Long-Term Neurotoxic Effects of Early Life Exposure to Tetrachloroethyene-Contaminated Drinking Water

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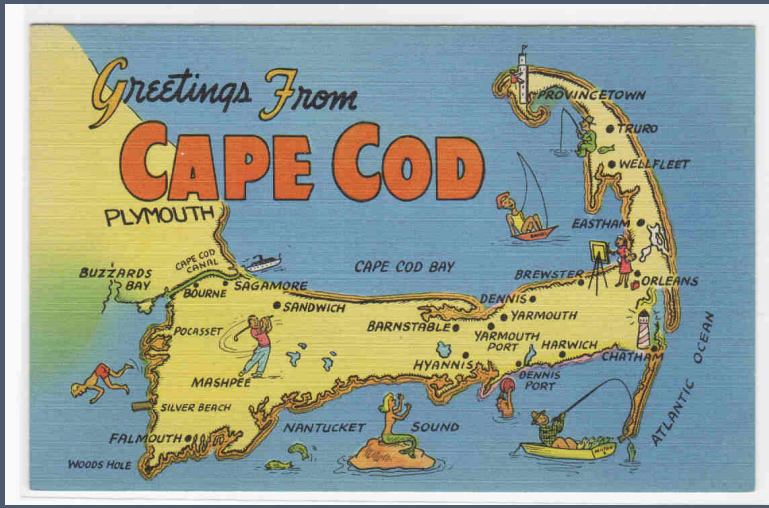
Overview of Presentation

- Setting of research ---Cape Cod, MA
- How tetrachloroethylene contaminated Cape Cod's drinking water
- Methods and results of birth cohort study
- Context of findings and conclusions

Cape Cod, Massachusetts

About Cape Cod



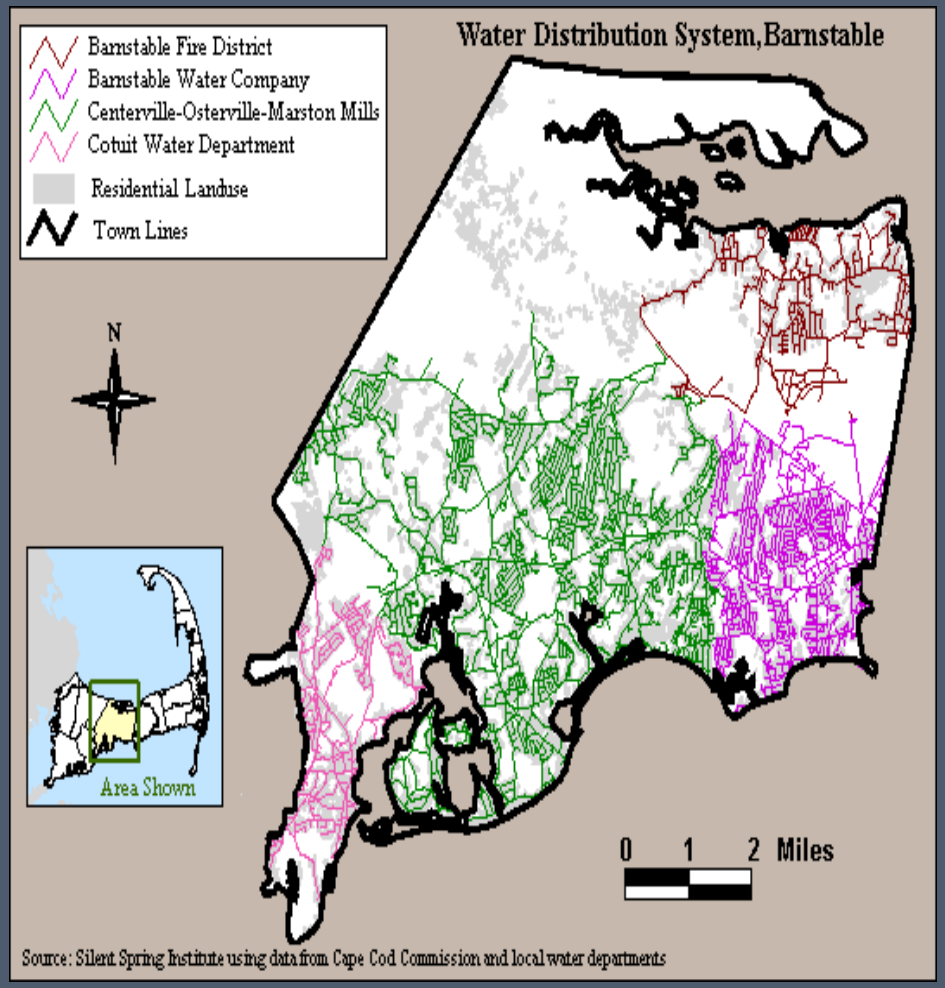
- 15 towns on “the Cape”
- ~ 200,000 permanent residents
- Mainly White, non-Hispanic
- Small Native American population
- Tremendous population growth skewed towards older ages

