Preliminary Remediation Goals for Radionuclides (PRG) Calculator

External Verification Study Record
June 17 – August 8, 2022

CONTENTS:

Verification Study Charge for:

U.S. Environmental Protection Agency (EPA), "Preliminary Remediation Goals for Radionuclides" (PRG) electronic calculator http://epa-prgs.ornl.gov/radionuclides/

Background:

EMS, Inc., under contract EP-W-13-016 with EPA's Office of Superfund Remediation and Technology Innovation, has been asked to conduct a third external, independent verification study of the "Preliminary Remediation Goals for Radionuclides" electronic calculator. EPA developed the electronic calculator to help risk assessors, remedial project managers, and others involved with risk assessment and decision making at sites with radioactively contaminated soil, water, and air. The electronic calculator provides guidance for establishing risk-based PRGs for radioactively contaminated sites regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980.

A new peak PRG output option was added to the main calculator in June 2021 to calculate the activity of the parent radionuclide to be protective of the peak excess lifetime cancer risk (ELCR) for the entire decay chain over time. A new output option to select a time period of interest was added in May 2022.

The PRG calculator results were previously externally verified twice and externally peer-reviewed twice, but equations for the peak PRG output function have not yet been externally verified.

The PRG calculator is available at https://epa-prgs.ornl.gov/cgi-bin/radionuclides/rprg_search, and the User's Guide is available at https://epa-prgs.ornl.gov/radionuclides/users_guide.html.

Verification Study Charge:

According to EPA's Guidance on the Development, Evaluation, and Application of Environmental Models (2009), v*erification* refers to activities designed to confirm that the mathematical framework embodied in the module is correct and that the calculations the calculator yields compare favorably with those obtained using known analytical solutions or numerical solutions from simulators based on similar or identical mathematical frameworks. In addition, the study will ensure that sources of error, such as rounding, are minimal. The equations used in the calculator are listed at https://epa-prgs.ornl.gov/radionuclides/equations.html.

Reviewers are encouraged to choose:

- Radionuclides from the "common isotopes" list and some other isotopes from the "complete list" of radionuclides (Note that 2 or 3 isotopes at a time will be a lot faster than picking more.)

- Using the peak PRG option (the first source and decay output in the list), with various "Peak Time Periods".
- Using site-specific option, both "Database hierarchy defaults" and "User Provided".
- Using the "Risk Output Option."
- Using different "Scenarios" and "Media", but at least including the more common scenarios/media (e.g., Resident (Soil, Tap Water, Fish), Outdoor Worker (Soil), Farmer (Combined Soil and Biota, Combined Water and Biota).

An explanation of how to use the calculator is provided below.

We are enlisting two or three subject matter experts for this verification study. Your comments and recommendations will be used to verify existing equations and calculations so that the final version will reflect sound technical information and guidance.

As an independent tester of the PRG electronic calculator, we ask you to examine the numerical technique of the calculations for consistency with the conceptual model and governing equations.

When your verification study is complete, e-mail your comments to EMS's Project Manager (Cindy Eyer, cindy.eyer@emsus.com) on or before **August 8, 2022**. Please submit your comments in Microsoft Word and reference each comment to a specific step in the calculator and equation (http://epa-prgs.ornl.gov/radionuclides/equations.html). For specific comments or text edits on the user's guide, you may copy and paste text into Microsoft Word and indicate edits or comments using track changes or the comments feature. *Please do not handwrite your comments.*

How to Use the Calculator:

Step 1: Select a target risk for cancer toxicity of 10^{-6}, 10^{-5}, or 10^{-4}, or select "Other" to manually enter an alternate risk value.

Step 2: Choose one of eight land-use scenarios (resident, indoor worker, outdoor worker, composite worker, construction worker (site-specific only), recreator (site-specific only), farmer, or soil to groundwater) and choose the media (soil, air, tap water, 2-D external exposure, fish). Some of these exposure scenarios have multiple media choices; other scenarios will only involve one media so a choice will not appear.

Step 3: Under the Select Site Info Type choose either "Defaults" to get PRGs based on default exposure parameters or "Site-Specific" to change some of the exposure parameters.

Step 4: Choose whether or not risk output is desired.

Step 5: Select the units for the results – picocuries per gram, which are the units usually used in the United States, or becquerels per gram, which most of the rest of the world uses.

Step 6: Select one or more radionuclides for which you want to develop PRGs. Do not use the Select All option.

Step 7: Choose from one of the four Source and Decay Output Options.

Step 8: Choose from one of the five Peak Time Period Options.

Dr. Boby Abu-Eid

U.S. Nuclear Regulatory Commission

Verification Study of the Updated Sections of the EPA PRG Calculator

Summary

Boby Abu-Eid

July 15, 2022

I have conducted a quick review of the new peak PRG calculation equations; the following comments/remarks are provided:

1. The equations provided for decay of radionuclides and progenies were found accurate as they were based on the classical Bateman Equations.
2. The peak time considering only decay and default transfer factors for a specific a single radionuclide appear to be accurate.
3. The equations shown particularly for the resident scenario, considering the timeframe options in the calculator, do not appear to consider formal radionuclide transport analysis in environmental media (e.g., contaminated zone, unsaturated zone, groundwater, surface water) of both parent radionuclides and progenies.
4. It is unclear of how the locations of the receptor and well-water, as well as transport and dilution factor of radionuclides in the subsurface aquifer are calculated, as these factors could impact the analytical results and related equations for drinking and irrigation pathways associated with radionuclide and its progenies. It seems conservative assumptions are used based on release of radionuclides from soil to soil-leachate and primitive transport through the underlying soil to the aquifer. These issues could impact concentrations in water withdrawn from the well for irrigation as well as drinking water.
5. It is unclear how the concentration of radionuclides in fish was derived. Bio-transfer factor is applicable when the concentration of radionuclides and progenies in a pond or lake are known, the equations appear to lack such analysis.
6. The text in the updated guidance confuses between "sensitivity analysis" and "uncertainty analysis" for the peak calculations. In this regard, sensitivity analysis is typically derived based on different runs using different value of a specific sensitive parameter. Uncertainty analysis is based on probabilistic distribution of variable physical or behavior parameters and/or use of different conceptual models.
7. I have conducted a few runs for certain radionuclides. The results appear to be highly conservative using the peak risk for each radionuclide and associated progenies.
8. I did not try to compare or verify risk/dose results with other common codes/models used by NRC staff, or DOE such as DandD and/or RESRAD codes. I recommend, that EPA contractor conducts such comparative analysis and reports on verification of the PRG calculator.
9. I recommend EPA PRG contractor consults NRC documents for details of environmental pathway equations, parameters, and suggested approaches to uncertainty analysis in risk/dose peak calculations using risk-informed probabilistic approach to avoid unnecessary overestimation of dose/risk to members of the public. Examples of suggested documents

include: NUREG/CR-5512; NUREG/CR6937, NUREG/CR-7189, NUREG/CR-7038; NUREG/CR-7267.

10. Recommend EPA contractor consider review of ANL verification report # ANL/EVS/TM-15/1 for further verification and benchmarking of the new peak PRG calculations.
11. Please see other detailed comments I submitted earlier, as peer reviewer, on the PRG approaches, assumptions, and methodologies.

N.B.

1. Due to limitation of my available time I will be unable to do more work on verification of the updated PRG.

2. The above comments/remarks represent only my opinion to the best of my knowledge, and do not necessarily represent NRC views.

Background:

A new peak PRG output option was added to the main calculator in June 2021 to calculate the activity of the parent radionuclide to be protective of the peak excess lifetime cancer risk (ELCR) for the entire decay chain over time. A new output option to select a time period of interest was added in May 2022.

The PRG calculator results were previously externally verified twice and externally peerreviewed twice, but equations for the peak PRG output function have not yet been externally verified.

The PRG calculator is available at https://epa-prgs.ornl.gov/cgi-bin/radionuclides/rprg_search, and the User's Guide is available at https://epa-prgs.ornl.gov/radionuclides/users_guide.html.

Verification Study Charge:

According to EPA's Guidance on the Development, Evaluation, and Application of Environmental Models (2009), v*erification* refers to activities designed to confirm that the mathematical framework embodied in the module is correct and that the calculations the calculator yields compare favorably with those obtained using known analytical solutions or numerical solutions from simulators based on similar or identical mathematical frameworks. In addition, the study will ensure that sources of error, such as rounding, are minimal. The equations used in the calculator are listed at https://epaprgs.ornl.gov/radionuclides/equations.html.

Boby Abu-Eid, Ph.D.

Dr. Eid is a Senior Level (SLS) Advisor at the US NRC. He provides high level advice on technical and policy issues involving decommissioning, uranium recovery, low-level waste, and environmental protection. He is a member of multi-agency workgroups on radiological surveys (MARSSIM) and NRC's lead representative on multi-agency workgroup for laboratory analysis (MARLAP). Before joining the NRC in March 1991, Dr. Eid conducted research and/or taught at: MIT, University of Bonn in Germany, Kuwait Institute for Scientific Research in Kuwait, and Carnegie Institution of Washington. In his present position, Dr. Eid key activities involve technical/policy analysis for decommissioning, waste management, and environmental protection. His current focus includes risk analysis and insights, safety reviews, development of models/codes for decommissioning and waste management, assessing new technology developments and potential applications, and development of multi-agency (e.g.; Federal) guidance and protocols, as well as development of international standards (e.g; IAEA). He was a key contributor to assessment and development of NRC regulations and guidance for cleanup and decommissioning for license termination and site release. He holds Ph.D. from MIT. He is recipient of NRC's meritorious service award and on the advisory board of national and international conferences, and author or co-author of over 60 published articles. He is a master chess player and interested in collection of arts and gemstones. He can be reached at: Boby.abu-eid@nrc.gov

Verification Study Conflict of Interest Certification
Boby Abu-Eid

Verification study: **Preliminary Remediation Goals (PRG) for Radionuclides Electronic Calculator**

A conflict of interest or lack of impartiality exists when the proposed participant personally (or the reviewer's immediate family), or his or her employer, has financial interests that may be affected by the results of the verification study; or may provide an unfair competitive advantage to the participant (or employer); or if the participant's objectivity in performing the verification study may be impaired due to other factors. When the Participant knows that a reasonable person with knowledge of the facts may question the participant's impartiality or financial involvement, an apparent lack of impartiality or conflict of interest exists.

The following questions, if answered affirmatively, represent potential or apparent lack of impartiality (*any affirmative answers should be explained in an attachment*):

- Did you contribute to the development of the calculator being verified, or were you consulted during its development, or did you offer comments or suggestions to any drafts or versions of the document during its development? ☐ No ☐ Yes
- Do you know of any reason that you might be unable to provide impartial advice on the matter under consideration in this verification study, or any reason that your impartiality in the matter might be questioned? ☐ No ☐ Yes
- Have you had any previous involvement with the calculator under consideration? ☐ No ☐ Yes
- Have you served on previous advisory panels, committees, or subcommittees that have addressed the topic under consideration? ☐ No ☐ Yes
- Have you made any public statements (written or oral) on the issue? ☐ No ☐ Yes
- Have you made any public statements that would indicate to an observer that you have taken a position on the issue under consideration? ☐ No ☐ Yes
- Do you, your family, or your employer have any financial interest(s) in the matter or topic under this verification study, or could someone with access to relevant facts reasonably conclude that you (or your family or employer) stand to benefit from a particular outcome of this verification study? ☐ No ☐ Yes

With regard to real or apparent conflicts of interest or questions of impartiality, the following provisions shall apply for the duration of this verification study:

(a) Participant warrants, to the best of his/her knowledge and belief, that there are no relevant facts or circumstances that could give rise to an actual, apparent, or potential organizational or personal conflict of interest, or that Participant has disclosed all such relevant information to EMS or to EPA.

(b) Participant agrees that if an actual, apparent, or potential personal or organizational conflict of interest is identified during performance of this verification study, he/she immediately will make a full disclosure in writing to EMS. This disclosure shall include a description of actions that Participant (or his/her employer) has taken or proposes to take after consultation with EMS to avoid, mitigate, or neutralize the actual, apparent, or potential organizational conflict of interest. Participant shall continue performance until notified by EMS of any contrary action to be taken.

