George G. Killough
Hendecagon Corporation

Education

A.B., Mathematics Education, University of North Carolina at Chapel Hill, 1961
Member Pi Mu Epsilon honorary mathematics society
M.A., Mathematics, University of Tennessee at Knoxville, 1963
One additional year of graduate study under a NASA grant, University of Tennessee at Knoxville, 1963–1964

Experience

January 2010–present. Retired

Hendecagon Corporation
Founder and CEO, Oak Ridge, Tennessee (July 1987–December 2009)

Hendecagon Corporation is a consulting firm specializing in innovative applications of mathematical and statistical methods to environmental assessments of radiological and chemical pollutants. Participated in the development of the DECOM and DECHEM programs for radionuclides and chemicals, respectively, in soils, groundwater, and food chain. Provided systems analysis and programming for MICROAIRDOS version 2.0. Through Hendecagon Corporation, served as consultant to Radiological Assessments Corporation (now named Risk Assessments Corporation, RAC) for the Fernald and the Savannah River Site dose reconstruction projects, sponsored by the Centers for Disease Control and Prevention (CDC), and the Rocky Flats dose reconstruction, sponsored by the Colorado Department of Public Health and Environment. Provided simulations and analysis for the Radionuclide Soil Action Level Oversight Panel as partial fulfillment of a contract between RAC and the Rocky Flats Citizen's Advisory Board.

Oak Ridge National Laboratory
Research Staff Member, Environmental Sciences Division and Health and Safety Research Division, Oak Ridge, Tennessee (1974–July 1987)

Co-edited a major radiological assessment methodology handbook. Provided technical assistance to Liquid Metal Fast Breeder Reactor and High Temperature Gas Cooled Reactor programs by carrying out research in the environmental transport and dosimetry of ^{14}C released from these fuel cycles. Led the development of the INREM II internal dose methodology for radionuclides released from the LWR fuel cycle; INREM II became the dosimetry basis of the USEPA RADRISK methodology. Led the development of the RAGTIME dynamic food-chain model for radioactive pollutants in agricultural systems. Led the modification of the TACT III accident evaluation code for the U.S. Nuclear Regulatory Commission. Participated extensively in National Science Foundation- and U.S. Department of Energy-sponsored basic research projects in modeling the global carbon cycle for prediction of the "greenhouse effect." Developed an age-dependent approach to iodine dose reconstruction for application to clinical histories of ^{131}I exposure for the U.S. Food and Drug Administration. Developed a dynamic global transport model for tritium released to the environment (TRICYCLE). After retiring from the Laboratory, I developed the RAGTIME87 dynamic food-chain model (a reimplementation of the earlier RAGTIME model) and

collaborated in the model's participation in an international validation exercise initiated by the Swedish National Institute for Radiation Protection.

Oak Ridge National Laboratory
Consultant, Environmental Sciences Division, Oak Ridge, Tennessee (1972–1973)
Developed the INDOS codes for implementation of ICRP Publication 10 internal dose methodology.

East Tennessee State University
Assistant and Associate Professor of Mathematics, Johnson City, Tennessee (1966–1974)
Conducted courses in analysis, linear algebra, differential equations, numerical methods, and computer science. Contributed to the formulation of curricula and programs for a proposed department of computer science, which was subsequently established. Organized and conducted computer orientation seminars for faculty members. Supervised numerous master's theses in mathematics and participated in the doctoral program of the College of Education.

University of Tennessee at Knoxville
Instructor in Mathematics (1964–1966)
Taught courses in calculus, probability theory, ordinary and partial differential equations, complex variable, and calculus of finite differences for students of science and engineering. Consultant to the Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Professional Memberships

ACM
Health Physics Society
Sigma Xi

Scientific/Technical Interests

Numerical methods, computer simulation of dynamic systems, stochastic modeling of pollutant transport in the environment, radiation dose modeling, probability, and statistics. Programming languages: C, Fortran95, Perl, Python.

Publications

Author or joint author of more than 50 scientific and technical publications.

R.W. Hornung, S.M. Pinney, J. Lodwick, **G.G. Killough**, D.E. Brewer, and J. Nasuta. "Estimation of Radon Exposures to Workers at the Fernald Feed Materials Production Center, 1952–1988." To appear in *Journal Of Exposure Science And Environmental Epidemiology*.

