Modeling of the EMRAS II Urban Working Group Seoul Scenario Using the RESRAD-RDD Methodology

Presented at the Urban WG Meeting
Vienna, Austria
October 18, 2011

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Presentation Outline

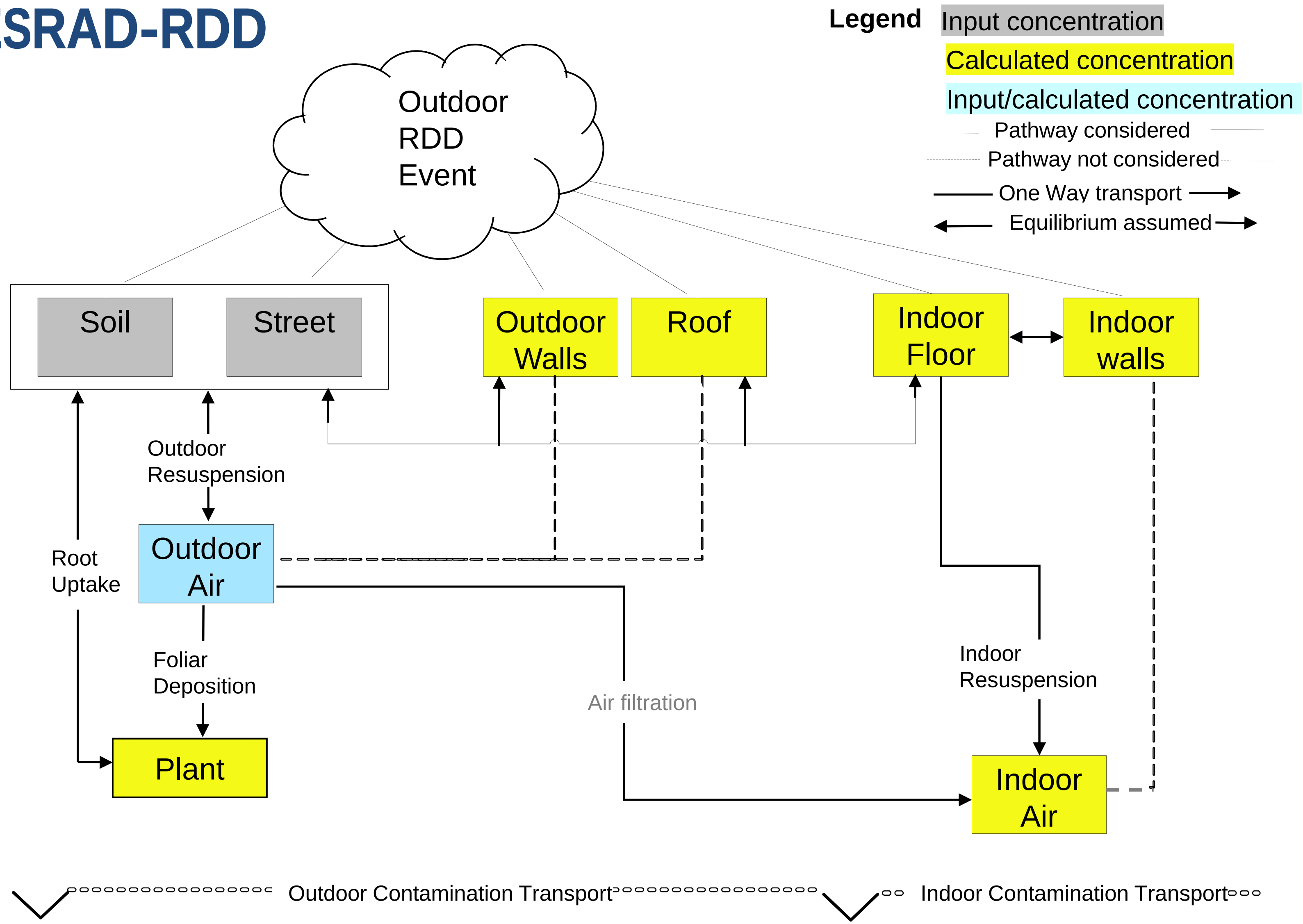
- RESRAD-RDD conceptual Model

- Seoul scenario and modeling end points
  - Initial ground surface concentration
  - Partitioning factors for different surfaces
  - Modeling endpoints
  - Weathering coefficient

- Exposure pathways and dose calculations
  - Exposure pathways
  - Exposure Scenarios
  - Dose calculations
  - Countermeasures

- Results
  - Contamination density variation with time and countermeasures
  - External dose rate variations with time and countermeasures
  - Contribution of different surfaces to external dose rate
  - External annual and cumulative dose variations with time and countermeasures
  - Internal annual and cumulative dose variations with time and countermeasures

Conceptual Model of Environmental Transport in RESRAD-RDD



Seoul Scenario – Initial Deposition and Partitioning

Initial Estimated Concentrations (Bq/m^2) on to the Reference Surface Used in the Modeling Under Three Weather Conditions

Dry	Light rain	Heavy rain
5.29E+07	2.83E+09	1.72E+10

Initial estimated concentration for Co-60 and Pu-239 was assumed to be the same

Assumed Initial Partitioning Factors Relative to Reference Surface

Deposition	Lawn	Exterior walls	Roofs	Interior floor*	Interior walls	Paved areas
Dry	0.9	0.1	0.7	0.04	0.02	0.4
Wet	0.7	0.015	0.7	0.055	0.0275	0.55

