# Modelling Approach and Preliminary Results for Countermeasure Exercise

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- Overview of METRO-K (Korean Urban Radioactive Contamination Model)
- Modelling Approach on Deposition
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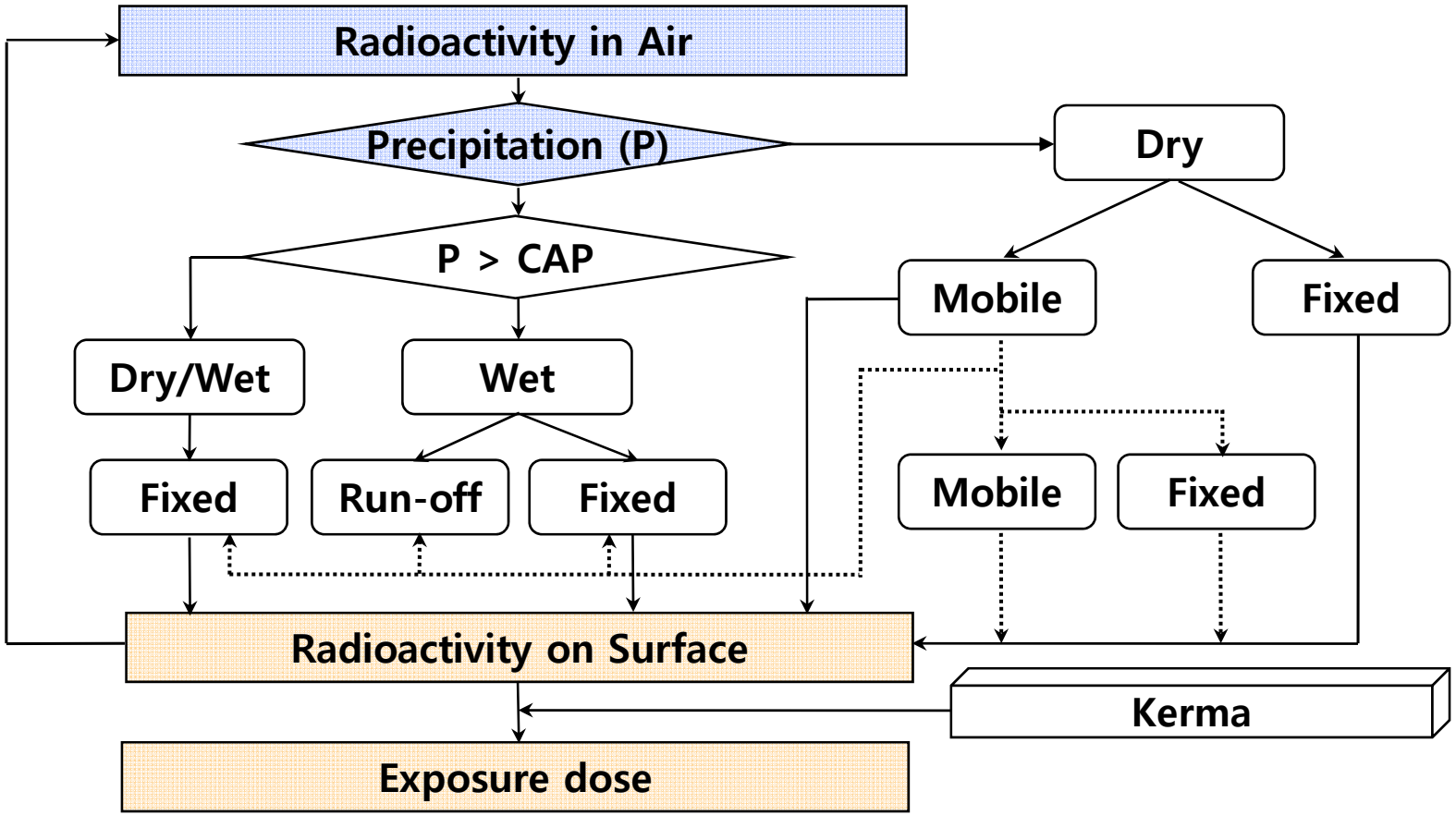
# Characteristics of METRO-K

- Based on analytical method using experimental and empirical data
  - Easy to understand due to simple math. structures
  - Less input data
- Compose easily a complex urban environment using just 5 types of surfaces
- Apply easily various remediation measures to different surfaces separately

# Contamination Mechanisms

- Dry & wet depositions
- Run-off
- Retention on surface of radionuclide in run-off water
- Environmental removals
  - Natural processes such as wind, precipitation and migration into soil
  - Artificial processes such as traffic and walker
- Radioactive decay

