Radiation-induced genetic effects in Europe and the Chernobyl Nuclear Power Plant catastrophe
Content

- Genetic effects
- Dosimetry
- Fallout and genetic effects: own publications
- Sex odds and atmospheric atomic bomb testing
- Sex odds in USA, Europe, and parts of Asia: 1970 – 2007
- Ecological dose-response
- Possible scale of reproductive detriment due to the Chernobyl accident
- Conclusion
Genetic effects – **Definition**

**Discovery of X–ray mutagenesis by HJ Muller 1926**

- Muller carried out experiments with varied doses of X-rays to *Drosophila*. A connection between radiation and lethal mutations emerged.

- By 1928, others had replicated his results, expanding them to other model organisms such as wasps and maize.

**Definition** A genetic effect may be the result of radioactivity or substances that cause damage to (the genes of) a reproductive cell (sperm or egg), or a somatic cell, which can then be passed from one generation to another, or may induce disease (e.g. cancer) in an individual. 

http://www.doh.wa.gov/Hanford/publications/overview/genetic.html

- **Examples** Sex odds, birth defects, stillbirths, leukemia, thyroid cancer

Genetic effects – sex odds (or less systematically: sex ratio)

Genetic theory for the human sex odds at birth

Irradiated parents and offspring gender

- Fathers only => sex odds
- Mothers only => sex odds
- Both parents => ???

Dosimetry – *Fallout and dose formation*

**Working hypothesis**

In the first few years after the ChNPP accident, deposition of

\[
46.6 \text{ kBq/m}^2 \text{ Cs-137} \\
+ 23.3 \text{ kBq/m}^2 \text{ Cs-134}
\]

generated an effective dose of \(1 \text{ mSv/a}\)


*BStMLU and BStMELF* (1987). Radioaktive Kontamination der Böden in Bayern. Munich: Bayerische Staatsministerien für Landesentwicklung und Umweltfragen (BStMLU) und für Ernährung, Landwirtschaft und Forsten (BStMELF)
Fallout and genetic effects: own publications

➢ Perinatal mortality and stillbirths

➢ Birth defects
  Scherb H, Weigelt E Congenital Malformation and Stillbirth in Germany and Europe Before and After the Chernobyl Nuclear Power Plant Accident. ESPR - Environ Sci & Pollut Res, 10 Special (1) 2003 Dec, 117-125
  Scherb H, Weigelt E Cleft lip and cleft palate birth rate in Bavaria before and after the Chernobyl nuclear power plant accident [Article in German, Abstract in English]. Mund Kiefer Gesichtschir. 2004 Mar;8(2):106-10

➢ Sex odds in Europe
Fallout and genetic effects: own publications – examples


**Fig. 1** Stillbirth proportion for the combined two most highly contaminated districts in Bavaria: Augsburg-City (53.7 kBq/m²) and Berchtesgaden (50.3 kBq/m²) including change-point (CP) and reduced change-point (CPr) models.

**Fig. 2** Stillbirth proportions for Bavaria+GDR, West Berlin, Denmark, Hungary, Iceland, Latvia, Norway, Poland, and Sweden combined, change-point (CP) and reduced change-point (CPr) models.
Fallout and genetic effects: own publications – *examples*

2. Example: Stillbirth in Finland, 1977 – 1992  
prevalence data by exposure quintiles

![Graphs showing prevalence data by exposure quintiles](image)

| Mean $\mu$Sv 5/86 from Chernobyl in Finish Population quintiles |
|-----------------|---|
| Q1              | 6.6 |
| Q2              | 13.0 |
| Q3              | 31.0 |
| Q4              | 70.0 |
| Q5              | 137.9 |
| total           | 51.7 |
Fallout and genetic effects: own publications – *examples*

2. Example: Stillbirth in Finland, 1977 – 1992  *spatial temporal model*

<table>
<thead>
<tr>
<th>Year</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977</td>
<td>6.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.003</td>
</tr>
<tr>
<td>1982</td>
<td>13.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.004</td>
</tr>
<tr>
<td>1987</td>
<td>31.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.005</td>
</tr>
<tr>
<td>1992</td>
<td>70.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.006</td>
</tr>
<tr>
<td>1977</td>
<td>137.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.007</td>
</tr>
<tr>
<td>1982</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>1992</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fallout and genetic effects: own publications – examples

