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Participation in IAEA Model Validation Programs — A Summary of RESRAD Experience

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Presented at ERAD Webinar

August 16, 2017

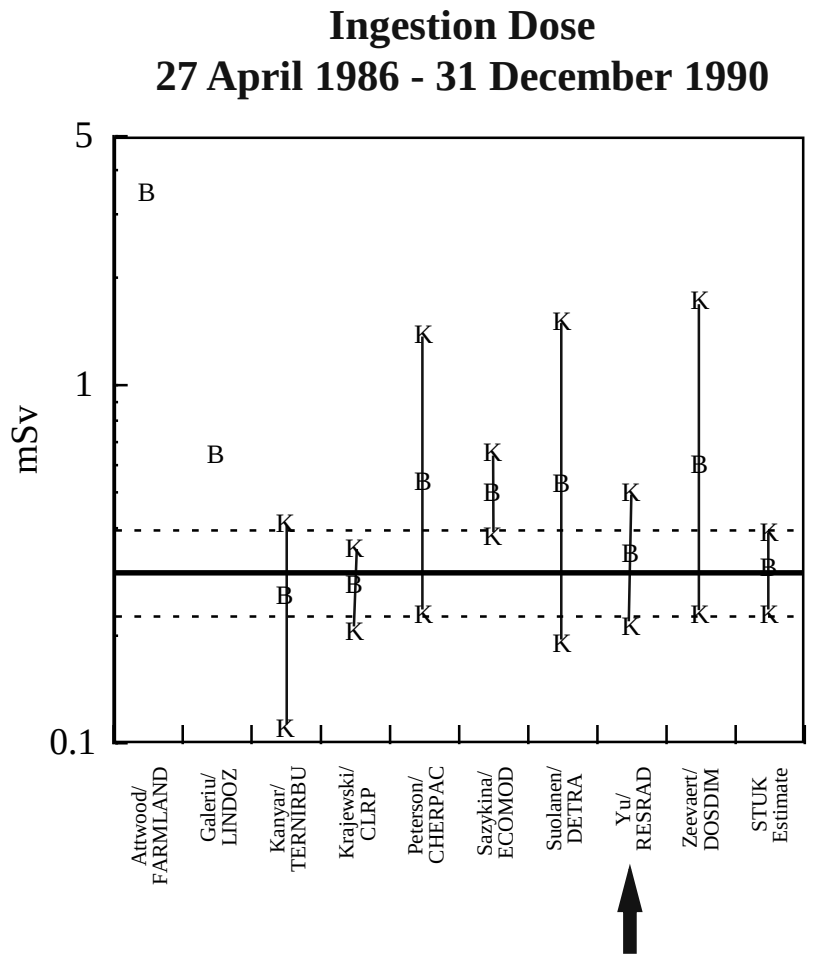
Participation in IAEA Model Testing/Validation Programs Started in 1990

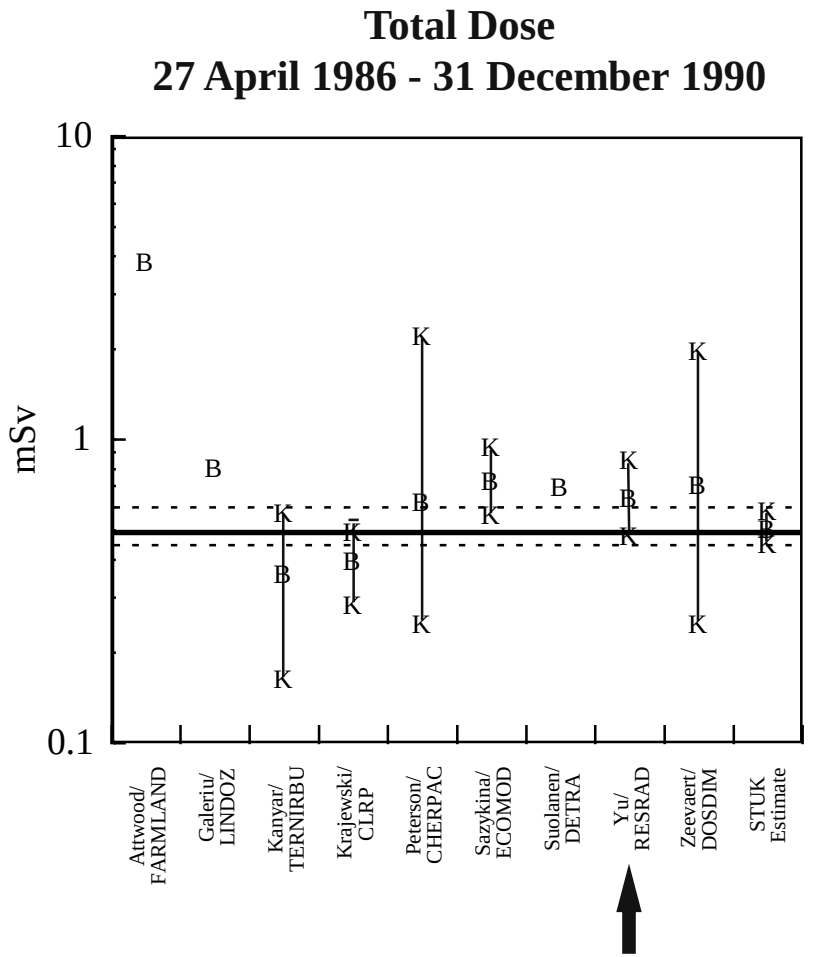
- 1985-1991: **BIOMOVS** — BIOspheric Model Validation Study
- 1988-1994: **VAMP** — Validation of Model Predictions (Chernobyl data): RESRAD-ONSITE
- 1991-1996: **BIOMOVS II** — BIOspheric Model Validation Study II: RESRAD-ONSITE and RESRAD-OFFSITE
- 1996-2001: **BIOMASS** — BIOsphere Modelling and ASSessment: RESRAD-OFFSITE
- 2003-2011: **EMRAS I & II** — Environmental Modelling for RAdiation Safety I & II: RESRAD-OFFSITE, RESRAD-BIOTA, and RESRAD-RDD
- 2012-2015: **MODARIA I** — MOdelling and DAta for Radiological Impact Assessment (10 WGs): RESRAD-OFFSITE, RESRAD-BIOTA, and RESRAD-RDD
- 2016-2019: **MODARIA II** — MOdelling and DAta for Radiological Impact Assessment II (7 WGs): RESRAD-OFFSITE, RESRAD-BIOTA, and RESRAD-RDD