Cape Cod Seniors

MASHPEE WAMPANOAG TRIBE

Source of Drinking Water on Cape Cod

- Main source is ground water aquifer tapped using shallow wells.
- Local water companies pump and deliver water to homes through pipe distribution system
- Most homes receive public water; some have private wells



What is tetrachloroethylene?

How does it typically contaminate drinking water?

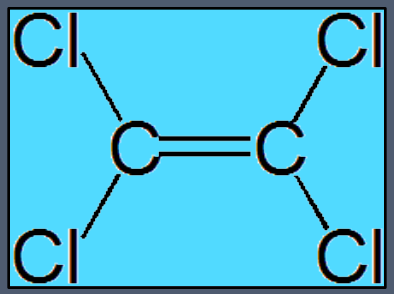
- Important solvent used in dry cleaning and metal degreasing
- ~650,000 people in US are exposed through work
- Used in small, geographically dispersed, and poorly controlled facilities --dry cleaners and garages
- Common drinking water contaminant in US
  - 11% of wells
  - 38% of surface water

Unusual source of contamination on Cape Cod

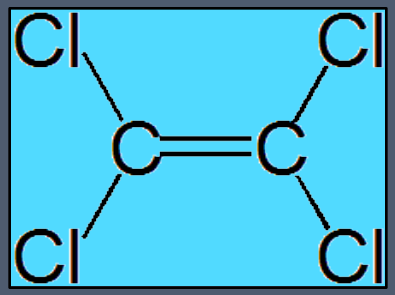
- Source = vinyl liner applied to inside of water distribution pipes
- Introduced in 1969 in response to complaints about metallic taste of water
- Slurry composed of vinyl toluene resin dissolved in PCE was sprayed onto inner pipe surface
- Assumed PCE would disappear in curing process but, because of inadequate drying time, substantial quantities remained and leached into drinking water supplies

Extent of Problem

- Contamination discovered by accident in 1980 when water was tested for other compounds
- 660 miles of vinyl-lined (VL) pipes installed in 91 Massachusetts communities
- 24% installed on Cape Cod because of substantial residential development
- Water tests revealed PCE levels in affected pipes ranging from 1.5 to 7,750 ppb, depending on rate of water flow



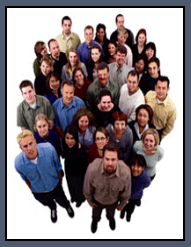
Our Research



Our team has used this “natural experiment” to learn about health effects of PCE in drinking water among individuals exposed during adulthood and in early life

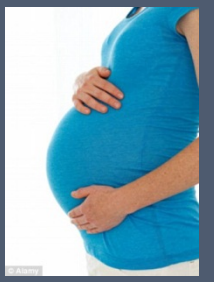
Birth cohort study of neurotoxic effects stemming from early life exposure

Neurotoxicity of PCE



- PCE is a recognized animal and human neurotoxin
- Most human research has been conducted among occupationally exposed adults
- Acute exposure: headaches, dizziness, unconsciousness, death from respiratory depression
- Chronic exposure: impairments in memory, attention, vision problems
- Little information on impact of early life exposure especially in community settings
- Only a few small studies of short-term outcomes

