‘DIRTY BOMB’ EXPLOSION IN A CITY AREA: WHAT DO WE NEED TO KNOW FOR PREPAREDNESS ?

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Possible sources


IAEA

Example of 'orphaned' sources:
Two containers, each with 1300 TBq ^{90}Sr, found in a forest in Georgia in 2002.

For comparison, the total ^{90}Sr release from Chernobyl was estimated to ca. 8000 TBq (Sohier, 2002).

Key factors: availability, sufficient source strength, transportability, physical half-life, types of radiation/energies, physicochemical form

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Some important radionuclides of concern in connection with 'dirty bombs'

Radionuclide	Typical physicochemical form of large existing sources	Existing strong sources and their strengths
^{60}Co	Metal (can be dissolved in acid - liquid)	Sterilisation irradiator (up to 400,000 TBq). Teletherapy source (up to 1000 TBq)
^{90}Sr	Ceramic ($SrTiO_3$) - insoluble, brittle, soft (Mohs hardness: 5.5), can be powdered	Radioisotope thermoelectric generator (1000-10.000 TBq)
^{137}Cs	Salt (CsCl) (can be dissolved - liquid)	Sterilisation irradiator (up to 400,000 TBq). Teletherapy source (up to 1000 TBq)
^{192}Ir	Metal – soft - Mohs hardness 6.5 (can be powdered), insoluble in water	Industrial radiography source (up to 50 TBq)
^{226}Ra	Salt ($RaSO_4$) (can be powdered), very low solubility	Old therapy source (up to 5 TBq)
^{238}Pu	Ceramic (PuO_2) - insoluble, can be powdered	Radioisotope thermoelectric generator (up to 5,000 TBq)
^{241}Am	Pressed ceramic powder (AmO_2)	Well logging source (up to 1 TBq).
^{252}Cf	Ceramic (Cf_2O_3) - insoluble	Well logging source (up to 0.1 TBq).

(see, e.g., Harper et al., 2007; Ferguson et al., 2003; Argonne, 2005)

Crucial parameter: Initial physicochemical form

Harper et al. (Sandia Natl. Lab.), 2007

Powders: Typically 20-80 % aerosolised
Depends on, e.g., original powder size and porosity
Phase transition possible at high pressure

Ceramics: Typically 2-40 % aerosolised, no phase transition

Metals: Very little cobalt (<0.2 %) aerosolised

Liquids: Formation of (slightly) submicroneous particles after evaporation, depending on construction. Almost full aerosolisation is possible.

Debris of ^{60}Co after high explosion

Particle size spectrum for ceramics

Much of the mass in the 30-100 µm range, and smaller peak at a few microns (Harper et al., 2007)

In-line with measurements made after the Thule accident in 1968 (also a conventional explosion dispersing a solid, radioactive material with a very high melting point).

In Thule, only 1.3 % of the particles were larger than ca. 18 µm, but these carried nearly 80 % of the activity.

Pinnick et al. (1983) consistently found similar spectra when conducting blast experiments impacting on different soils.

Relevant particle sizes and their pre and post deposition behaviour are not considered in current European decision support systems.