# Schematic Diagram of METRO-K




CAP : Critical Amount of Precipitation

# Modelling of Initial Deposition

- **No rain (dry process)**

$$C_s = 86400\, C_a\, v_d$$

Time-integrated air concentration

Dry deposition velocity

- **Rain ≤ CAP (dry+wet processes)**

$$C_s = 86400\, C_a\, v_d + 1\times10^{-3}\, C_a\, P\, w_p$$

daily rainfall

Washout ratio

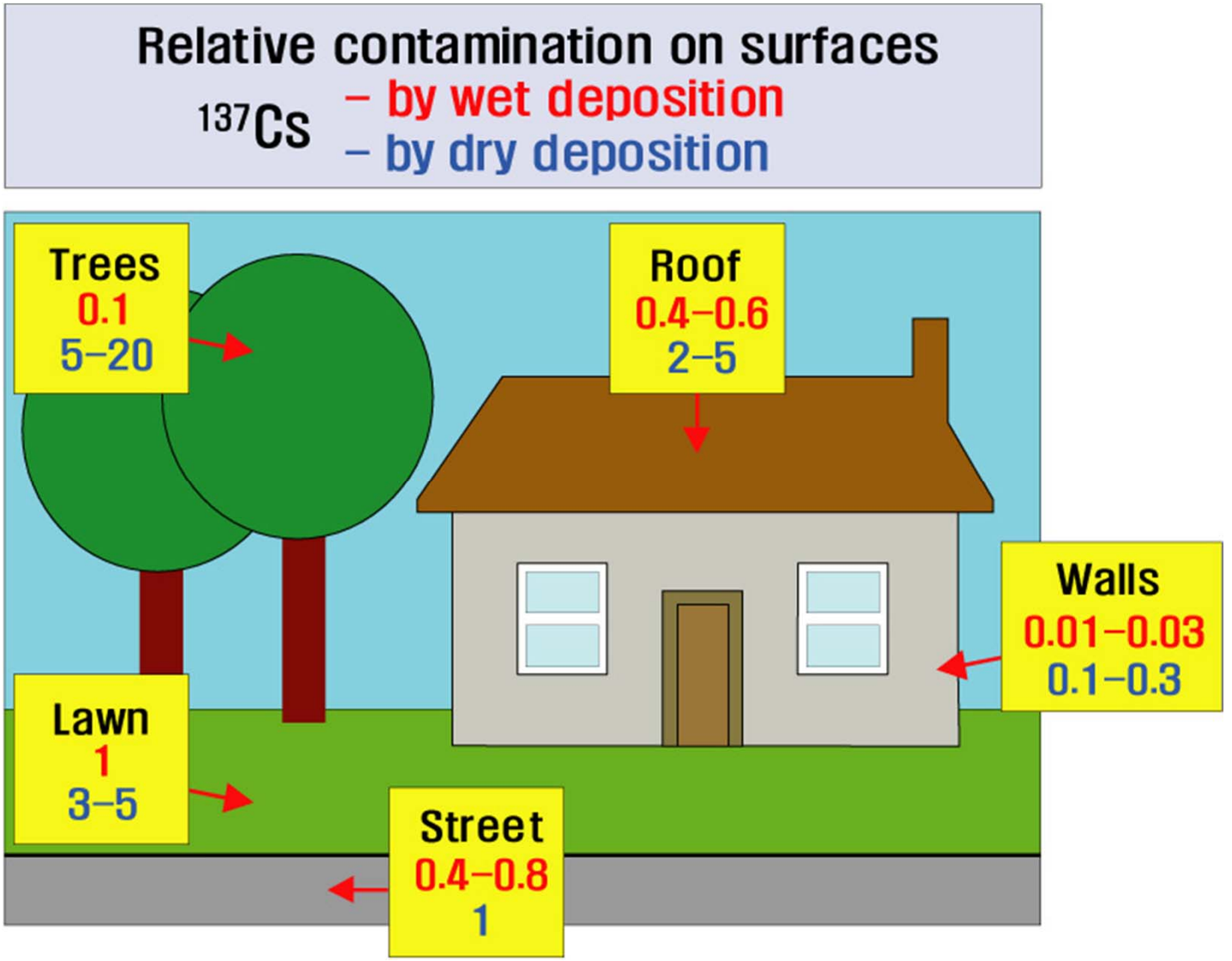
- **Rain > CAP (wet process)**

$$C_s = 1\times10^{-3}\, C_a \left[P_c + (P - P_c)\, f_{ret}\right] w_p$$

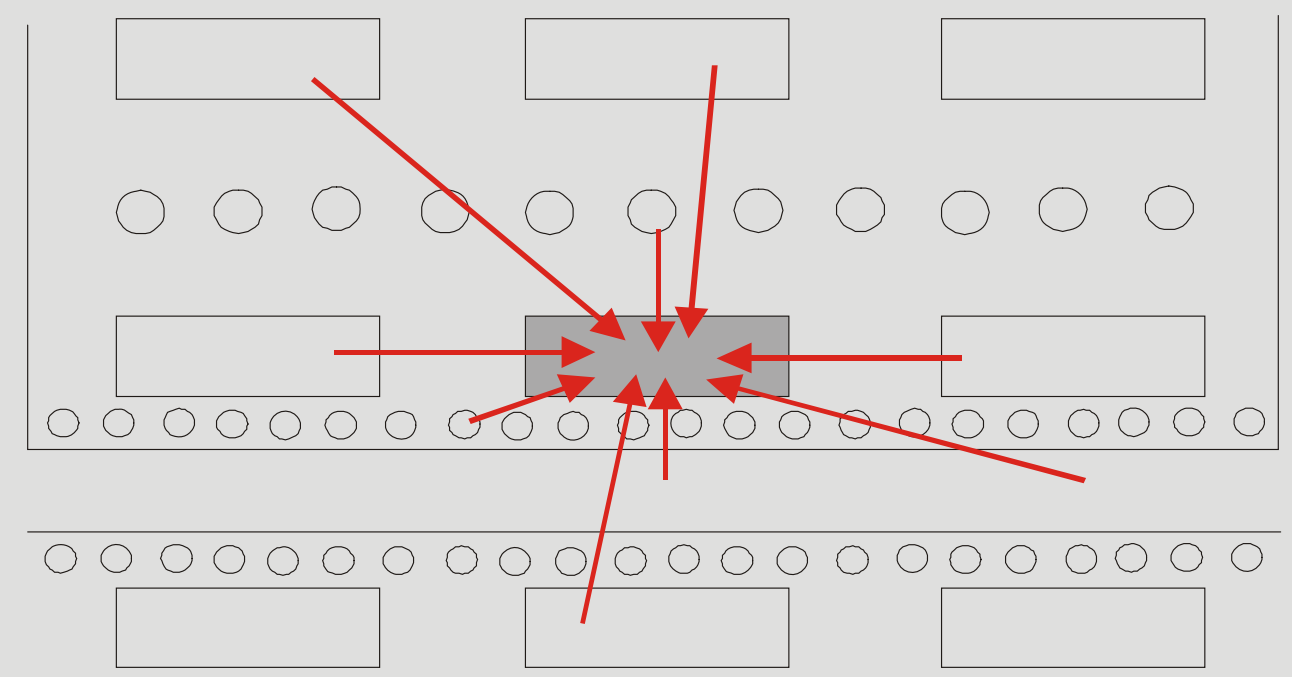
CAP

retained fraction