2. Example: Stillbirth in Finland, 1977 – 1992  dose specific risk

<table>
<thead>
<tr>
<th>OR per mSv/a</th>
<th>1.25</th>
</tr>
</thead>
<tbody>
<tr>
<td>95% CL</td>
<td>[1.10, 1.42]</td>
</tr>
<tr>
<td>p-value</td>
<td>0.0006</td>
</tr>
</tbody>
</table>
Fallout and genetic effects: own publications – examples

3. Example: Sex odds and fallout (dose) in Germany  spatial distribution of fallout

Bavaria

former GDR
Fallout and genetic effects: own publications – examples

3. Example: Sex odds and fallout (dose) in Germany 1986+1987 depending on the excess dose by Chernobyl fallout: 0.0143 (mSv/a)/ (kBq/m2)

| OR/(mSv/a) | 1.0380 |
| 95%-CI     | [1.0126, 1.0640] |
| p-value    | 0.0031 |
Fallout and genetic effects: own publications – examples


Sex odds ratios per mSv/a and 95% CL (adjusted for pre period, and non-adj.)

**Fig. 5:** Birth prevalences of two congenital heart malformations (ICD7454+ICD7455, n = 2797) in Bavaria; stratification according to contamination of districts (see Table 1)

| Table 1: The ten least and most contaminated districts in Bavaria, mean $^{137}$Cs measurements |
|-----------------------------------------------|-----------------------------------------------|
| District                                      | $^{137}$Cs kBq/m² | District                                      | $^{137}$Cs kBq/m² |
| Augsburg, City                               | 53.7             | Schweinfurt, City                            | 5.3              |
| Baiersbronn                                   | 50.3             | Neumarkt, City                              | 4.9              |
| Germering, Pforzheim                         | 49.5             | Mittelfranken, City                         | 4.7              |
| Memmingen, City                              | 48.2             | Main-Spessart, City                         | 4.6              |
| Ulm/Neckar                                    | 36.6             | Würzburg, City                              | 4.6              |
| Augsburg                                      | 12.3             | Regenstaufen, City                          | 4.4              |
| Aichach-Friedberg                            | 10.6             | Regenstaufen, City                          | 3.9              |
| Landshut-Laden                                | 9.3              | Regenstaufen, City                          | 3.7              |
| Neuburg-Schrobenhausen                       | 27.7             | Regenstaufen, City                          | 3.1              |
Sex odds and atmospheric atomic bomb testing

Similar effects on the sex odds as recently published have already been observed in the USA and in Europe on a global scale in the 1960s and 1970s, but have not yet been acknowledged as possible effects of atmospheric atomic bomb test fallout. Note, the “missing boys” in the “sex ratio literature” may be “less missing girls” from the 1970s onward, after the atmospheric atomic bomb test ban.

Sex odds in USA, Europe, and parts of Asia: 1970 – 2007

USA

Live birth sex odds: USA

sex odds

1.040  1.045  1.050  1.055  1.060


ChNPP
### Sex odds in USA, Europe, and parts of Asia: 1970 – 2007

#### Europe and parts of Asia

<table>
<thead>
<tr>
<th>Europe IIIa, 1970-2007, complete data</th>
<th>Births and sex odds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>Luxembourg</td>
</tr>
<tr>
<td>France</td>
<td>Malta</td>
</tr>
<tr>
<td>Ireland</td>
<td>Netherlands</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Europe IIIb, 1970-2007, complete data</th>
<th>Births and sex odds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albania</td>
<td>Germany</td>
</tr>
<tr>
<td>Austria</td>
<td>Greece</td>
</tr>
<tr>
<td>Belarus</td>
<td>Hungary</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>Iceland</td>
</tr>
<tr>
<td>Czechoslovakia (f.)</td>
<td>Italy</td>
</tr>
<tr>
<td>Denmark</td>
<td>Latvia</td>
</tr>
<tr>
<td>Estonia</td>
<td>Lithuania</td>
</tr>
<tr>
<td>Finland</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Former SU Republics, 1980-2005, incomplete data</th>
<th>Births and sex odds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kazakhstan (E)</td>
<td>Tajikistan</td>
</tr>
<tr>
<td>Kyrgyzstan</td>
<td>Turkmenistan</td>
</tr>
<tr>
<td>Moldova (E)</td>
<td>Ukraine (E)</td>
</tr>
</tbody>
</table>