Experience and Lessons Learned From Participation in IAEA Modeling Programs

- Compared/benchmarked RESRAD codes with international models using hypothetical and realistic scenarios
- Verified/validated various models/modules used in RESRAD family of codes with real data sets such as Chernobyl accident data
- Improved/enhanced RESRAD models and parameters such as the probabilistic analysis capability and transfer factors database, etc.
- Increased confidence level on the models implemented in codes and application of the models
- Learned that:
  - “Model cannot be validated; Model can only be invalidated”
  - “Model should be simple, but not simpler”
  - “All models are wrong, some are useful”

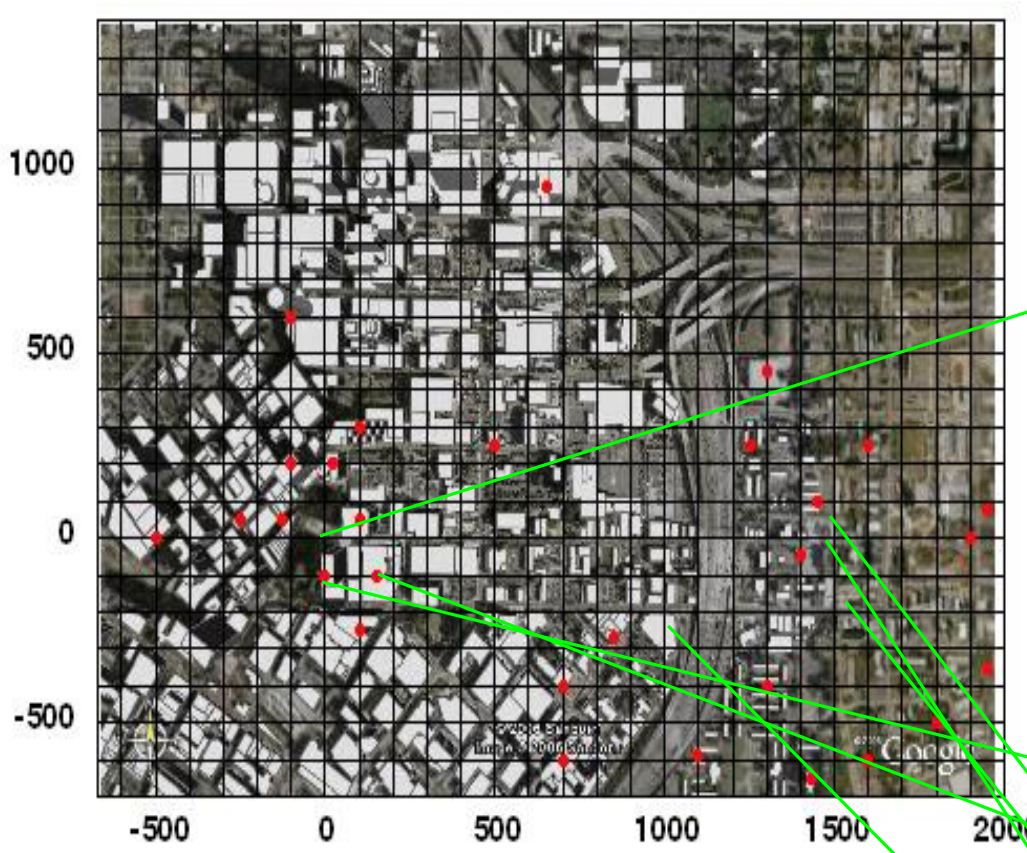
Application of RESRAD-ONSITE to VAMP Scenario S (Southern Finland)