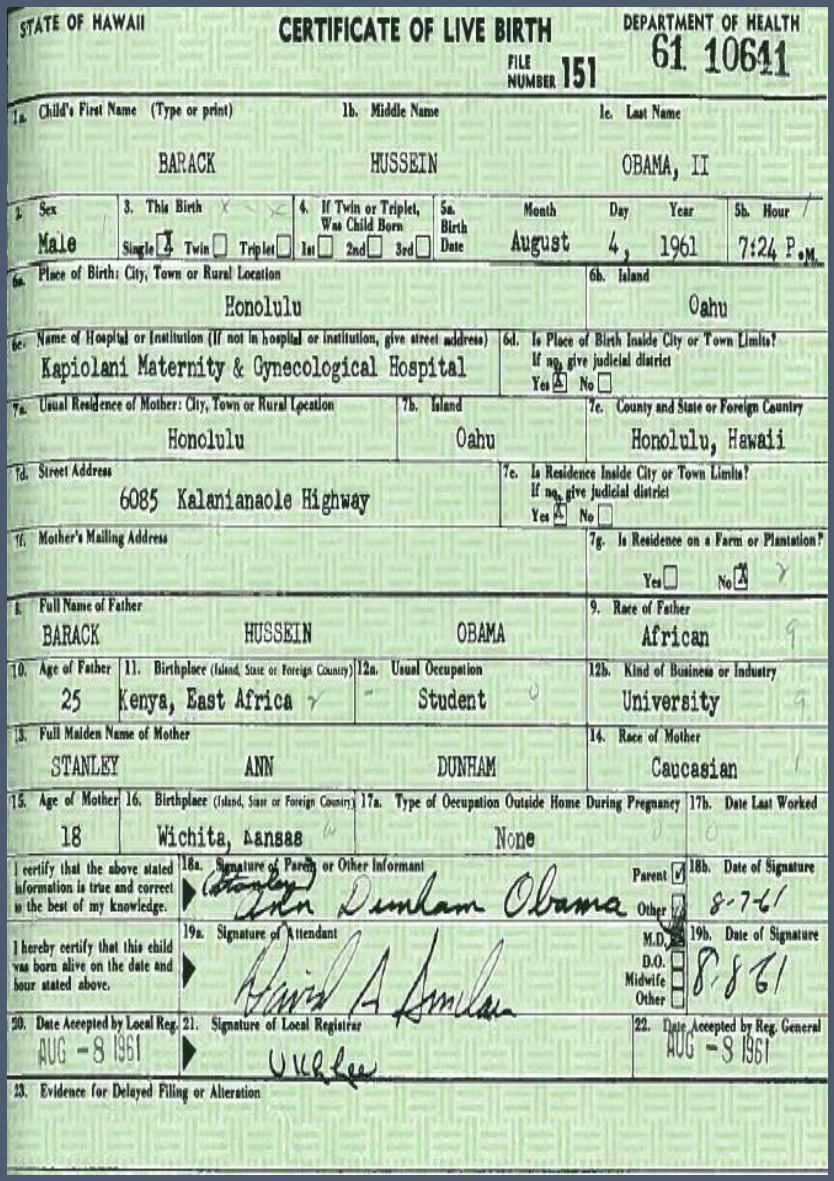
Cape Cod Health Study



- Retrospective cohort study to examine long-term neurotoxic effects of early life exposure to PCE in environmental setting
  - Broad view of neurotoxicity: diminished performance on neuropsychological tests, vision problems, structural brain changes, risk-taking behaviors, mental illness
- Source population: children born from 1969-1983 to women who lived in Cape Cod towns with vinyl-lined pipes
- Study compared two groups:
  - (1) children with early life exposure
  - (2) unexposed children

Cape Cod Health Study

- Reviewed over 14,000 birth records to identify 1,910 exposed and 1,928 unexposed children
- Mothers and children were traced and invited to participate



STATE OF HAWAII — CERTIFICATE OF LIVE BIRTH — DEPARTMENT OF HEALTH

FILE NUMBER 151 — 61 10641

1a. Child's First Name (Type or print)	1b. Middle Name	1c. Last Name
BARACK	HUSSEIN	OBAMA, II

2. Sex	3. This Birth — Single / Twin / Triplet	4. If Twin or Triplet, Was Child Born — 1st / 2nd / 3rd	5a. Birth Date — Month	Day	Year	5b. Hour	
Male	Single [X] Twin [ ] Triplet [ ]	1st [ ] 2nd [ ] 3rd [ ]	August	4,	1961	7:24 P.M.	