40 countries with territory in Europe + 4 Asian countries; Spain omitted because of unusual trend; also ommitted: Andorra, Liechtenstein, Monaco, Turkey, and Vatican due to no data at all, or essentially incomplete data.
Sex odds in USA, Europe, and parts of Asia: 1970 – 2007

Pertinent demographic INTERNET data bases

http://data.euro.who.int/hfadb/
http://www.coe.int/t/e/social_cohesion/population/BELTAB2.xls
http://epp.eurostat.ec.europa.eu/portal/page?_pageid=0,1136184,0_45572595&_dad=portal&_schema=PORTAL
http://www.johnstonsarchive.net/policy/abortion/ab-poland.html
Sex odds in USA, Europe, and parts of Asia: 1970 – 2007

Western Europe – less exposed

Live birth sex odds: Europe III.a
Sex odds in USA, Europe, and parts of Asia: 1970 – 2007

Central and eastern Europe – moderately or highly exposed

Live birth sex odds: Europe III.b

![Graph showing sex odds over years in Europe from 1966 to 2010. The graph indicates a trend with a significant drop in 1986, possibly due to the Chernobyl Nuclear Power Plant accident (ChNPP).]
Sex odds in USA, Europe, and parts of Asia: 1970 – 2007

Former SU republics, parts of Asia – presumable high exposure

Live birth sex odds: Asia — former SU republics

sex odds

1.045 - 1.065


ChNPP
Sex odds in USA, Europe, and parts of Asia: 1970 – 2007

Summary: USA, Europe, and parts of Asia
Ecological dose-response

➢ **Hypothesis**  
Jump heights in sex odds after Chernobyl are depending on the amount of fallout (=> national excess average effective doses)

➢ **Test**  
Consider sex odds ratios in countries with differing levels of fallout after Chernobyl

➢ **Fallout level**  
- **low**  
  - France
- **intermediate**  
  - Denmark, Germany, Italy, Yugoslavia (f.)
- **high**  
  - Belarus, Russian Federation
Ecological dose-response

Live birth sex odds: France

sex odds

1.040 1.045 1.050 1.055 1.060 1.065 1.070 1.075 1.080


ChNPP
Ecological dose-response

Live birth sex odds: Germany

sex odds


ChNPP

Helmholtz Zentrum München
German Research Center for Environmental Health
Ecological dose-response

Live birth sex odds: Italy

sex odds

1.040 1.045 1.050 1.055 1.060 1.065 1.070 1.075 1.080


ChNPP
Ecological dose-response

Live birth sex odds: Yugoslavia (f.)

sex odds


ChNPP
Ecological dose-response

Live birth sex odds: Russian Federation

sex odds

1.040 1.045 1.050 1.055 1.060 1.065 1.070 1.075 1.080


ChNPP
Ecological dose-response

Live birth sex odds: Belarus

sex odds

1080
1.075
1.070
1.065
1.060
1.055
1.050
1.045
1.040


ChNPP

Helmholtz Zentrum München
German Research Center for Environmental Health
Ecological dose-response

Live birth sex odds: Denmark

sex odds


ChNPP
Ecological dose-response *(German collective dose data)*

<table>
<thead>
<tr>
<th>Gebiet</th>
<th>Effektive Dosis im 1. Jahr (mSv)</th>
<th>Gesamte effektive Dosis für die nach dem Unfall folgenden 50 Jahre (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voralpengebiet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Süßlich Donau</td>
<td>0,5-1,1</td>
<td>0,6</td>
</tr>
<tr>
<td>Nördlich Donau</td>
<td></td>
<td>0,2</td>
</tr>
</tbody>
</table>
Ecological dose-response ("national dosimetry")

Sex odds ratio by "optimum" national average effective dose estimates (jump heights in 1987 interpreted as dose)

- F: France
- G: Germany (standard)
- I: Italy
- Y: Yugoslavia (f.)
- R: Russian Federation
- B: Belarus
- D: Denmark
Ecological dose-response ("national dosimetry")

Optimum excess collective doses per year in France, Italy, former Yugoslavia, Russian Federation, Belarus, and Denmark based on the linearity assumption, the jump heights in 1987 and the overall excess collective dose in Germany of 0.15 mSv/year from 1987 to 2007 (Germany serves as a standard)