Long-term dose prediction compared very well with calculated dose based on observation data

Application of RESRAD-RDD to EMRAS Urban WG Hypothetical Scenario

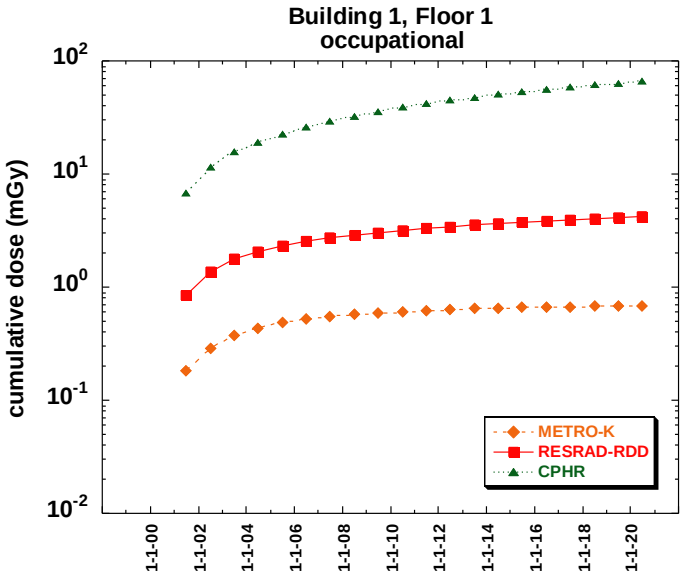


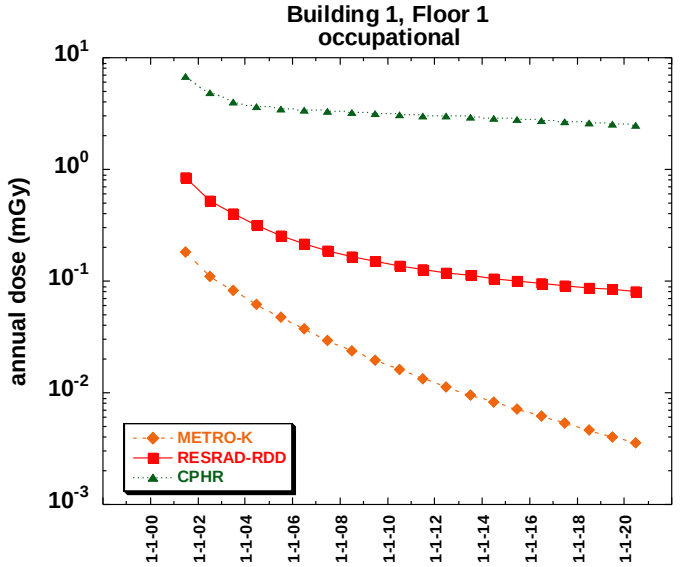
- The hypothetical event (1 5-kg) conventional explosion of an RDD containing Cs-137 in powder form) is assumed to originate at the fountain in the park area at (0, 0). The park area is surrounded by buildings.