6a. Place of Birth: City, Town or Rural Location	6b. Island
Honolulu	Oahu
6c. Name of Hospital or Institution (If not in hospital or institution, give street address)	6d. Is Place of Birth Inside City or Town Limits? If no, give judicial district — Yes [X] No [ ]
Kapiolani Maternity & Gynecological Hospital	
7a. Usual Residence of Mother: City, Town or Rural Location	7b. Island / 7c. County and State or Foreign Country
Honolulu	Oahu / Honolulu, Hawaii
7d. Street Address	7e. Is Residence Inside City or Town Limits? If no, give judicial district — Yes [X] No [ ]
6085 Kalanianaole Highway	
7f. Mother's Mailing Address	7g. Is Residence on a Farm or Plantation? Yes [ ] No [X]

8. Full Name of Father			9. Race of Father
BARACK	HUSSEIN	OBAMA	African
10. Age of Father	11. Birthplace (Island, State or Foreign Country)	12a. Usual Occupation	12b. Kind of Business or Industry
25	Kenya, East Africa	Student	University
13. Full Maiden Name of Mother			14. Race of Mother
STANLEY	ANN	DUNHAM	Caucasian
15. Age of Mother	16. Birthplace (Island, State or Foreign Country)	17a. Type of Occupation Outside Home During Pregnancy	17b. Date Last Worked
18	Wichita, Kansas	None	

I certify that the above stated information is true and correct to the best of my knowledge.	18a. Signature of Parent or Other Informant: Stanley Ann Dunham Obama — Parent [X] Other [ ]	18b. Date of Signature: 8-7-61
I hereby certify that this child was born alive on the date and hour stated above.	19a. Signature of Attendant: David A Sinclair — M.D. [X] D.O. [ ] Midwife [ ] Other [ ]	19b. Date of Signature: 8-8-61
20. Date Accepted by Local Reg.: AUG - 8 1961	21. Signature of Local Registrar: U K Lee	22. Date Accepted by Reg. General: AUG - 9 1961

23. Evidence for Delayed Filing or Alteration

Data Collection

Traced mothers and children returned self-administered questionnaires on

- Demographic characteristics, occupational and non-occupational sources of solvent exposure, and other confounding variables
- Bathing habits
- Tap and bottled water consumption
- Drinking water source (private vs. public)

Data Collection

- Children provided information on risk-taking behaviors during teen and adults years
  - Cigarette smoking
  - Alcoholic beverage consumption
  - Illicit drug use