The near zone of a blast

Shrapnel and large particles will deposit within short distance

Example of gravitational settling of large particles

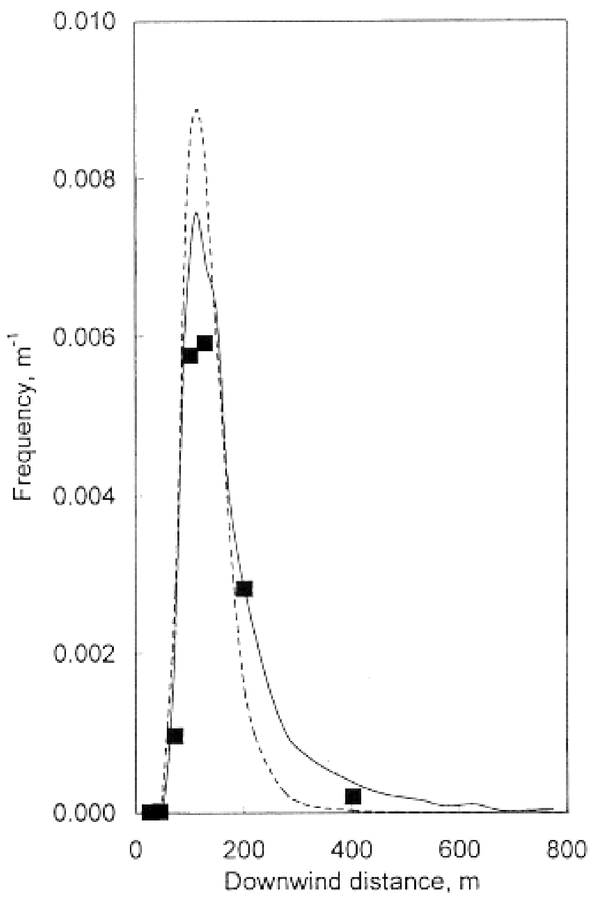

Fig. 1. Deposition curve for the conditions corresponding to those of the original Trial 5 (average wind speed at the release height, $u_{15\,m} = 7.31\ m\,s^{-1}$, $z_0 = 0.023$ m): (■ experimental data points (Hage, 1961); - - - - FDM; —— PTM).

Dispersion of ca. 50 µm glass particles

Release height 15 m

The air is clean within one minute.

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ARGOS and ’dirty bombs’

In relation to radiological terror scenarios, ARGOS is needed to:

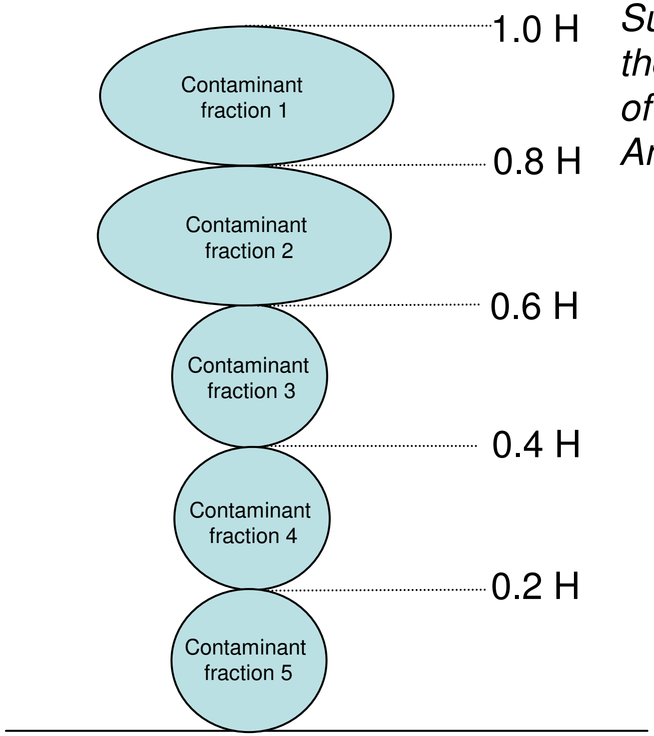
- develop an effective operational preparedness based on plausible scenarios.

- support in early phase decision making, where measurements are scarce. Note that some of the most likely radionuclides in terror attacks are pure beta or alpha emitters and would literally take ages to measure over an urban area.

- enable optimised long-term dose reduction, which requires prognoses of doses that would be received over years (with and without countermeasures).