- Building locations where dose is to be estimated

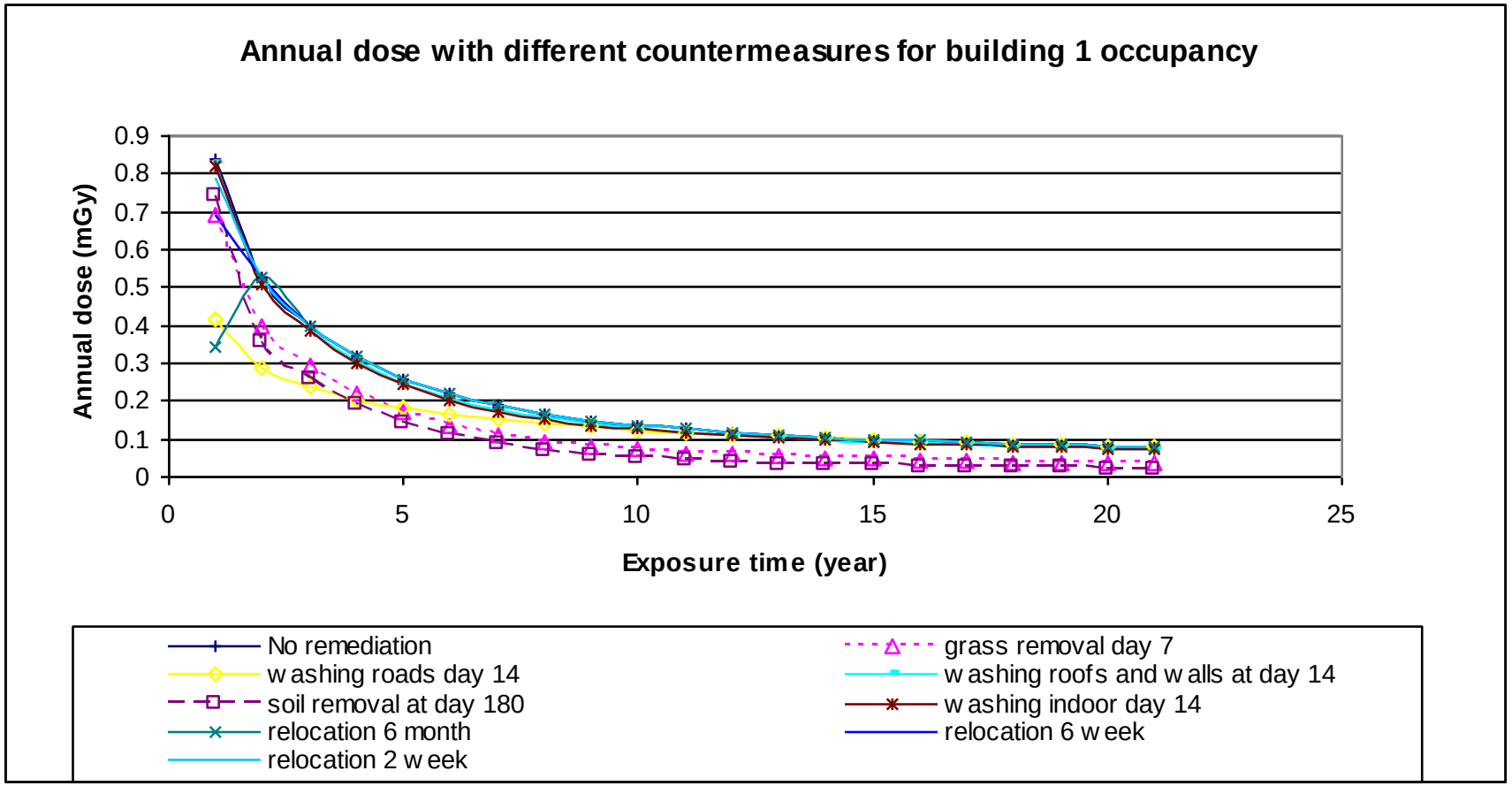
Building number	x-coordinate	y-coordinate	Building use
1	44	-60	Office
2	129	-60	Parking garage
3	1504	191	School
4	1528	-170	Super market
5	1498	-2	House
6	1020	-278	Apartment building

IAEA EMRAS Urban WG RESRAD-RDD Results





RESRAD-RDD Results on Annual Dose with Different Countermeasures



Application of RESRAD-BIOTA to EMRAS I and II Biota Working Groups

- Participated in many exercises conducted under EMRAS I and EMRAS II Biota Working Groups
- Some of the exercises are now used in RESRAD-BIOTA training workbook
- EMRAS I exercises:
  - Exercise 1: Dose Conversion Coefficient (DCC) Comparison
  - Exercise 2: Evaluation of Concentrations Predicted by Models
  - Exercise 3: Perch Lake (Chalk River Lab) Freshwater Scenario (measured concentration data)
  - Exercise 4: Chernobyl Terrestrial Scenario (measured data)
- EMRAS II exercises:
  - Beaverlodge, Canada
    - *A uranium mining and milling site – water, sediment, and fish activity concentrations data available from lakes downstream of the mine*
  - Little Forest Burial Ground, Australia
    - *Waste trenches – contaminants include uranium isotopes, H-3, plutonium isotopes, Am-241, Cs-137, and Sr-90*

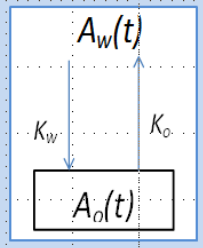
Developed New Dynamic Model by Participating in MODARIA Biota Modeling Working Group Activities

Dynamic Modeling Methodology

Model

Governing Equation:

$$\frac{dA_0(t)}{dt} = k_w A_w(t) - (k_0 + \lambda) A_0(t)$$



Solution:

$$A_0^{n+1} = k_w \cdot \Delta t \cdot A_w^{n+1} + A_0^{n} e^{-(k_0+\lambda)\Delta t}$$

A_0 : radionuclide concentration in the organism [Bq/kg]

A_w: radionuclide concentration in water [Bq/m3]

λ: radioactive decay constant [1/day]

k_w: uptake (or absorption) constant related to food and water ingestion [1/day]

k_0 biological excretion constant (= ln2/(biological half-life))

The concentration in the organism at the next time step is equal to the amount of activity uptake $k_w A_w \Delta t$ and the amount of radioactivity remained from the previous time step (i.e., subtracts what is excreted through biological processes and lost through decay).

