Cancer Occurrence in Offsite Neighborhoods Near the Santa Susana Field Laboratory

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Reasons for Concern

- Intensive testing of rocket fuels
- Usage of solvents, chemicals, metals, radionuclides
- Presumed carcinogen contamination
- Lymphomas and lung cancers among workers
- History of accidents, spills and releases
- Possible dispersion offsite by air and water
- Safety conditions relaxed, inadequate monitoring
- History of secrecy and non-responsive
Reasons for Scientific skepticism

• Lack of any clear risk found by previous searches
Previous searches were Inconclusive

<table>
<thead>
<tr>
<th>Study</th>
<th>Periods</th>
<th>Locations</th>
<th>Cancers</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perkins-Wright</td>
<td>1978-82</td>
<td>5 LA Tracts</td>
<td>11 Sites</td>
<td>Single Tract Bladder 1.5 83-7 Overall: Inconclusive</td>
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<tr>
<td></td>
<td>1983-87</td>
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<tr>
<td>Coye-Goldman</td>
<td>1973-82</td>
<td>Aggregated Tracts by County</td>
<td>14 Sites</td>
<td>Bladder 1.3 83-88 LA tracts</td>
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<tr>
<td></td>
<td>1983-88</td>
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<td>aggregated</td>
<td>Lung 1.1 88-89 VEN Tracts Suspect Confounding</td>
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<tr>
<td></td>
<td>1988-89</td>
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<tr>
<td>Nasseri</td>
<td>1988-95</td>
<td>Aggregated VEN Co Tracts</td>
<td>12 Sites</td>
<td>No positive findings</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>aggregated</td>
<td></td>
</tr>
<tr>
<td>Morgenstern</td>
<td>1988-95</td>
<td>Aggregated LA, VEN Blocks</td>
<td>9 Sites</td>
<td>Lung 1.1 Middle Belt 88-95 Melanoma 1.2 Middle Belt 96-02</td>
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<tr>
<td></td>
<td>1996-02</td>
<td>in 3 belts by Distance</td>
<td>aggregated</td>
<td>Thyroid ? Proximity effect</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td>Aerodigestive? Proximity effect</td>
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</table>
# Problems with Previous searches

<table>
<thead>
<tr>
<th>Study</th>
<th>Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perkins-Wright</td>
<td>Multiple comparisons without adjustment</td>
</tr>
<tr>
<td></td>
<td>Weak associations</td>
</tr>
<tr>
<td></td>
<td>Bias: response to cluster report</td>
</tr>
<tr>
<td></td>
<td>Confounded by Race and Social Class</td>
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<tr>
<td>Coye-Goldman</td>
<td>Multiple comparisons without adjustment</td>
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<td>Weak associations</td>
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<td></td>
<td>Aggregation obfuscates location</td>
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<tr>
<td></td>
<td>Confounded by Social Class</td>
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<tr>
<td>Nasseri</td>
<td>Multiple comparisons without adjustment</td>
</tr>
<tr>
<td></td>
<td>Aggregation obfuscates location</td>
</tr>
<tr>
<td></td>
<td>Low statistical power</td>
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<tr>
<td></td>
<td>Confounded by Social Class</td>
</tr>
<tr>
<td>Morgenstern</td>
<td>Multiple comparisons without adjustment</td>
</tr>
<tr>
<td></td>
<td>Weak associations</td>
</tr>
<tr>
<td></td>
<td>Aggregation obfuscates location; Distance is not dose</td>
</tr>
<tr>
<td></td>
<td>Confounding by Social Class</td>
</tr>
</tbody>
</table>
Reasons for Scientific skepticism

- Ambiguous and controversial exposure estimates
- The presence of a carcinogen, especially when technology permits detection of very low levels, does not necessarily constitute a major hazard
- High dose levels are needed to produce a measurable cancer excess
Effect of Industrial exposure to hexavalent chromium:
Mean level 790 micrograms/cubic meter of air

2042 Exposed

59 Cases

UNAFFECTED, 0.971, 97%

LUNG CANCER, 0.029, 3%

2071 Unexposed

25 Cases

UNAFFECTED, 0.988, 99%

LUNG CANCER, 0.012, 1%
Carcinogenesis increases linearly with dose.
Projected effect of Strongest Community Exposure to Hexavalent Chromium