Boby Abu-Eid

☐ Check here if any explanation is attached

Signature Date 06/23/2022

Boby Abu-Eid

Printed Name

US Nuclear Regulatory Commission

Affiliation/Organization

N.B.: Regarding Q in bullet #4: I was involved as a peer reviewer of the previous PRG version (e.g., not the current revision) regarding approach and methodology documents, not the specific calculations in this revision.

Bart Eklund

Haley & Aldrich

M E M O R A N D U M

TO: Cindy Eyer (EMS)

FROM: Bart Eklund (Haley & Aldrich)

RE: Review of US EPA's PRG Calculator

DATE: July 20, 2022

General Comments –
The Peak PRG output option is an important improvement to the existing tool set. The PRG calculator is a sophisticated tool that quickly calculates risk or dose for various complex scenarios. The PRG calculator steers users towards appropriate defaults while still allowing users to substitute site-specific or other information to customize the evaluation. The tool has a number of helpful features, including the ability to download results in an Excel format and graphical output.

No generic tables are currently available from the home page.

Accuracy of Calculations –
Various spot checks of the calculations for individual isotopes did not identify any errors or issues. All results were within rounding errors for the third significant figure. An example for air exposure of indoor air workers is attached.

I did not identify a way to check the accuracy of the Bateman solver either via manual calculations or via downloaded Excel files from the PRG calculator. The reasonableness of the reported values was evaluated based on the PRGs for individual isotopes, their half-lives, etc.

Recommendations –
On the home page, the link to the PRG Calculator is not prominent. Some users may proceed to the bottom of the page and use the links provided there (which do not incorporate the Peak PRG output option), mistakenly thinking those are the recommended versions. I suggest making the link to the PRG Calculator more prominent (e.g., a large red button). It also would be helpful to add a note to the table at the bottom of the home page to explicitly state that these links cannot be used to calculate Peak PRG output.

If given several options, some risk assessors will tend to consider all options and use the most conservative output. So, it would be helpful in the PRG Calculator, for Source and Decay Output Options, to caution against using the secular equilibrium option for options where it is overly conservative.

The user's guide and other documentation could be improved by providing guidance based on which model option is likely to be appropriate for various types of sites that may be encountered in the Superfund program:

- Abandoned uranium mines – Secular equilibrium PRGs;
- Refined products (e.g., smoke detectors) – Peak PRGs;
- Mix of radioisotopes – Peak PRGs and Parent-only PRGs; and
- TENORM – seek expert advice.

- inhalation (without half-life decay)

$$PRG_{iw\text{-}air\text{-}inh}\left(pCi/m^3\right) = \frac{TR}{SF_i\left(\frac{risk}{pCi}\right) \times EF_{iw}\left(\frac{250\ days}{year}\right) \times ED_{iw}(25\ years) \times ET_{iw}\left(\frac{8\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times IRA_{iw}\left(\frac{60\ m^3}{day}\right)}$$

TR	PRG (pCi/m3)	TR	Sfi	Other Inputs	PRG Calc. Result (pCi/m3)	%RPD	Peak PRG (pCi/m3)	Peak/PRG
Am-241	2.12E-04	1.00E-06	3.77E-08	125,000	5145H037	0.09%	5149H037	102%
H-3	9.45E+00	1.00E-06	8.47E-13	125,000	<177H.33	0.05%	419H.34	186%
Rn-222	3.51E+00	1.00E-06	2.28E-12	125,000	6184H.33	-0.04%	:1<4H034	23%
U-238	3.39E-04	1.00E-06	2.36E-08	125,000	616;H037	0.29%	8186H038	16%

- external exposure to ionizing radiation (without half-life decay)

$$PRG_{iw\text{-}air\text{-}sub}\left(pCi/m^3\right) = \frac{TR}{SF_{sub}\left(\frac{risk/year}{pCi/m^3}\right) \times EF_{iw}\left(\frac{250\ days}{year}\right) \times \left(\frac{1\ year}{365\ day}\right) \times ED_{iw}(25\ years) \times ET_{iw}\left(\frac{8\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times GSF_a(1.0)}$$

TR	PRG (pCi/m3)	TR	Sfi	Other Inputs	PRG Calc. Result (pCi/m3)	%RPD	Peak PRG (pCi/m3)	Peak/PRG
Am-241	3.02E+03	1.00E-06	5.80E-11	5.7078	6135H.36	0.02%	613;H.36	102%
H-3	N/A	1.00E-06	0.00E+00	5.7078	0	NC	Q2D	
Rn-222	1.08E+05	1.00E-06	1.62E-12	5.7078	413;H.38	0.14%	618H.37	35%
U-238	6.69E+05	1.00E-06	2.62E-13	5.7078	913H.38	-0.19%	5155H.34	0.003%

BART EKLUND

Senior Technical Expert

EDUCATION

B.S., Chemistry, University of Illinois, 1980

PROFESSIONAL REGISTRATIONS

1999: Certified Industrial Hygienist (CIH) (Reg. No. 7908)

PROFESSIONAL SOCIETIES

ASTM International, Member since 2007
International Society for Indoor Air Quality and Climate (ISIAQ), Member since 2011

SPECIAL STUDIES AND COURSES

40-Hour OSHA Hazardous Waste Operations and Emergency Response Training (29 CFR 1910.120)
8-Hour OSHA HAZWOPER Refresher Training
8-Hour OSHA Site Supervisor Training

Bart is an internationally recognized expert in air quality issues, particular those associated with contaminated soils and waters. He often works on very large, multimedia, multidisciplinary problems that require an unusually wide breadth of knowledge. He has worked for over 35 years on the measurement, modeling, and control of air emissions from area sources, such as landfills, surface impoundments, spill sites, and construction activities. He has developed measurement approaches for addressing fugitive emission sources and has performed numerous studies to characterize worker and community exposures. Bart has conducted air quality studies on six continents, ranging from measuring greenhouse gas emissions from pig farms to modeling air emissions associated with the disassembly of nuclear weapons. Bart has worked with various continuous and hi-vol methods and has addressed criteria pollutants, particulate matter (TSP, PM_{10}, and $PM_{2.5}$), VOCs, SVOCs, PCBs, dioxins, H_2S, methane, metals and other elements, tritium, radon, pesticides, aldehydes, organic acids, amines, silica, and asbestos.

He is well known in the vapor intrusion (VI) field. He first began studying VI in 1989 and has evaluated vapor intrusion for over 350 sites located in 43 states in the U.S. and in 14 other countries. He was a member of the team that developed the ITRC VI guidance in 2007 and has contributed to State VI guidance documents for Kansas and Georgia. He helped organize five specialty conferences devoted to VI. He has developed standard approaches for site investigations and data evaluation. For example, he was the primary author of the ASTM D7663 standard for soil gas sampling and was an author of the ASTM E2993 standard for evaluating methane hazard.

Bart has served as a testifying expert in U.S. State and Federal Courts, as well as for permit hearings, enforcement actions, and international arbitration. His areas of expertise include air measurements (ambient air, indoor air, soil gas, emission flux), vapor intrusion (VI) studies, air quality at remediation sites, emission modeling, fate & transport studies, and odor studies.

WORK HISTORY

2021 – Present:	Haley & Aldrich, Senior Technical Expert
2015 – 2021	AECOM, Vice President, Vapor Intrusion Leader for the Global Remediation Practice, Director of Air Quality Practice in the Americas
1999 – 2014	URS, Principal Scientist
1980 – 1999	Radian Corporation, Scientist & Project Manager
1978 – 1979	United States Geological Survey (USGS), Assistant Hydrologist

AWARDS

URS Award of Excellence, Safety Category (URS Pyramid Award). 2013.

URS Award of Excellence, Project Management Category (URS Pyramid Award). 2012.

Richard S. Ladd D18 Standards Development Award from ASTM for work on Standard D7663 (Soil Gas Sampling). 2012.

Additional Project Experience

Vapor Intrusion

Mr. Eklund has designed field measurement programs and/or performed data evaluation to address VI for over 350 sites in 43 States plus VI sites in Australia, Belgium, Canada, Diego Garcia, Ireland, Italy, Lebanon, Malaysia, Mexico, New Zealand, Poland, Sweden, Switzerland, and the UK. This work has included many large and/or notable sites, including the following:

Site	Location	# of Structures	Type of Area	Comments
Carrier	Syracuse, NY	1 dozen	Industrial	Chlorinated solvent site
Lockheed	Moorestown, NJ	3 dozen	Suburban	Evaluated VI for on-site and off-site buildings
Dow Midland	Midland, MI	>700	Industrial Site	>77 buildings tested to date. >1,600 paired indoor air & sub-slab samples
Sturgis Superfund Site	Sturgis, MI	150	Residential	Mitigation systems installed in 8 houses
Village of Roxana	Roxana, IL	160 in study area	Residential	Indoor air testing at >40 houses
Conrail Railyard Superfund Site	Elkhart, IN	>100 in study area	Residential	65 houses selected for testing. Mitigation systems installed in 10 houses.
McConnell Air Force Base	Wichita, KS	1,337 acres	Mixed Use	On-going site-wide investigation
FCX Superfund Site	Statesville, NC	>100 in study area	Urban Mixed Use	~3 dozen buildings studied including houses and school
LBMH Laurel Bay	Beaufort, SC	1,100	Residential	970 acre Marine Corps housing development
Fairchild Air Force Base	Spokane, WA	4	Mixed use	Real-time detection of indoor emission sources
Kast	Carson, CA	285	Residential	>1,400 indoor air samples
MacGaffey and Main Superfund Site	Roswell, NM	>100 in study area	500-acre urban site	On-going testing at residential and commercial buildings
Motorola 52nd Street Superfund Site	Phoenix, AZ	>1,000	Urban area with 7-mile long plume	Assisted state agency in reviewing PRP submittals

Indoor Air Studies

Rental Car Facility, Fairbanks, Alaska, 2019 – Investigated indoor air quality issues in a maintenance and storage area. The work included reviewing SDS for materials stored and/or used at the facility.

Bureau of Engraving and Printing, Fort Worth, Texas, 2016 – A building survey and measurement study was performed to address indoor air quality related to use of printing inks. The building HVAC system and work areas were inspected and recommendations provided for system upgrades.

Lockheed, Fort Worth, Texas, 2015 – A building survey and measurement study was performed to address worker concerns about indoor air quality. The building HVAC system and work areas were inspected. Measurements made of carbon dioxide, relative humidity, and temperature to assess the adequacy of the building ventilation.

City of Austin, Walnut Creek Wastewater Treatment Facility, 2012 – A study was performed to address indoor air quality at two buildings for particulate matter, metals, acid gases, ammonia, hydrogen sulfide, organic vapors, asbestos, mold, and pathogens. Seven indoor and two outdoor locations were sampled. The study was performed, in part, to evaluate the performance of the existing building ventilation system. In addition, measurements of face velocity were made at exhaust hoods in the analytical laboratories.

Dallas Area Regional Transit (DART), 2012 – A building survey and measurement study was performed to address worker concerns about indoor air quality. The building HVAC system and vehicle maintenance areas were inspected. Measurements made of carbon dioxide, relative humidity, and temperature to assess the adequacy of the building ventilation.

Private Client, Austin, Texas, 2012 – A building inspection and survey were performed for a building owner after the previous tenant had removed radioactive sources from the premises (two ^{192}Ir sources that were each originally approximately 100 Curies in strength and one ^{60}Co source that was originally approximately 30 to 40 Curies in strength). Radiation measurements were made at the site on May 25, 2012. The measurements were made using a Ludlum Model 3 Survey Meter (S/N 160385) with a Ludlum Model 44-2 scintillation-type detector.

City of Austin, Austin-Bergstrom International Airport, 2010 – A building survey and measurement study was performed to address worker concerns about indoor air quality. The building HVAC system was inspected and measurements made of carbon dioxide, relative humidity, and temperature to assess the adequacy of the building ventilation. In addition, mold sampling was performed indoors and out.

Private Client, Austin, TX, 2010 – A building survey and inspection were performed at a vacant building undergoing remediation for mold. To address odor complaints, hydrogen sulfide (H_2S) measurements were made at locations throughout the building. Sewer drains and other potential sources of odors.

Air Quality at Remediation and Construction Sites

Mr. Eklund developed USEPA guidance for addressing air quality at Superfund and other hazardous waste sites, including guidance documents for estimating air emissions, modeling air quality impacts, measuring community exposure, and controlling air emissions. Has applied that knowledge at numerous hazardous waste sites, including the following projects**:**

Santa Clara Valley Water District, Air Quality During Dam Construction, California. Designed and initiated the Construction Air Monitoring Plan for naturally occurring asbestos (NOA) and metals. The construction of a new tunnel and retrofit of the existing Anderson Dam is expected to continue through the year 2030.