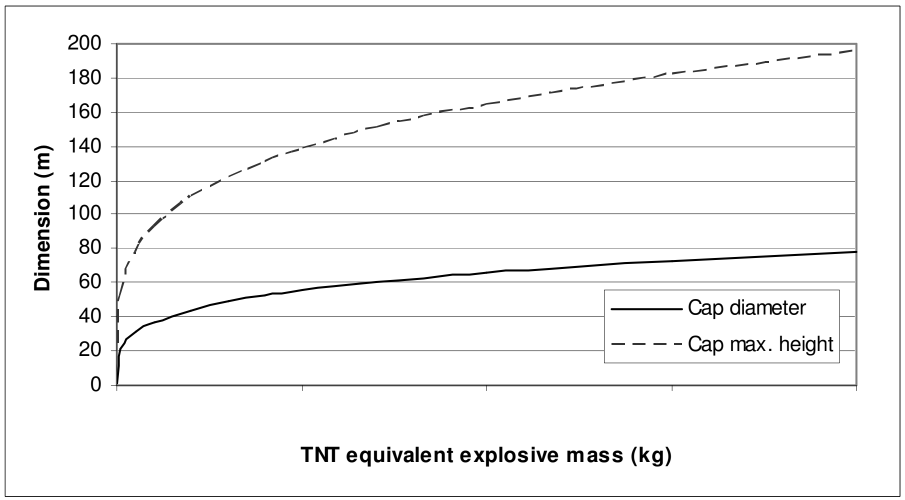
Some of the parameterisation in ARGOS

Deposition relations are given in ARGOS data libraries for four different particle size intervals and five different weather categories (dry dep., dep. in heavy rain, dep. in light rain, dry dep. on snow-covered area, dep. in snow). Indoor concentrations described relative to outdoor for all particle sizes.



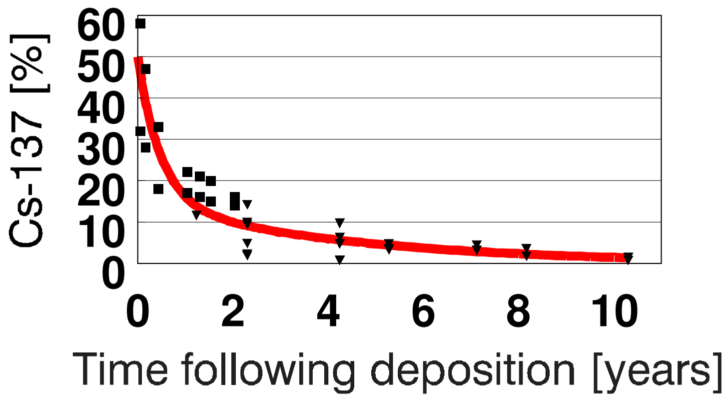
Suggested model with relative dimensions and relative distribution of the aerosolised contaminant mass in different parts of the cap and stem of a cloud modelled by 5 individual 'puffs' – e.g., based on early American blast experiments (Church, 1969) (left).

Plume rise height and initial dimen-sions - US exp. (right).



Natural and forced removal from 'urban' surfaces: (Currently not implemented in ARGOS)

Chernobyl-experience for streets



Different particle characteristics lead to different post-deposition behaviour.

Spraying of inert water solutions on similar limestone walls removed two-thirds of the caesium contamination in Pripyat, but only about one-fifth of the caesium contamination in Vladimirovka (Roed & Andersson, 1996).

Clark and Cobbin (1964) recorded a DF of 50 when hosing a street contaminated by 44-100 µm particles.

Possible dose contributions from a ’dirty bomb’

- Internal dose from inhalation during plume passage
- Internal dose from inhalation of resuspended contaminants
- External dose from the passing contaminated plume
- External dose from contamination on outdoor surfaces
- External dose from contamination on indoor surfaces
- External and internal dose from contamination deposited on humans
- External dose from contaminants transferred onto humans by contact
- Internal dose from inadvertent ingestion (contact transfer, food items)