<table>
<thead>
<tr>
<th></th>
<th>Micrograms chromium(^6/m^3)</th>
<th>Lung cancers /100,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workplace</td>
<td>790</td>
<td>1700</td>
</tr>
<tr>
<td>Community</td>
<td>0.04</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Thus exposure at the point of the highest known emission of carcinogen in California, about one extra case per million would appear (i.e. in the average census tract, **one extra case every 200 years**).
Dispersion of carcinogen emissions

Point of carcinogen emission

KILOMETERS

ZONES

ZONE 1
POP 2000

ZONE 2
POP 5000 (~ CT SIZE)

ZONE 3
POP 15,000

ZONE 4
POP 60,000

KILOMETERS
Emission dose level to individuals is variable

- Chemicals rapidly disperse into air/water

- As the distance from the site increases:
  - More people are exposed
  - Exposure dose is lower

- Dispersion results in dilution: dose is inversely proportional to distance
Impact of point emission if dose is thought to double the risk

<table>
<thead>
<tr>
<th></th>
<th>Population</th>
<th>Distance</th>
<th>Attributable Risk</th>
<th># Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>At Source</td>
<td>50</td>
<td>0.1 km</td>
<td>100/100,000</td>
<td>0.05</td>
</tr>
<tr>
<td>Zone 1</td>
<td>2000</td>
<td>0.3 km</td>
<td>11/100,000</td>
<td>0.22</td>
</tr>
<tr>
<td>Zone 2</td>
<td>5000</td>
<td>0.5 km</td>
<td>4/100,000</td>
<td>0.20</td>
</tr>
<tr>
<td>Zone 3</td>
<td>15,000</td>
<td>1.0 km</td>
<td>1/100,000</td>
<td>0.15</td>
</tr>
<tr>
<td>Zone 4</td>
<td>60,000</td>
<td>2.0 km</td>
<td>0.25/100,000</td>
<td>0.15</td>
</tr>
<tr>
<td>Zone 5</td>
<td>120,000</td>
<td>3.0 km</td>
<td>0.10/100,000</td>
<td>0.12</td>
</tr>
</tbody>
</table>

No more than a single additional case would be expected
Reasons for Scientific skepticism

• Absence of historical precedents
Precedents: Environmental cancer clusters do occur (other than occupational risks)

Fallon, NV: 2000-2001, 16 ALL cases occurred, 0.3 expected
    Host to thousands of diverse visitors

Libby, MT: Multiple cases of mesothelioma in a small town
    Tailings of asbestos-containing vermiculite

Cappadocia, Turkey: Cluster of cases of mesothelioma
Greece, Italy, New Caledonia: Clusters of mesothelioma
    From building materials or whitewash with asbestos

Ukraine/Belorus: Localized thyroid cancer in young persons
    From nuclear fallout

Taiwan, Chile, Argentina, Bangladesh: Localized bladder cancer
    Groundwater contaminated with natural arsenic deposits
Churchill County (Fallon) ALL Cluster Rate compared to California Rates

- **California**
- **Inyo-Mono Co**
- **Churchill Co.**
If dose is usually weak, why are “clusters” found? Two different circumstances

**Strong** direct exposure, highly targeted at close quarters
   - Household asbestos, person to person virus
     - Sufficient dose by *short-term but intense* exposure
     - Sufficient dose to *single families or compounds*

**Strong** indirect or distant exposure, disseminated by air/water/soil
   - Chernobyl, waterborne arsenic, asbestos tailings
     - Sufficient dose by *continuous cumulative* exposure over the long-term
     - Sufficient dose disseminated to *multiple adjacent localities*

**Weak** exposure
   - Rare cancers undetectable, common ones lost within random variation
Random (Poisson) distribution of Lung Carcinoma occurring in 49 Localities of 5000 Persons each over 5 Years + Unexpected Cases?

If the cancer is not rare, the usual cases outnumber the added ones (and vary in number by chance)
The Challenge

• Some offside residents may have been exposed to carcinogens at some dose.

