# Health effects of naturally occurring radionuclides in drinking water

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CORES symposium on radon and NORM

# Ecological studies of radionuclides and cancer

- Majority of studies assessing health effects of natural radionuclides have been geographical correlation studies
- They compare typical exposure levels and occurrence of cancer (incidence or mortality) in the entire population
  - Exposure indicators crude
  - Often the cancer rates for population with both exposed and unexposed people
  - No individual level data
  - No information on exposure among cancer cases specifically
  - Associations, rather than effects
  - Cross-level bias (ecological fallacy): Relationships at aggregate level do not necessarily reflect those at individual level
  - Rarely information on other risk factors for cancer

# Radium and cancer: Ecological studies

| Reference | Region | Exposure | Outcome | Findings | Comment |
|---|---|---|---|---|---|
| Lyman 1986 | Florida, 27 counties | 50 private wells, counties with >10% exceeding 5 pCi/l | Leukemia incidence and mortality | Leukemia incidence associated with Ra, but not mortality | Only 14% of population using wells |
| O'Brien 1987 | Florida, 27 counties | As above | Leukemia and bone cancer mortality 1978-82 | For AML, RR=1.4 (95% CI 1.2-1.7), no association for all leukemia or bone cancer | 1/3 of the population had moved to area within 5 years |
| Bean 1982 | Iowa, 28 towns (9 with 'high exposure') | Tap water, Ra226 >5 pCi/l | Incidence of six cancer types 1969-74 | Incidence of lung, breast and male bladder increased (RR 1.3-1.7), colon, rectum and prostate not | Effect of smoking? |

# Studies on radium and cancer

- Guse et al. 2002
- Wisconsin, USA
- Zip code areas
- Radium activity concentrations in public water supplies
  - Exposure levels around 2 pCi/l (mean and median) ~0.07 Bq/l
- Semi-ecological design: Exposure assigned based on residential area of the cases and controls
- Cases with **osteosarcoma** (N=319)
- Controls (N=3198)
- Odds ratio 0.98 (95% CI 0.93-1.04) per pCi/l

# Radon and childhood leukemia

- Kohli et al 2000
- Semi-ecological study
- Cohort with 50,000 children, only 22 cases during 9-year follow-up
- Residence classified as low to high radon risk, based on radon maps
- Some indications of increased risk associated with ‘high-radon areas’ but findings inconsistent

# Drinking water uranium and cancer: Ecological studies

| Reference | Region | Exposure | Outcome | Results | Comments |
|---|---|---|---|---|---|
| Piispanen 1991 | Northern Finland, 261 regions (25x25 km) | Not described | Cancer incidence 1972-1982 | Both negative and positive correlations | Exploratory analysis |
| Wagner 2011 | South Carolina, 169 census tracts | Groundwater uranium, quartiles (highest >0.84 µg/l) | Breast kidney and colorectal cancer incidence 1996-2005 | Non-significant positive correlation | Inadequate exposure assessment |
| Radespiel-Tröger 2013 | Bavaria, 461 municipalities | Tap water, mean 0.9 µg/l | Cancer incidence in 2002-2008 | For U>5 µg/l, incidence of male leukemia and kidney cancer increased, no association with colorectal, lung, breast, prostate, bladder | |

# Radon in drinking water and cancer, ecological studies

| Reference | Region | Exposure | Outcome | Results | Comments |
|---|---|---|---|---|---|
| Hess 1983 | Maine, 16 counties | Wells | Mortality from lung, reproductive and all cancers 1950-69 | Associations with female lung cancer, male reproductive cancers, all female cancers (r=0.5-0.6) | Only correlation coefficients reported |
| Collman 1991 | North Carolina, 75 counties | Public water supplies, tertiles (high exposure >1400 Bq/l) | Childhood leukemia, childhood cancers, adult cancers | RR 1.3 for childhood leukemia, 1.2 for al childhood cancer, no association with adult cancers | |
| Messier 2017 | South Carolina, census tracts | Groundwater | Stomach and lung cancer incidence 1999-2009 | Increases in lung cancer with 3% per 100 Bq/l, 'high-radon cluster' with RR=1.3 for both lung and stomach cancer | Exposure assessment? |

# Individual levels studies

- Case-control, cohort or case-cohort design
- Exposure assessment for each participant
- Information on other risk factors
- Risk estimates per unit dose

# Radium and osteosarcoma

- Finkelstein & Krieger 1996
- 238 cases with child/adolescent osteosarcoma
  - Dg 1964-1988
- 432 controls with other cancers
- Only <50% of eligible subjects recruited
- Water samples form each dwelling only for 14% of cases and 10% of controls
- High vs low exposure (>0.7 mBq/l vs <0.7 mBq/l) OR=1.2 (95% CI 0.8-1.8)
  - No dose-response

# Finnish case-cohort study

- Kurttio et al. 2006, Auvinen et al. 2002, 2005
- Cohort of 140,000 outside municipal water system
- Analysis restricted to wells drilled in bedrock
- ‘Controls’: Sample from the cohort
  - Average radon 320 Bq/l (median 130 Bq/l)
  - Average uranium 0.1 Bq/l (U-234 & U-238)
  - Average radium-226 0.01 Bq/l
- Cases
  - 88 stomach cancer
  - 61 bladder cancer
  - 51 kidney cancer
  - 35 leukemia
- Annual effective doses 0.1-0.3 mSv/year, mainly kidney and bone marrow
- No clear associations observed, wide confidence intervals due to small sample size

# Kidney effects of uranium in drinking water

# Uranium and the kidney

- Uranium is a heavy metal
- Chemical toxicity affecting mainly proximal tubulus
- Clear evidence from animal studies
- Provisional guideline value of WHO (2012) 30 µg/l

# Human (population-level) studies

| Reference | Uranium | Indicator | Participants | Findings | Comments |
|---|---|---|---|---|---|
| Kurttio 2002 | Median 15 µg/l, Intake 36 µg/d | Fractional excretion of calcium, phosphate, glucose, NAD. LDH, ALP, GGT, GST | 325 Finns with wells drilled in bedrock | Increased calcium and phosphate excretion, no effect on others | |
| Mao et al. 1995 | Exposed group 15-20 µg/l | Urine albumin/creatinine | 60 exposed, 40 non-exposed | Increased albuminuria | Effect not seen in albumin concentrati on |
| Limson Zamora 1998 | Median in high-exposure group 100 µg/l | Urinary glucose, LD, GGT, AFOS, creatinine, protein | 30 high, 20 low exposure | Increased glucose excretion (also LD in men) | |
| Selden 2009 | Median 7 µg/l, mean 25 µg/l | U-glucose, phosphate, calcium, NA, albumin, protein creatinine | 301 Swedes with wells drilled in bedrock | Increased beta-2-macroglobulin, no dose-response | No effect on other indicators |