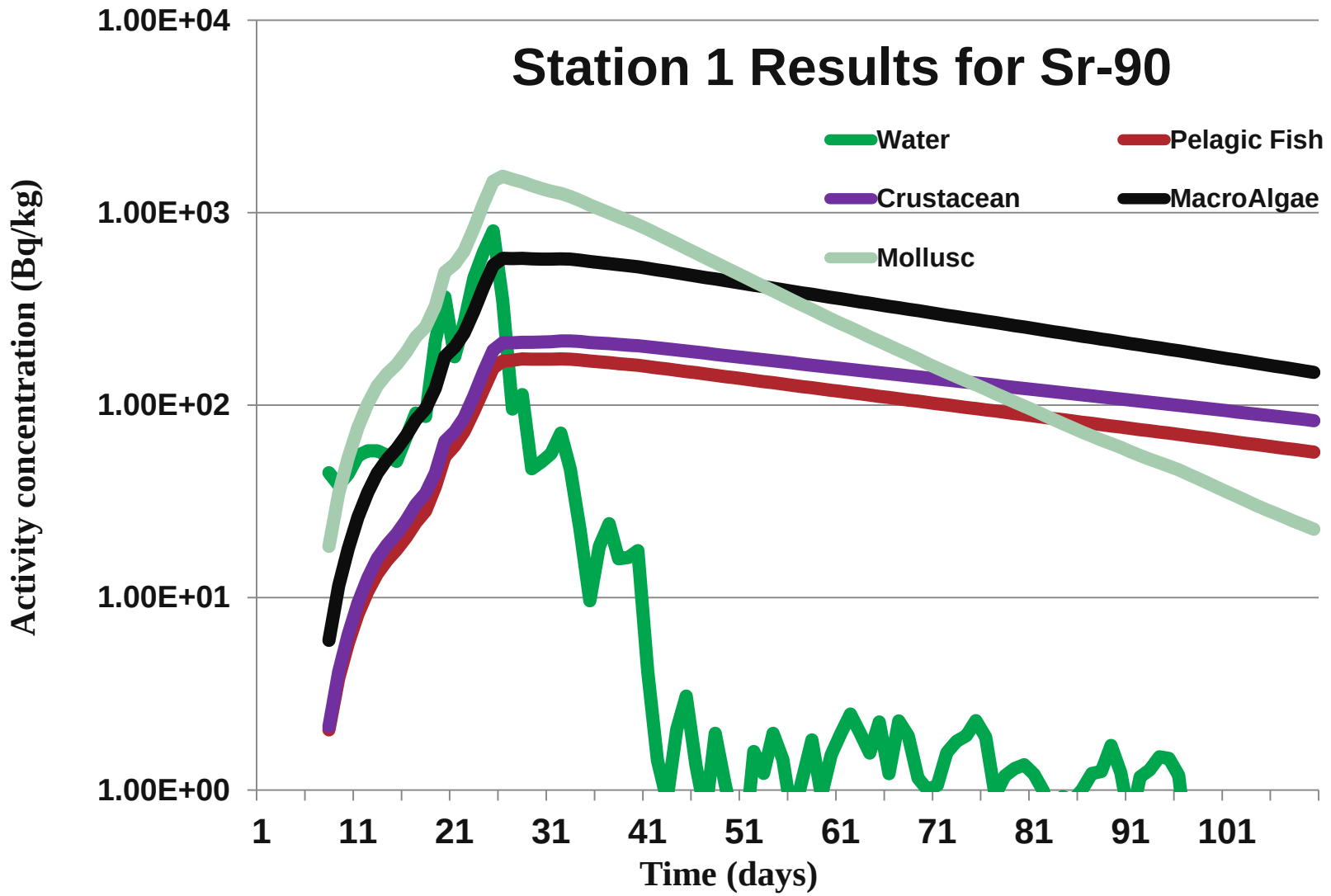
Note: Under a steady state condition $k_w = (k_0 + \lambda) \cdot \frac{A_0}{A_w}$ where A_0/A_w is the steady state concentration ratio of the radionuclide. This radionuclide concentration ratio is related to stable isotope concentration ratio (CR) by the following equation (IAEA TRS 472):

$$\frac{A_0}{A_w} = CR \times \frac{k_0}{k_0 + \lambda} \qquad k_w = k_0 \times CR$$