• They may well have some added cancer risk.

• The challenge is to see if a measureable and unambiguous increase in risk has been produced.

• Must examine individual neoplasms and individual tracts.
To demonstrate an unambiguous association:

- Increase must be at least 50%, a relative risk of 1.5 (there are too many alternative explanations for a weaker link)
- Chance must be excluded
- Adjacent tracts (localities) offsite should have high exposure in common
- Here is a local example
Carcinoma of the Oropharynx
Steps in Linking Environmental Carcinogenicity to a Particular Locality

1. Assess the likelihood that any association between cancer incidence and a residential locality could be explained by chance.

2. Ensure that any such association cannot be explained by a bias.

3. Ensure that any such association cannot be explained by the characteristics of local residents.
1. Assessing chance

- The conventional method is to identify by computation any excess difference which is statistically significant at the level of 95% confidence.

- Method is based on the appropriate distribution of random possible results—chance can never be ruled out, just quantified at an arbitrary level.

- We perform this exercise to screen tract/cancers.
By arbitrary convention, “significance” means that if the same circumstance were repeated 100 times, no more than 2.5% of the results would show the same unusual high outcome by chance alone (like the red dot below).
2. Bias comes in several forms

- Registry errors: unlikely, because ascertainment is very complete and in effect done blindly to place, age, race, etc.

- Census errors: underestimation of the number of persons, especially high risk persons, makes the excess look too large. This is a common problem in rapidly changing neighborhoods.

- Texas sharpshooting: If investigation is initiated by a reported “cluster”, we already know the rate is not going to be low, and the statistical test is meaningless.
"TEXAS SHARPSHOOTING"

AIM, SHOOT, AND ONLY THEN--
DRAW THE TARGET
The more cancers, periods, and tracts tried, the more likely are extreme findings.

Solution: instead of relying upon “significance” for each tract/cancer, we screen all tract-cancer combinations by significance, then calculate how often each extreme result could occur by chance among all CA tracts.

The following Poisson table gives this percentage for selected observed numbers given the number expected.
Percent of searches expected to find N or more cases observed according to the mean expected

<table>
<thead>
<tr>
<th>Mean expected</th>
<th>1 Obs</th>
<th>2 Obs</th>
<th>3 Obs</th>
<th>4 Obs</th>
<th>5 Obs</th>
<th>6 Obs</th>
<th>7 Obs</th>
<th>8 Obs</th>
<th>9 Obs</th>
<th>10 Obs</th>
<th>11 Obs</th>
<th>12 Obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>63.2%</td>
<td>26.4%</td>
<td>8.0%</td>
<td>1.9%</td>
<td>0.4%</td>
<td>0.1%</td>
<td>0.01%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>59.3%</td>
<td>32.2%</td>
<td>14.2%</td>
<td>5.2%</td>
<td>1.6%</td>
<td>0.4%</td>
<td>0.1%</td>
<td>0.02%</td>
<td>0.01%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>58.4%</td>
<td>36.0%</td>
<td>19.2%</td>
<td>9.1%</td>
<td>3.4%</td>
<td>1.2%</td>
<td>0.4%</td>
<td>0.1%</td>
<td>0.03%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>56.7%</td>
<td>37.1%</td>
<td>21.5%</td>
<td>11.1%</td>
<td>5.1%</td>
<td>2.1%</td>
<td>0.8%</td>
<td>0.3%</td>
<td>0.1%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>55.8%</td>
<td>38.3%</td>
<td>23.7%</td>
<td>13.3%</td>
<td>6.8%</td>
<td>3.2%</td>
<td>1.3%</td>
<td>0.5%</td>
<td></td>
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</tr>
<tr>
<td>6</td>
<td>55.4%</td>
<td>39.3%</td>
<td>25.5%</td>
<td>15.2%</td>
<td>8.3%</td>
<td>4.2%</td>
<td>1.9%</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54.9%</td>
<td>40.0%</td>
<td>27.0%</td>
<td>16.9%</td>
<td>9.8%</td>
<td>5.3%</td>
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<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54.8%</td>
<td>40.8%</td>
<td>28.4%</td>
<td>18.4%</td>
<td>11.3%</td>
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<tr>
<td>9</td>
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<td></td>
<td></td>
<td></td>
<td>54.3%</td>
<td>41.1%</td>
<td>29.2%</td>
<td>19.5%</td>
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<tr>
<td>10</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>45.3%</td>
<td>32.8%</td>
<td>21.4%</td>
<td></td>
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</tr>
</tbody>
</table>
For example:

- When 2 cases are expected and 6 are observed, 1.6% of localities of that size would find as many or more than 6 by chance.