San Francisco Public Utility Commission, Air Quality During Dam Construction, California. For the Calaveras Dam Replacement Project (CDRP), Bart served as the air quality expert for the design team on the $500+ million project to replace the existing earth & rock dam. The 12 million yd3 of material handled contained large amounts of Naturally Occurring Asbestos (NOA). Over 37,000 air samples were collected to address NOA. CDRP was the 2018 AEG project of the year.

Pfizer, Air Quality During Remediation, North Haven, CT. Managed air monitoring effort during 2013-2014 for project to remediate a former pharmaceutical facility. In addition to real-time PM_{10} monitoring, over 120 samples were collected and analyzed for lead (Pb) and PCBs.

Conoco Phillips, Air Quality During Remediation, Cayce, SC. Managed air monitoring effort during 2011-2013 for Cayce Remediation project to remove contaminated soils in an industrial area. Approximately 600 air samples were collected and analyzed for PM_{10}, lead (Pb), and arsenic (As).

Confidential Client, Air Quality During Demolition, New Bedford, MA. Managed a four-station fenceline air monitoring network during 2011 to address PCBs, asbestos, silica, mercury, and other pollutants from the demolition of a contaminated industrial complex at a Superfund site.

Conoco Phillips, Air Quality During Remediation, Weymouth, MA. Managed air monitoring effort during 2003-2007 for project to remediate contaminated soils in a residential area near Boston. Over 4,000 samples were collected and analyzed for PM_{10}, lead (Pb), arsenic (As), and chromium (Cr). Over 150 air samples were collected and analyzed for polyaromatic hydrocarbons (PAHs).

Conoco Phillips, Air Quality During Remediation, Lake Charles, LA. Managed air monitoring effort during 2002-2003 on West Ditch project to remediate sediments contaminated with 1,2-dichloroethane (EDC). The air monitoring effort included both on-site GC analyses of grab samples and off-site TO-15 analysis of over 400 twenty-four hour canister samples.

Air Emissions from Area Sources

Expert, Effect of Deposition of Metals on Surface Waters, Mining Site in Western US: Measured the rate of deposition of particulate matter and various metals over a two-year period. Developed model to address the fate and transport of selected metals across the local watershed and calculated the relative contribution from each source. Reviewed the available literature on vehicle tires and brakes as sources of metals.

Expert, Treatment of Petroleum-Contaminated Soils, Colorado, 2014-2015: Estimated air emissions from biotreatment of impacted soils to be used as daily cover at MSW landfill. Project won the 2018 State of Colorado Grand Conceptor award from the American Council of Engineering Companies (ACEC).

Project Manager, Air Emissions Study, Wyoming, 2013: Air emission rates of VOCs were measured from wastewater treatment at a facility treating 400,000 barrels per month of oil & gas exploration and production waters.

Lead Scientist, Air Emissions from Landtreatment of Oil & Gas Wastes, Weld County, CO, 2012-2013: Designed and implemented studies to measure air emissions from the biotreatment of contaminated soils, cuttings, and other wastes from E&P activities.

Project Manager, Air Emissions Study, Illinois, 2010: Air emission rates of VOCs were measured from coker quench water tanks.

Consulting Expert, Confidential Client, Western US, 2010: Evaluated monitoring data for particulate matter and metals associated with a Superfund site. Addressed potential contribution from background sources such as uncontaminated surface soils, forest fires, and volcanic activity.

Project Manager, Air Emissions Study, Denver, CO: Managed a multi-phase project to measure fugitive emissions from contaminated soils at the Rocky Mountain Arsenal near Denver, CO. Emission fluxes were measured to estimate the possible emissions to be expected for various remediation and emission control options. The odor potential of the waste material was determined.

Project Manager, Landfill Gas Study, USEPA, New York, NY, $1M: Managed study to characterize air emissions from the largest municipal landfill in the U.S. Over 40,000 measurements were made and the overall emission rate of methane, carbon dioxide, hydrogen sulfide, mercury, and over 120 individual VOCs were developed for each major emission source present at the landfill.

GHG Emissions / Emission Factor Development

Peer Reviewer, IPCC. Served as a peer reviewer to the Intergovernmental Panel on Climate Change (IPCC).

Project Manager, US EPA Study. Managed multi-year effort to develop emission factors for greenhouse gases from wastewater treatment systems. The work involved open path monitoring of emissions using FTIR and characterization of influent and effluent wastewater. Emission factors were developed for methane, carbon dioxide, nitrous oxide, ammonia, and other species for use in updating the national and global emission inventories for waste management facilities.

US EPA Study. Measured air emissions from wastewater treatment systems as part of effort to improve the accuracy of what is now the US EPA WATER9 model.

US EPA Study. In a series of US EPA-sponsored projects, developed and validated sampling and analysis procedures for measuring VOC emission rates from contaminated liquids and soils. Bench-scale studies were performed followed by several field sampling efforts to evaluate the feasibility of using the flux chamber method for this application. Based on these studies, the flux chamber was made a standard U.S. EPA sampling method.

Lead Scientist, US EPA Study. Directed US EPA-sponsored project to develop predictive models for estimating emissions of VOCs from soil handling activities such as excavation and dumping. The work included transect measurements at two sites and pilot-scale work to validate the models.

Mixed Waste/Department of Energy

US DOE, Air Quality During Nuclear Waste Disposal, Carlsbad, New Mexico: Over an approximately 25-year period, provided technical support on monitoring issues and predicted air quality impacts for the Waste Isolation Pilot Plant (WIPP). During that time, over 500,000 drums of transuranic, mixed waste were placed in a salt deposit two thousand feet below ground.

Pantex OB/OD - Managed project to assist the Pantex facility in permitting and regulatory compliance associated with the disassembly of nuclear warheads. The project included thermodynamic modeling to estimate emissions from open burning and open detonation of explosives, dispersion modeling, and BACT analysis. Air emission modeling was performed for the burning of >100 different chemicals and mixtures.

Los Alamos Fire Study – Field measurements were performed to develop emission factors for radioactive species, particulate matter, and combustion products from New Mexico pine forests. The results were used in evaluating the data from the Cerro Grande fire to assess natural versus anthropogenic contributions to air measurements made during the fire.

Los Alamos Air Emissions Study - Managed project to evaluate air quality for both the mixed waste and low-level radioactive waste disposal areas at LANL. The emission fluxes of radioactive gases (tritium and radon) from the landfill were measured. Specialized measurement equipment was designed and fabricated under this project. Measurements of the tritium emission flux were made at over 200 locations within the facility. CAP88 modeling was performed to assess the air quality impacts of the emissions.

Sandia (Tonopah) Air Monitoring Design Study - Directed project to assess migration of radioactive dust during above-ground weapons testing at a U.S. DOE facility. Ambient air monitoring approaches were developed to evaluate the environmental and human health impacts of testing activities in areas of suspected contamination. PM_{10} and TSP monitoring were performed during a series of weapons tests.

Ambient Air Monitoring

Project Manager, Ambient Air Monitoring Network, Corpus Christi, Texas, 2015-2016: Managed the installation and operation of a two-station air quality network in to continuously monitor particulate matter (PM_{10}) and meteorological parameters near waste lagoons. In addition, total suspended particulate (TSP) samples were collected every 6^{th} day for a year and analyzed for various metals.

Project Manager, Air Quality Near Natural Gas Facility, Arkansas, 2012: Measured various acid gases, VOCs, aldehydes, and glycols near a natural gas compressor station and dehydrator to address citizen concerns.

Project Manager, Ambient Air Monitoring Network, Vitória, Brazil, 1999-2000: Managed the installation and start-up of an eight-station air quality network in to monitor criteria pollutants, hydrocarbons, particulate matter (PM_{10} and TSP), and meteorological parameters.

Project Manager, Ambient Air Monitoring Network, San Antonio, Texas, 1999-2001: Managed a two-year monitoring program to assess potential impacts of dust and lead (Pb) emissions from a metals recycling facility in Texas. Total suspended particulates (TSP) data are collected continuously and lead data were collected every 6^{th} day.

Odor Studies / H_2S Monitoring

Expert, Evaluation of Odors from Remediation of MGP Site, Utah, 2019-2020: Designed air monitoring network to address on-site and community impacts.

Expert, Evaluation of Potential Odors from Proposed Fertilizer Plant, Florida, 2019: Reviewed project plans and odor modeling. Provided input to design of proposed facility to minimize fugitive emissions.

Task Leader, Evaluation of Potential Sites for Fertilizer Plant, 2019: Reviewed possible sites in several states and provided recommendations regarding potential odor impacts.

Expert Witness, H_2S-Related Litigation, Texas, 2015-2017: Assessed claims of potential hazard related to deep-well disposal of acid gases from oil & gas production activities.

Expert, Evaluation of Odors from Poultry Waste, North Carolina, 2017: Evaluated effect of proposed control measures.

Expert, Evaluation of Wastewater Treatment Air Emissions, Tennessee, 2013: Evaluated odor potential of current system design and proposed system upgrades.

Task Leader, Evaluation of Odor Impacts, Ashtabula, Ohio, 2012: Evaluated potential contribution of several facilities to odors reported in the community.

Task Leader, Evaluation of Odor Impacts, Fresno, California, 2010: Evaluated potential odor impacts at a proposed school site located near a rendering plant and other facilities.

Task Leader, Evaluation of Odor Impacts, Livingston, California, 2009-2010: Evaluated potential odor impacts from a rendering plant located near residential and commercial areas.

Expert Witness, **2008-2009**: Served as an expert for three related cases in Florida involving alleged odor and other air quality impacts from construction & demolition (C&D) landfills containing hurricane debris. Evaluated air emissions from fires at the landfills and open burning at a local DoD facility.

Task Leader, Evaluation of Air Quality Impacts, Roseville, California, 2005-2007: Evaluated potential odor and other air quality impacts of a proposed large-scale land development adjacent to an existing municipal solid-waste landfill and composting facility.

Task Leader, Evaluation of Odor Impacts, Louisville, Kentucky, 2007: Performed atmospheric dispersion modeling to evaluate potential odor impacts for a chemical facility. Determined the potential change in odor impacts if controls were added to certain process units.

Expert Witness, **2006**: Served as an expert for an air quality case involving dairy farms. The lawsuit was in the US District Court for the Eastern District of California.

Project Manager, Odor/Gas Emission Study, Austin, Texas, 2003: Evaluated the historical and future odor potential of three adjacent municipal solid-waste landfills under contract to Travis County. As part of this work, options for odor control and monitoring were developed.

Expert Witness, 2001-2003: Served as an expert witness for a permit hearing in Nebraska and an enforcement action in Texas related to odor issues for wastewater treatment facilities for an industrial client. Also provided litigation support for both Federal (DOJ) and Civil (toxic tort) lawsuits involving wastewater treatment facilities for this same client.

Project Manager, Ambient Air Monitoring Network, Dakota City, Nebraska, 2000-2001: Managed the installation and operation of a nine-station air quality network in to monitor hydrogen sulfide (H_2S) near a wastewater treatment facility. In addition, air emissions from wastewater treatment lagoons were directly measured.

Air Quality Task Leader, Pepe Field Superfund Site, Boonton, NJ, 1998-1999: Managed air quality work for the Pepe Field Superfund site in New Jersey. Over 60,000 ppm of H_2S had been found in wells at the site. The work included obtaining air permits, characterizing the baseline air quality, and characterizing worker and community exposures.

Methane

Leader, ASTM Task Group, 2021-2022: Currently leading task group that is updating existing ASTM standard to evaluate methane hazard.

ASTM E2993-16 Standard Guide for Evaluating Potential Methane Hazard in the Vadose Zone: Participated in task group and was one of the primary authors of the standard.

Technical Expert, Methane Hazard Evaluation, Private Client, 2013: Evaluated potential hazard associated with a site in Southern California slated for property transfer.

Technical Expert, Vapor Intrusion Study, Private Client, 2011-12: Evaluated potential hazard associated with methane at a former quarry / landfill slated for commercial development.

Technical Expert, Methane Hazard Evaluation, Private Client, 2011: Evaluated potential hazard associated with methane at a former landfill site slated for residential development.