Examples of other important parameters

Deposition on and clearance from humans

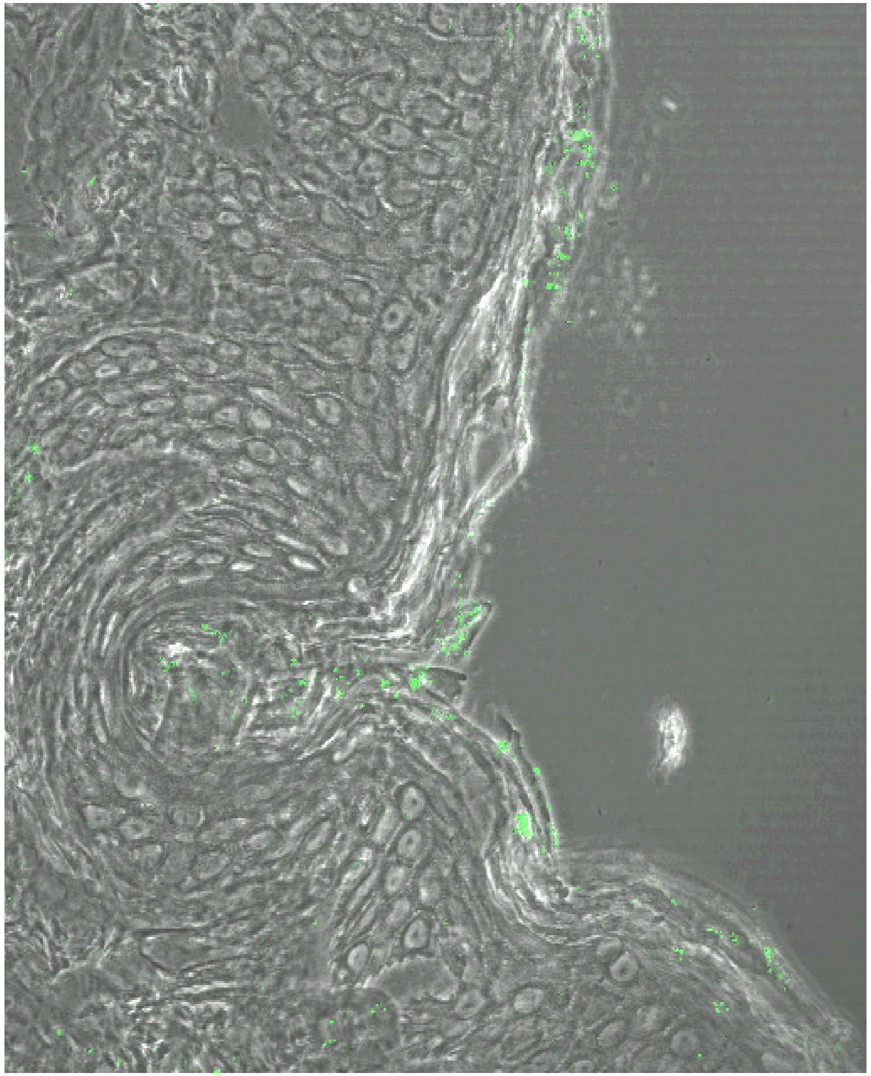
Indoor deposition and clearance

Contact transfer factors

Resuspension factors in/outdoors

Protective effect of dwellings (ventilation rate, deposition rate, filter factor, time spent indoors)

Dose conversion factors for ’new’ radionuclides, incl. pure beta emitters.



An other aspect: atmospheric dispersion modelling

In atmospheric dispersion models so far applied in European decision support systems, inhabited areas are simply modelled as areas with enhanced surface roughness and different deposition rates compared with open areas.