G.G. Killough and P.S. Rohwer. 2006. "^{14}C Dose Coefficients," Letter to the Editor. *Health Physics* **90**(3): 273–275.

G.G. Killough and D.W. Schmidt. 2000. "Uncertainty Analysis of Exposure to Radon Released from the Former Feed Materials Production Center." *Journal of Environmental Radioactivity* **49**: 127–156.

J.E. Till, **G.G. Killough**, K.R. Meyer, W.K. Sinclair, P.G. Voillequé, S.K. Rope, and M.J. Case. 2000. "The Fernald Dosimetry Reconstruction Project." *Technology* **7**: 279–295.

G.G. Killough, A.S. Rood, J.W. Aanenson, K.R. Meyer, H.A. Grogan, and W.K. Sinclair. 2000. *Task 5: Independent Calculation.* Radionuclide Soil Action Level Oversight Panel. RAC Report No. 16-RSALOP-RSAL-1999-FINAL, Risk Assessments Corporation, Neeses, South Carolina.

J.W. Aanenson, **G.G. Killough**, K.R. Meyer, and A.S. Rood. 1999. *Task 3: Inputs and Assumptions.* Radionuclide Soil Action Level Oversight Panel. RAC Report No. 16-RSALOP-RSAL-1999-FINAL, Risk Assessments Corporation, Neeses, South Carolina.

G.G. Killough, A.S. Rood, J.M. Weber, and K.R. Meyer. 1999. *Task 2: Computer Models.* Radionuclide Soil Action Level Oversight Panel. RAC Report No. 4-RSALOP-1999-FINAL, Risk Assessments Corporation, Neeses, South Carolina.

G.G. Killough, S.K. Rope, B. Shleien, and P.G. Voillequé. 1999. "Nonlinear Estimation of Weathering Rate Parameters for Uranium in Surface Soil near a Nuclear Facility." *Journal of Environmental Radioactivity* **45**: 95–118.

J.F. Rogers, **G.G. Killough**, S.J. Thompson, C.L. Addy, R.E. McKeown, and D.J. Cowen. 1999. "Estimating Environmental Exposures to Sulfur Dioxide from Multiple Industrial Sources for a Case Control Study." *Journal of Exposure Analysis and Environmental Epidemiology* **9**: 535–545.

J.F. Rogers and **G.G. Killough**. 1997. "Historical Dose Reconstruction Project: Estimating the Population at Risk." *Health Physics* **72**(2): 186–194.

K.R. Meyer, P.G. Voillequé, D.W. Schmidt, S.K. Rope, **G.G. Killough**, B. Shleien, R.E. Moore, M.J. Case, and J.E. Till. "Overview of the Fernald Dosimetry Reconstruction Project and Source Term Estimates for 1951–1988." *Health Physics* **71**(4): 425–437.

G.G. Killough, M.J. Case, K.R. Meyer, R.E. Moore, S.K. Rope, D.W. Schmidt, B. Shleien, W.K. Sinclair, P.G. Voillequé, and J.E. Till. 1996. *Task 6: Radiation Doses and Risk to Residents from FMPC Operations from 1951–1988, Volume I and Volume II—The Fernald Dosimetry Reconstruction Project*. RAC Report No. 4-CDC-Fernald-1966-DRAFT, Radiological Assessments Corporation, Neeses, South Carolina.

G.G. Killough, M.J. Case, K.R. Meyer, R.E. Moore, J.F. Rogers, S.K. Rope, D.W. Schmidt, B. Shleien, J.E. Till, and P.G. Voillequé. 1993. *The Fernald Dosimetry Reconstruction Project—Task 4: Envrionmental Pathways—Models and Validation*. RAC Report No. CDC-3, Radiological Assessments Corporation, Neeses, South Carolina.

P.G. Voillequé, K.R. Meyer, D.W. Schmidt, S.K. Rope, **G.G. Killough**, M.J. Case, R.E. Moore, B. Shleien, and J.E. Till. 1995. The Fernald Dosimetry Reconstruction Project—Tasks 2 and 3: Radionuclide Source Terms and Uncertainties. RAC Report No. CDC-5, Radiological Assessments Corporation, Neeses, South Carolina.