Technical Expert, Vapor Intrusion Study, Private Client, 2010: Evaluated potential for groundwater saturated with methane to pose a VI hazard at a site where a piping failure had occurred.

Technical Expert, Vapor Intrusion Study, Private Client, 1999-2004: Evaluated potential for vapor intrusion of methane for a contaminated site in the Middle East.

Worker Exposure Studies

Industrial Hygienist: Evaluated potential worker exposure to Tetra-Ethyl Lead (TEL) for drilling activities in soils impacted with relatively high levels of lead.

IH Investigator: Evaluated potential worker exposures to benzene at oil & gas sites during tank gauging activities.

IH Investigator: Advised utility on potential worker exposure issues related to confined space work in sewers with elevated hydrogen sulfide levels and/or other environmental issues.

Industrial Hygienist: Reviewed MSDS information and advised transportation authority on use of various chemicals in rail cars and buses.

IH Investigator: Evaluated worker exposures at metal sandblasting and painting operations.

IH Investigator: Investigated worker complaints of chemical exposure at an oil refinery in Texas.

Expert Witness: Worked on several related legal cases to evaluate historical exposures of workers to ethylene dichloride (EDC) at LA chemical plants. Exposure scenarios have been developed for various work functions and average long-term and maximum short-term exposures have been estimated and compared with available monitoring records.

Expert Witness: Evaluated historical worker exposure at a Texas chemical plant to emissions from wastewater treatment facility as part of a legal case.

Accident / Emergency Release Investigations

Expert, Ambient Air Monitoring, Illinois, 2019: For the site of a plant explosion, identified analytes of concern and appropriate monitoring methods to address potential air impacts during site investigation.

Expert, Worker Safety Evaluation, Arizona, 2019: Evaluated deposition of metals, PAHs, and PFAS at and near the site of a fire at a battery storage site.

Expert Witness, Deposition Related to Fire Event, 2017-2018: Modeled atmospheric deposition related to a fire as part of litigation support. Reviewed modeling done by plaintiffs' expert. One key area of disagreement was the appropriate settling velocity to use for deposition.

Modeling, Release of Amines, 2015: Estimated the emission rate of amines from a weld crack and conducted atmospheric dispersion modeling to estimate the concentrations in air downwind of the release.

Team Member: emergency response team for quick response to rail transport accidents involving organic chemicals, radioactive soils, etc. Evaluated the potential exposures of both workers and the near-by community.

Process Safety

Chemical and Radiant Heat Modeling: Evaluated potential hazards associated with emergency releases at a proposed amine facility. Worked with design team to determine appropriate height for emergency stacks.

Chemical Modeling: Determined minimal acceptable height for emergency release stacks at a proposed CO_2 sequestration facility.

Audits

US DOE: Performed systems audit of tritium sampling network at a US DOE facility to investigate source of bias in data.

California Utility: Performed systems audit of groundwater remediation/municipal water treatment plant and associated analytical laboratories in response to customer complaints regarding water quality.

California Regulatory Agency: Performed systems audit of emission flux monitoring program at municipal solid-waste landfill.

Eklund Publication List

Journal Articles and Book Chapters

1. Eklund, B., C. Ricondo, H. Artz-Patton, J. Milose, and C.W. Wong. Development of a Default Vapor Intrusion Attenuation Factor for Industrial Buildings. Groundwater Monitoring & Remediation. (submitted)

2. Ma, J., T. McHugh, and B. Eklund. Flux Chamber Measurements Should Play a More Important Role in Contaminated Site Management. Environ. Sci. & Technol. Vol. 54, pp11645-11647. September 16, 2020.

3. Eklund, B., J. Roadifer, N. Wong, and M. Forrest. NOA Air Quality Lessons Learned During Calaveras Dam Replacement Project. Environmental and Engineering Geoscience, Vol. 36, No. 1, pp. 35-38. February 2020.

4. Eklund, B., L. Beckley, and R. Rago. Overview of State Approaches to Vapor Intrusion: 2018. Remediation, Vol. 28, Issue 4, pp. 23-35. Autumn 2018.

5. Yao, Y., I. Verginelli, E. Suuberg, and B. Eklund. Examining the Use of USEPA's Generic Attenuation Factor in Determining Groundwater Screening Levels for Vapor Intrusion. Groundwater Monitoring & Remediation. Vol. 38, No. 2, pp.79-89. Spring 2018.

6. McHugh, T., P. Loll, and B. Eklund. Recent Advances in Vapor Intrusion Site Investigations. Journal of Environmental Management. Vol. 204, Part 2. Pp.783-792. December 15, 2017.

7. McAlary, T., T. McHugh, B. Eklund, C. Lutes, E. Suuberg, H. Hayes, K. Pennell, D. Folkes, H. Dawson, R. Truesdale, L. Beckley, and C. Holton. Comments and Corrections to: "The Emperor's Old Clothes: An Inconvenient Truth About Currently Accepted Vapor Intrusion Assessment Methods," and "Emperor's Old Clothes Revisited," Two Recent Editorials by Mark Kram. Groundwater Monitoring & Remediation. Vol. 36, No. 3, pp.84-87. Summer 2016.

8. Eklund, B., C. Fitzgerald, M. Wade, R. Wilder, and D. LaMond. Controlling Air Toxics Emissions From Remediation by Monitoring of Surrogate Parameters. Remediation. Vol. 24, Issue 4, pp127-138, Autumn 2014.

9. Eklund, B., L. Beckley, V. Yates, and T. McHugh. Overview of State Approaches to Vapor Intrusion. Remediation. Vol. 22, Issue 4, pp7-20, Autumn (Fall) 2012.

10. Eklund, B. Proposed Regulatory Framework for Evaluating the Methane Hazard due to Vapor Intrusion. Environmental Manager. Air & Waste Management Association. February 2011.

11. Eklund, B. Letter to the Editor, Re: Soil-Gas Sampling Methods. GWM&R, Vol. 29, No. 3, pp54-55. Summer 2009.

12. Eklund, B. and D. Burrows. Prediction of Indoor Air Quality from Soil Gas Data at Industrial Buildings. GWM&R, Vol. 29, No. 1, pp118-125. Winter 2009.

13. Eklund, B., S. Burkes, P. Morris, and L. Mosconi. Spatial and Temporal Variability in VOC Levels Within a Commercial Retail Building. Indoor Air, Vol. 18, pp365-374. October 2008.

14. Eklund, B. International Approaches to Vapor Intrusion. Environmental Manager. Air & Waste Management Association. July 2007.

15. Eklund, B. and M. Simon. Concentration of Tetrachloroethylene in Indoor Air at a Former Dry Cleaner Facility as a Function of Subsurface Contamination – A Case Study. J. Air Waste Manage. Assoc., Vol 57, pp753-760. June 2007.

16. Eklund, B., D. Folkes, J. Kabel, and R. Farnum. An Overview of State Approaches to Vapor Intrusion. Environmental Manager. Air & Waste Management Association. February 2007.

17. Traister, M, G. Plantz, and B. Eklund. Highlights from A&WMA's Vapor Intrusion Specialty Conference. Environmental Manager. Air & Waste Management Association. February 2007.

18. Eklund, B. When Vapors Intrude. Environmental Manager. Air & Waste Management Association. February 2005.

19. Eklund, B., C.H. Williams, L.W. Bontempo, M. Isbell, and K.R. Loos. Development and Validation of a Canister Method for Measuring Ethylene Oxide in Ambient Air. Environ. Sci. & Technol, Vol. 38, No. 15, pp4200-4205. August 1, 2004.

20. Lowell, P. and B. Eklund. VOC Emission Fluxes as a Function of Lateral Distance from the Source. Environmental Progress, Vol. 23, No. 1, pp52-58. April 2004.

21. Eklund, B. Comparison of Line- and Point-Source Releases of Tracer Gases. Atmospheric Environment, Vol. 33, No. 7, pp1065-1072. March 1999.

22. Eklund, B. E. Anderson, B. Walker, and D. Burrows. Characterization of Landfill Gas Composition at the Fresh Kills Municipal Solid-Waste Landfill. Environ. Sci. & Technol., Vol. 32, No. 14, August 1, 1998.

23. Eklund, B., M. Eltgroth, and S. Templeman. Modeling Atmospheric Dispersion. In: Encyclopedia of Environmental Analysis and Remediation, R.A. Myers Editor. pp2855-2876. John Wiley & Sons, NY, NY. 1998.

24. Eklund, B. and T. Nelson. Evaluation of VOC Emission Measurement Methods for Paint Spray Booths. J. Air Waste Manage. Assoc., Vol. 45, No. 3, pp. 196-205, 1995.

25. Eklund, B. Practical Guidance for Flux Chamber Measurements of Fugitive Volatile Organic Emission Rates. J. Air Waste Manage. Assoc., Vol. 42, No. 12, pp. 1583-92, 1992.

26. Eklund, B. and J. Summerhays. Procedures for Estimating Emissions From the Cleanup of Superfund Sites. J. Air Waste Manage. Assoc., Vol. 40, No. 1, pp 17-23, 1990.

27. Balfour, W.D., C.E. Schmidt, and B.M. Eklund. Sampling Approaches for the Measurement of Volatile Compounds at Hazardous Waste Sites. Journal of Hazardous Materials, 14, 135-148, 1987.

28. Eklund, B.M., W.D. Balfour, and C.E. Schmidt. Measurement of Fugitive Volatile Organic Compound Emission Rates with an Emission Isolation Flux Chamber. Environmental Progress, Vol. 4, No. 3, August 1985.

Peer Review

Mr. Eklund has served as a peer reviewer for the following journals and publications:

- **Atmospheric Environment.** Published by Elsevier.
- **Energy**. Published by Elsevier;
- **Environmental Engineering Science.** Published by Mary Ann Liebert**,** Inc.;
- **Environmental and Engineering Geoscience**. Published by the Association of Engineering Geologists (AEG) and the Geological Society of America (GSA);
- **Environmental Pollution**. Published by Elsevier;
- **Environmental Science and Pollution Research**. Published by Springer;
- **Environmental Science: Processes & Impacts**. Published by the Royal Society of Chemistry (RCS);
- **Environmental Science & Technology** (ES&T). Published by the American Chemical Society (ACS);
- **Ground Water Monitoring & Remediation**. Published by the National Ground Water Association (NGWA);
- **Human and Ecological Risk Assessment**. Published by the Association for Environmental Health and Sciences Foundation (AEHS).
- **Indoor Air**. Published by the Int. Society of Indoor Air Quality and Climate (ISIAQ);
- **Journal of the Air & Waste Management Association (JAWMA)**;
- **Journal of Chromatographic Sciences**;
- **Journal of Contaminant Hydrology**. Published by Elsevier.
- **Journal of Environmental Quality**. Published by the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America;
- **Science of the Total Environment.** Published by Elsevier; and
- **Current Protocols in Field Analytical Chemistry**. Published by John Wiley & Sons.

Mr. Eklund also has served as a peer reviewer for the **Intergovernmental Panel on Climate Change** (IPCC)[Established by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP)]. The IPCC was awarded the Nobel Peace Prize in 2007.

Conference Organization

Mr. Eklund has been an organizer of the following specialty conferences:

1. **Vapor Intrusion 2010.** Sponsored by the Air & Waste Management Association (AWMA). Chicago, IL. September 29-30, 2010.

2. **Vapor Intrusion 2009**. Sponsored by the Air & Waste Management Association (AWMA). San Diego, CA. January 28-30, 2009.

3. **Vapor Intrusion: Learning From the Challenges**. Sponsored by the Air & Waste Management Association (AWMA). Providence, RI. September 26-28, 2007.

4. **Vapor Intrusion: The Next Great Environmental Challenge – An Update**. Sponsored by the Air & Waste Management Association (AWMA). Los Angeles, CA. September 13-15, 2006.

5. **Vapor Intrusion – The Next Great Environmental Challenge**. Sponsored by the Air & Waste Management Association (AWMA). Philadelphia, PA. January 25-27, 2006.

Mr. Eklund has organized sessions at many technical conferences, including:

- Inhalation Exposures from Subsurface Contamination. **Fourth International Symposium on Bioremediation and Sustainable Environmental Technologies**, Sponsored by Battelle. Miami, FL. May 22-25, 2017.

- Addressing Petroleum Vapor Intrusion. **Tenth International Conference on Remediation of Chlorinated and Recalcitrant Compounds**, Sponsored by Battelle. Palm Springs, CA. May 22-26, 2016.