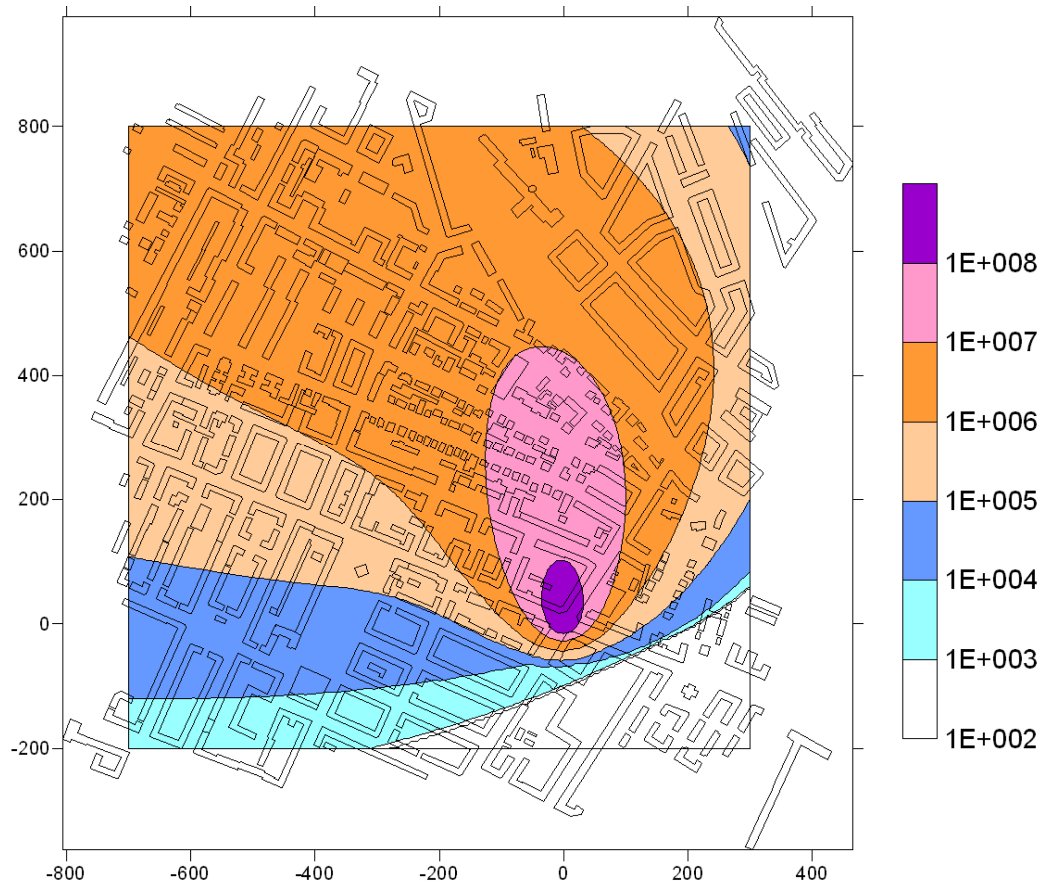
Presence of buildings has three effects modelled in the new high resolution urban dispersion model, URD, for implementation in ARGOS:

1) It limits the size of the horizontal eddies present in the atmosphere and thereby limits the large scale horizontal dispersion.

2) It enhances the smaller scale dispersion by creating more small scale turbulence.

