKE DETECTORS - A RADIOACTIVE WASTE PROBLEM?

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INTRODUCTION

A common form of domestic smoke detector is the ionisation chamber smoke detector. A small radioactive source provides the ionisation and when smoke enters the sensitive volume the change in voltage is sensed electronically. The use of domestic ionisation chamber smoke detectors is widespread and is recommended by fire authorities and insurance companies. That one million such detectors were imported into New South Wales in 1994 is an indication of the numbers involved. The typical radioactive source in a domestic smoke detector is Am 241, which is regarded as one of the more hazardous radionuclides. If it is such a hazardous material, should it be allowed in the normal household without any control? Or, in a smoke detector, is it in a less hazardous form than assumed in the ICRP recommendations and do its benefits outweigh its possible risks?

In spite of the apparent hazard of Am 241, the possession of the radioactive source in smoke detectors is generally exempt from any form of regulation. Waste regulations, however, set requirements for the disposal of Am 241 and these regulations can be interpreted as applying to smoke detectors. We appear to have a situation where a home owner can legally purchase any number of smoke detectors but when they fail there are Codes of Practice that prevent them being disposed of.

On the other hand, smoke detectors have a direct life saving function and reports indicate that smoke detectors can reduce both injury and property damage by up to 50%. Do these benefits from the use of smoke detectors compensate for any radiological risk?

THE HAZARDS OF AMERICIUM 241

From ICRP Publication 68 (1), the occupational annual limit on intake by inhalation(ALI_{inh}) for an aerosol with an activity median aerodynamic diameter (AMAD) of 1 μm is 500 Bq. The ingestion ALI is 100 kBq. Thus a typical smoke detector with an Americium source of 40 kBq contains about 80 times the ALI_{inh} and about half the ALI_{ing} for an adult worker. Table 1 (based on reference 2) gives the ALIs for inhalation and ingestion for members of the public of different ages. The typical source contains about 2700 times the ALI_{inh} and about 15 times the ALI_{ing} for a one year old.

The majority of Am 241 sources used in domestic smoke detectors are the oxide form. The radionuclide in a gold matrix, sintered at high temperature, is sealed between a silver backing and a thin gold or gold alloy cover, (3). They are robust and can survive quite severe treatment without damage.

Table 1. Am 241 ALIs at different ages.

Exposed person	ALI_{inh} Bq	ALI_{ing} Bq
One year old	15	2.7×10^3
Ten year old	25	4.5×10^3
Adult	26	5×10^3

RADIOLOGICAL ACCIDENTS WITH SMOKE DETECTORS

There do not appear to be any reports of inhalation accidents in the literature.

A case of ingestion by a person who swallowed two Am 241 smoke detector sources of 2.5 μCi (about 100 kBq) each, has been reported (4). The sources were later voided with very little physical damage. The report concluded that the sources lost less than 1 % of their activity and that much less than 1.5 % of the activity released was absorbed into the blood. The authors of the report concluded: "If the sources of Am 241 involved in this incident are representative of those incorporated in domestic smoke detectors, then the most important conclusion that can be drawn is that they are remarkably secure." Current Am 241 smoke detector sources are similar in physical structure, but smaller activities are now used.

CALCULATED RADIATION DOSES FROM THE USE OF SMOKE DETECTORS

External radiation

The OECD (5) has estimated an external dose of 160 nSv from Am 241 to the inhabitants of a protected house.

Inhalation

Table 2. Estimated doses from a fire involving a smoke detector source.

Age	Breathing rate m^3/h	Intake Bq	Dose mSv
1 year	0.35	0.88	0.059
10 years	1.12	2.8	0.11
Adult	3.0	7.5	0.29

For inhalation to occur the source material must become airborne. No inhalation doses will be received under normal operating conditions. The most obvious way for inhalation doses to occur is in a fire. According to the OECD (5) less than 1 % of the Am 241 in the smoke detector source is released in a 925 ^{0} fire. If 0.5% of the material is released and assumed to be distributed in a small room of 20 m^3, then the concentration would be 10 Bq/m^3. ICRP Publication 66 (6) gives an 1 year old child's breathing rate of 0.35 m^3/h during light exercise and a male adult breathing rate of 3 m^3/h during heavy exercise.

Assuming exposure in the small room of no more than a quarter of an hour, the child's intake would be 0.9 Bq and the adults intake would be 8 Bq. Using these values the adult dose would be no more than 0.3 mSv or an child's dose no more than 0.06 mSv. (See Table 2).

If a smoke detector is in a waste stream that goes to an incinerator, there could be a release of the source material if the incinerator temperature is high. Any Am 241 not released will report to the ash and probably go to a municipal tip.

Table 3. Estimated doses from high temperature incineration of a smoke detector source.

Age	Breathing rate m^3/h	Intake Bq	Dose µSv
1 year	0.35	1.75×10^{-4}	1.2×10^{-2}
10 years	1.12	5.6×10^{-4}	2.2×10^{-2}
Adult	3.0	1.5×10^{-3}	5.8×10^{-2}

If 1 % of the source material is released and discharged through a 20 m high stack, and the release occurs over 10 minutes, then the airborne concentration on the ground 50 m downwind would be about 3×10^{-3} Bq/m^3. At that location a child's dose would be 12 nSv and an adult's dose would be 60 nSv. (See Table 3.)