- Ambient Air Monitoring in the World's Mega-cities. **Annual Meeting of the Air and Waste Management Association**. Multiple years, 1996 –2000

- Ambient Air Monitoring at Hazardous Waste Sites. **Annual Meeting of the Air and Waste Management Association**. Multiple years, 1987 – 1995

Mr. Eklund has also served as a peer reviewer for papers at the following conferences:

- **Indoor Air 2016**, Ghent, Belgium;
- **Healthy Buildings 2015 America**, Boulder, Colorado;
- **Indoor Air 2014**, Hong Kong; and
- **Indoor Air 2011**, Austin, Texas.

US Government Publications

1. McAlary, T., R. Ettinger, P. Johnson, B. Eklund, H. Hayes, D. Chadwick, and I. Rivera-Duarte. Review of Best Practices, Knowledge and Data Gaps, and Research Opportunities for the U.S. Department of Navy Vapor Intrusion Focus Areas. Technical Report 1982, US Navy, SSC Pacific, San Diego, CA. May 2009.

2. Eklund, B., et al. Grand Plaza Site Investigation Using the Triad Approach and Evaluation of Vapor Intrusion. US EPA, NRMRL, Cincinnati, OH, EPA/540/R-07/002. September 2006.

3. Eklund, B., P. Thompson, A. Inglis, W. Wheeless, W. Horton, and S. Roe. Air Emissions From the Treatment of Soils Contaminated With Petroleum Fuels and Other Substances. US EPA, Control Technology Center, EPA-600/R-97-116. October 1997.

4. Doorn, M., R. Strait, W. Barnard, and B. Eklund. Estimates of Global Greenhouse Gas Emissions From Industrial and Domestic Wastewater Treatment. US EPA, ORD, EPA-600/R-97-091. September 1997.

5. Eklund, B. and J. LaCosse. Field Measurement of Greenhouse Gas Emission Rates and Development of Emission Factors for Wastewater Treatment. US EPA, ORD, EPA-600/R-97-094. July 1997.

6. Vold, E. and B. Eklund. Preliminary Summary of Evaporation Measurements Made at Los Alamos Area G. Los Alamos National Laboratories. Report LA-UR-96-3499. Support Document for Area G Performance Assessment. September 1996.

7. Vold, E. and B. Eklund. Preliminary Summary of Soil Moisture Measurements Made at Los Alamos Area G. Los Alamos National Laboratories. Report LA-UR-96-3498. 1996

8. Vold, E. and B. Eklund. Determination of In-Situ Vapor Phase Diffusion Coefficient at a Mesa Top Waste Disposal Facility. Los Alamos National Laboratories. Report LA-UR-96-1848. May 22, 1996.

9. Eklund, B., E. Anderson, B. Walker, and D. Burrows. Determination of Landfill Gas Composition and Pollutant Emission Rates at Fresh Kills Landfill. US EPA Region II, EPA 902-R-95-001. December 1995.

10. Eklund, B. Measurement of Emission Fluxes from Technical Area 54, Areas G and L. Los Alamos National Laboratories. Report LA-UR-95-3891. March 1995.

11. Hendler, A., B. Eklund, E. Anderson, and B. Bray. Guidance for Ambient Air Monitoring at Superfund Sites. EPA-451/R-93-007. May 1993.

12. Ranum, D. and B. Eklund. Compilation of Information on Real-Time Air Monitors for Use at Superfund Sites. EPA-451/R-93-008. May 1993.

13. Hueske, K., B. Eklund, and J. Barnett. Evaluation of Short-Term Air Action Levels for Superfund Sites. EPA-451/R-93-009. May 1993.

14. Eklund, B. and C. Dryden. Estimation of Air Impacts For Solidification and Stabilization Processes Used at Superfund Sites. EPA-451/R-93-006. April 1993.

15. Dulaney, W., Eklund, B. and C. Dryden. Estimation of Air Impacts For Thermal Desorption Units Used at Superfund Sites. EPA-451/R-93-005. April 1993.

16. Eklund, B. and C. Dryden. Estimation of Air Impacts From Area Sources of Particulate Matter Emissions at Superfund Sites. EPA-451/R-93-004. April 1993.

17. Dulaney, W., Eklund, B. and C. Dryden. Estimation of Air Impacts For Bioventing Systems Used at Superfund Sites. EPA-451/R-93-003. April 1993.

18. Eklund, B. and C. Albert. Models For Estimating Air Emission Rates From Superfund Remedial Actions. EPA-451/R-93-001 (NTIS PB93-186807). March 1993.

19. Eklund, B., et al. Control of Air Emissions From Superfund Sites. U.S. EPA, Center for Environmental Research Information. EPA/625/R-92/012. November 1992.

20. Eklund, B. Procedures for Conducting Air Pathway Analyses for Superfund Activities, Interim Final Documents: Volume 1 - Overview of Air Pathway Assessments for Superfund Sites (Revised), EPA-450/1-89-001a (NTIS PB93-173987). November 1992.

21. Draves, J. and B. Eklund. Applicability of Open Path Monitors for Superfund Site Clean-Up. EPA-451/R-92-001, May 1992.

22. Eklund, B., S. Smith, and A. Hendler. Estimation of Air Impacts For the Excavation of Contaminated Soil. EPA 450/1-92-004 (NTIS PB92-171925), March 1992.

23. Eklund, B., S. Smith, P. Thompson, and A. Malik. Estimation of Air Impacts For Soil Vapor Extraction (SVE) Systems. EPA 450/1-92-001 (NTIS PB92-143676), January 1992.

24. Eklund, B., S. Smith, and M. Hunt. Estimation of Air Impacts For Air Stripping of Contaminated Water. EPA-450/1-91-002 (NTIS PB91-211888), May 1991 (Revised August 1991).

25. Eklund, B., C. Petrinec, D. Ranum, and L. Howlett. Database of Emission Rate Measurement Projects - Draft Technical Note. EPA-450/1-91-002 (NTIS PB91-222059LDL), May 1991.

26. Thompson, P., A. Ingles, and B. Eklund. Emission Factors For Superfund Remediation Technologies. EPA-450/1-91-001 (NTIS PB91-190-975), March 1991.

27. Eklund, B., et al. Procedures for Conducting Air Pathway Analyses for Superfund Activities, Interim Final Documents: Volume 2 - Estimation of Baseline Air Emissions at Superfund Sites, EPA-450/1-89-002a (NTIS PB90-270588), August 1990.

28. Eklund, B., et al. Procedures for Conducting Air Pathway Analyses for Superfund Activities, Interim Final Documents: Volume 3 - Estimation of Air Emissions From Clean-up Activities at Superfund Sites, EPA-450/1-89-003 (NTIS PB89-180061/AS), Jan. 1989.

29. Devitt, D.A., R.B. Evans, W.A. Jury, T.H. Starks, B. Eklund, and A. Gholson. Soil Gas Sensing for Detection and Mapping of Volatile Organics. EPA/600/8-87/036 (NTIS PB87-228516), 1987.

30. Eklund, B. and W. Crow. Survey of Vendors of External Petroleum Leak Monitoring Devices for Use with Underground Storage Tanks. EPA 600/4-87-016 (NTIS PB87-212346), March 1987.

31. Nelson, T.P., B.M. Eklund, and R.G. Wetherold. Field Assessment of Surface Impoundment Air Emissions and Their Control Using an Inflated Dome and Carbon Adsorption System. EPA/600/2-87/009 (NTIS PB87-145942), 1987.

32. Eklund, B.M., T.P. Nelson, and R.G. Wetherold. Field Assessment of Air Emissions and Their Control at a Refinery Land Treatment Facility. EPA 600/2-86-086 A&B (NTIS PB88-124540 and PB88-124557), September 1986.

Other Selected Publications

1. Eklund, B. Trichloroethylene, Vapor Intrusion, and Indoor Air. Environmental Law Institute blog. August 26, 2019. Available at: https://www.eli.org/vibrant-environment-blog/trichloroethylene-vapor-intrusion-and-indoor-air

2. ASTM D7663-12 (2018). Standard Practice for Active Soil Gas Sampling in the Vadose Zone for Vapor Intrusion Evaluations. Revised 2018.

3. ASTM E2993-16. Standard Guide for Evaluating Potential Hazard as a Result of Methane in the Vadose Zone. 2016.

4. Eklund, B. and S. Hou. New Directions in Risk Assessment. Revolve (published by WasteMINZ, Milford, New Zealand). July 2015.

5. Eklund, B. and V. Kremesec. Recommended Practices Manual for Decision Making in Vapor Intrusion Evaluation. Atlantic Richfield Company, A BP-Affiliated Company. September 4, 2006.

6. Eklund, B. Travis County Landfill Odor/Gas Emission Studies. Travis County, Austin, Texas. May 12, 2003.

7. Eklund, B. and S. Fincher. Guidance for Estimating Air Emissions From Open Burning / Open Detonation Activities. BWXT Pantex. August 2002.

8. Eklund, B. and E. Anderson. Flux Chamber Sampling and Analysis, Pre-Design Field Test, New Bedford Harbor Superfund Site. Foster Wheeler Env. Corp., June 15, 2001.

9. Eklund, B. and S. Mischler. Basin F Wastepile Treatability Study, Flux Chamber Operations. Foster Wheeler Env. Corp., Rocky Mountain Arsenal. January 12, 2000.

10. Eklund, B.M. Detection of Hydrocarbons in Groundwater by Analysis of Shallow Soil Gas/Vapor. American Petroleum Institute Publication No. 4394, May 1985.

Papers in Proceedings of Technical Conferences

1. Eklund, B. Optimization of Vapour Intrusion Decision-Making: Critique of Typical VI Policy & Guidance. Keynote Talk at Clean-Up 2017. Melbourne, Australia. September 10-13, 2017.

2. Eklund, B. Acceptance Criteria for Using VOC in Soils Data for VI Evaluations. In: Proceedings of A&WMA Vapor Intrusion Specialty Conference. San Diego, CA. December 7-8, 2016.

3. Eklund, B. Effect of Environmental Variables on Vapor Transport. In: Proceedings of AEHS 26th Annual International Conference on Soil, Water, Energy, and Air. San Diego, California. March 21-24, 2016.

4. Eklund, B., J. Sepich, and R. Legrand. Procedures for Evaluating Potential Methane Hazard at VI Sites. In: Proceedings of A&WMA Vapor Intrusion Specialty Conference. Cherry Hills, NJ. September 10-11, 2014.

5. Eklund, B. and T. McHugh. Summary of State Approaches to VI – 2012 Update. In: Proceedings of A&WMA Vapor Intrusion Specialty Conference. Denver, CO. October 3-4, 2012.

6. Eklund, B. Time-Integrated vs. Grab Sampling for Soil Gas. In: Proceedings of Clean-Up 2011. Sponsored by CRC-Care. Adelaide, Australia. September 12 – 15, 2011.

7. Eklund, B. Evaluation of Soil-Gas Sampling Rate. In: Proceedings of Indoor Air 2011, the 12th International Conference on Indoor Air Quality and Climate. Sponsored by ISIAQ. Austin, TX. June 5-10, 2011.

8. Eklund, B. Proposed Regulatory Framework for Evaluating the Methane Hazard due to Vapor Intrusion. In: Proceedings of A&WMA Vapor Intrusion Specialty Conference. Chicago, IL. September 29-30, 2010.

9. Eklund, B. Persistent and Pernicious Fallacies Related to Vapor Intrusion. In: Proceedings of 103rd Annual Meeting of the Air and Waste Management Association, Calgary, Alberta, June 22-25, 2010.

10. Eklund, B. Typical Spatial and Temporal Variability in VI Data Sets and Implications for Regulatory Policy. In: Proceedings of the Seventh International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Sponsored by Battelle. Monterey, CA. May 24-27, 2010.

11. Chadwick, B., I. Rivera-Duarte, T. McAlary, R. Ettinger, P. Johnson, B. Eklund, and H. Hayes. Navy's Review of State of the Art on Vapor Intrusion Assessment. In: Proceedings of the Seventh International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Sponsored by Battelle. Monterey, CA. May 24-27, 2010.

12. Eklund, B. What You Can Learn From an Airhead: Application of Air Quality Principles to Vapor Intrusion Studies. In: Proceedings of the 100th Annual Meeting of the Air and Waste Management Association, Pittsburgh, PA, June 26-29, 2007.