# Urban Contamination



# Exposure Dose

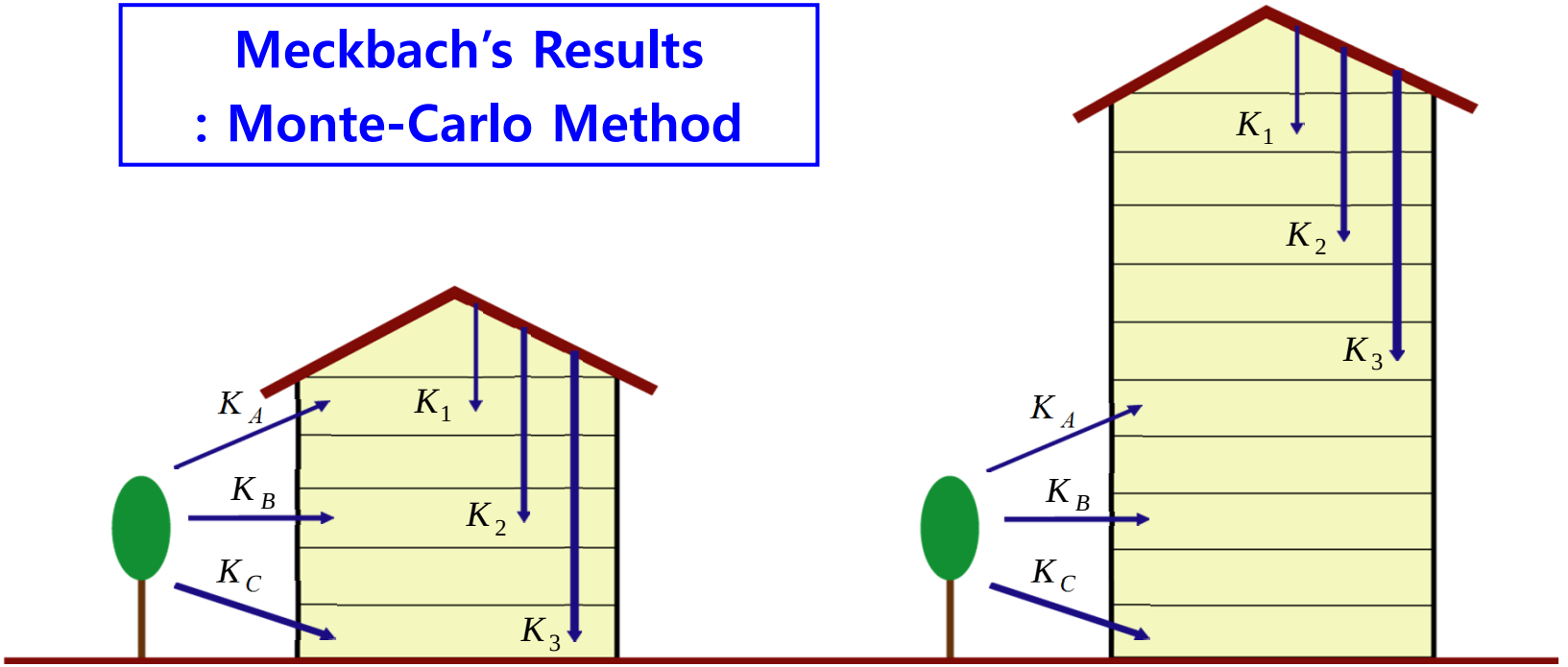


$$\dot{H}_i(t) = 8.64 \times 10^{-14} DCF_i \sum_k y_k \sum_j \omega_j D_j(t) \; k_{ijk}$$

**Kerma is a function of receptor location (i), contaminated surface(j), gamma energy(k)**

# Application of Kerma (1)

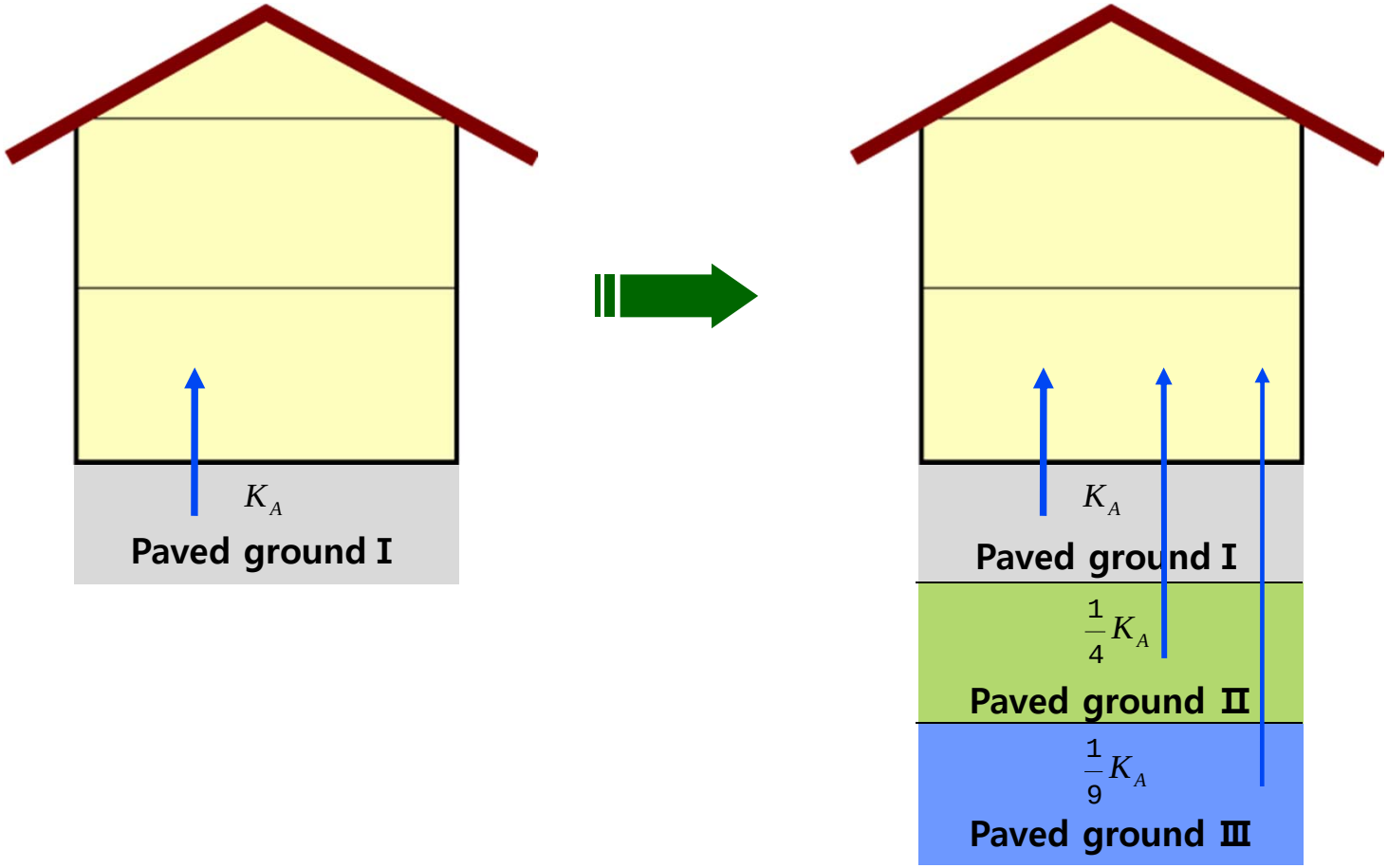
**Meckbach's Results**
**: Monte-Carlo Method**




**5 story building**
**(METRO-K)**

**10 story building**
**(Seoul scenario)**

# Application of Kerma (2)



# Environmental Removal

$$D(t) = D(0)\,exp(-\lambda_d\, t)\cdot$$
$$\left[A\,exp(-\lambda_{w,a}\, t) + (1-A)\,exp(-\lambda_{w,b}\, t)\right]$$