•Interior floor concentration is assumed to be 10% of outside concentration

Other initial partitioning factors based on Chernobyl accident data (Anderson 2003)

Eight Modeling End Points

- Contamination density at three outdoor test locations
- External dose rates at 6 specified locations (3 outside and 3 inside building 1) from all relevant surfaces
- Contribution to the external dose rates at 6 above locations from each surface and identification of the three most important surfaces
- Annual and cumulative external doses for two exposure scenarios
- Annual and cumulative internal doses for two exposure scenarios
- Countermeasure effectiveness in terms of external dose rate reduction
- Countermeasure effectiveness in terms of external dose reduction
- Countermeasure effectiveness in terms of internal dose reduction

*For modeling purposes building characteristics, receptor locations and receptor characteristics were specified and all calculations were carried forward for 5 years. All predictions were made with no countermeasure and were repeated with different countermeasures.

Weathering Correction

Weathering Coefficients used for Seoul Scenario

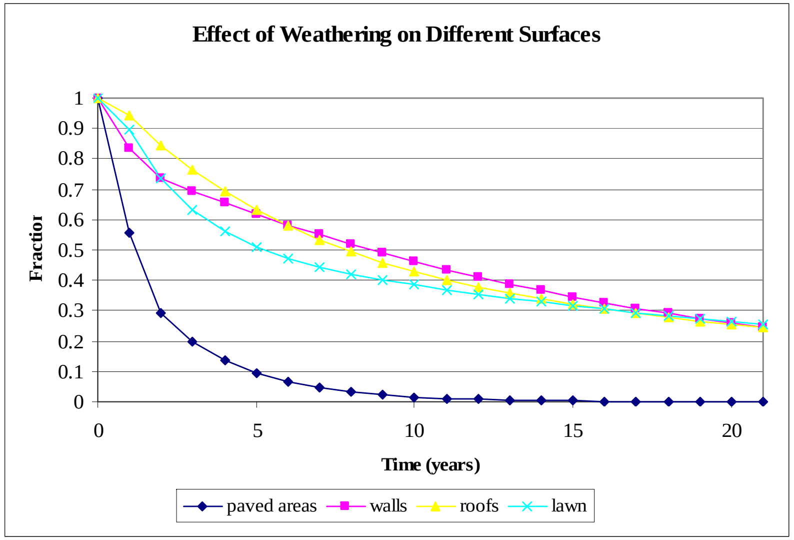
Surface	Mobile fraction (a)	Shorter half-life ($\ln 2/b$), yr	Longer half-life ($\ln 2/c$), yr
Street (paved areas)	0.5	0.2	2
Soil (lawn)	0.46	1.5	50
Roof/Sloped roofs	0.5	4	50
Exterior Wall	0.2	0.2	20
Interior Floor	0.5	0.2	2
Interior Wall	0.2	0.2	20

$$\overline{WCF} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} [a\, e^{-(bt)} + (1-a) e^{-(ct)}] e^{-\lambda t} dt$$

•Paved surfaces and interior floor weather very fast due to small half-lifves.

•Walls initially weather faster compared with roofs and lawns due to small shorter half-life, but later weathering is faster for lawn and roof because lawn and roof have much higher mobile fractions compared with walls.

•Lawn weathers faster compared with roof due to small shorter half-life.



Pathways Considered for Dose Calculations

- Direct external
  - External exposure (groundshine) to contaminants on streets/soils while outdoors
  - External exposure to contaminants on exterior walls while indoors
  - External exposure to contaminants on roofs while indoors
  - External exposure to contaminants on interior walls while indoors
  - External exposure to contaminants on interior floors while indoors
  - External exposure to contaminants on streets/soils while indoors
- Inhalation
  - Inhalation exposure while outdoors (resuspension of contaminants from streets/soils only)
  - Inhalation exposure while indoors (indoor air contamination results from both outdoor air contamination and resuspension of contaminants on interior floors)

Two Exposure Scenarios: One in Business Area and Other in Park Area

Exposure Scenario Assumptions				
	Indoor		Outdoor	
Region	Duration (hrs/wk)	Inhalation rate (m3/hr)	Duration (hrs/wk)	Inhalation rate (m3/hr)
Region - 1 (Business area)	40	0.5	5	1.0
Region - 2 (Park area)	0	NA	3	1.5

Building/source	Floor length (m)	Floor width (m)	Floor height (m)	Thickness of walls (cm)	Thickness of roof (cm)	Material of walls/roof	Material density (g/cm3)
Office building	30	30	2.75	1	10	Aluminum/ Concrete	2.7/2.4
Lawn/paved area	Infinite	Infinite	NA	NA	NA	NA	NA

Dose Calculation for External Pathways

$$Dose_{ext,n,g}(t) = C_s(0) \times P_n \times \overline{WCF_n}(t) \times OF_{n,g} \times SF \times GRC \times DCF_{n,g}$$

$Dose_{ext,\ n,g}(t)$ = dose from external pathways at time t (mrem/yr),

$C_s(0)$ = concentration on streets/soil at t = 0 (pCi/m^2),

P_n = Initial partitioning factor for surface n,

$\overline{WCF_n}(t)$ = average weathering and radiological decay correction factor at time t,

n = index for surface,

g = index for external exposure geometries,

$OF_{n,g}$ = occupancy factor (time fraction of a year),

SF = shielding factor,

GRC = ground roughness correction factor (assumed = 1 for all surfaces), and

$DCF_{n,g}$ = external dose conversion factor [(mrem/yr) per (pCi/m^2)].