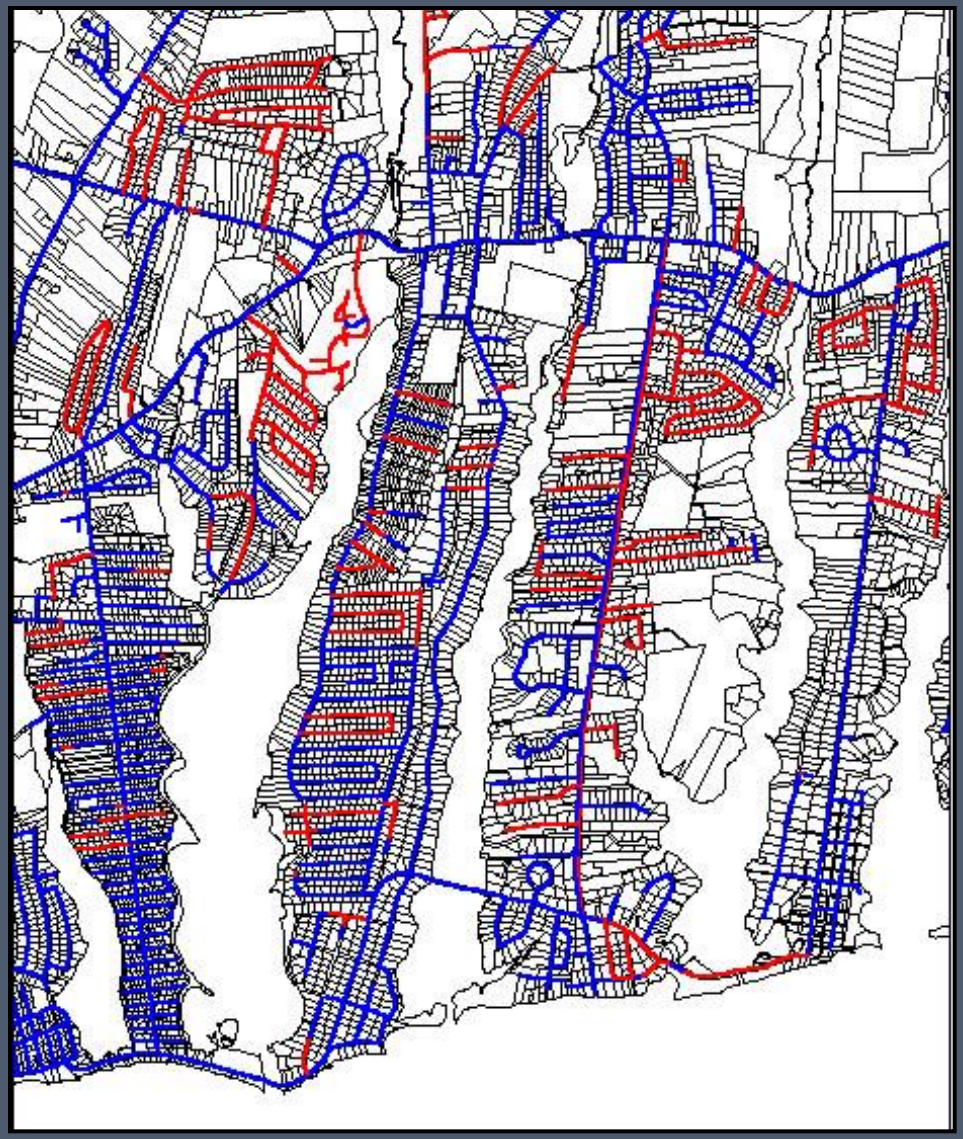
PCE Exposure Assessment

- Based on leaching and transport model that estimated relative mass of PCE delivered to each residence from prenatal period through child's fifth birthday

- Three pieces of information needed for determining PCE exposure
  - (1) VL pipe locations
  - (2) Subjects' residential locations
  - (3) Leaching and transport algorithm