# Application of Countermeasures

For the countermeasure effectiveness, a single DRF, which have been reviewed in previous EMRAS, is applied for each countermeasure

# Radioactive Decay

$^{60}Co$ (5.3 yr) → $^{60}Ni$ (Stable)

| Energy (MeV) | Yield (%) |
|---|---|
| 0.69382 | 0.0163 |
| 1.1732 | 100 |
| 1.3325 | 100 |

$^{239}Pu$ (2 x $10^4$ yr) → $^{235}U$ (7 x $10^8$ yr) →

| Energy (MeV) | Yield(%) |
|---|---|
| 0.044141 | 0.0136 |
| 0.000476 | 0.11291 |

# Resuspension

- Internal dose due to inhalation of resuspended particles is considered
- Inhalation dose is evaluated from concentration of soil and sidewalk(paved surface) using a time-dependent resuspension factor
- Seasonality of resuspsension is not considered, and the same resuspension factor is applied for all radionuclides

$$K(t) = \left[10^{-6}\ exp(-0.01t) + 10^{-9}\right]$$

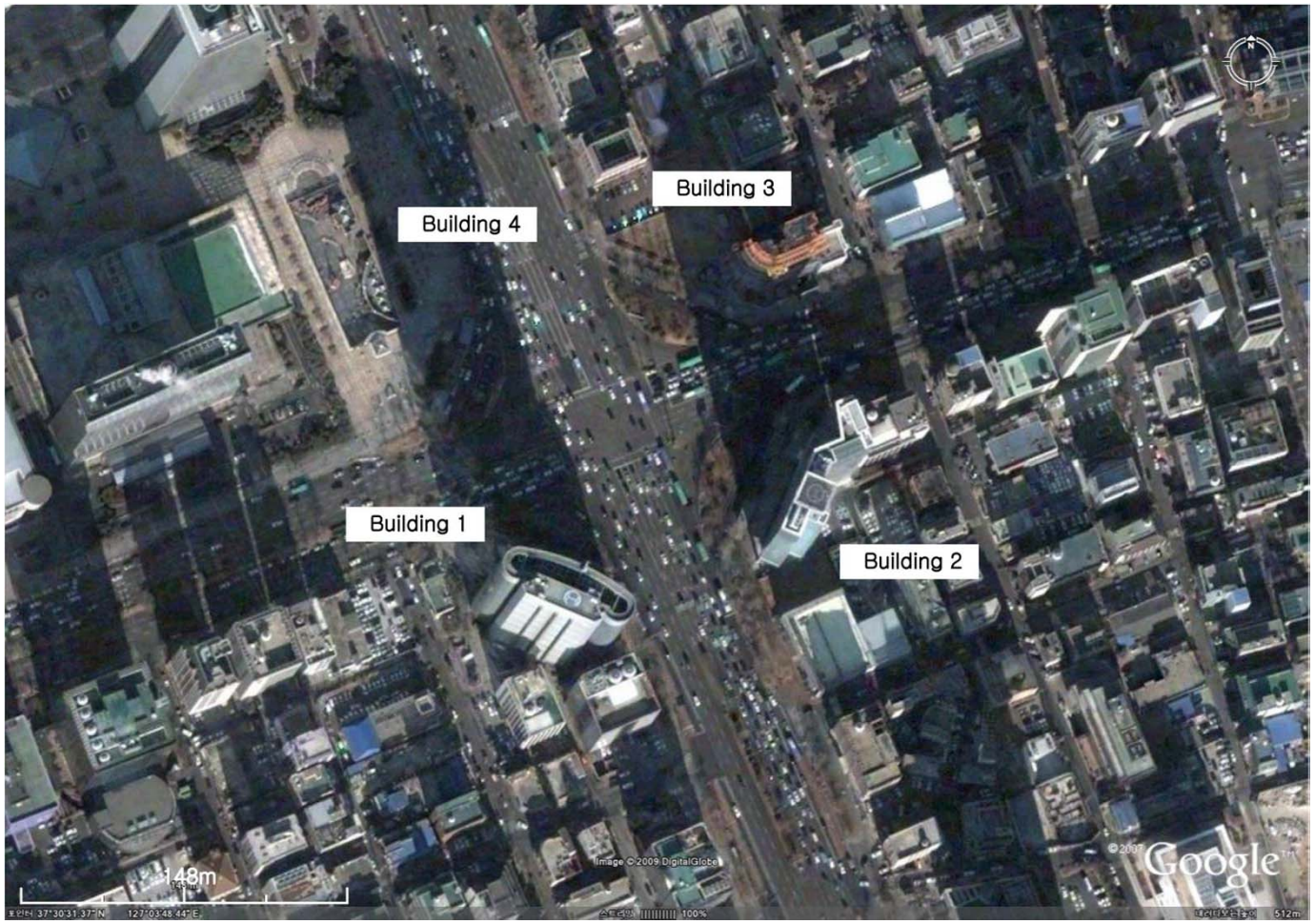
$K$ : resuspension factor (1/m)

$t$ : time following a deposition (day)

# Assumptions

- External dose resulting from Pu-239 contamination is not considered
- For internal dose due to inhalation, dose coefficients based on ICRP-60 are applied
- For seasonal dependence of external dose, depositions onto trees on the street and in the park on Jan. are 10% and 50% of those on July, respectively
- Environmental behaviors due to snow (in general) in winter are the same those due to rain in summer