G.G. Killough and D.C. Kocher. 1988. "A Model for Global Cycling of Tritium." *Fusion Technology* **14**(2/2B): 1115–1120.

G.G. Killough and D.E. Dunning, Jr. 1987. "Analysis of Uncertainties in CRAC2 Calculations: The Inhalation Pathway." In: Uncertainty in Risk Assessment, Risk Management, and Decision Making (V.T. Covello, L.B. Lave, A. Moghissi, and V.R.R. Uppuluri, Eds.), 287–303. Plenum Press , New York.

D.C. Kocher and **G.G. Killough**. 1987. "Global Cycling of Tritium and Iodine-129." Proceedings of the Seminar on Cycling of Long-lived Radionuclides in the Biosphere, Madrid, Spain, September 15–19, 1986.

D.C. Kocher, R.C. Ward, **G.G. Killough**, D.E. Dunning, Jr., B.B. Hicks, R.P. Hosker, Jr., J.-Y. Ku, and K.S. Rao. 1987. "Sensitivity and Uncertainty Studies of the CRAC2 Computer Code." *Risk Analysis* **7**(4): 497–507.

G.G. Killough and D.C. Kocher. 1986. "Global Environmental Transport Models for Tritium." *Fusion Technology* **8**(2/2): 2569–2574.

G.G. Killough and K.F. Eckerman. 1986. "An Age- and Sex-dependent Model for Estimating Radioiodine Dose to a Normal Thyroid." In: *Fourth International Radiopharmaceutical Dosimetry Symposium — Proceedings of a Conference Held at Oak Ridge, Tennessee, November 5–8, 1985* (A.T. Schlafke-Stelson and E.E. Watson, eds.), pp. 613–627. CONF-851113 (DE86010102), Oak Ridge Associated Universities, Oak Ridge, TN.

G.G. Killough and K.F. Eckerman. 1986. An Age- and Sex-specific Estimation of Dose to a Normal Thyroid from Clinical Administration of Iodine-131. NUREG/CR-3955, ORNL/TM-9800, Oak Ridge National Laboratory, Oak Ridge, TN.

C.F. Baes, Jr., and **G.G. Killough**. 1986. "Chemical and Biological Processes in CO_2 Ocean Models." Chapter 17 in: *The Changing Carbon Cycle — A Global Analysis* (J.R. Trabalka and D.E. Reichle, eds.), pp. 329–347. Springer-Verlag, New York.

C.F. Baes, Jr., and **G.G. Killough**. 1985. *A Two Dimensional CO_2 Ocean Model Including the Biological Processes.* DOE/NBB-0070, TRO21, U.S. Department of Energy, Washington, DC 20545.

D.C. Kocher, R.C. Ward, **G.G. Killough**, D.E. Dunning, Jr., B.B. Hicks, R.P. Hosker, Jr., J.-Y. Ku, and K.S. Rao. 1985. *Sensitivity and Uncertainty Studies of the CRAC2 Computer Code.* NUREG/CR-4038, ORNL-6114, Oak Ridge National Laboratory, Oak Ridge, TN.

W.R. Emanuel, I.Y.-S. Fung, **G.G. Killough**, B. Moore, III, and T.-H. Peng. 1985. "Modeling the Global Carbon Cycle and Changes in the Atmospheric Carbon Dioxide Levels." Chapter 7 in: *Atmospheric Carbon Dioxide and the Global Carbon Cycle* (J.R. Trabalka, ed.), pp. 141–173. DOE/ER-0239, U.S. Department of Energy, Washington, DC 20545.

G.G. Killough and K.F. Eckerman. 1984. "A Conversational Eigenanalysis Program for Solving Differential Equations." In: *Proceedings of the 17th Midyear Topical Symposium of the Health Physics Society*, Pasco, WA, February 5–9, 1984.

G.G. Killough, J.E. Till, E.L. Etnier, B.D. Murphy, and R.J. Raridon. 1984. "Dose Equivalent due to Atmospheric Releases of Carbon-14." Chapter 11 in: *Models and Parameters for Environmental Radiological Assessments* (C.W. Miller, ed.). DOE/TIC-11468, U.S. Department of Energy, Washington, DC.