Dose Calculation for Inhalation Pathways

$$C_o(t) = C_s(0) \times \overline{WCF_s \times RF_o}$$

$$C_i(t) = C_o(t) \times SHF_{inh} + C_{floor}(t) \times RF_i$$

C_o (t) = outdoor air concentration at time t (pCi/m^3),

C_i (t) = indoor air concentration at time t (pCi/m^3),

SHF_{inh} = indoor dust filtration factor = 0.55, and

RF_i = indoor resuspension factor = 1×10^{-6} m^{-1}.

$$Dose_{inh}(t) = [C_o(\mathrm{t})\ \ or\ \ C_i(t)] \times OF \times \mathrm{IR} \times DCF_{inh}$$

$Dose_{inh}$(t) = inhalation dose at time t (mrem/yr),

IR = inhalation rate while staying outdoors or indoors (m^3/yr),

OF = occupancy factor (fraction of time spent outdoors or indoors), and

DCF_{inh} = inhalation dose conversion factor from ICRP-72 (mrem/pCi).

Resuspension and Average Outdoor Air Concentration Correction Factors

$$RF_o(t) = \left(\frac{1 \times 10^{-6}}{t}\right) (m^{-1}) \quad \text{for} \quad t = 1 - 1000 \quad \text{days}$$

$$= 1 \times 10^{-9} (m^{-1}) \quad \text{for t} > 1000 \ \text{days}$$

$$= 1 \times 10^{-6} (m^{-1}) \quad \text{for t} < 1 \ \text{day}$$

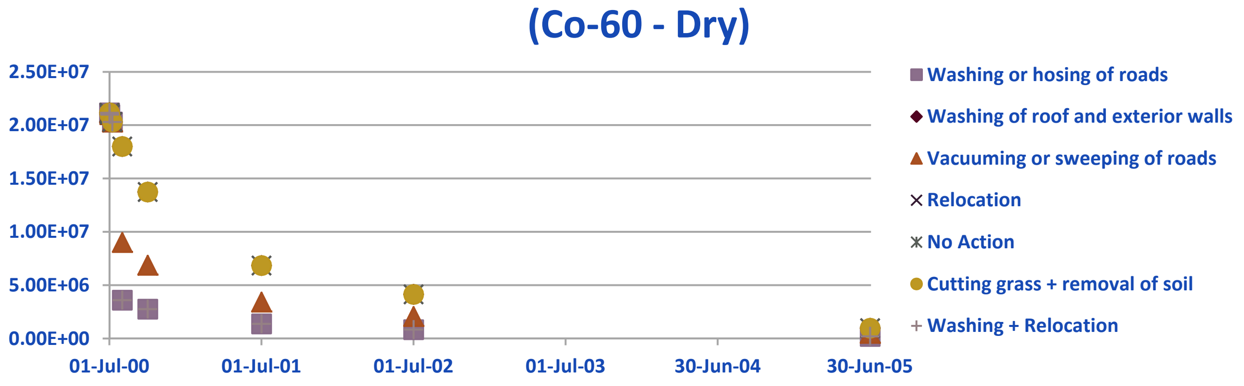
t = time in days after deposition,

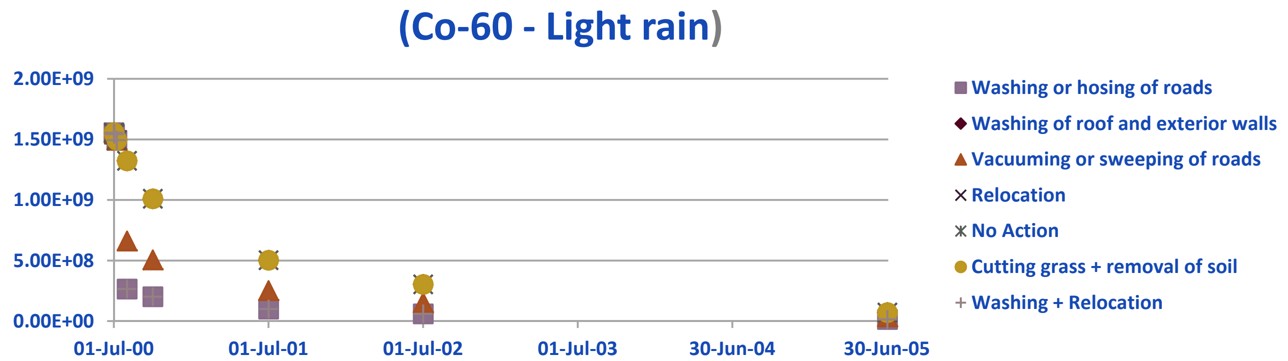
$$\overline{WCF \times RF_o} = \frac{\int_{t_1}^{t_2} RF_o(t)[a e^{-(bt)} + (1-a)e^{-(ct)}]e^{-\lambda t} dt}{t_2 - t_1}$$