# Test Site – Region 1




**Building 1**

**#1 : ground floor**

**#2 : 10th floor**

**#3 : 24th floor**
**(top floor)**

**#4 : outside**
**(block sidewalk)**

# Test Site – Region 2

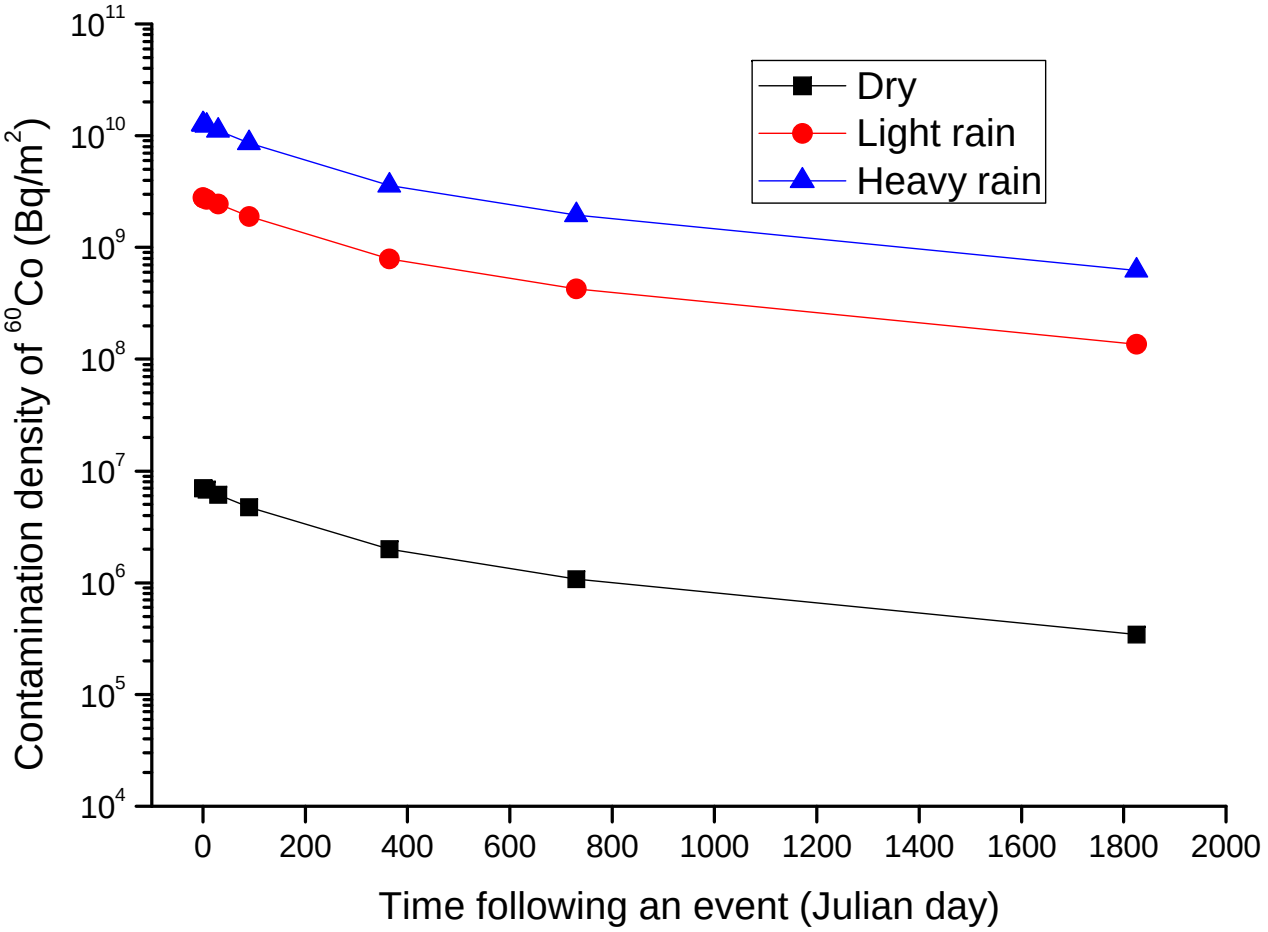