D.E. Dunning, Jr., **G.G. Killough**, and H.R. Meyer. 1984. "Estimates of Committed Dose Equivalent from Internal Exposure." Chapter 9 in: *Models and Parameters for Environmental Radiological Assessments* (C.W. Miller, ed.). DOE/TIC-11468, U.S. Department of Energy, Washington, DC.

D.C. Kocher and **G.G. Killough**. 1984. "A Review of Global Environmental Transport Models for ^{3}H, ^{14}C, ^{85}Kr, and ^{129}I." In: *Radioactive Waste Management,* Vol. 5, pp. 181–196. IAEA-CN-43/419, International Atomic Energy Agency, Vienna.

W.R. Emanuel, **G.G. Killough**, W.M. Post, and H.H. Shugart. 1984. "Modeling Terrestrial Ecosystems in the Global Carbon Cycle with Shifts in Carbon Storage Capacity by Land-use Change." *Ecology* **65**(3): 970–983.

G.G. Killough and K.F. Eckerman. 1983. "Internal Dosimetry." Chapter 7 in: *Radiological Assessment: A Textbook on Environmental Dose Analysis* (J.E. Till and H.R. Meyer, eds.). U.S. Nuclear Regulatory Commission, Washington, DC.

C.S. Sims and **G.G. Killough**. 1983. "Neutron Fluence-to–Dose Equivalent Conversion Factors: A Comparison of Data Sets and Interpolation Methods." *Radiation Protection Dosimetry* **5**(1): 45–48.

G.G. Killough, C.L. Begovich, A.L. Sjoreen, and L.W. Bell. 1983. *A Guide for the TACT III Computer Code,* final report. NUREG/CR-3287, ORNL/TM-87633, U.S. Nuclear Regulatory Commission, Washington, DC.

G.G. Killough. 1982. *Derivation of Dose Conversion Factors for Tritium.* NUREG/CR-2523, ORNL-5853. Oak Ridge National Laboratory, Oak Ridge, TN.

W.R. Emanuel, **G.G. Killough**, W.M. Post, and H.H. Shugart. 1982. "Modeling Terrestrial Carbon Cycling at the Global Scale." In: *Global Dynamics of Biospheric Carbon,* Proceedings of a symposium held at the Annual Meeting of the Ecological Society of America under the auspices of the American Institute of Biological Sciences, August 17, 1981 (S. Brown, ed.), pp. 166–194. CONF-8108131, Carbon Dioxide Research Division, U.S. Department of Energy, Washington, DC.

J.C. Pleasant, L.M. McDowell-Boyer, and **G.G. Killough**. 1982. *RAGBEEF: A FORTRAN IV Implementation of a Time-dependent Model for Radionuclide Contamination of Beef.* NUREG/CR-2610, ORNL/TM-8011, Oak Ridge National Laboratory, Oak Ridge, TN.

G.G. Killough and W.R. Emanuel. 1981. "A Comparison of Several Models of Carbon Turnover in the Ocean with Respect to their Distributions of Transit Time and Age, and Response to Atmospheric CO_2 and ^{14}C." *Tellus* **33**: 274–290.

W.R. Emanuel, **G.G. Killough**, and J.S. Olson. 1981. "Modelling the Circulation of Carbon in the World's Terrestrial Ecosystems." Sect. 5.10 in: *Global Carbon Modelling — SCOPE 16* (B. Bolin, ed.). John Wiley and Sons Ltd., Chichester.

D.E. Dunning, Jr., and **G.G. Killough**. 1981. "A Comparison of Effective Dose Equivalents from Three Major Internal Dose Compilations." *Radiation Protection Dosimetry* **1**(1): 3–9.

C.S. Sims and **G.G. Killough**. 1981. Reference Dosimetry for Various Health Physics Research Reactor Spectra. ORNL/TM-7748, Oak Ridge National Laboratory, Oak Ridge, TN.