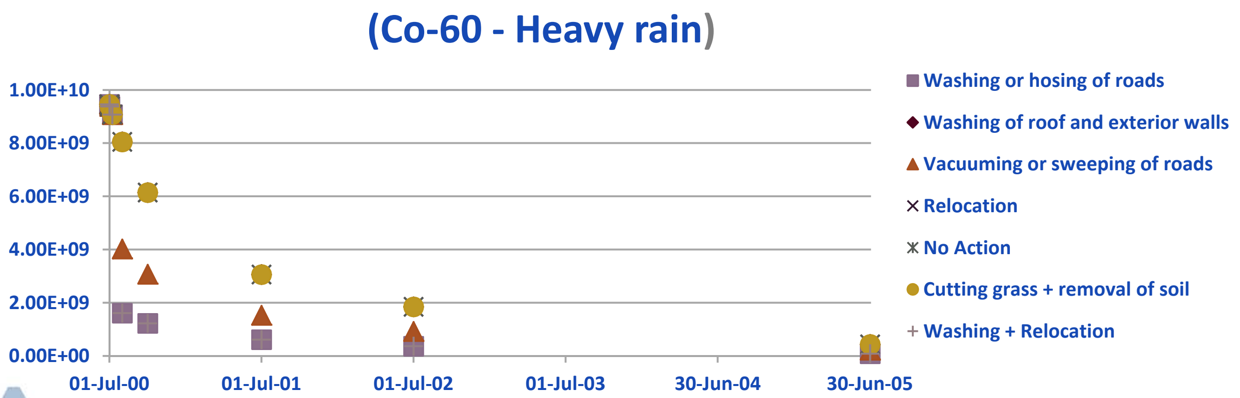
Countermeasures Considered and Decontamination Factors Assumed for Dose Modeling

Serial Number	Countermeasure	Decontamination Factor (DF)	Time	Applicability in paved area	Applicability in soil area
# 1	No remediation	none	Day 0	yes	yes
# 2	Relocation	infinite	First six week	yes	yes
# 4	Vacuuming or sweeping of roads	2	Day 14	yes	no
# 5	Washing or hosing of roads	5	Day 14	yes	no
# 6	Washing of roof and exterior walls	1.4 (roof) and 10 (exterior walls)	Day 14	no	no
# 7	Cutting of grass and removal of soil	3 (grass cutting) and 10 (soil removal)	Day 7 (grass cutting) and Day 180 (soil removal)	no	yes
# 9	Relocation and road cleaning by washing	Infinite (no dose during relocation) and 5 (washing of road)	First six weeks (relocation) and Day 14 (road cleaning)	yes	yes