**Park Area**

**E1 : dirt pathway**

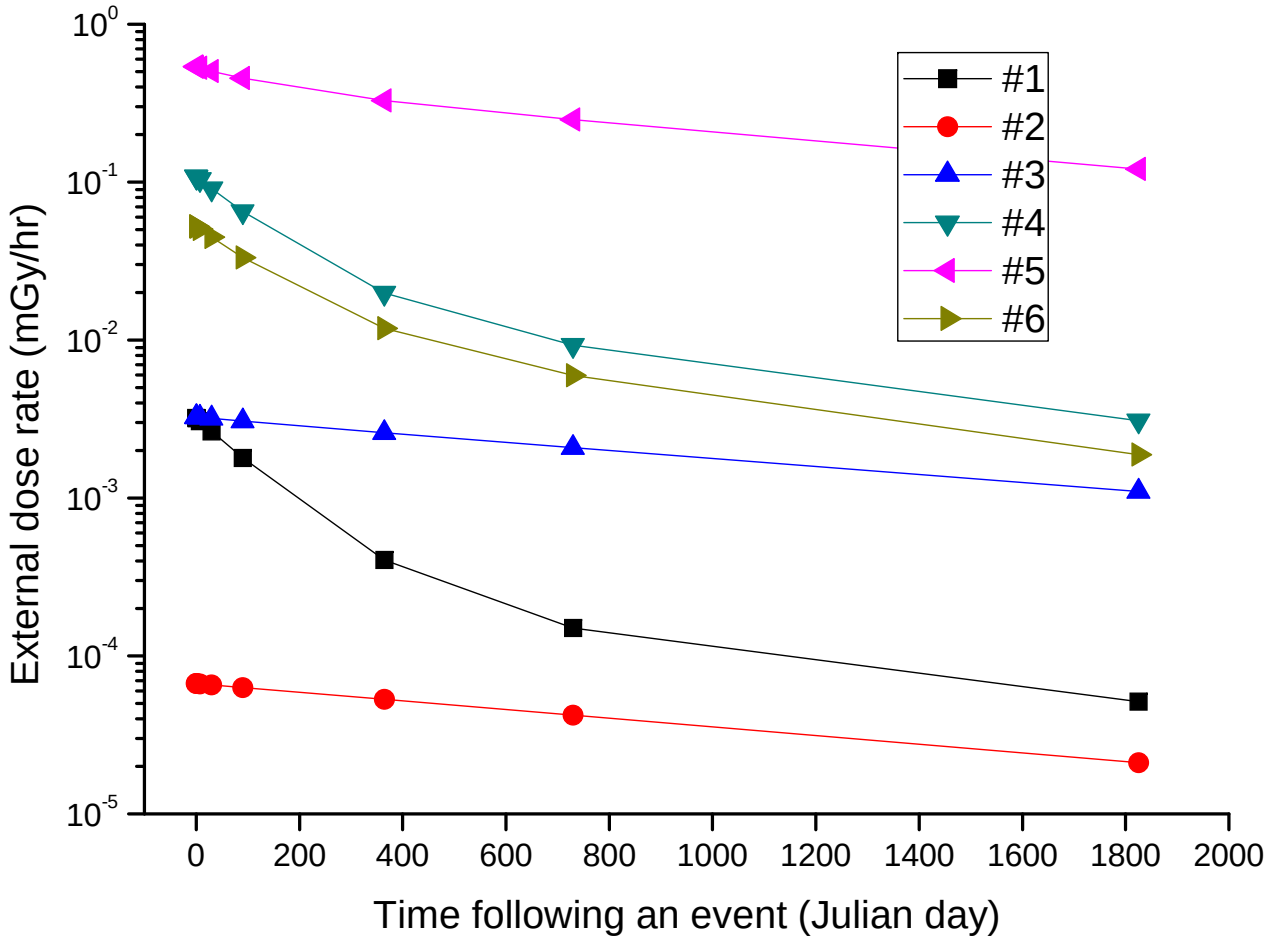
**E2 : parking lot (concrete)**

# Results

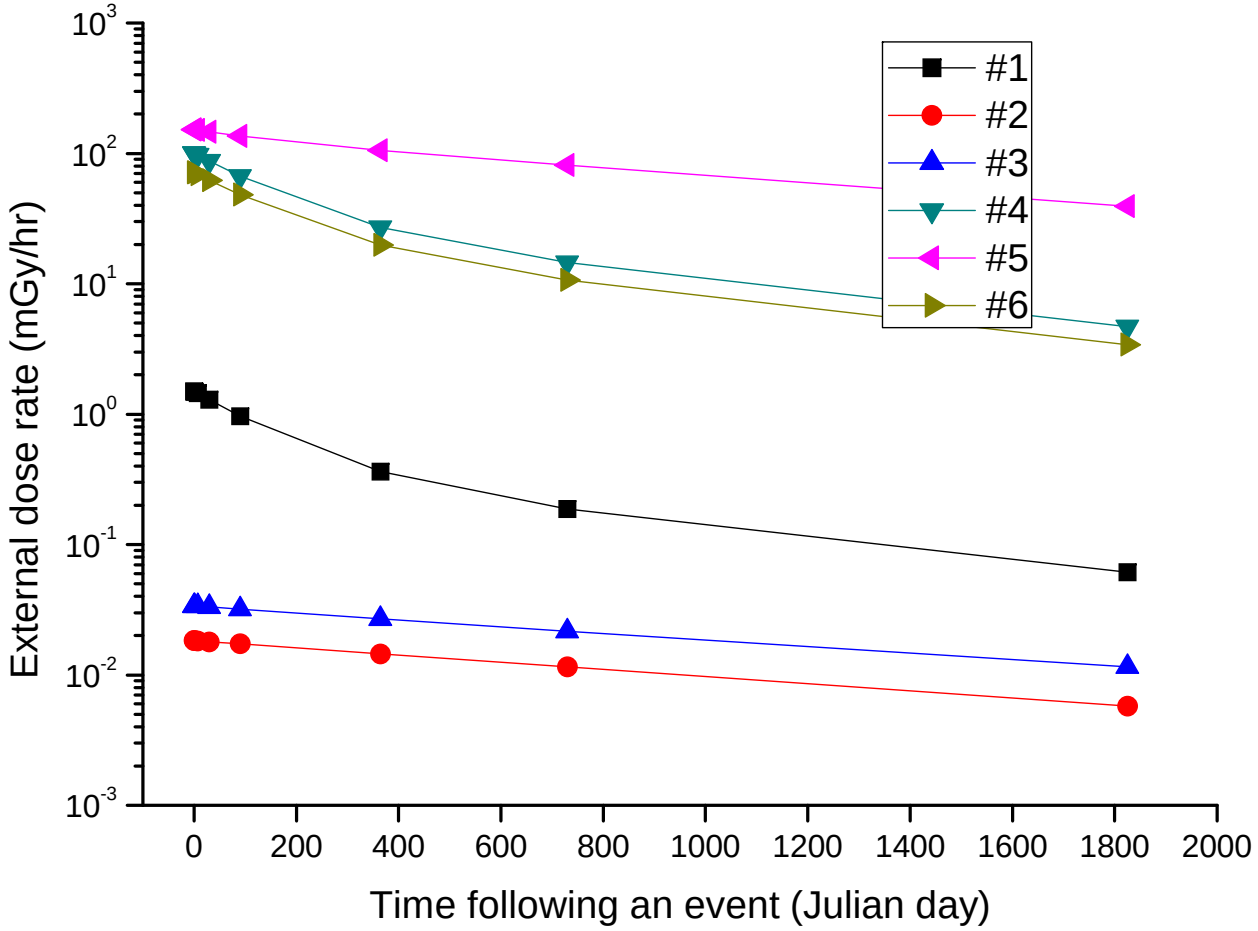
## $^{60}$Co, No CM, Region 1, Outside, June