- That means in 160 California localities
3. Explore alternative explanations for any cluster: *They are important considerations*

- Other known causes of that particular cancer
  - Rarely measureable by locality: example -- smoking

- Race/Ethnicity, (approximate by tract)
  - Measureable surrogate causes like — skin color

- Education and Income (approximate by tract)
  - Measureable surrogate for causes like — sexual and reproductive history
A rough commonality of lifestyle characterizes the residents of any neighborhood.

- Neighborhood choice is personal and particular
  - Preferred location, location, location
- Thus birds of a feather tend to flock together
- Obvious on both County and Census tract levels
  - Ethnicity, education, friends, habits, occupation
- Shows up in cancer patterns
California County Median Household Income
According to Percent of College-Educated Adult Women
(Counties of more than 50K)

Percent Women > 25 Years with BA/BS

Annual Household K$

Bay Area
Central Valley
Other Urban Counties
Other Semi-rural Counties
Trends in Incidence of Breast Cancer among White Females from California Counties differing in Median Income and Educational Attainment

Annual Age-adjusted Incidence/100K

Period

Contra Costa
Imperial
Kern
Los Angeles
Marin
San Francisco
San Joaquin
San Mateo
Santa Clara
Stanislaus
Tulare
California
Trends in Incidence of Malignant Melanoma among Whites from California Counties differing in Median Income and Educational Attainment

- Contra Costa
- Imperial
- Kern
- Los Angeles
- Marin
- San Francisco
- San Joaquin
- San Mateo
- Santa Clara
- Stanislaus
- Tulare
- California

Annual Age-adjusted Incidence/100K

Period:
- 1988-94
- 1995-01
- 2002-8
Trends in Incidence of Female Lung Cancer among Whites from California Counties differing in Median Income and Educational Attainment

Annual Age-adjusted Incidence/100K

Period

1988-94
1995-01
2002-8

Contra Costa
Imperial
Kern
Los Angeles
Marin
San Francisco
San Joaquin
San Mateo
Santa Clara
Stanislaus
Tulare
California
From Counties to Census tracts

• We define localities as census tracts because the census gives us accurate populations by age and sex.

• Census tracts are smaller than counties, averaging about 5000 persons but varying in size from hundreds to tens of thousands.

• Thus variation in cancer occurrence comes from three factors, usually in this order:
  – Size of the tract population
  – Chance
  – Prevalence of causal factors
Colon Carcinoma in LA

Distribution of census tracts by relative risk (males)

Pink >1.0, Red > 1.5
Because the tract size varies, we can describe the tracts by the number of cases expected and observed rather than by rate.

- For a given expected case number horizontally, we represent each tract vertically by a dot for the observed case number.

- Lines showing both a standard risk (50% increase) and a measure of "significance" are shown.

- A dot above the lines in red represents a "significant" increase.

- Those occurring by chance will usually touch a line. The higher the red dot, the higher the incidence.

- Different cancers show different patterns depending on how localized high risk is found.
Census Tracts at high risk of COL
according to the number of observed and expected cases

- High risk CT
- RR=1.5
- 95% UCI
- Expected
- Other CT
Female Colon Cancer

The graph illustrates the observed versus expected cases of female colon cancer. The y-axis represents the observed cases, while the x-axis represents the expected cases. The red dots represent high-risk cases, and the lines indicate the risk ratio (RR) of 1.5, the 95% upper confidence interval (UCI), and the expected cases.
Male Kaposi Sarcoma

SES = Adj for SES

Expected cases
KAPOSI SARCOMA
CENSUS TRACTS BY MAJORITY CASE RACE/ETHNICITY
Female Breast Cancer