Contamination Density (Bq/m2) at Outdoor Paved Area





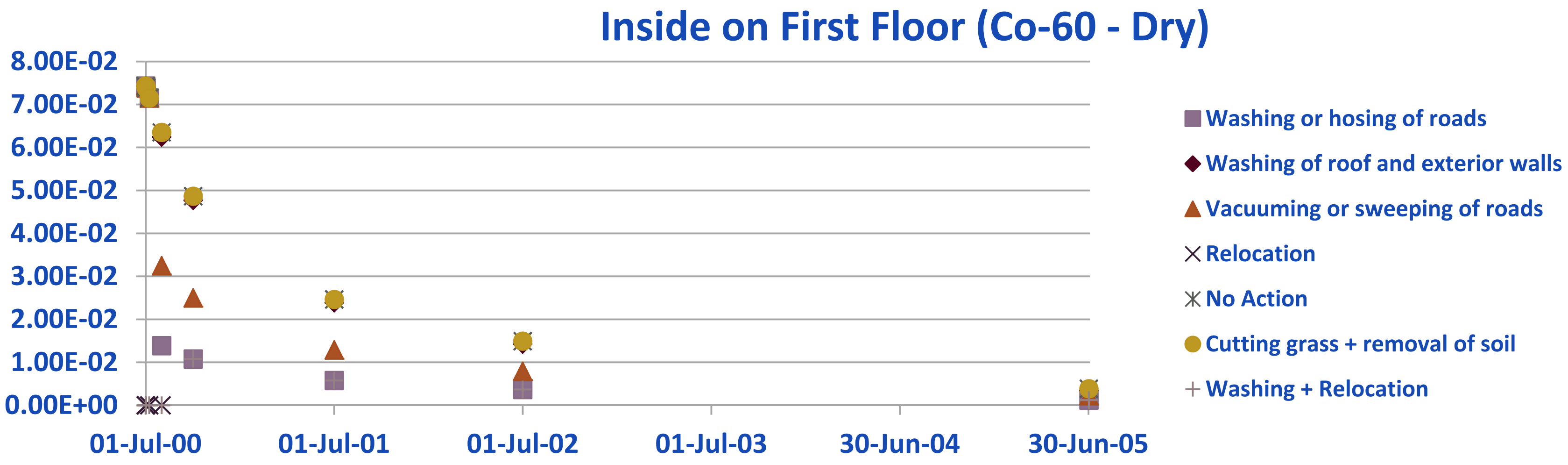


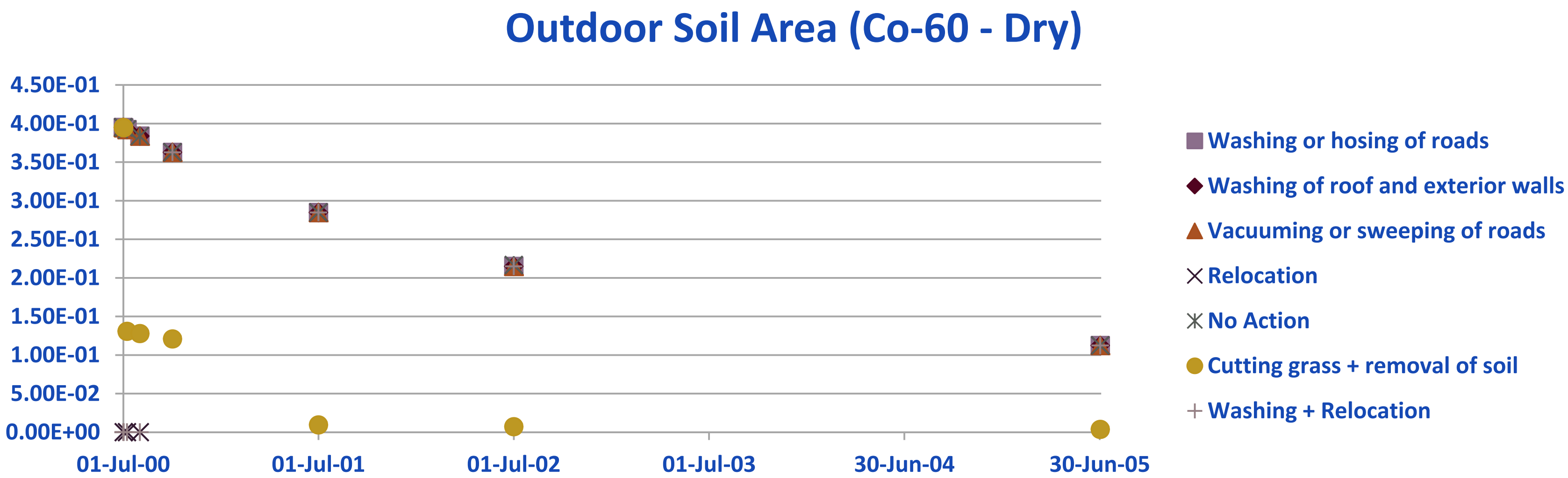
Same trend in three weather conditions, the only difference is due to the difference in initial deposition.

For the options (no action, relocation, and cutting grass + removal of soil) the contamination density in the paved area does not change.

The washing of road results in the maximum change in the contamination density.

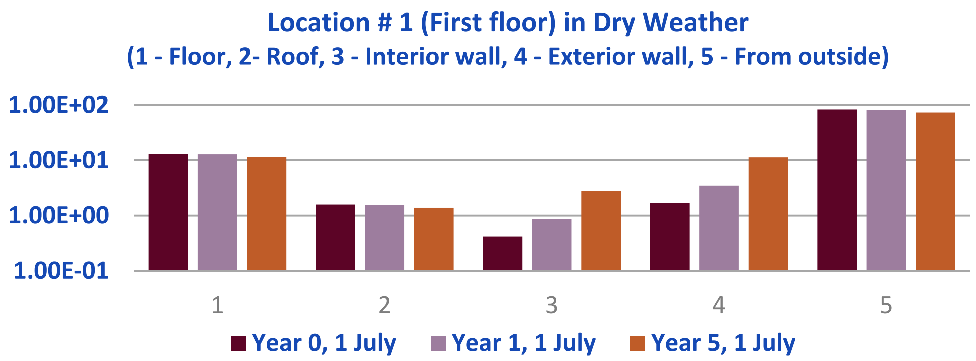
External Dose Rate (mGy/h)