# Results
## $^{60}$Co, No rain, No CM, June

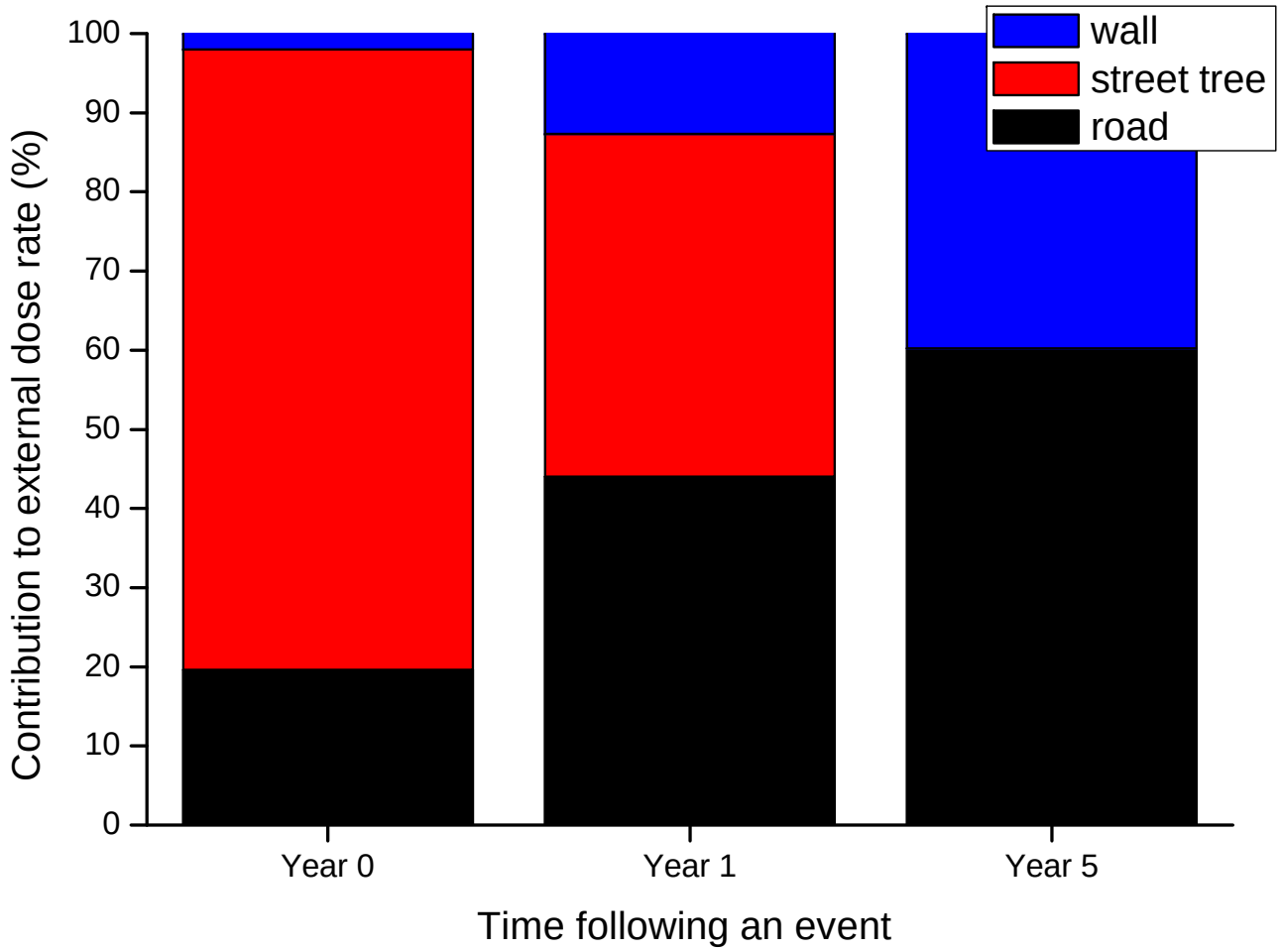


# Results
## $^{60}$Co, Heavy rain, No CM, June



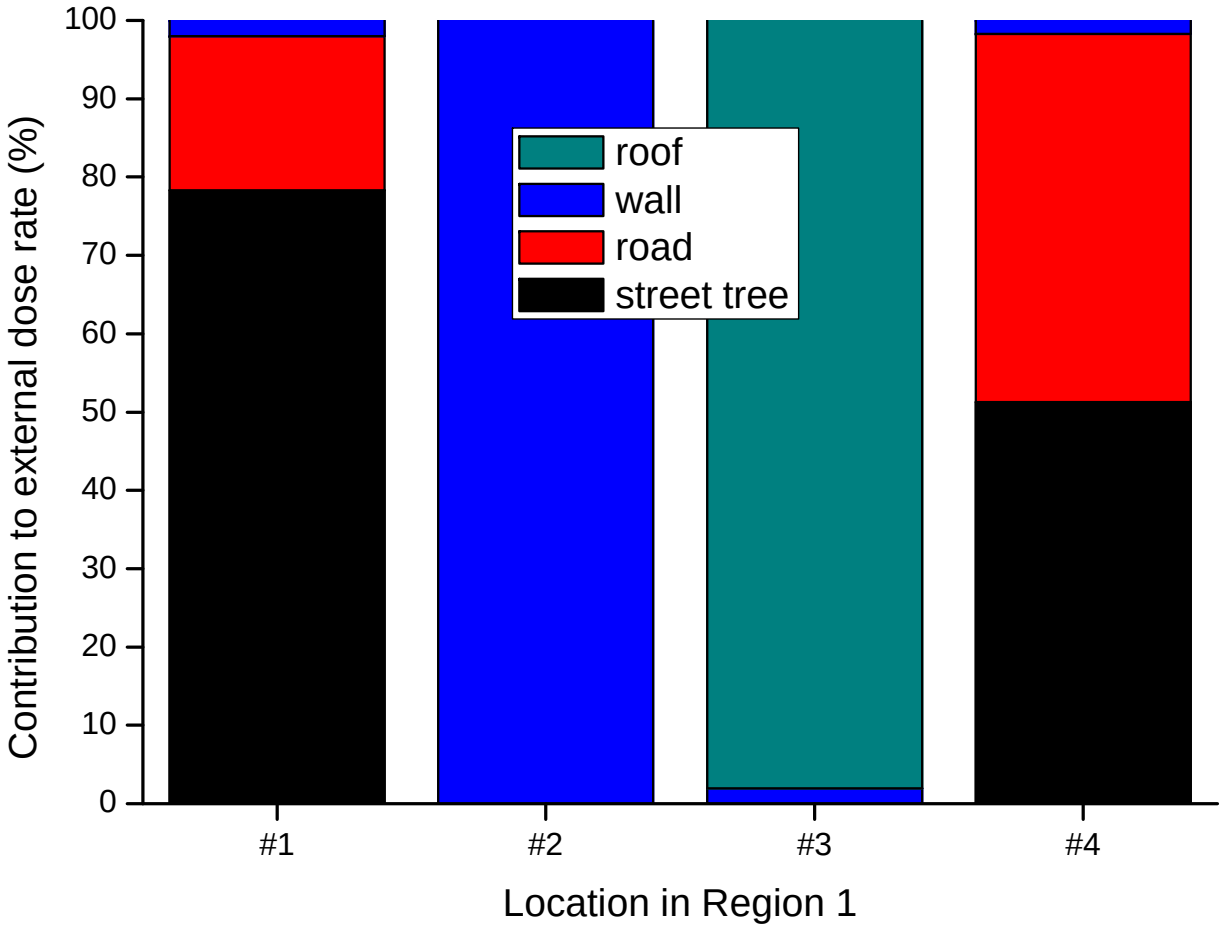
# Results

## $^{60}$Co, No rain, No CM, Region 1, Ground floor, June



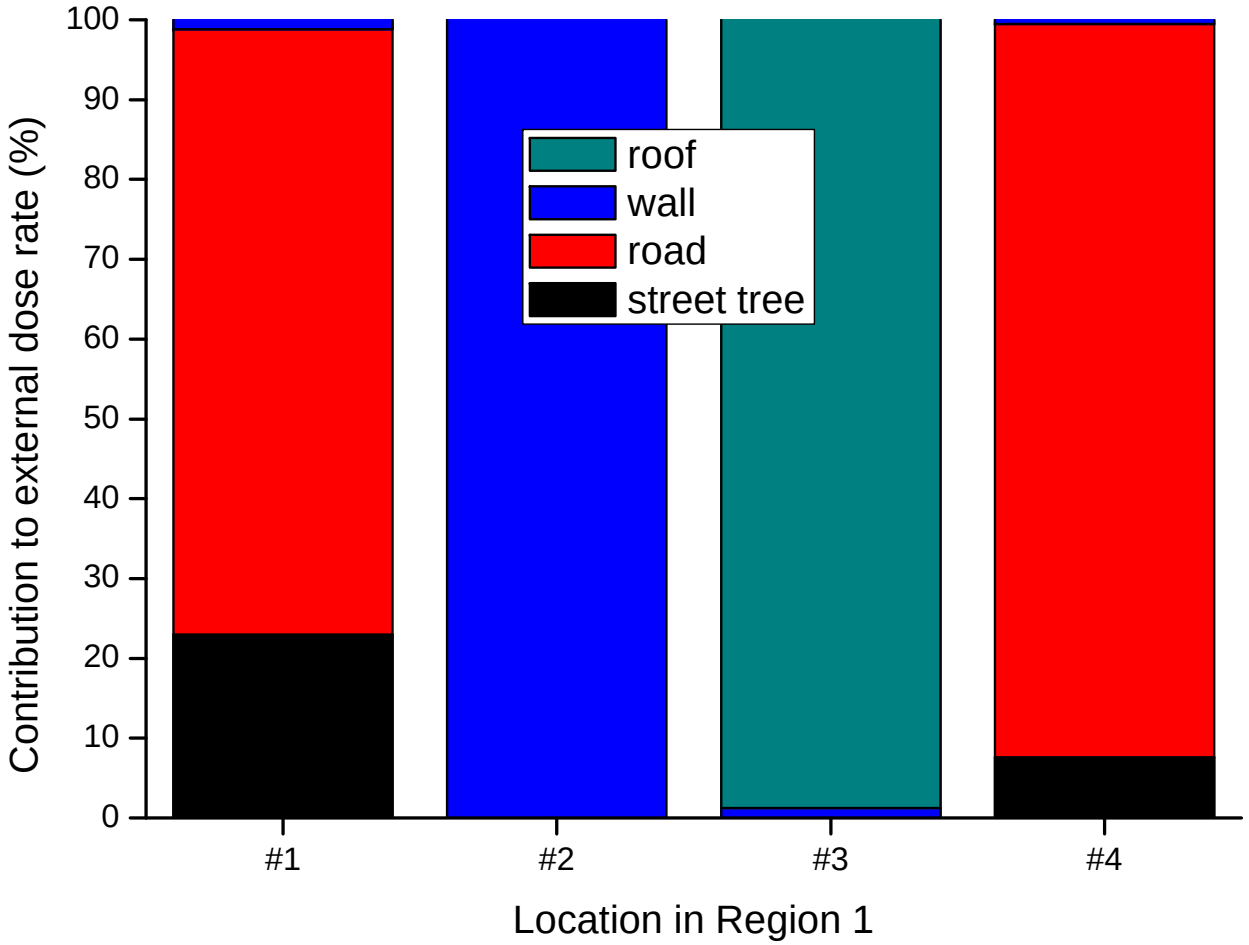