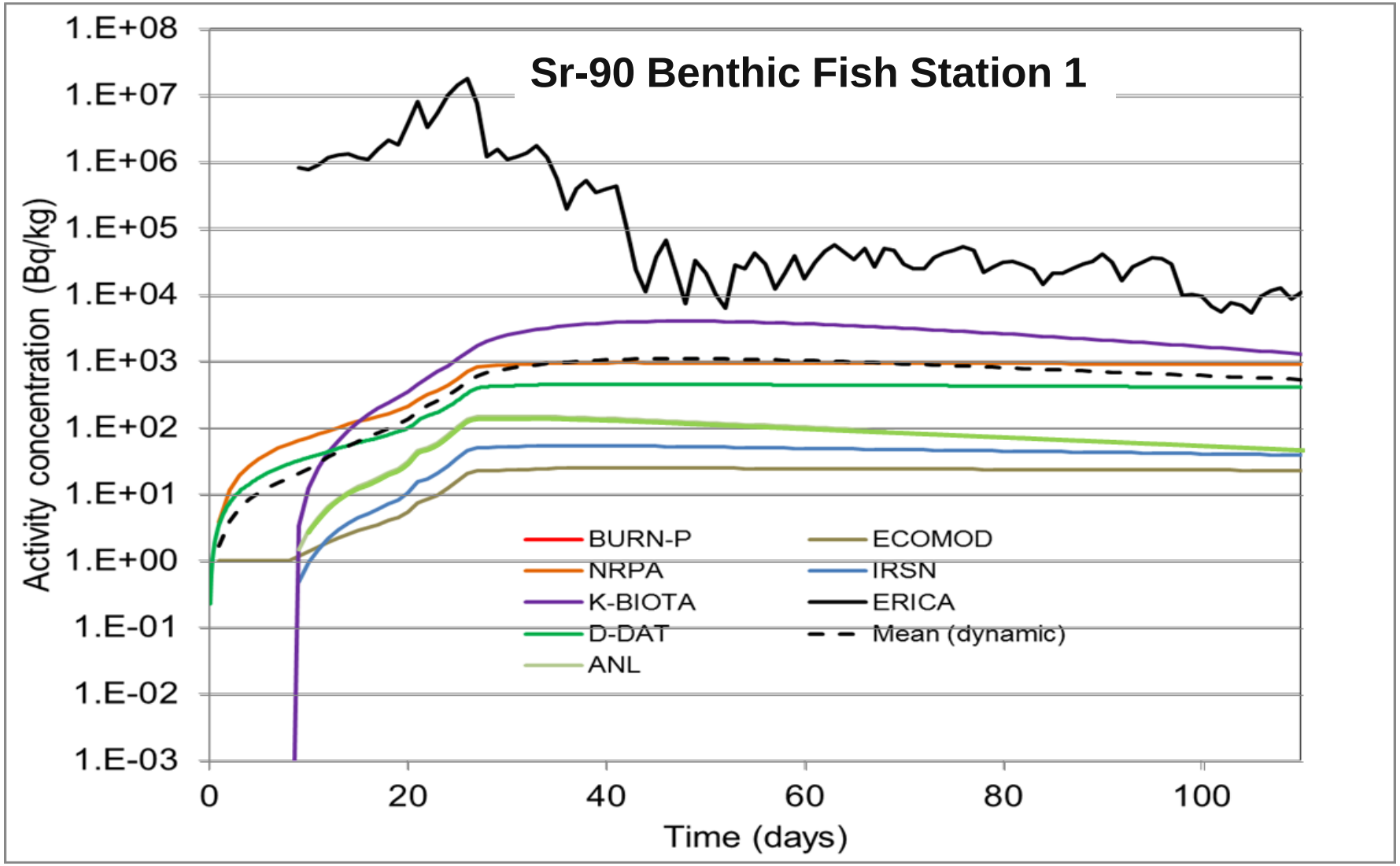
Inputs

Time dependent water concentration of three radionuclides (Cs-137, I-131, and Sr-90) in near-surface and near-bottom seawater along with sediment concentration was provided in the scenario description for four coastal stations.

RESRAD Dynamic Modeling Results (New Capability)



Model-Model Comparison of Dynamic Modeling Results



List of Select Journal Articles Resulting from Participating in IAEA Model Validation Programs