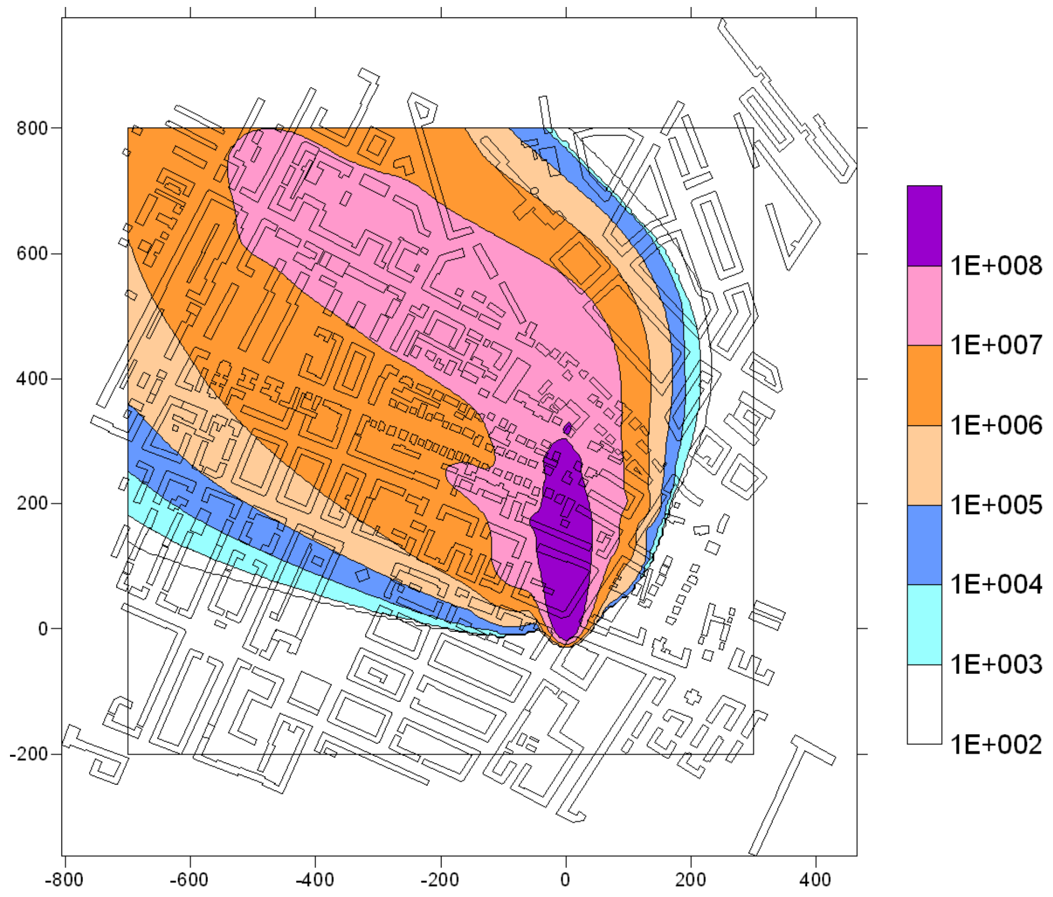
3) It delays part of the dispersion by retaining aerosols in more or less stationary recirculation zones on the downstream side of the buildings.

Frederiksberg (Copenhagen) model case study (1)



RIMPUFF estimate of the time integrated air concentration [Bq s/m^3] at ground level. No building influence.

Frederiksberg (Copenhagen) model case study (2)



URD estimate of the time integrated air concentration [Bq s/m^3] at ground level, with all three building effects modelled.

Publication of ^{90}Sr scenario calculations

Radiation Protection Dosimetry Advance Access published June 10, 2008

Radiation Protection Dosimetry (2008), pp. 1–11

doi:10.1093/rpd/ncn173

ESTIMATION OF HEALTH HAZARDS RESULTING FROM A RADIOLOGICAL TERRORIST ATTACK IN A CITY

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Received March 28 2008, revised May 5 2008, accepted May 6 2008

In recent years, the concern for protection of urban populations against terror attacks involving radiological, biological or chemical substances has attracted increasing attention. It sets new demands to decision support and consequence assessment tools, where the focus has traditionally been on accidental exposure. The aim of the present study was to illustrate issues that need to be considered in evaluating the radiological consequences of a 'dirty bomb' explosion. This is done through a worked example of simplified calculations of relative dose contributions for a specific 'dirty bomb' scenario leading to atmospheric dispersion of ^{90}Sr contamination over a city area. Also, the requirements of atmospheric dispersion models for such scenarios are discussed.

Conclusions

1) Concept/parameterisation methodology for ARGOS for RDD's has been defined and work initiated (pre/post deposition).

2) Deposition parameter libraries, e.g., created for all relevant particle sizes for 5 weather categories, and for all urban surface types.

3) Initial plume dimensions modelled in ARGOS as function of TNT equivalent explosive mass, based on series of blast experiments.

4) ARGOS will include high-resolution in-town dispersion model.

5) Disclosure of security sensitive parameters in new ARGOS subject to strict clearance procedures.