D.E. Dunning, Jr., **G.G. Killough**, S.R. Bernard, J.C. Pleasant, and P.J. Walsh. 1981. *Estimates of Internal Dose Equivalent to 22 Target Organs for Radionuclides Occurring in Routine Releases from Nuclear Fuel-cycle Facilities, Vol. III.* NUREG/CR-0150, Vol. 3; ORNL/NUREG/TM-190/V3, Oak Ridge National Laboratory, Oak Ridge, TN.

G.G. Killough. 1980. "A Dynamic Model for Estimating Radiation Dose to the World Population from Releases of ^{14}C to the Atmosphere." *Health Physics* **38**: 169–200.

W.R. Emanuel, J.S. Olson, and **G.G. Killough**. 1980. "The Expanded Use of Fossil Fuels by the U.S. and the Global Carbon Dioxide Problem." *Journal of Environmental Management* **10**: 37–40.

F.O. Hoffman, G. Schwarz, and **G.G. Killough**. 1980. "A Critique of the Use of ICRP-29's 'Robustness Index' in Evaluating Uncertainties Associated with Radiological Assessment Models." *Health Physics* **39**: 367–369.

W.R. Emanuel, **G.G. Killough**, and H.H. Shugart, Jr. 1980. "Calibration and Testing of Models of the Global Carbon Cycle." In: *Proceedings of the 1980 International Conference on Cybernetics and Society.* IEEE Press, New York.

J.C. Pleasant, L.M. McDowell-Boyer, and **G.G. Killough**. 1980. *RAGTIME: A FORTRAN IV Implementation of a Time-dependent Model for Radionuclides in Agricultural Systems — First Progress Report.* NUREG/CR-1196, ORNL/NUREG/TM-371, Oak Ridge National Laboratory, Oak Ridge, TN.

D.E. Dunning, Jr., J.C. Pleasant, and **G.G. Killough**. 1980. SFACTOR: A Computer Code for Calculating Dose Equivalent to a Target Organ per Microcurie-day Residence of a Radionuclide in a Source Organ — Supplementary Report. NUREG/CR-1523, ORNL/NUREG/TM-85/S1, Oak Ridge National Laboratory, Oak Ridge, TN.

J.E. Till, H.R. Meyer, E.L. Etnier, E.S. Bomar, R.D. Gentry, **G.G. Killough**, P.S. Rohwer, V.J. Tennery, and C.C. Travis. 1980. *Tritium — An Analysis of Key Environmental and Dosimetric Questions.* ORNL/TM-6990, Oak Ridge National Laboratory, Oak Ridge, TN.

D.E. Dunning, Jr., S.R. Bernard, P.J. Walsh, **G.G. Killough**, and J.C. Pleasant. 1979. *Estimates of Internal Dose Equivalent to 22 Target Organs for Radionuclides Occurring in Routine Releases from Nuclear Fuel-cycle Facilities, Vol. II.* NUREG/CR-0150, Vol. 2; ORNL/NUREG/TM-190/V2, Oak Ridge National Laboratory, Oak Ridge, TN.

E.A. Bondietti, J.R. Trabalka, C.T. Garten, and **G.G. Killough**. 1979. "Biogeochemistry of Actinides: A Nuclear Fuel Cycle Perspective." In: *Radioactive Waste in Geologic Storage,* ACS Symposium Series 100 (S. Fried, ed.). American Chemical Society, Washington, DC.

G.G. Killough, D.E. Dunning, Jr., and J.C. Pleasant. 1978. *INREM II: A Computer Implementation of Recent Models for Estimating the Dose Equivalent to Organs of Man from an Inhaled or Ingested Radionuclide.* NUREG/CR-00114, ORNL/NUREG/TM-84, Oak Ridge National Laboratory, Oak Ridge, TN.

G.G. Killough, D.E. Dunning, Jr., S.R. Bernard, and J.C. Pleasant. 1978. *Estimates of Internal Dose Equivalent to 22 Target Organs for Radionuclides Occurring in Routine Releases from Nuclear Fuel-cycle Facilities, Vol. I.* NUREG/CR-0150, ORNL/NUREG/TM-190, Oak Ridge National Laboratory, Oak Ridge, TN.