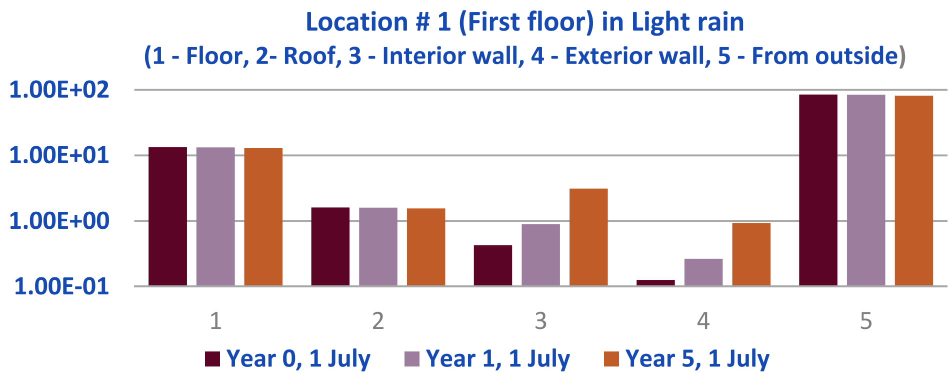


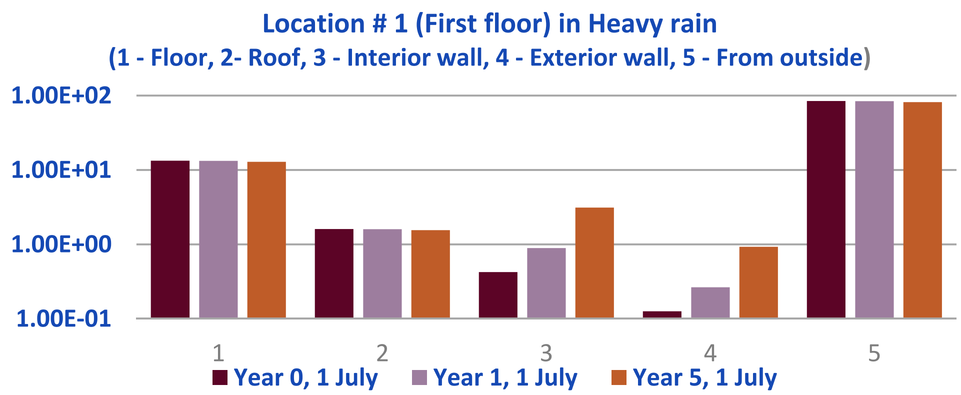


The external dose rate is much higher at outdoor soil area compared to inside on first floor. The most external dose is reduced by Washing or hosing of road at inside location whereas cutting grass and removing soil is most effective countermeasure for outdoor soil area.

External Dose Rate Contributions from Different Surfaces



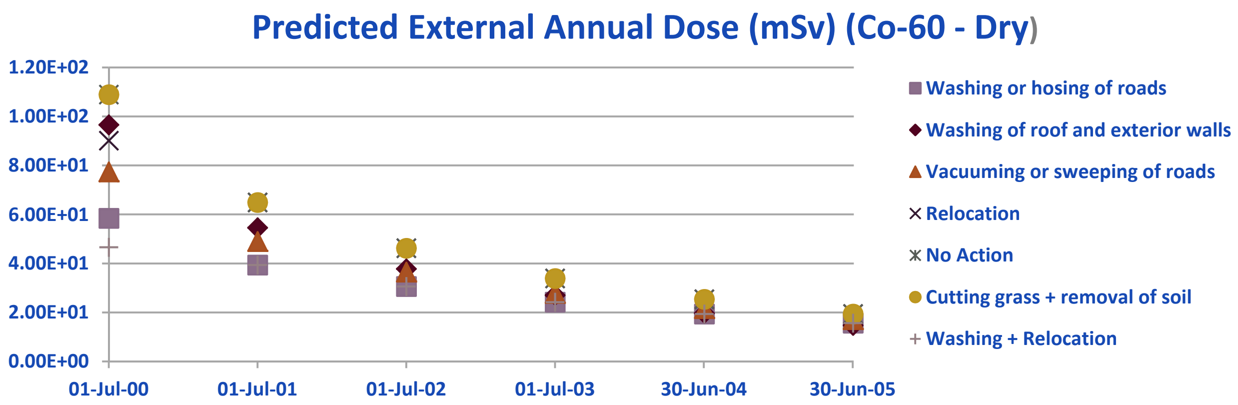


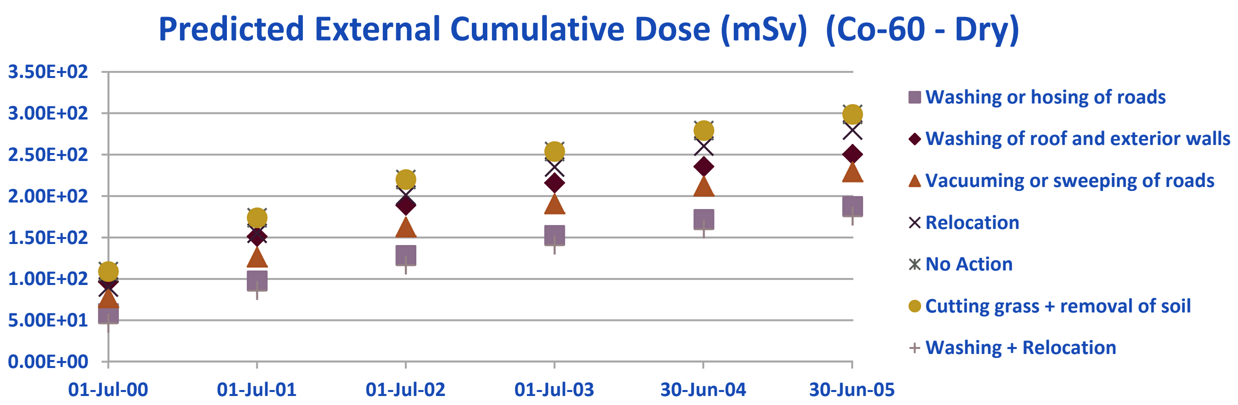


Maximum contribution is From outside followed by contribution from floor

Wall contribution increases With time due to difference In weathering from different surfaces