<table>
<thead>
<tr>
<th>Country</th>
<th>jump OR</th>
<th>mSv/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>1.0002</td>
<td>0.02</td>
</tr>
<tr>
<td>Germany</td>
<td>1.0018</td>
<td>0.15</td>
</tr>
<tr>
<td>Italy</td>
<td>1.0027</td>
<td>0.22</td>
</tr>
<tr>
<td>Yugoslavia (f.)</td>
<td>1.0074</td>
<td>0.61</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>1.0090</td>
<td>0.74</td>
</tr>
<tr>
<td>Belarus</td>
<td>1.0092</td>
<td>0.75</td>
</tr>
<tr>
<td>Denmark</td>
<td>1.0104</td>
<td>0.85</td>
</tr>
<tr>
<td><strong>jump OR per mSv</strong></td>
<td><strong>1.0121</strong></td>
<td></td>
</tr>
</tbody>
</table>
Possible scale of reproductive detriment due to the Chernobyl accident

### Possible scale of lost or impaired children after Chernobyl in all of Europe and the part of Asia covered

<table>
<thead>
<tr>
<th></th>
<th>Observed 1987 ≤ Births ≤ 2007</th>
<th>Expected Births</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>183 802 030</td>
<td>184 883 430</td>
</tr>
<tr>
<td>male</td>
<td>94 446 893</td>
<td>94 696 447</td>
</tr>
<tr>
<td>female</td>
<td>89 355 137</td>
<td>90 186 983</td>
</tr>
<tr>
<td>sex odds</td>
<td>1.0570</td>
<td>1.0500</td>
</tr>
<tr>
<td>missing boys</td>
<td>249 554</td>
<td></td>
</tr>
<tr>
<td>missing girls</td>
<td>831 846</td>
<td></td>
</tr>
</tbody>
</table>

**sex OR/mSv**

| 1.0145 (1.0021–1.0271) | 0.460 |

**1987 ≤ Births ≤ 2007**

- BD 3%(LB)+0.5%(TB): 6 437 689
- OR/mSv*: 1.54

**BD doubling dose**: 1.61

- OR BD+SB: 1.22
- **Excess BD+SB**: 1 415 769

**Lost or impaired children**: 2.5 millions

Conclusion

**UNSCEAR**\(^1\) states “The estimate of risk” (at 1 Gray) “for congenital abnormalities is about 2,000 cases per million live births (compared to 60,000 cases per million live births)”

\[
RR/1\text{Gy}=\frac{62,000}{60,000}=1.033
\]

This means **Doubling Dose=21.3 Gy**

As we have shown for congenital malformations\(^2,3\) (e.g. malformations of the heart, deformities, Down syndrome, using data from the Bavarian congenital malformation data set), the doubling dose is in the order of magnitude of below a few mSv. Thus,

**UNSCEAR is in error at least at 3 orders of magnitude**

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1. UNSCEAR 2001 Report, Hereditary Effects of Radiation, Scientific Annex, p. 82
3. Sperling K et al. Low dose irradiation and nondisjunction: Lessons from Chernobyl, 19th Annual Meeting of the German Society of Human Genetics, April 8-10, 2008, Hanover, Germany, Abstractbook, p. 174-175
Conclusion

The consistency of our results implies

- there is harm of ionizing radiation below 1 mSv, or
- the dose concept is invalid altogether, or
- the exposure after Chernobyl was higher than assumed, or
- some combination of the above points

Genetic effects of ionizing radiation in humans, animals (and plants) should be investigated more objectively and more thoroughly

- birth defects
- stillbirths
- secondary sex ratio
- cancer induction, e.g. leukemia
- combinatory effects (radiation & chemicals)
- synergistic effects
Concluding remark

A Wake-Up Call for Everyone
Who Dislikes Cancer and Inherited Afflictions

Spring 1997
By John W. Gofman, M.D., Ph.D.
Egan O'Connor, Executive Director of CNR

In our own view, it is quite possible that a permanent doubling of the "background" dose of ionizing radiation, worldwide, would very gradually double mankind's burden of inherited afflictions --- from mental handicaps to predispositions to emotional disorders, cardiovascular diseases, cancers, immune-system disorders, and so forth. Such a doubling would be the greatest imaginable crime against humanity (nature ...)
Thank you

Dr. Hagen Scherb and Dr. Kristina Voigt
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