Original Map of Water Pipes

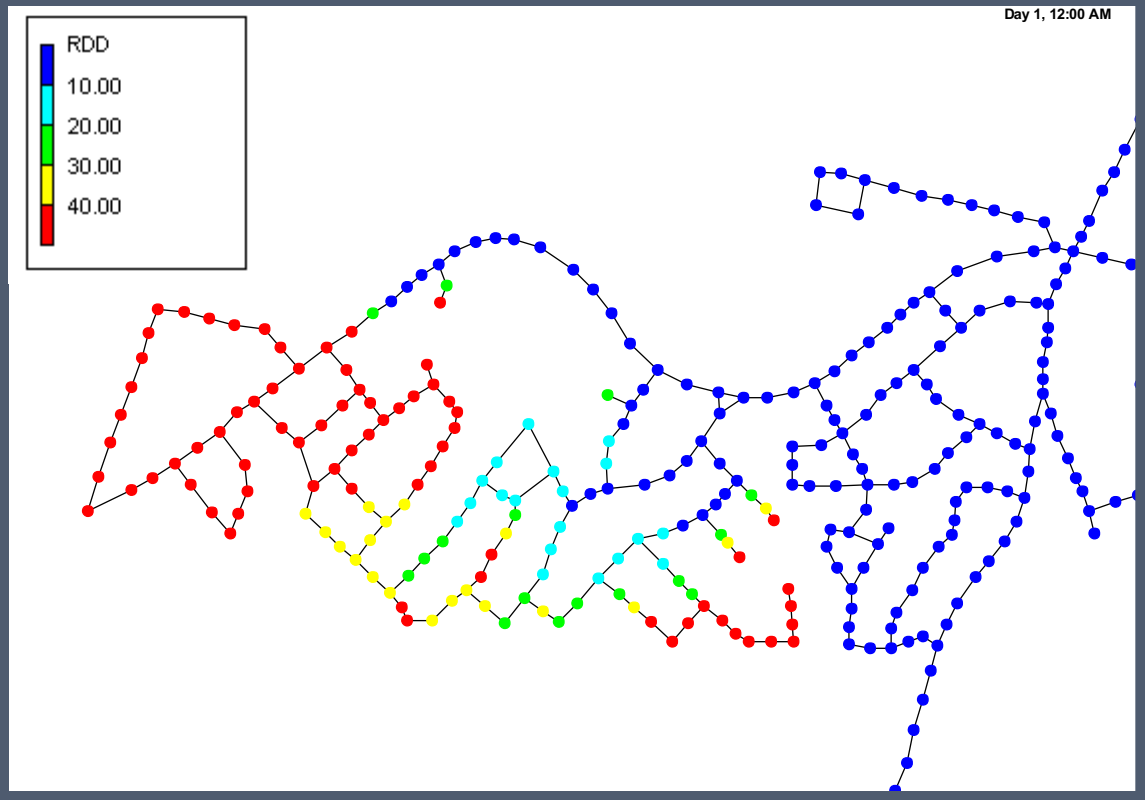
GIS Maps of Water Pipes



= Vinyl-lined pipe

= Other pipe

Leaching and Transport Algorithm Estimated Annual Mass of PCE Entering the Residence



Characteristics of Study Population

Characteristic	Subjects with Prenatal and Early Childhood Exposure N=831	Unexposed Subjects N=547
Current age, mean (sd)	29.2 (3.6)	29.6 (3.8)
% Female	60.2	60.5
% White	98.4	98.5
% College graduate	61.4	61.2
% Ever had job with solvent exposure	14.8	13.0
% History of mental illness	24.4	21.4
% Mother received prenatal care	95.5	95.1
% Mother smoked cigarettes during gestation	21.9	20.7
% Mother consumed alcoholic beverages during gestation	36.3	36.8

Findings:
Frequency of Risk-Taking Behaviors

Risk-Taking Behaviors	Frequency (%)
Ever binge drinker as a teen (4/5 alcoholic beverages at a time)	35%
Ever used illicit drugs as teen	55%
Even used major drugs as adult (excl. marijuana)	33%
Ever used crack/cocaine as adult	20%
Ever used hallucinogens as adult	18%
Ever used heroin as adult	3%

Findings: Risk-Taking Behaviors

- Highly exposed individuals experienced 30% to 40% increases in risk of using major illicit drugs
  - Risk Ratio for teen use: 1.4 (95% CI: 1.1-1.7)
  - Risk Ratio for adult use: 1.3 (95% CI: 1.1-1.5)

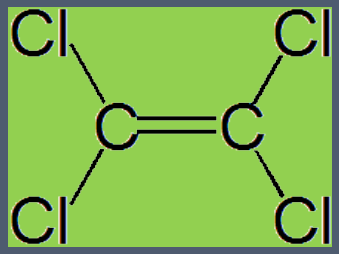
- These increases in risk rose to 50-60% for use of 2+ major drugs
  - Risk Ratio for teen use: 1.6 (95% CI: 1.2-2.2)
  - Risk Ratio for adult use: 1.5 (95% CI: 1.2-2.9)

- Specific drugs for which increases were observed included crack/cocaine, psychedelics/hallucinogens, club/designer drugs, Ritalin without a prescription, and heroin
  - Risk Ratios for specific drugs: 1.4 - 2.1

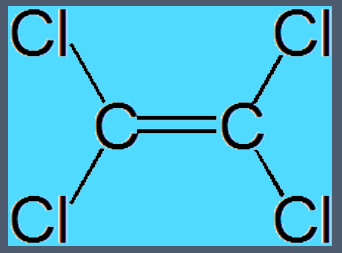
- 30-60% increases in the risk of certain smoking and drinking behaviors were also seen among highly exposed subjects