D.E. Dunning, Jr., and **G.G. Killough**. 1978. "Internal Radiation Dose Calculations with the INREM II Computer Code." In: *Tagungsbericht Radioaktivität und Umwelt, 12*. Jahrestagung, Norderney, 2.–6. Oktober 1978, Fachverband für Strahlenschutz e.V.: 680–695. Norderney, Federal Republic of Germany.

J.E. Till and **G.G. Killough**. 1978. "Scenarios of ^{14}C Releases to the Atmosphere by the World Nuclear Industry and Estimated Radiological Impacts." In: *Tagungsbericht Radioaktivität und Umwelt, 12*. Jahrestagung, Norderney, 2.–6. Oktober 1978, Fachverband für Strahlenschutz e.V.: 680–695. Norderney, Federal Republic of Germany.

G.G. Killough and J.E. Till. 1978. "Scenarios of ^{14}C Releases from the World Nuclear Power Industry from 1975 to 2020 and the Estimated Radiological Impact." *Nuclear Safety* **19**: 602–617.

J.E. Till and **G.G. Killough**. 1978. "Scenarios of ^{14}C Releases from the World Nuclear Power Industry 1975–2020 and Estimated Radiological Insult to the Population." In: *Airborne Radioactivity* (D.T. Shaw, ed.), pp. 131–160. American Nuclear Society, Lagrange Park, IL.

G.G. Killough and P.S. Rohwer. 1978. "A New Look at the Dosimetry of ^{14}C Released to the Atmosphere as Carbon Dioxide." *Health Physics* **34**: 141–159.

P.J. Walsh, **G.G. Killough**, and P.S. Rohwer. 1978. "Composite Hazard Index for Assessing Limiting Exposures to Environmental Pollutants: Formulation and Derivation." *Environmental Science and Technology* **12**: 799–802.

G.G. Killough. 1977. A Diffusion-type Model of the Global Carbon Cycle for the Estimation of Dose to the World Population from Releases of Carbon-14 to the Atmosphere. ORNL-5269, Oak Ridge National Laboratory, Oak Ridge, TN.

D.E. Dunning, Jr., J.C. Pleasant, and **G.G. Killough**. 1977. *SFACTOR: A Computer Code for Calculating Dose Equivalent to a Target Organ per Microcurie-day Residence of a Radionuclide in a Source Organ.* ORNL/NUREG/TM-85, Oak Ridge National Laboratory, Oak Ridge, TN.

P.J. Walsh, **G.G. Killough**, D.C. Parzyck, P.S. Rohwer, E.M. Rupp, B.L. Whitfield, R.S. Booth, and R.J. Raridon. 1977. *CUMEX — A Cumulative Hazard Index for Assessing Limiting Exposures to Environmental Pollutants.* ORNL-5263, Oak Ridge National Laboratory, Oak Ridge, TN.

G.G. Killough and L.R. McKay (eds.). 1976. *A Methodology for Calculating Radiation Doses from Radioactivity Released to the Environment.* ORNL-4992, Oak Ridge National Laboratory, Oak Ridge, TN.

R.F. Ling and **G.G. Killough**. 1976. "Probability Tables for Cluster Analysis Based on a Theory of Random Graphs." *Journal of the American Statistical Association* **71**: 293–300.

G.G. Killough, K.R. Dixon, N.T. Edwards, B.D. Murphy, P.S. Rohwer, W.F. Harris, and S.V. Kaye. 1976. *Progress Report on Evaluation of Potential Impact of ^{14}C Releases from an HTGR Reprocessing Facility.* ORNL/TM-5284, Oak Ridge National Laboratory, Oak Ridge, TN.

G.G. Killough, P.S. Rohwer, and W.D. Turner. 1975. *INREM — A FORTRAN Code which Implements ICRP 2 Models of Internal Radiation Dose to Man.* ORNL-5003, Oak Ridge National Laboratory, Oak Ridge, TN.

G.G. Killough and P.S. Rohwer. 1974. *INDOS — Conversational Computer Codes to Implement ICRP-10 Models for Estimation of Internal Radiation Dose to Man.* ORNL-4916, Oak Ridge National Laboratory, Oak Ridge, TN.

G.G. Killough. 1968. "Points of Divergence for the Iteration of Meromorphic Functions." *Journal of the Tennessee Academy of Science* **43** (4).