13. Eklund, B., D. Folkes, J. Kabel, and S. Lock. What Fresh Hell is This? – Understanding Different State Approaches to VI. In: Proceedings of Vapor Intrusion: The Next Great Environmental Challenge – An Update, Sponsored by the Air & Waste Management Association (AWMA). Los Angeles, CA. September 13-15, 2006.

14. Kremesec, V. and B. Eklund. The Importance of Background VOC Concentrations in Petroleum Hydrocarbon Vapor Intrusion Decision Making. In: Proceedings of Vapor Intrusion: The Next Great Environmental Challenge – An Update, Sponsored by the Air & Waste Management Association (AWMA). Los Angeles, CA. September 13-15, 2006.

15. Rehage, J., B. Eklund, S. Brown, S. Fain, J. Blake, and W. Harris. Vapor Intrusion Assessment of Commercial Buildings at the Former Chanute Air Force Base. In: Proceedings of the Fifth International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Sponsored by Battelle. Monterey, CA. May 22-25, 2006.

16. Eklund, B. Onward Through the Fog – A Historical Perspective on Vapor Intrusion. In: Proceedings of Vapor Intrusion – The Next Great Environmental Challenge, Sponsored by the Air & Waste Management Association (AWMA). Philadelphia, PA. January 25-27, 2006.

17. Kremensec, V. and B. Eklund. Understanding (and Discerning) the Importance of Background VOC Concentrations in VI Decision Making. In: Proceedings of Vapor Intrusion – The Next Great Environmental Challenge, Sponsored by the Air & Waste Management Association (AWMA). Philadelphia, PA. January 25-27, 2006.

18. Eklund, B. and D. Burrows. Quality Control Considerations for Gas-Phase Measurements in Vapor Intrusion Studies. Symposium on Air Quality Measurement and Technology – 2005. Sponsored by the Air & Waste Management Association (AWMA). San Francisco, California. April 19-21, 2005.

19. Eklund, B, H. Williams, W. Bontempo, K. Loos, and W. Gulledge. Further Evaluation of a Canister Method for Measuring Ethylene Oxide in Ambient Air. Symposium on Air Quality Measurement Methods and Technology - 2004, Air & Waste Management Association, Research Triangle Park, NC. April 19-22, 2004.

20. Eklund, B, H. Williams, W. Bontempo, M. Isbell, and W. Gulledge. Evaluation of a Canister Method for Measuring Ethylene Oxide in Ambient Air. Symposium on Air Quality Measurement Methods and Technology - 2002, Air & Waste Management Association, San Francisco, CA. November 13-15, 2002.

21. Eklund, B. Measured PCB Emission Fluxes From Dredging Operations at New Bedford Harbor Superfund Site. In: Proceedings of the Air & Waste Management Association's 94th Annual Conference & Exhibition, Orlando, FL. June 24-28, 2001.

22. Eklund, B. Comparison of $PM_{2.5}$ and PM_{10} Monitoring Results at a Former Refinery in Casper, WY. In: Proceedings of the Air & Waste Management Association's 93rd Annual Conference & Exhibition, Salt Lake City, UT. June 2000.

23. Eklund, B. Overview of the Design, Installation, and Operation of Ambient Air Monitoring Networks. Presented at the International Conference on Environmental Monitoring and Protection, Kyoto, Japan, November 27, 1997.

24. Kagann, R., S. Kode, R. Scotto, and B. Eklund. "Open-Path FTIR Perimeter Measurements at the Fresh Kills Landfill to Estimate Concentrations of HAPs at a Nearby Shopping Mall" (Paper 96-TA26A.03). Presented at the 89th Annual Meeting of the Air and Waste Management Association, Nashville, TN, June 23-28, 1996.

25. Schmidt, C.E., T. Card, D. Suder, B. Eklund, J. Gustafson, G. DeVaull, and L. Hentz. "Assessment of Odor Emissions Using US EPA Flux Chamber and Olfactory Odor Measurement" (Paper 96-FA147.04). Presented at the 89th Annual Meeting of the Air and Waste Management Association, Nashville, TN, June 23-28, 1996.

26. Doorn, M., B. Eklund, and J. LaCosse. "Greenhouse Gases from Anaerobic Decomposition of Waste." Presented at EPA/AWMA Conference titled Emission Inventory: Applications and Improvement, Raleigh, NC, November 1-3, 1994.

27. Eklund, B. "Sampling and Analytical Methods to Minimize VOC Losses from Soil Samples" (Paper 94-RP127B.06). Presented at the 87th Annual Meeting of the Air and Waste Management Association, Cincinnati, OH, June 19-24, 1994.

28. Eklund, B. and T.P. Nelson. "Evaluation of VOC Emission Measurement Methods for Paint Spray Booths" (Paper 93-TA-33.04). Presented at the 86th Annual Meeting of the Air and Waste Management Association, Denver, CO, June 14-18, 1993.

29. Eklund, B. and J. Padgett. "Overview of Recently Develop Guidance for Performing Air Pathway Assessments" (Paper 93-MP-22.03). Presented at the 86th Annual Meeting of the Air and Waste Management Association, Denver, CO, June 14-18, 1993.

30. Hueske, K., Eklund, B., J. Barnett and M. Hansen. "Compilation and Evaluation of Short-Term Air Action Levels for Superfund Sites" (Paper 93-TP-64.04). Presented at the 86th Annual Meeting of the A&WMA, Denver, CO, June 14-18, 1993.

31. Eklund, B. and J. Durham. "Estimation of Emissions, Ambient Air Concentrations, and Health Effects from the Excavation of Contaminated Soil" (Paper No. 92-11.11). Presented at the 85th Annual Meeting of the Air and Waste Management Association, Kansas City, MO, June 21-26, 1992.

32. Eklund, B. "Practical Guidance for Flux Chamber Measurements of Fugitive Volatile Organic Emission Rates" (Paper No. 92-66.07). Presented at the 85th Annual Meeting of the Air and Waste Management Association, Kansas City, MO, June 21-26, 1992.

33. Draves, J. and B. Eklund. "Applicability of Open Path Monitors for Superfund Sites" (Paper No. 92-11.10). Presented at the 85th Annual Meeting of the Air and Waste Management Association, Kansas City, MO, June 21-26, 1992.

34. Scotto, R.L., et al. "VOC Emission Rate Determination Using Open-Path FTIR Spectroscopy During Pilot Scale Site Disturbance and Remediation Activities: A Case Study Using the Ratio Technique" (Paper No. 92-83.04). Presented at the 85th Annual Meeting of the Air and Waste Management Association, Kansas City, MO, June 21-26, 1992.

35. Eklund, B. "Evaluation of Air Emissions From the Remediation of DOD Sites" In: Proceedings of the 18th Environmental Symposium & Exhibition: "DOD & Industry: Leveraging Resources for Environmental Leadership" (pp165-169). American Defense Preparedness Association, Washington, DC, February 1992.

36. Eklund, B., S. Smith, J. Durham, and J. Touma. "Estimation of Emissions, Ambient Air Concentrations, and Health Effects from Air Stripping of Contaminated Water" (Paper No. 91-13.3). Presented at the 84th Annual Meeting of the Air and Waste Management Association, Vancouver, BC, June 16-21, 1991.

37. Eklund, B. P. Thompson, and J. Durham. "Emission Factors for Superfund Remediation Technologies" (Paper No. 91-180.57). Presented at the 84th Annual Meeting of the Air and Waste Management Association, Vancouver, BC, June 16-21, 1991.

38. Eklund, B., D. Ranum, D. Orr, and J. Summerhays. "Estimation of VOC Emissions From Soils Handling Operations at Superfund Sites". Presented at the 83nd Annual Meeting of the Air and Waste Management Association, Pittsburgh, PA, June 24-29, 1990.

39. Eklund, A.G. and B. Eklund. "Vapor Monitoring." Presented at the 1989 Washington Conference on Underground Storage Tanks, Sponsored by Inside EPA and CEEM, Alexandria, VA, July 11-12, 1989.

40. Eklund, B. and J. Summerhays. "Procedures for Estimating Emissions From the Cleanup of Superfund Sites". Presented at the 82nd Annual Meeting of the Air and Waste Management Association, Anaheim, CA, June 25-30, 1989.

41. Eklund, A.G. and B. Eklund. "Theory of Vapor Monitoring." Presented at EPA Seminars on Leak Detection and Monitoring Methods for Underground Storage Tanks in Boston, MA, Dallas, TX, Orlando, FL, and San Diego, CA, May to June, 1989.

42. Eklund, A.G. and B. Eklund. "Groundwater Monitoring Hardware and Vapor Monitoring Hardware For Underground Storage Tanks." Presented at EPA Seminars on Leak Detection and Monitoring Methods for Underground Storage Tanks in Boston, MA, Dallas, TX, Orlando, FL, and San Diego, CA, May to June, 1989.

43. Eklund, B., K. Wert, F. Scheffel, and J. Summerhays. "Estimation of Emissions From the Cleanup of Superfund Sites." Presented at the 25th Annual Meeting of the APCA Pacific Northwest International Section - Chemicals in the Environment, Whistler, British Columbia, Canada, November 1988.

44. Eklund, A.G. and B. Eklund. "External Petroleum Leak and Release Detection Monitoring Systems For Use With Underground Storage Tanks." Presented at EPA Seminars on Leak Detection Methods for Underground Storage Tanks in San Francisco, CA, King of Prussia, PA, Atlanta, GA, and Rosemont, IL, September to November, 1988.

45. Eklund, B., D. Green, B. Blaney, and L. Brown. "Assessment of Volatile Organic Air Emissions From an Industrial Aerated Wastewater Treatment Tank." In: Proceedings of the 14th Annual EPA Symposium on Land Disposal, Remedial Action, Incineration and Treatment of Hazardous Waste, Cincinnati, OH. EPA/600/9-88/021 (pp468-475). July 1988.

46. Eklund, B. and D. Balfour. "Assessment of VOC Emissions from Hazardous Waste Sources." Presented at the Texas Spring Environmental Conference sponsored by the State Bar of Texas and others, Austin, TX, May 1987.*

47. Green, D. and B. Eklund. "Field Assessment of the Fate of Volatile Organics in Aerated Waste Treatment Systems." Presented at the 13th Annual EPA Symposium on Land Disposal, Remedial Action, Incineration and Treatment of Hazardous Waste, Cincinnati, OH, May 1987.

48. Eklund, B., M. Kienbusch, D. Ranum, and T. Harrison. "Development of a Sampling Method for Measuring VOC Emissions from Surface Impoundments." Presented at the EPA/APCA Symposium on Measurement of Toxic and Related Air Pollutants, May 1987.

49. Eklund, B.M. and W.L. Crow. "Development of Performance Criteria and Test Methods for Evaluation of Underground Storage Tank Leak Monitors." Presented at the Ground-Water and Subsurface Monitoring Technology Transfer Symposium, Las Vegas, NV, November 18-20, 1986.

50. Eklund, B.M. "Evaluation of Methods for Leak Detection in Underground Storage Tanks and Connected Piping." Presented at the 79th Annual Meeting of the Air Pollution Control Association, Minneapolis, MN, June 1986.

51. Wetherold, R.G., B.M. Eklund, B.L. Blaney, and S.A. Thornloe. "Assessment of Volatile Organic Emissions from a Petroleum Refinery Landtreatment Site." Presented at the Hazardous Materials Control Research Institute's 3rd National Conference on Hazardous Wastes and Hazardous Materials, March 1986. EPA 600/D-86-074 (NTIS WE-RS-00679).

52. Wetherold, R.G., B.M. Eklund, and T.P. Nelson. "A Case Study of Direct Control of Emissions from a Surface Impoundment." Presented at the 11th Annual EPA Symposium on Land Disposal, Remedial Action, Incineration and Treatment of Hazardous Waste, April 1985.

53. Balfour, W.D., B.M. Eklund, and S.J. Williamson. "Measurement of Volatile Organic Emissions from Subsurface Contaminants." Presented at the National Conference on Management of Uncontrolled Hazardous Waste Sites, September 1984.

54. Eklund, B.M., W.D. Balfour, and C.E. Schmidt. "Measurement of Fugitive Volatile Organic Compound Emission Rates with an Emission Isolation Flux Chamber." Presented at the Annual Meeting of the American Institute of Chemical Engineers, August 1984.

Other Recent Technical Presentations

1. Eklund, B. California VI Guidance and Steady State Considerations. AEHS 31st Annual Conference, Virtual. March 16, 2022.