- Vives i Batlle, J., N.A. Beresford, K. Beaugelin-Seiller, R. Bezhenar, J. Brown, J.-J. Cheng, M. Cujic, S. Dragovic, C. Duffa, B. Fievet, A. Hosseini, K.T. Jungi, S. Kamboj, D.-K. Keum, A. Kryshev, D. LePoire, V. Maderich, B.-I. Min, R. Peri_a~nez, T. Sazykina, K.-S. Suh, C. Yu, C. Wang, R. Heling, Inter-Comparison of Dynamic Models for Radionuclide Transfer to Marine Biota in a Fukushima Accident Scenario, J. Environmental Radioactivity, 153, 31-50, 2016.
- C. Yu, J.-J. Cheng, and S. Kamboj. Effects of the New Wildlife Transfer Factors on RESRAD-BIOTA's Screening Biota Concentration Guides and Previous Model Comparison Studies. *Journal of Environmental Radioactivity,* Vol. 126, *338-351*, Dec. 2013.
- M.P. Johansen, S. Kamboj, W.W. Kuhne. 2013. Whole-organisms concentration ratios for plutonium in wildlife from past US nuclear research data. *Journal of Environmental Radioactivity,* Volume 126, December 2013, Pages 412-419.
- Johansen, M. P., C.L. Barnett, N.A. Beresford, J.E. Brown, M. Černe, B.J. Howard, S. Kamboj, D-K. Keum, B. Smodiš, J.R. Twining, H. Vandenhove, J. Vives i Batlle, M.D. Wood, C. Yu, *Assessing doses to terrestrial wildlife at a radioactive waste disposal site: inter-comparison of modelling approaches*, Sci Total Environ Vol. 427-428, pp. 238-246, 2012.
- Vives i Batlle, J., K. Beaugelin-Seiller, N.A. Beresford, D. Copplestone, J. Horyna, A. Hosseini, M. Johansen, S. Kamboj, D-K. Keum, N. Kurosawa, L. Newsome, G. Olyslaegers, H. Vandenhove, S. Ryufuku, S. Vives Lynch, M.D. Wood, C. Yu, *The estimation of absorbed dose rates for non-human biota: an extended inter-comparison*, Journal of Radiation and Environmental Biophysics (2011) 50:231-251.
- Beresford, N. A., C. L. Barnett, J. E. Brown, J-J Cheng, D. Copplestone, S. Gaschak, A. Hosseini, B. J. Howard, S. Kamboj, T. Nedveckaite, G. Olyslaegers, J. T. Smith, J. Vives i Batlle, S.Vives-Lynch, and C. Yu, *Predicting the radiation exposure of terrestrial wildlife in the Chernobyl exclusion zone: an international comparison of approaches*, J. Radiol. Prot. 30 (2010) 341-373.
- Yankovich, T. L., J. Vives i Batlle, S. Vives-Lynch, N. A. Beresford, C. L. Barnett, K. Beaugelin-Seiller, J. E. Brown, J-J Cheng, D. Copplestone, R. Heling, A. Hosseini, B. J. Howard, S. Kamboj, A. I. Kryshev, T. Nedveckaite, J. T. Smith, and M. D. Wood, An international model validation exercise on radionuclide transfer and doses to freshwater biota, Radiol. Prot. 30 (2010) 299-340.

List (Cont'd)

- Beresford, N.A., Barnett, C.L., Brown, J., Cheng, J.J., Copplestone, D., Filistovic, V., Hosseini, A., Howard, B.J., Jones, S.R., Kamboj, S., Kryshev, A., Nedveckaite, T., Olyslaegers, G., Saxén, R., Sazykina, T., Vives i Batlle, J., Vives-Lynch, S., Yankovich, T. and Yu, C., "*Inter-comparison of models to estimate radionuclide activity concentrations in non-human biota",* Radiation and Environmental Biophysics, 47(4):491–514, August 2008.
- Nicholas A. Beresford, Mikhail Balonov, Karine Beaugelin-Seiller, Justin Brown,David Copplestone, Joanne L. Hingston, Jan Horyna, Ali Hosseini, Brenda J. Howard, Sunita Kamboj, Tatjana Nedveckaite, Geert Olyslaegers, Tatiana Sazykina, Jordi Vives i Batlle, Tamara L. Yankovic, and Charley Yu, "*An international comparison of models and approaches for the estimation of the radiological exposure of non-human biota*." Applied Radiation and Isotopes, 66 (11):1745-1749, November 2008.
- J. Vives i Batlle, K. Beaugelin-Seiller, N.A. Beresford, D. Copplestone, J. Horyna, A. Hosseini, M. Johansen, S. Kamboj, D-K. Keum, N. Kurosawa, L. Newsome, G. Olyslaegers, H. Vandenhove, S. Ryufuku, S. Vives Lynch, M.D. Wood, C. Yu, *The estimation of absorbed dose rates for non-human biota: an extended inter-comparison*, submitted to Journal of Radiation and Environmental Biophysics, June 2010.
- Beresford, N.A., C. L. Barnett, K. Beaugelin-Seiller, J.E. Brown, J.-J. Cheng, D. Copplestone, S. Gaschak, J.L. Hinston, J. Horyna, A. Hosseini, B.J. Howard, S. Kamboj, A. Kryshev, T. Nedveckaite, G. Olyslaegers, T. Sazykina, J. T. Smith, T. Telleria, J. Vives i Batlle, T.L. Yankovich, T. Sazykina, R. Heling, M.D. Wood, and C. Yu, "Findings and Recommendations from an International Comparison of Models and Approaches for the Estimation of Radiological Exposure to Non-Human Biota," *Radioprotection*, *44*(5), pp.565-570, 2009.
- O'Brien, R.S., P. McDonald, C. Yu, V. Koukouliou, L. Setlow, J. Horyna, D. P. Sanchéz, T. al-Khayat, P. Waggitt, G. Olyslaegers, T. Zeevaert, A. Canoba, V. Amado, and K. Ivanova. "Environmental Modelling of NORM." *Radioprotection, 44*(5), pp.23-28, 2009.
- Thiessen, K.M., Andersson, K.G., Batandjieva, B., Cheng, J.-J., Hwang, W.T., Kaiser, J.C., Kamboj, S., Steiner, M., Tomás, J., Trifunovic, D., and Yu, C. Modelling the long-term consequences of a hypothetical dispersal of radioactivity in an urban area including remediation alternatives. Journal of Environmental Radioactivity 100:445-455, 2009.

