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## **C-14 Dose Calculation Methods at Nuclear Power Plants**

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**RETS/REMP Workshop – Oak Brook  
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# C-14 Dose Calculation History

- 1977 NRC Regulatory Guide 1.109 Provides For The Calculation Of C-14 Doses
- 1981 NRC “Our Data Show That C-14 Will Not Make A Significant Contribution To The Doses”
- 1985 NCRP “Carbon-14 From Power Reactors Will Accumulate In The Atmosphere, but the Dose To Human Beings Will Be Insignificant For The Foreseeable Future”
- 2007 – 2009 Discussions With NRC About C-14 Reporting
- 2009 NRC Issues Regulatory Guide 1.21 Revision 2
  - C-14 Principle Radionuclide
- 2011 First Reporting Of C-14 For The Year 2010

# C-14 Dose Calculation Methods - Report

- Accumulation of Industry Practices And Methods
  - Some Methods May Be Considered Best Practices
  - A Few Methods Were Assessed But Not Utilized To Date In Reports To NRC
  - Found Different Methods For The Same Effect (Example: Growing Season)

# C-14 Dose Calculation Methods–Report

- History And Regulatory Guidance
- A Section Of Equations For C-14 Dose Calculations
  - References Provided
- Treatment Of Various Factors – Context Of The Equations
  - Source Term (Inorganic – Organic/Measurements)
  - Atmospheric Dispersion (Periods Of Photosynthesis)
  - Dose Factors
  - Intake & Ingestion Factors
  - Dose Calculation Periods (Quarterly & Annually)
  - The Annual Report Treatment (Special Sections)
- Appendix – Comparison of ICRP-2 & ICRP-72 Dose Factors

# C-14 Dose Calculation Methods - Observations

- C-14 Source Terms
  - Few Sites Have Sampled For C-14
  - PWRs (Sampling Ranged from 94% to 97% Hydrocarbons)
  - With Limited Sampling Many PWRs Used 80% Hydrocarbons For Reporting Purposes (Conservative Based On IAEA Technical Series #421)
  - One BWR Utilized An Old NRC Contract Report To Establish A 10 % Hydrocarbon Fraction (Actual Measurements At This Site)
  - Many BWR Sites Used 100% CO<sub>2</sub>
  - Many Sites Have Utilized The EPRI “Estimation Of C-14 In Nuclear Plant Effluents” (TR 1021106)

# C-14 Dose Calculation Methods - Observations

- p Factor For Intermittent Releases
- Defined in Regulatory Guide 1.109
$$p = \frac{\text{Total Annual Release Time Of C-14}}{\text{Total Time Photosynthesis Occurs (Default 4,400 Hrs)}}$$
- One Utility Evaluated The p Factor For Waste Gas Decay Tanks (70 % Of The Total C-14 Released)
- For This Case p Was .348 or 34.8%
- For Continuous Releases  $p=1.0$

## C-14 Dose Calculation Methods - Observations

- One Utility Evaluated Limiting the Dose Calculation For Ingestion To Daylight Hours (Over Different Multi-Year Time Periods)
  - In General The  $X/Q$  Was Less At Most Locations (Due To Greater Atmospheric In-Stability During Daylight Hours)
  - There Were A Limited Number Of Locations For Which  $X/Q$  Was Higher
- Caution Is Indicated
  - The Source Term Should Also Be For The Same Period As The  $X/Q$
- Although The Assessment Was Conducted, It Was Not Used For The Dose Calculations

## C-14 Dose Calculation Methods - Observations

- Most Used The NRC Defaults For Fraction Produce Ingested And Fraction Of Leafy Vegetables Grown In Garden
- Periods For Dose Calculations/Growing Season
  - Most Sites Compute Doses Annually
  - A Few Sites Compute Doses Quarterly
    - Divided The Source Term Evenly Between Quarters
    - Site Did Not Perform The Vegetation Pathway Calculation In 1<sup>st</sup> Quarter (Inc. Fruit, Milk, and Meat)
    - Site Did Not Include Calculation for Fruits & Vegetables In 4<sup>th</sup> Quarter
  - One Site Utilized A Report Provided By State Agriculture Department To Determine The Growing Season (By Quarter)



## C-14 Dose Calculation Tools & Codes

- Many Used The Spread Sheet Provided By Ken Sejkora
- Some Used Vendor Supplied Codes (i.e. Canberra)
- Some Used NRC Code - GASPAR
- Some Used Several Methods Or Codes To Verify The Results

# C-14 Data & Calculated Doses (Mostly NRC Pre-Submittal)

Site	Assumed Source Term (Ci/site)	Calculated Dose From C-14 (mRem)	Total Body (mRem)	Critical Organ	Critical Pathway	% CO <sub>2</sub>
BWR	10.36 Total	1.61 E-1	3.22E-2	Child Bone	Ingestion (veg)	95
PWR	13.9 /unit	3.68E-1 /unit	7.2E-2 /unit	Child Bone	Ingestion (veg)	30
PWR	20.35	4.78	9.50E-1	Child Bone	Ingestion (veg)	20
PWR	20.23	9.18E-1	1.82E-1	Child Bone	Ingestion (veg)	20
PWR	22.47	3.35E-1	6.66E-2	Child Bone	Ingestion (veg)	20
PWR	21.0	0.325	6.48 E-2	Child Bone	Ingestion (veg)	26
PWR	4.2	8.82E-2	1.76E-2	Child Bone	Ingestion (veg)	
BWR	11.1	5.16E-2		Child Bone	Ingestion (veg + inh)	100
BWR	18.8	1.563E-01		Child Bone	Ingestion (veg + inh. + milk + meat)	100
BWR	17.78	7.12E-2	1.42E-2	Child Bone	Ingestion (Fruit, grain, non-leafy veg)	100

Source: Industry C-14 Conference Calls (Sampling Of Data)

# C-14 Dose Calculation Methods

- Contributors To Date
  - John Doroski
  - Caryle Ingram
  - Clay Madden
  - Mike Millinor
  - Ken Sejkora
  - Mike Roberts (RETS/REMP Paper)
  - Douglas Wahl
- Open Invitation For Others To Participate
- A Special Thank You For The C-14 Conference Calls

# Next Steps & Contact Information

- Review NRC Submittals
- Include Any Remaining Information
- Final Composition

## Contact Information

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