2. Eklund, B., J. Milose, L. DeGrazia, C. Ricondo, H. Artz-Patton. More Data from Large Industrial Buildings – VI Attenuation Factors and Seasonal Variability. AEHS 30th Annual Conference, Virtual. March 27, 2021.

3. Eklund, B. and M. Hale. Comparison of Real-Time TCE Measurement Methods for VI Studies. AEHS 36th Annual Conference on Soils, Sediments, Water, and Energy. October 19-23, 2020.

4. Eklund, B., J. Milose, L. DeGrazia, C. Ricondo, and H. Artz-Patton. VI Attenuation Factors and Seasonal Variability at Large Industrial Buildings. AEHS 29th Annual Conference, San Diego, CA. March 20, 2019.

5. Eklund, B., J. Roadifer, N. Wong, and M. Forrest. NOA – Applying Lessons Learned During Calaveras Dam Replacement Project to a New Site. AEG 2018 Annual Meeting. San Francisco, CA. September 15-23, 2018.

6. Eklund, B. It Ain't Over Til It's Over – A Look at the "First Fracking Verdict Ever." Presented to Austin Bar Association, Joint Meeting of the Environmental Section and the Oil & Gas Section. May 9, 2018.

7. Eklund, B., L. Beckley, and R. Rago. Summary of State Approaches to Vapor Intrusion – 2018 Update. Poster at Eleventh International Conference on the Remediation of Chlorinated and Recalcitrant Compounds. Palm Springs, CA. April 8 – 12, 2018.

8. Eklund, B. New Directions in Risk Assessment, Measurement, and Communication. Keynote address at WasteMINZ Roundup 2015, Auckland, New Zealand, April 23, 2015.

Workshops

1. Instructor at Princeton Groundwater's Remediation Course, Virtual, November 2021. Mr. Eklund also will be an instructor at all future offerings of the course: Remediation Course (princeton-groundwater.com)

2. Instructor at 1-Day Workshop. Intrusão de Vapores. Brazil. Sponsored by AESAS and Senac. October 26, 2021.

3. Instructor at 1-Day Workshop. Characterisation and Evaluation of Vapour Intrusion. Melbourne, Australia. September 10, 2017.

4. Instructor for Web Seminar. Effect of Environmental Variables on Soil-Gas Testing at Vapor Intrusion Sites. AECOM Technology Transfer Webinar for International Clients. August 1, 2017.

5. Instructor for Web Seminar. Fate and Transport of VOC Vapors in the Vadose Zone. AECOM Technology Transfer Webinar for International Clients. February 26, 2015.

6. Instructor for Web Seminar. Vapor Intrusion: Today's Litigation, Regulatory, and Scientific Landscape. The American Law Institute. July 14, 2014.

7. Instructor for Web Seminar. Vapor Intrusion: Legal Concerns, Risk Management, and Scientific Factors for Attorneys and Their Clients. The American Law Institute. May 13, 2013.

8. Instructor at 1-Day Workshop. Characterisation and Evaluation of Vapour Intrusion. Adelaide, Australia. September 11, 2011.

9. Instructor at 3-Day Workshop. Vapor Intrusion with an Emphasis on Flux Chamber Approach. Taipei, Taiwan. August 1 – 3, 2011.

10. Instructor at 1/2 –Day Workshop. Rischio Sanitario – Inalazione di Vapori. Rome, Italy. October 7, 2010.

11. Instructor at multiple ½-Day Workshops. Sampling and Analysis Methods for Vapor Intrusion (Course AIR-206) and Data Evaluation for Vapor Intrusion Studies (Course AIR-268). Sponsored by A&WMA. Providence, Rhode Island. September 25, 2006; San Diego, California, January 27, 2009; and Chicago, IL, September 28, 2010.

12. Instructor at three 1-Day Workshops. Vapor Intrusion. Sponsored by the Pennsylvania Department of Environmental Protection (PADEP). Harrisburg, Valley Forge, and Pittsburgh, PA. October – December, 2008.

13. Instructor at 3-hour Workshops. Vapor Intrusion. Melbourne, Australia and Auckland, New Zealand. May 2007.

14. Instructor for 2-hour Web Seminar. VISE – Vapor Intrusion Seminar for Everyone. Sponsored by A&WMA. October 18, 2006.

15. Instructor at multiple 1-Day Workshops. Characterization and Evaluation of Vapor Intrusion (Course AIR-231). Sponsored by A&WMA. San Francisco, CA, April 18, 2005; Philadelphia, PA, January 24, 2006; and Los Angeles, CA, September 12, 2006.

16. Instructor at ½-Day Workshop. Technical Guidance for Indoor Air Vapor Intrusion. Sponsored by STL. Phoenix, AZ, October 6, 2004.

17. Instructor at 1-Day Workshop. Vapor Intrusion Guidance. Sponsored by the Pennsylvania DEP. Harrisburg, PA, November 18, 2003.

18. Instructor at 1 Day Workshop. Metodologias y Technicas de Monitoreo Ambiental Para la Evaluacion de la Calidad del Aire. Buenos Aires, Argentina, April 20, 1999.

19. Instructor at 3 Day Workshop. Air Monitoring Seminar. Sponsored by the University de Los Andes. Bogota, Colombia, April 14-16, 1997.

20. Instructor at 3 Day Workshop. Air Quality Seminar. Sponsored by the U.S. AID. Alba Uilia, Romania, November 1-3, 1994.

21. Instructor at 2 Day Workshop. Air Pathway Analysis at Hazardous Waste Sites Workshop. Sponsored by U.S. EPA/AWMA. Washington, DC, April 5-6, 1993.

22. Instructor at 1 Day Workshop. Dust and Vapor Suppression Workshop. Sponsored by U.S. EPA. Dallas, TX, November 1991.

23. Instructor at six multi-day Workshops. Air Pathway Analysis at Superfund Sites. Sponsored by U.S. EPA. Dallas, TX, Atlanta, GE, Seattle, WA, San Francisco, CA, San Antonio, TX and Arlington, VA, 1989-1990.

Verification Study Conflict of Interest Certification

Verification study: **Preliminary Remediation Goals (PRG) for Radionuclides Electronic Calculator**

A conflict of interest or lack of impartiality exists when the proposed participant personally (or the reviewer's immediate family), or his or her employer, has financial interests that may be affected by the results of the verification study; or may provide an unfair competitive advantage to the participant (or employer); or if the participant's objectivity in performing the verification study may be impaired due to other factors. When the Participant knows that a reasonable person with knowledge of the facts may question the participant's impartiality or financial involvement, an apparent lack of impartiality or conflict of interest exists.

The following questions, if answered affirmatively, represent potential or apparent lack of impartiality (*any affirmative answers should be explained in an attachment*):

- Did you contribute to the development of the calculator being verified, or were you consulted during its development, or did you offer comments or suggestions to any drafts or versions of the document during its development? ☒ No ☐ Yes
- Do you know of any reason that you might be unable to provide impartial advice on the matter under consideration in this verification study, or any reason that your impartiality in the matter might be questioned? ☒ No ☐ Yes
- Have you had any previous involvement with the calculator under consideration? ☒ No ☐ Yes
- Have you served on previous advisory panels, committees, or subcommittees that have addressed the topic under consideration? ☒ No ☐ Yes
- Have you made any public statements (written or oral) on the issue? ☒ No ☐ Yes
- Have you made any public statements that would indicate to an observer that you have taken a position on the issue under consideration? ☒ No ☐ Yes
- Do you, your family, or your employer have any financial interest(s) in the matter or topic under this verification study, or could someone with access to relevant facts reasonably conclude that you (or your family or employer) stand to benefit from a particular outcome of this verification study? ☒ No ☐ Yes

With regard to real or apparent conflicts of interest or questions of impartiality, the following provisions shall apply for the duration of this verification study:

(a) Participant warrants, to the best of his/her knowledge and belief, that there are no relevant facts or circumstances that could give rise to an actual, apparent, or potential organizational or personal conflict of interest, or that Participant has disclosed all such relevant information to EMS or to EPA.
(b) Participant agrees that if an actual, apparent, or potential personal or organizational conflict of interest is identified during performance of this verification study, he/she immediately will make a full disclosure in writing to EMS. This disclosure shall include a description of actions that Participant (or his/her employer) has taken or proposes to take after consultation with EMS to avoid, mitigate, or neutralize the actual, apparent, or potential organizational conflict of interest. Participant shall continue performance until notified by EMS of any contrary action to be taken.

Bart Eklund 6-23-2022

Signature Date

☐ Check here if any explanation is attached

BART EKLUND

Printed Name

Haley & Aldrich

Affiliation/Organization

Brooke Stagich

Savannah River National Laboratory

The following scenarios were reviewed:

4.1 Resident

4.2 Composite Worker

4.5 Construction Worker

4.6 Recreator

4.8 Farmer

The following radionuclides were reviewed:

H-3

Cs-137 plus progeny

Rn-220 plus progenies

Sr-90 plus progeny

Finding 1:

- Scenario: **Resident (Soil & Water) – Sections 4.1.1 and 4.1.4**
  - Exposure route: **Consumption of fruits and vegetables**
    - Problem: **The calculation for Cereal Grain**
      - PRG calculator output for $IFCG_{res\text{-}adj}$: 611800 g
      - My calculated value based on the equation and inputs: 574980 g
      - I only encountered this issue with the resident scenario, and it did not appear to be specific to one nuclide. I ran the calculator twice with different nuclides and both showed the same issue.

Findings 2 & 3:

- Scenario: **Construction Worker (Soil Exposure to Other Construction Activities) – Section 4.5.4**
  - Exposure route: **Inhalation of particulates emitted from soil**
    - Problem: **Calculating PEF'$_{sc}$ (M_{excav} specifically) – Section 4.10.3**
      - There is an error in the equations provided in the User Guide (Section 4.10.3)
      - The equation provided:

$$M_{excav}(g) = 0.35 \times 0.0016 \times \left(\frac{U_m\left(\frac{m}{s}\right)}{2.2}\right)^{1.3} \times \rho_{soil}\left(\frac{mg}{m^3}\right) \times A_{excav}\left(m^2\right) \times d_{excav}(m) \times NA_{dump} \times \left(\frac{1{,}000\ g}{kg}\right)$$

      - The equation that's being used and is provided on the parameter input page:

$$M_{excav}\left(g\right) = 0.35 \times 0.0016 \times \frac{\left(\frac{U_m\left(\frac{m}{s}\right)}{2.2}\right)^{1.3}}{\left(\frac{M_{m\text{-}excav}\left(\%\right)}{2}\right)^{1.4}} \times \rho_{soil}\left(\frac{Mg}{m^3}\right) \times A_{excav}\left(m^2\right) \times d_{excav}\left(m\right) \times N_{A\text{-}dump} \times 1000\left(\frac{g}{kg}\right)$$

    - Problem: **Calculating PEF'sc (M_{wind} specifically) – Section 4.10.3**
      - PRG calculator output for M_{wind}: 5.13E+04 g
      - My calculated value based on the equation and inputs: 8.80E+03 g
        - I performed the calculation via excel and by hand, and both gave the same result.