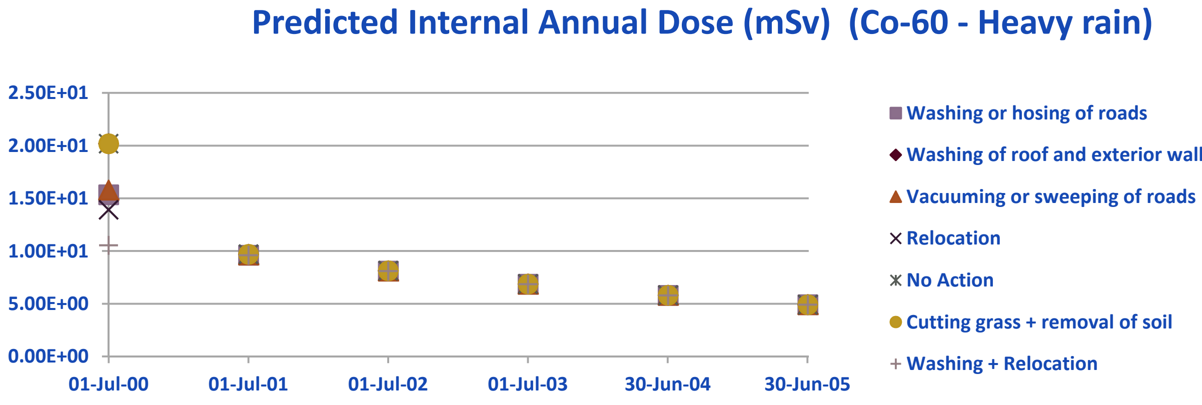
Variation of Predicted External Dose Indoor on First Floor with Time and Countermeasure

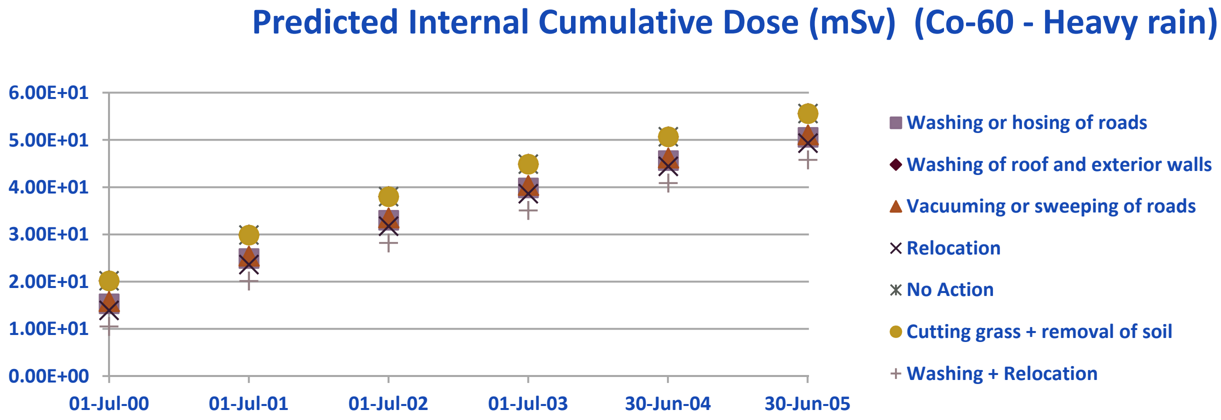




Washing of roads results in the maximum change in external annual dose.
Washing of roads + relocation results in the maximum change in external cumulative dose.

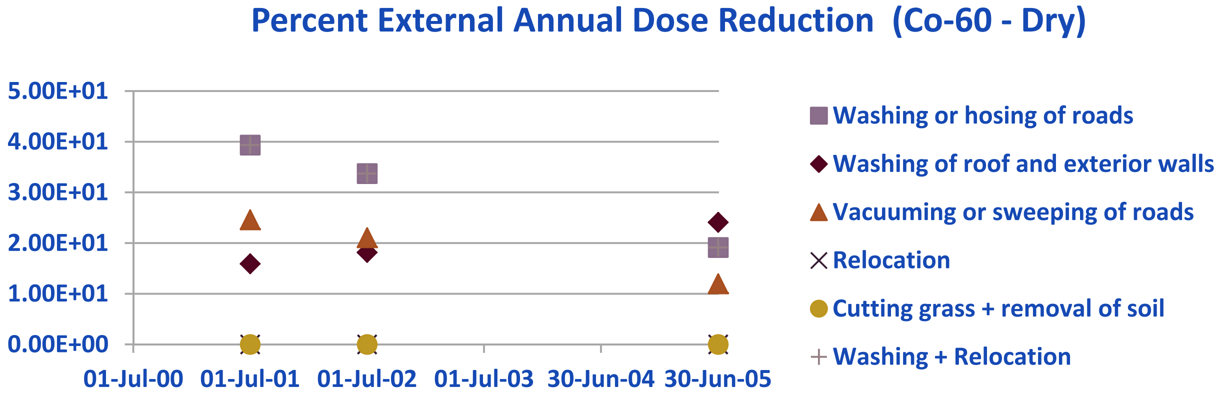
Variation of Predicted Internal Dose Indoor on First Floor with Time and Countermeasure