# Results

## $^{60}$Co, No rain, No CM, Year 0, June



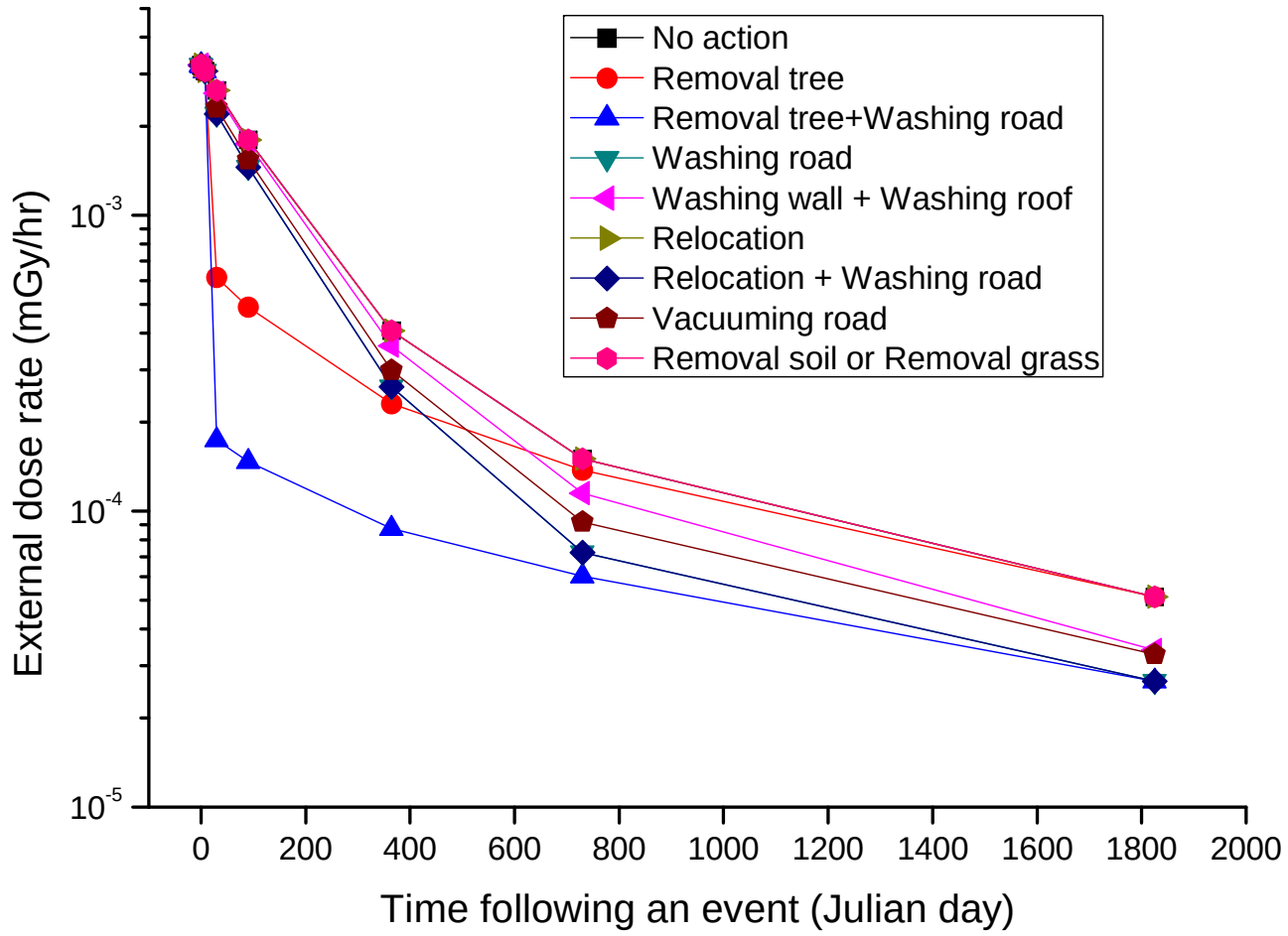
# Results

## $^{60}$Co, Heavy rain, No CM, Year 0, June



# Results

## $^{60}$Co, No rain, Region 1, Ground floor, June



# Results

## $^{60}$Co, No rain, No CM, Region 1, Ground floor