Summary of Risk Taking Behaviors

Risk Taking Behaviors	Strength of Association
Cigarette Smoking	+
Alcoholic Beverage Consumption	+
Illicit Drug Use	++

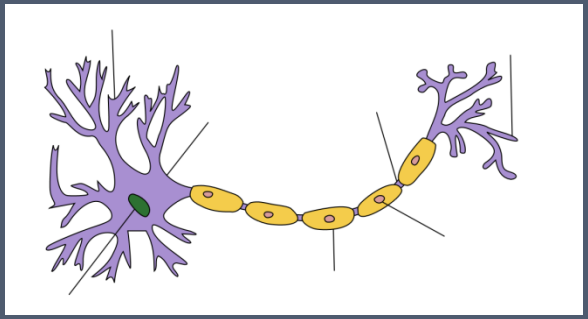


Context of Findings



- Biological plausibility for neurotoxic effects:
  - PCE is a small, fat soluble molecule that can cross the placenta and blood brain barrier
  - PCE has high affinity for lipophilic tissues of the CNS

- Mode of action is unknown; possible mechanisms include:
  - Changes in fatty acid profile of brain
  - Loss of myelin
  - Apoptotic neuro-degeneration



Context of Findings

Publication	Exposure	Study Population	Results
Till (2001, Toronto)	Maternal occupational exposure to solvents during pregnancy	Pre-school children N=61	Lower language scores, more behavioral problems
Laslo-Baker (2004, Toronto)	Maternal occupational exposure to solvents during pregnancy	Pre-school children N=32	Lower language scores, more inattention and hyperactivity
Eskenazi (1988, New Haven)	Maternal occupational exposure to solvents during pregnancy	Pre-school children N=41	No deficits in intellectual ability, memory
Spector (1999, 2005) NY	Environmental exposure to solvents from nearby dry cleaning facility	Children at daycare center N=40	No impact on cognition or behavior

Conclusions

- Study demonstrates how scientists can take advantage of a unique "natural experiment" to learn about health effects of an environmental pollutant

- Fortuitous circumstances
  - Availability of historical data
  - High prevalence and wide range of exposure levels
  - Little confounding due to irregular contamination pattern

- Challenges
  - Historical exposure assessments → misclassification which may have biased the results towards null
  - Little information on social environment, an important determinant of risk-taking behavior

Conclusions

- Newly funded study is examining combined impact of early life exposure to environmental and social stressors on substance use
- PCE remains a common drinking water contaminant, so it's important to determine its impact on the health of vulnerable populations
- Goal of this research is to provide is a sound scientific basis for policy makers to ensure that drinking water supplies are safe for all to consume

References

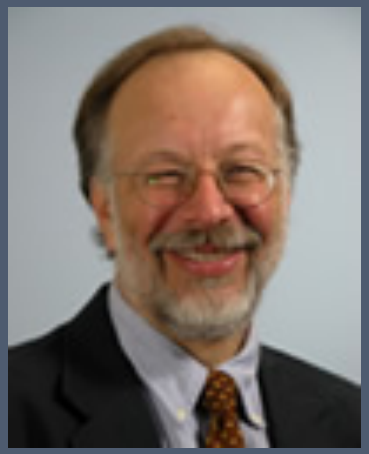
- Aschengrau A, Janulewicz P, White R, et al. Long-term neurotoxic effects of early life exposure to tetrachloroethylene-contaminated drinking water. Ann Global Health 2016; 82:169-179.

- Aschengrau A, Weinberg J, Janulewicz P et al. Affinity for risky behaviors following prenatal and early childhood exposure to tetrachloroethylene. Environ Health 2011; 10: 102.

- Gallagher LE, Webster TF, Aschengrau A. Associations between teenage drug and alcohol use and early life exposure to tetrachloroethylene and alcohol. *Environmental Health* 2017; 16:26.

Thanks to my colleagues…..

David Ozonoff



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