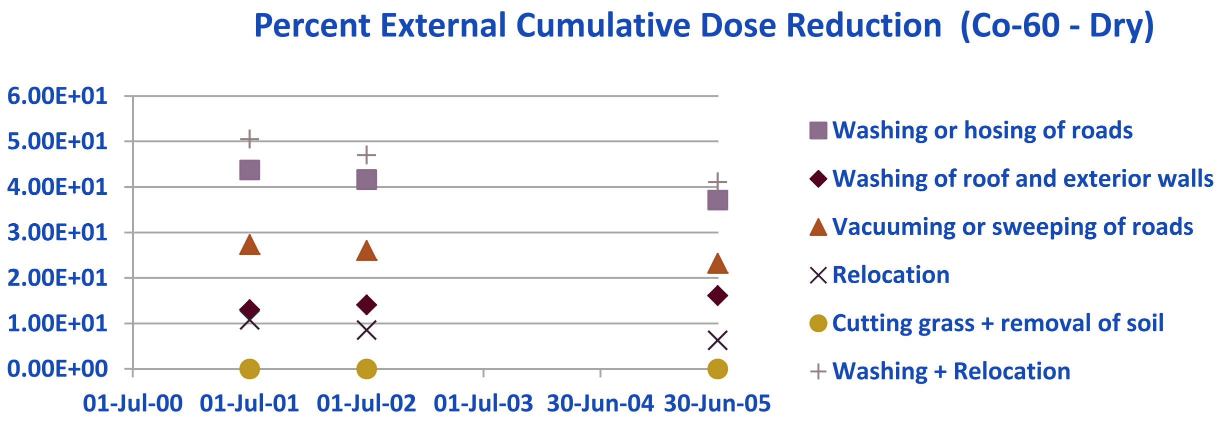




Except for time zero there is not much change in internal annual dose.
Washing of roads + relocation results in the maximum reduction in internal cumulative dose.

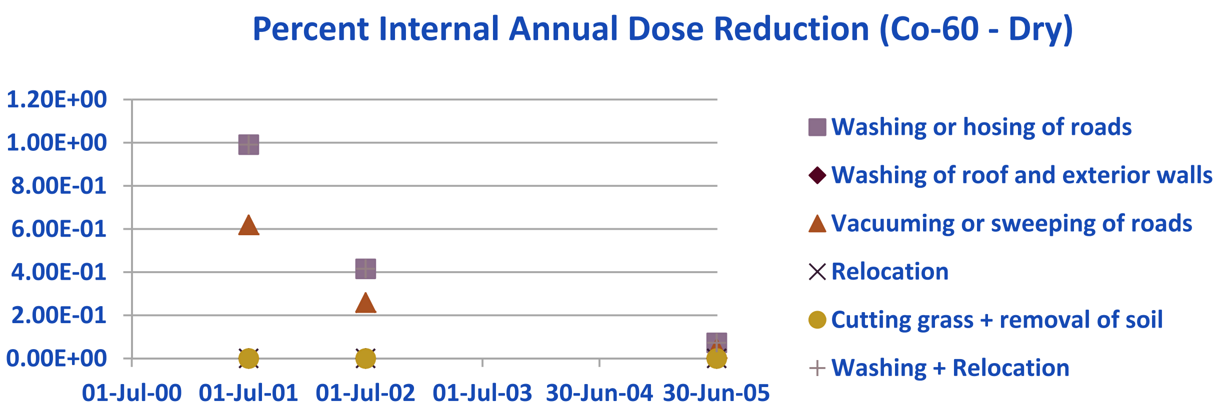
Variation of Percent External Dose Reduction on First Floor with Time and Countermeasures

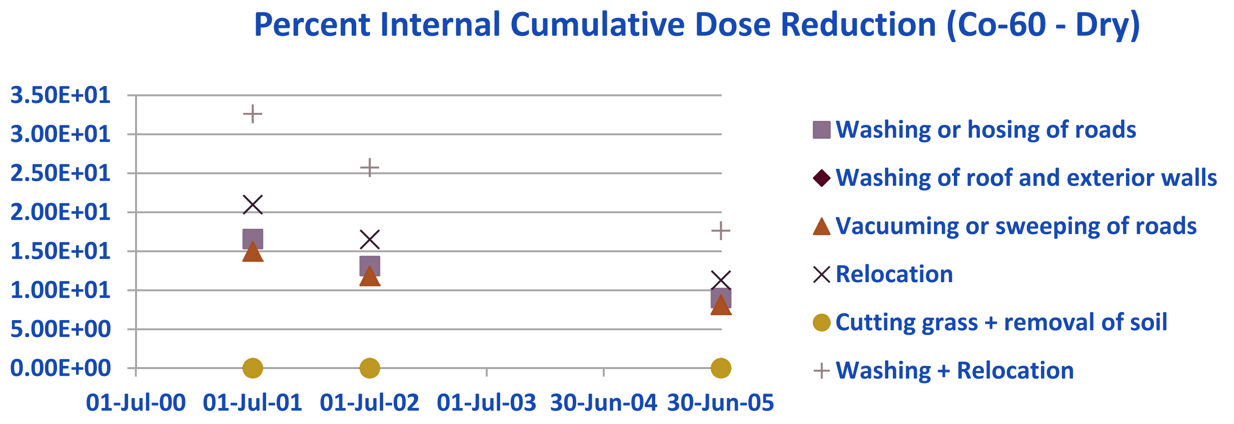




The percent dose reduction from washing of roof and exterior wall increases with time because of difference in weathering of contamination on different surfaces.

Variation of Percent Internal Dose Reduction on First Floor with Time and Countermeasures





The percent dose reduction changes with time.