Ingestion

Using the value from Rundo *et al.*(4) for the activity released from an ingested smoke detector source, then the "intake" from a swallowed source would be no more than 400 Bq resulting in an adult dose of 80 µSv or a child"s dose of 150 µSv. A smoke detector disposed of in a municipal tip could leach radioactivity to a local water course. Immersion tests (7) have indicated very slow leach rates. The movement of Am 241, once leached from the source, has been estimated (5) to be 10^{-4} of the ground water velocity. Public radiation doses due to leaching from a tip would be negligible.

Table 4. Estimated doses from use of smoke detectors.

Age	External dose. µSv	Inhalation dose from incinerator. µSv	Accidental inhalation dose from fire. µSv	Accidental ingestion dose. µSv
1 year	0.16	1.2×10^{-2}	59	150
10 years	0.16	2.2×10^{-2}	110	90
Adult	0.16	5.8×10^{-2}	290	80

RISKS FROM THE USE OF SMOKE DETECTORS

Table 4 summarises the possible doses from each pathway discussed above. The once in a lifetime inhalation dose from a fire is the most significant dose. How many people are assumed to be exposed to inhalation of Am 241 in a domestic fire is therefore critical in assessing the overall risk.

THE BENEFITS OF SMOKE DETECTORS

The OECD report (5) indicated that 40 % of fire deaths could be prevented by the use of smoke detectors. Gratz and Hawkins (8) indicated up to 39 % reduction in death and injury and the US National Fire Data Center (9) indicated about 50 %. Similar percentages are reported for reductions in property loss. The OECD report quotes a figure of 18 fire casualties per million population per year, 70 % of which occur in private dwellings. If these data apply to Australia, there are about 13 fire casualties per million per year in private dwellings and about 6 of these could be prevented by the widespread use of smoke detectors.

ALARA

Assuming that each year one adult person in a hundred is involved in a domestic fire inhalation event, one adult person in a thousand is involved in an incinerator fire inhalation event and one 10 year old in a hundred ingests a source, the average annual dose would be about 0.16 μSv. (That is, for the assumptions used, the inhalation and ingestion accident doses have negligible effect on the average dose.)

Using the ICRP (10) probability for stochastic effects of 7.3 % per Sv this would result in 1.2×10^{-2} stochastic effects per million per year. It must be pointed out that natural background radiation is about 2 mSv per year so the calculated increase in annual dose would not result in any observable health effects.

It has been estimated that there are about 13 fire casualties per million per year in private dwellings and that 6 of these could be prevented by the widespread use of smoke detectors. The ratio between probable reduction in fire casualties and possible radiation detriment is 500 to one. This takes no any account of the reduction in property damage.

CONCLUSIONS

The benefits from the use of domestic smoke detectors are at least 500 times greater than the possible harm.

The application of ALARA requires that the radiation detriment be reduced until further reduction is not cost effective. The radiation dose calculated here is so small that any cost to reduce it further would not be cost effective.

If ionisation smoke detectors are the most effective type, and if Am 241 remains the nuclide of choice for domestic smoke detectors then regulators must recognise the fact that the method of construction of the source material makes significant accidental exposure unlikely, the benefits far outweigh the risks, and the exemption that applies to ownership should be extended to the disposal of these sources.

REFERENCES

1. ICRP Publication 68 (Annals of the ICRP Vol. 24, No. 4, 1995) *Dose Coefficients for Intakes of Radionuclides by Workers*. Pergamon Press, Oxford.
2. IAEA. *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources*. IAEA, Vienna, 1994
3. Ramaswami A. *Preparation of Americium Source for Smoke Detector*, BARC, Bombay, 1994.
4. Rundo J, Fairman W D, Essling M and Huff D R. *Ingestion of Am 241 Sources Intended for Domestic Smoke Detectors: Report of a Case*. Health Physics, vol. 33, pp 561-566. Pergamon Press, Oxford. 1977.
5. *Recommendations for Ionization Chamber Smoke Detectors in Implementation of Radiation Protection Standards*. OECD NEA, 1977.
6. ICRP Publication 66. (Annals of the ICRP Vol. 24, No. 1-3, 1994) *Human Respiratory Tract Model for Radiological Protection*. Pergamon Press, Oxford
7. *A Summary of an Integrity Testing Programme on Alpha Foils used in Ionisation Chamber Smoke Detectors*. TRC Report No. 378, 1975.
8. Gratz David B and Hawkins Raymond E. *Evaluation of Smoke Detectors in Homes. Interim Report Phase 1*. Federal Emergency Management Agency. US Fire Administration. Washington, 1980.
9. National Fire Data Center. *Report to Congress on Fire Protection Systems*. US Fire Administration. Washington, 1981.
10. ICRP Publication 60. (Annals of ICRP Vol. 21, No. 1-3, 1990) *1990 Recommendations of the International Commission on Radiological Protection*. Pergamon Press, Oxford.