Age-specific incidence by race/ethnicity
(females)

- Latino
- Black
- Non-Latino White
- Asian

age intervals (5 years)
Female Lung Adenocarcinoma

Age-specific incidence by race/ethnicity (females)

- Latino
- Black
- Non-Latino White
- Asian

age-specific incidence rate vs. age intervals (5 years)
Bladder Cancer

Age-specific incidence by race/ethnicity (males)

- Latino
- Black
- Non-Latino White
- Asian

age-specific incidence rate vs. age intervals (5 years)
Other cancers higher in other Race/Ethnicity groups

- Prostate cancer higher in African-Americans
- Liver cancer higher in East Asian-Americans
- Gall Bladder and stomach cancer higher in Latino-Americans
CENSUS TRACTS BY SOCIAL CLASS
Malignant Melanoma

Age-adjusted incidence by socio-economic status (males)

- High: 20
- High-mid: 15
- Medium: 10
- Mid-low: 5
- Low: 2.5

(age-adjusted incidence per 100,000)
Female Breast Cancer

Age-adjusted incidence by socio-economic status (females)

- **High**: 120
- **High-mid**: 100
- **Medium**: 80
- **Mid-low**: 60
- **Low**: 40
Cancer of the Cervix

Age-adjusted incidence by socio-economic status (females)
Female Cancer of the Cervix

- **High risk CT**
- **RR=1.5**
- **95% UCI**
- **Expected**

The graph shows observed versus expected cases with a trend line indicating a relative risk of 1.5.
Female Cancer of the Cervix

SES = Adj for SES

Expected cases

0
10
20
30

0
10
20
30
Cancers “cluster” for different reasons

- Lung cancer clusters by smoking, race, education
- Oropharynx cancer by smoking/drinking
- Cervical cancer by self/partner’s sexual activity
- Kaposi sarcoma clustered by sexual preference
- Prostate cancer clusters by race, access to care
- Stomach cancer clusters by history of poverty
- Liver cancer clusters by parental ethnicity
- Thyroid cancer clusters by access to screening
- Mesothelioma clusters by occupation
- Melanoma clusters by race and education
- Breast cancer clusters by education/occupation
Characteristics of SSRL Offsite Tracts

• They are not characteristic of their respective Counties in terms of:
  – Income and, doubtless, education
  – Race/ethnicity
Median Family Income of Counties and of High Risk Tracts

- Los Angeles County
- LA Co. High Risk Tracts
- Ventura County
- Ven. Co High Risk Tracts
From where do case reports come?

- Cancer reporting is mandatory since 1988
- California Cancer Registry covers the State
- All invasive malignancies (a few benign tumors)
- All cases found in a CA resident at diagnosis
- Hospitals collect reports to maintain certification
- Non-hospital labs, death certificates covered
- Reports returned to the place of residence
- Around 99% complete by regular audits using sampling and death certificates
Malignancies according to Annual (Age-Adjusted) New Cases /100,000

• 50+: M Prostate, F Breast

• 30-49: MF Lung, M/F Colorectum

• 10-29: MF Melanoma, M Oropharynx, M Bladder, F Ovary, F Endometrium, MF Non-Hodgkin Lymphoma, M Leukemia

• 5-9: M Stomach, M Larynx, M Testes, F Melanoma, F Thyroid

• <5: M Thyroid, M Penis, F Stomach, F Larynx, F Bladder, MF Liver, MF Esophagus, MF Gallbladder, MF Hodgkin Lymphoma, MF Eye
Selection of malignancies

• Every cancer has a unique set of causes
  – (A few exposures, i.e. smoking, cause a portion of several cancers, but the rate of cancer at all sites is not informative)

• Cancers were selected for assessment:

• In all, thirteen different malignancies
  – The four most common cancers
  – Others possibly caused by chemicals/radiation
<table>
<thead>
<tr>
<th>Neoplasm</th>
<th>Major Causes</th>
<th>Descriptive Predictors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung</td>
<td>Cigarette smoking</td>
<td>Blue collar occupation</td>
</tr>
<tr>
<td>Bladder</td>
<td>Cigarettes, aniline dyes (rare)</td>
<td>White Race</td>
</tr>
<tr>
<td>Pancreas</td>
<td>Cigarette smoking</td>
<td>None strong</td>
</tr>
<tr>
<td>Oropharynx</td>
<td>Tobacco, Alcohol, Pap.Virus</td>
<td>None strong</td>
</tr>
<tr>
<td>Leukemia</td>
<td>Genes, benzene, ? virus</td>
<td>None strong</td>
</tr>
<tr>
<td>Breast</td>
<td>Genes, Hormones</td>
<td>Higher education</td>
</tr>
<tr>
<td>Colorectal</td>
<td>Genes, Diet, Activity</td>
<td>None strong</td>
</tr>
<tr>
<td>Prostate</td>
<td>Genes, Diet</td>
<td>Race, Age, Access to screening</td>
</tr>
<tr>
<td>Thyroid</td>
<td>Ionizing radiation (rare)</td>
<td>Access to screening</td>
</tr>
<tr>
<td>Brain</td>
<td>Ionizing Radiation (rare)</td>
<td>None strong</td>
</tr>
<tr>
<td>Liver</td>
<td>Hepatitis B, C viruses</td>
<td>National origin</td>
</tr>
<tr>
<td>NHL</td>
<td>Immune depletion</td>
<td>None strong</td>
</tr>
<tr>
<td>Melanoma</td>
<td>Sunlight, light skin</td>
<td>Race, Higher education</td>
</tr>
</tbody>
</table>
Screening Methods

• Genders assessed separately
• Three time periods:
  – Separate denominators from 3 censuses

• All census tracts within 5 miles of SSFL
  – 1988-95: 22 VEN, 16 LA census tracts
  – 1996-2003: 29 VEN, 17 LA census tracts
  – 2004-2010: 29 VEN, 17 LA census tracts

• Number of comparisons:
  – 130 period-tracts X 24 gender-cancers = 3120 searches
  – Up to 78 (3 per gender-cancer) “significantly” high-risk tracts by chance
Screening Criteria

- Significantly higher rate than County mean at the 95% confidence level ($p < 0.05$)
- At least a 50% increase in risk ($RR > 1.5$)
- Histological (Causal) homogeneity of excess
To find a result consistent with local cancer causation by disbursed carcinogen

- Consistent risk over calendar time
- High risk for both genders in the same area
- Higher risk proximate to SSRL
- Geographic clustering of high risk areas
- Pattern consistent with dispersion flow
- We screen by a relative risk (RR) of 1.5, but if RR is below 2.0, any observed case would likely have occurred anyway

- No plausible alternative explanation is available
Reasons for Caution in Assessing Impact

- 3 “Significant” excesses each are expected by chance
- No known clear evidence of personal exposure
- Waterborne and airborne dispersion imprecise
- Dosage is unknown
- Exposed workers are likely to reside together
- Census errors: rapid local growth may distort incidence estimates
- Evaluation is based on residential address at diagnosis
## Summary Screening Findings

<table>
<thead>
<tr>
<th>Neoplasm</th>
<th>“Significant” tract-periods</th>
<th>In Both genders</th>
<th>In Adjacent tracts</th>
<th>In 2 or more periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breast</td>
<td>26 (3 exp)</td>
<td>---</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Melanoma</td>
<td>23 (6 exp)</td>
<td>8</td>
<td>17</td>
<td>7</td>
</tr>
<tr>
<td>Colorectal</td>
<td>7 (6 exp)</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Lung</td>
<td>4 (6 exp)</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Prostate</td>
<td>4 (3 exp)</td>
<td>---</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Thyroid</td>
<td>3 (6 exp)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Brain</td>
<td>3 (6 exp)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>NHL</td>
<td>2 (6 exp)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Leukemia</td>
<td>1 (6 exp)</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Bladder</td>
<td>1 (6 exp)</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Oropharynx</td>
<td>0 (6 exp)</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Liver</td>
<td>0 (6 exp)</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Pancreas</td>
<td>0 (6 exp)</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Period</td>
<td>Males</td>
<td>Females</td>
<td>Both</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>-------</td>
<td>---------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>1988-1995</td>
<td><img src="blue_triangle.png" alt="Blue Triangle" /></td>
<td><img src="yellow_triangle.png" alt="Yellow Triangle" /></td>
<td><img src="red_triangle.png" alt="Red Triangle" /></td>
<td></td>
</tr>
<tr>
<td>1996-2003</td>
<td><img src="blue_circle.png" alt="Blue Circle" /></td>
<td><img src="yellow_circle.png" alt="Yellow Circle" /></td>
<td><img src="red_circle.png" alt="Red Circle" /></td>
<td></td>
</tr>
<tr>
<td>2004-2010</td>
<td><img src="blue_square.png" alt="Blue Square" /></td>
<td><img src="yellow_square.png" alt="Yellow Square" /></td>
<td><img src="red_square.png" alt="Red Square" /></td>
<td></td>
</tr>
</tbody>
</table>
Malignant Melanoma 1988-1995
Malignant Melanoma 2004-2010
Malignant Melanoma
Malignant Melanoma
Malignant Melanoma-Adjusted for SES
MALE MELANOMA
Breast cancer 2004-2010
Thyroid Cancer
Prostate Cancer
Likely effects of Lifestyle
Some clustering of risk is expected