Possible Findings:

- These are only findings found regarding differences not attributed to errors in calculations and may not be significant to the overall verification.
- Scenario: **Composite Worker (Soil & Air) – Sections 4.2.1 and 4.2.3**
  - Exposure route: **Inhalation of particulates emitted from soil & inhalation**
    - Problem: **The Cs-137 PRG values**
      - PRG calculator outputs:
        - $PRG_{com\text{-}sol\text{-}inh}$: 9.67E+04
        - $PRG_{com\text{-}air\text{-}inh}$: 7.11E+02
      - My calculated values based on the equations and inputs:
        - $PRG_{com\text{-}sol\text{-}inh}$: 9.71E+04
        - $PRG_{com\text{-}air\text{-}inh}$: 7.14E+02
- Scenario: **Construction Worker (Soil) – Sections 4.5.1 and 4.5.4**
  - Exposure route: **Incidental ingestion of soil**
    - Problem: **The Pb-212 PRG values**
      - PRG calculator outputs:
        - $PRG_{con\text{-}sol\text{-}ing}$ & $PRG_{con\text{-}sol\text{-}ingsa}$: 9.23E+02
      - My calculated values based on the equations and inputs:
        - $PRG_{con\text{-}sol\text{-}ing}$ & $PRG_{con\text{-}sol\text{-}ingsa}$: 9.25E+02
  - Exposure route: **Inhalation of particulates emitted from soil**
    - Problem: **The Sr-90 and Cs-137 PRG values**
      - PRG calculator outputs:
        - $PRG_{con\text{-}sol\text{-}inh}$ for Sr-90: 5.70E+02
        - $PRG_{con\text{-}sol\text{-}inhsa}$ for Cs-137: 3.69E+04
      - My calculated values based on the equations and inputs:
        - $PRG_{con\text{-}sol\text{-}inh}$ for Sr-90: 5.68E+02
        - $PRG_{con\text{-}sol\text{-}inhsa}$ for Cs-137: 3.71E+04
- Scenario: **Farmer (Water) – Section 4.8.3**
  - Exposure route: **Immersion in tap water**
    - Problem: **The Po-216 and Pb-212 PRG values**
      - PRG calculator outputs:
        - $PRG_{far\text{-}wat\text{-}imm}$ for Po-216: 6.42E+09
        - $PRG_{far\text{-}wat\text{-}imm}$ for Pb-212: 7.46E+05
      - My calculated values based on the equations and inputs:
        - $PRG_{far\text{-}wat\text{-}imm}$ for Po-216: 6.44E+09
        - $PRG_{far\text{-}wat\text{-}imm}$ for Pb-212: 7.43E+05

Suggestion:

- Sections 4.10.1, 4.10.2, and 4.10.3
  - When trying to understand an equation and potentially an error in the equation, one step is to try to account for the units. Some of the equations in these sections contain variables that do not have units and the units that are provided do not account for the output units. The equations include numerical values, it is unknown if these values include unit conversions, and literature explaining these values was not available. It may be beneficial to update these equations to provide those units or an explanation for their omission.

- Scenario: **Resident (Soil & Water) – Sections 4.1.1 and 4.1.4**
  - Exposure route: **Consumption of fruits and vegetables**
    - Problem: **The calculation for Cereal Grain**
      - PRG calculator output for $IFCG_{res\text{-}adj}$: 611800 g
      - My calculated value based on the equation and inputs: 574980 g
      - I only encountered this issue with the resident scenario, and it did not appear to be specific to one nuclide. I ran the calculator twice with different nuclides and both showed the same issue.

$$IF_{res\text{-}adj}(g) = \left[\left(EF_{res\text{-}c}\left(\frac{350\ days}{yr}\right) \times ED_{res\text{-}c}(6\ yr) \times IR_{res\text{-}c}\left(\frac{g}{day}\right)\right) + \left(EF_{res\text{-}a}\left(\frac{350\ days}{yr}\right) \times ED_{res\text{-}a}(20\ yr) \times IR_{res\text{-}a}\left(\frac{g}{day}\right)\right)\right]$$

ED_{res} (soil exposure duration - resident) yr	26	26
$ED_{res\text{-}a}$ (soil exposure duration - resident adult) yr	20	20
$ED_{res\text{-}c}$ (soil exposure duration - resident child) yr	6	6
EF_{res} (soil exposure frequency - resident) day/yr	350	350
$EF_{res\text{-}a}$ (soil exposure frequency - resident adult) day/yr	350	350
$EF_{res\text{-}c}$ (soil exposure frequency - resident child) day/yr	350	350
$IRCG_{res\text{-}a}$ (cereal grain ingestion rate - resident adult) g/day	70.2	70.2
$IRCG_{res\text{-}c}$ (cereal grain ingestion rate - resident child) g/day	39.8	39.8

$$IFCG_{res\text{-}adj} = \left(350\frac{d}{y} \times 6\ y \times 39.8\frac{g}{d}\right) + \left(350\frac{d}{y} \times 20\ y \times 70.2\frac{g}{d}\right)$$

$$IFCG_{res\text{-}adj} = 83580\ g + 491400\ g = 574980\ g$$

$IFCG_{res\text{-}adj}$ (age-adjusted cereal grain ingestion fraction) g	611800	611800

❖ Scenario: **Construction Worker (Soil Exposure to Other Construction Activities) – Section 4.5.4**

➢ Exposure route: **Inhalation of particulates emitted from soil**

▪ Problem: **Calculating PEF'sc (M_{wind} specifically) – Section 4.10.3**

- PRG calculator output for M_{wind}: 5.13E+04 g
- My calculated value based on the equation and inputs: 8.80E+03 g
  - ♦ I performed the calculation via excel and by hand, and both gave the same result.

$$M_{wind}^{pc}(g) = 0.036 \times (1 - V) \times \left(\frac{U_m\left(\frac{m}{s}\right)}{U_t\left(\frac{m}{s}\right)}\right)^3 \times F(x) \times A_{surf}\left(m^2\right) \times ED_{con}(1\ year) \times \left(\frac{8,760\ hr}{yr}\right)$$

U_m (mean annual wind speed) m/s	4.69	4.69
U_t (equivalent threshold value) m/s	11.32	11.32
V (fraction of vegetative cover)	0	0
F(x) (function dependant on U_m/U_t derived using Cowherd et al. (1985))	0.194	0.194
A_{surf} (areal extent of site) m^2	2023.43	2023.43
ED_{cw} (exposure duration - construction worker) yr	1	1

$$M_{wind} = 0.036 \times (1\text{-}0) \times \left(\frac{4.69\frac{m}{s}}{11.32\frac{m}{s}}\right)^3 \times 0.194 \times 2023.43\ m^2 \times 1\ y \times 8760\frac{h}{y}$$

$$M_{wind} = 0.036 \times (1\text{-}0) \times (0.414311)^3 \times 0.194 \times 2023.43\ m^2 \times 1\ y \times 8760\frac{h}{y}$$

$$M_{wind} = 0.036 \times (1\text{-}0) \times 0.071118 \times 0.194 \times 2023.43\ m^2 \times 1\ y \times 8760\frac{h}{y} = 8803.91\ g$$

M_{wind} (dust emitted by wind erosion) g	51288.84717	51288.84717

Brooke Stagich

362 Candlestick Way • Martinez, GA 30907 • 706-306-0744 • bstagich@gmail.com

EDUCATION

Clemson University (2017 – present) Clemson, South Carolina

Master of Science in Environmental Engineering and Sciences
conc. in Environmental Health Physics May 2019

Courses include: Environmental Risk Assessment, Environmental Radioecology, Environmental Radiation Protection, Environmental Engineering Principles, Radiobiology, Environmental Chemistry, Environmental Nuclear Engineering

Augusta University (2016 – present) Augusta, Georgia
Formerly: Georgia Regents University (2013 – 2015)
Augusta State University (1996 – 2012)

Bachelor of Science in Chemistry conc. in nuclear science May 2016

Courses include: Intro to Nuclear Science, Intro to Nuclear Measurements, Apps of Nuclear Science, Advanced Nuclear Measurements, Laboratory, Management & Safety, Instrumental Analysis, Quantitative Analysis

RESEARCH EXPERIENCE

Savannah River National Lab Aiken, South Carolina

Senior Scientist in Environmental Dosimetry November 2019 – Present

Environmental Dosimetry Intern May 2015 – November 2019

- Determining a Correlation in Field and Lab Measurements of Cs-137 Concentrations in Deer at the Savannah River Site
  - Presented at Environmental Department Meeting at SRNL August 2015
  - Presented at Student Research Conference at Augusta University March 2016
- Dose Comparisons for a Site-Specific Representative Person Using the Age-Dependent Dose Coefficients in CAP88 PC Version 4.0
  - Presented at Health Physics Society Intern Presentations at SRNL July 2016
- Uncertainty/Sensitivity Analysis for the Savannah River National Laboratory's Environmental Dosimetry Model LADTAP XL©
  - Presented at Health Physics Society Annual Meeting July 2018
  - Presented at Summer Intern Technical Seminar August 2018

PUBLICATIONS

- **Stagich, B.H,** Moore, K.R, Newton, J.R, Dixon, K.L, and Jannik, G.T. (2016) "Dose comparisons for a site-specific representative person using the age-dependent dose coefficients in CAP88-PC version 4." *Health Physics Journal*, 112(4): 338-342.
- Minter, K.M, Jannik, G.T., **Stagich, B.H.**, Dixon, K.L, and Newton, J.R. (2018) "Comparison of the current center of site annual NESHAP dose modeling at the Savannah River Site with other assessment methods." *Health Physics Journal,* 114(4): 408-413.

HONORS

Outstanding Undergraduate Student in Nuclear Science May 2016
Nuclear Science Scholarship January 2015 – May 2016
Dade W. Moeller Scholarship Memorializing Kelly Austin August 2018 – May 2019

ACTIVITIES/CLUB

Clemson University Health Physics Society, *Member* August 2017 – May 2019
Health Physics Society, *Member* August 2017 - Present

SKILLS

Familiar with environmental dosimetry transport models, code development, and uncertainty analysis
- EPA CAP88 PC Version 4.0 and 4.1, LADTAP XL©, MAXDOSE-SR, POPDOSE-SR, RESRAD, and GoldSim©

Experienced in preparing scientific technical reports and updating annual reports
- SRS Annual Site Environmental Report (ASER), SRS Radiological Impact Report, SRS Composite Analysis Annual Review

Providing supervision and mentoring for other students and interns

REFERENCES

Nicole Martinez, Ph.D
Assistant Professor
Clemson University
864-656-1984
nmarti3@clemson.edu

Joseph Newton, Ph.D
Assistant Professor of Nuclear Science
Augusta University
706-729-2509
jnewton3@augusta.edu

Tim Jannik
Savannah River National Laboratory
803-819-8401
tim.jannik@srnl.doe.gov

Kenneth Dixon
Savannah River National Laboratory
803-725-5205
kenneth.dixon@srnl.doe.gov

Verification Study Conflict of Interest Certification

Verification study: **Preliminary Remediation Goals (PRG) for Radionuclides Electronic Calculator**

A conflict of interest or lack of impartiality exists when the proposed participant personally (or the reviewer's immediate family), or his or her employer, has financial interests that may be affected by the results of the verification study; or may provide an unfair competitive advantage to the participant (or employer); or if the participant's objectivity in performing the verification study may be impaired due to other factors. When the Participant knows that a reasonable person with knowledge of the facts may question the participant's impartiality or financial involvement, an apparent lack of impartiality or conflict of interest exists.

The following questions, if answered affirmatively, represent potential or apparent lack of impartiality (*any affirmative answers should be explained in an attachment*):

- Did you contribute to the development of the calculator being verified, or were you consulted during its development, or did you offer comments or suggestions to any drafts or versions of the document during its development? ☒ No ☐ Yes
- Do you know of any reason that you might be unable to provide impartial advice on the matter under consideration in this verification study, or any reason that your impartiality in the matter might be questioned? ☒ No ☐ Yes
- Have you had any previous involvement with the calculator under consideration? ☒ No ☐ Yes
- Have you served on previous advisory panels, committees, or subcommittees that have addressed the topic under consideration? ☒ No ☐ Yes
- Have you made any public statements (written or oral) on the issue? ☒ No ☐ Yes
- Have you made any public statements that would indicate to an observer that you have taken a position on the issue under consideration? ☒ No ☐ Yes
- Do you, your family, or your employer have any financial interest(s) in the matter or topic under this verification study, or could someone with access to relevant facts reasonably conclude that you (or your family or employer) stand to benefit from a particular outcome of this verification study? ☒ No ☐ Yes

With regard to real or apparent conflicts of interest or questions of impartiality, the following provisions shall apply for the duration of this verification study:

(a) Participant warrants, to the best of his/her knowledge and belief, that there are no relevant facts or circumstances that could give rise to an actual, apparent, or potential organizational or personal conflict of interest, or that Participant has disclosed all such relevant information to EMS or to EPA.
(b) Participant agrees that if an actual, apparent, or potential personal or organizational conflict of interest is identified during performance of this verification study, he/she immediately will make a full disclosure in writing to EMS. This disclosure shall include a description of actions that Participant (or his/her employer) has taken or proposes to take after consultation with EMS to avoid, mitigate, or neutralize the actual, apparent, or potential organizational conflict of interest. Participant shall continue performance until notified by EMS of any contrary action to be taken.

Brooke Stagich 07/12/2022 ☐ Check here if any explanation is attached

Signature Date

Brooke Stagich

Printed Name

Savannah River National Laboratory

Affiliation/Organization