List (Cont'd)

- NA Beresford[a*], CL Barnett[a], JE Brown[b], J-J Cheng[c], D Copplestone[d], S Gaschak[e], A Hosseini[b], BJ Howard[a], S Kamboj[c], T Nedveckaite[f], G Olyslaegers[g], JT Smith[h], J Vives i Batlle[i] & C Yu, An international comparison of approaches to assess the radiation exposure of wildlife to radioactivity: terrestrial species in the Chernobyl exclusion zone 2009
- Kamboj, S., Jing-Jy Cheng, C. Yu, S. Domotor, and A. Wallo, *"Modeling of the EMRAS Urban Working Group Hypothetical Scenario Using the RESRAD-RDD Methodology*," submitted to Journal of Environmental Radioactivity, September, 2008
- Beresford, N.A., Barnett, C.L., Brown, J., Cheng, J.J., Copplestone, D., Filistovic, V., Hosseini, A., Howard, B.J., Jones, S.R., Kamboj, S., Kryshev, A., Nedveckaite, T., Olyslaegers, G., Saxén, R., Sazykina, T., Vives i Batlle, J., Vives-Lynch, S., Yankovich, T. and Yu, C., "*Inter-comparison of models to estimate radionuclide activity concentrations in non-human biota",* Radiation and Environmental Biophysics, 47(4):491–514, August 2008.
- Nicholas A. Beresford, Mikhail Balonov, Karine Beaugelin-Seiller, Justin Brown,David Copplestone, Joanne L. Hingston, Jan Horyna, Ali Hosseini, Brenda J. Howard, Sunita Kamboj, Tatjana Nedveckaite, Geert Olyslaegers, Tatiana Sazykina, Jordi Vives i Batlle, Tamara L. Yankovic, and Charley Yu, "*An international comparison of models and approaches for the estimation of the radiological exposure of non-human biota*." Applied Radiation and Isotopes, 66 (*11*):1745-1749, November 2008.
- Thiessen, K.M., B. Batandjieva, K.G. Andersson, A. Arkhipov, T.W. Charnock, F. Gallay, S. Gaschak, V. Golikov, W.T. Hwang, J.C. Kaiser, S. Kamboj, M. Steiner, J. Tomás, D. Trifunovic, C. Yu, R.L. Zelmer, and B. Zlobenko, "*Improvement of modeling capabilities for assessing urban contamination: The EMRAS Urban Remediation Working Group*," Applied Radiation and Isotopes, 66 (11): 1741-1744, November 2008.

List (Cont'd)

- Vives i Batlle, J., Balonov, M., Beaugelin-Seiller, K., Beresford, N.A., Brown, J., Cheng, J-J., Copplestone, D., Doi, M., Filistovic, V., Golikov, S., Horyna, J., Hosseine, A., Howard, B.J., Jones, S.R., Kamboj, S., Kryshev, A., Nedveckaite, T., Olyslaegers, G., Pröhl, G., Sazykina, T., Ulanovsky, A., Vives-Lynch, S., Yankovich, T. and Yu, C., "Inter-comparison of models for the calculation of unweighted absorbed dose rates for non-human biota"*, Radiation and Environmental Biophysics, 46:349-373, July 2007.*
- Sweeck, L., B. Kanyar, P. Krajewski, A. Kryshev, P. Lietava, A. Nenyei, T. Sazykina, C. Yu, and T. Zeevaert, "Model Testing for the Remediation Assessment of a Radium Contaminated Site in Olen, Belgium," J. Environmental Radioactivity, *84*:245-258, 2005.
- Gnanapragasam, E. and C. Yu, Application of RESRAD-OFFSITE to two Probabilistic Test Scenarios, *Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management* 6(2): 112-119, 2002.
- Camus, H., R. Little, D. Acton, A. Aguero, D. Chambers, L. Chamney, J.L. Daroussin, J. Droppo, C. Ferry, E. Gnanapragasam, C. Hallam, J. Horyna, D. Lush, D. Stammose, T. Takahashi, L. Toro, and C. Yu, "Long-term Contaminant Migration and Impacts from Uranium Mill Tailings," Journal of Environmental Radioactivity 42 (1999) 189-304.

Thank You!