- Breast and Malignant Melanoma
  - Known strong risk of race and high income/education

- Prostate and Thyroid cancers
  - Known to often not progress; commonly found by asymptomatic screening (PSA, ultrasound) with high access to care (high income/education)

- Lung and Colorectal cancers
  - Strongly determined by habitual factors:
    - Smoking for lung, diet/physical inactivity for colorectal
Non-Hodgkin Lymphoma
MALE LEUKEMIA
These cancer rubrics oversimplify causal heterogeneity

- Brain: several excess cases are benign, slow-growing tumors with different causes

- Non-Hodgkin lymphoma excess includes at least five different malignancies known to have different causes

- Leukemia excess also is made up of three common and several uncommon varieties

- In each of these, the “high-risk” tracts identified were no more numerous than was expected by chance, and included cases of diverse, most having no known environmental causation
Excess of bladder cancer in one tract in 2004-2010

- Extreme finding: RR >4
- Case tumors had the same common histology
- Most residences scattered, but several are within one mile
- The most prevalent cause of bladder cancer is smoking
- Environmental causes are industrial, waterborne arsenic
- Diagnoses were not clustered in time
- The tract is more than 5 miles to the west of SSFL
- Residential community: no known exposure, specifically no high arsenic in tap water, no local industry, no increase in kidney cancer (another arsenic outcome)
- 66% of the cases were >75 at diagnosis, and all but one of those was over 85.
- Census may have undercounted seniors
<table>
<thead>
<tr>
<th>Neoplasm</th>
<th>“Significant” tract-periods</th>
<th>Observed/Expected number per tract</th>
<th>Interpretation</th>
<th>Estimated number of CA tracts with that many or more cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>NHL</td>
<td>2 (3 exp. by chance)</td>
<td>8/2.5</td>
<td>No clustering of high-risk tracts No evidence of proximity to SSFL Mixture of cell types, no trend</td>
<td>50-100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12/5.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brain</td>
<td>3 (3 exp. by chance)</td>
<td>6/0.9</td>
<td>No clustering of high-risk tracts No consistent proximity to SSFL Mixture of cell types, no trend</td>
<td>10-50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8/2.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>11/3.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leukemia</td>
<td>1 (3 exp. by chance)</td>
<td>7/1.3</td>
<td>No clustering of high risk tracts No evidence of proximity to SSFL Mixture of cell types, no trend</td>
<td>10</td>
</tr>
<tr>
<td>Bladder</td>
<td>1 (3 exp. by chance)</td>
<td>11/2.5</td>
<td>No clustering of high risk tracts No evidence of proximity to SSFL No evidence of carcinogens Preponderance of elderly cases ? Smoking, census error</td>
<td>1-2</td>
</tr>
</tbody>
</table>
Conclusion

- It is not possible to completely rule out any offsite carcinogenic effects from SSFL.

- No evidence of measureable offsite cancer causation occurring as a result of emissions from the SSFL was found.

- Further, no evidence of any cancer causation by any environmental factor was found.