Ionizing radiation and health of nuclear industry workers

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The data

Most of the data of our interest are published in papers [5] and [7] based on the study of about 600,000 radiation workers from 15 countries.

The mortality rate is drastically lower than "normal" in all causes (Figs 1,2,3). According to the authors of [5], the lowering of SMR can be attributed to Healthy Worker Effect (HWE). If HWE was a strong factor in the studies [5], the values of SMR should rather be lower than the ones summarized by Luckey [8,9] (see Fig. 4) or in [10,11] (Taiwan houses). Many researches also noted that the concept of HWE is useless in epidemiological studies [17-19].

Staying on the ground of pure data one should say that the SMR dependence on the dose cannot be unambiguously determined (Figs 2 and 3). The differences between data are much larger than declared statistical errors, so the only value which eventually makes sense is an average.

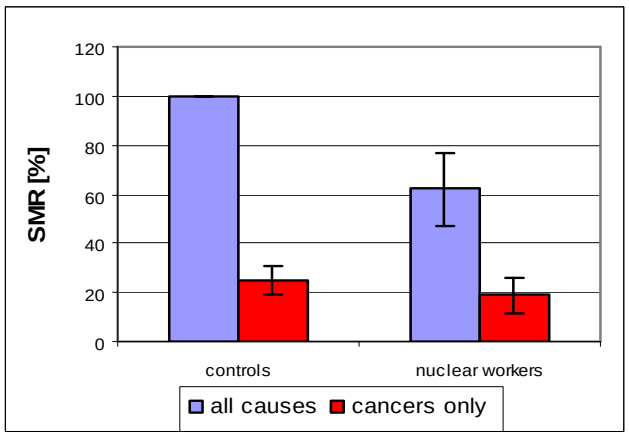

Fig.1. The SMR for all cancers (red pillars) and all causes (blue pillars) in two cases: control population (left) and nuclear installations workers (right)

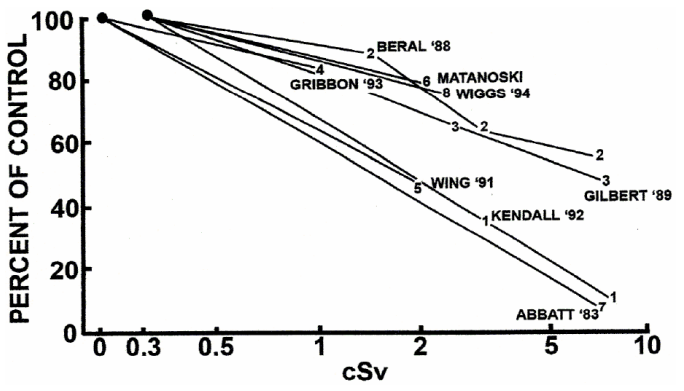

Fig. 4. Reduced cancer mortality in nuclear workers following exposure to ionising radiation. Data from Luckey [9].

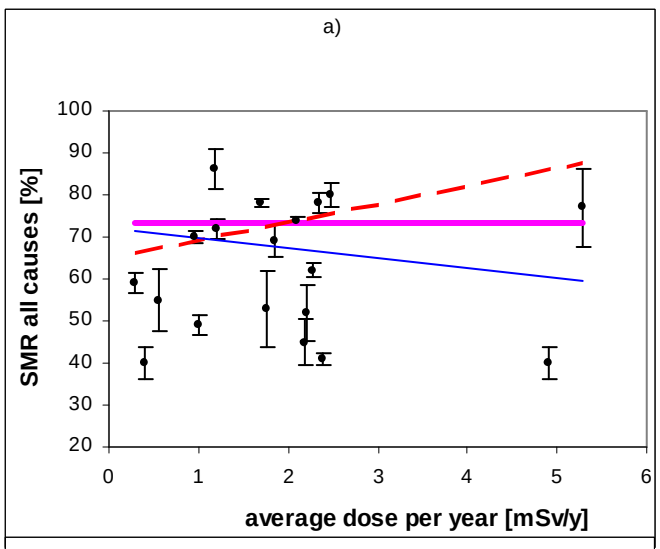

Fig.2. SMR [%] for deaths from all causes vs a) average dose per year [mSv/y]; b) average median per year [mSv/y]. The violet line gives an average by Bayesian analysis, dashed line with a slope is a Bayesian fit and the thin line is a standard χ^2 fit

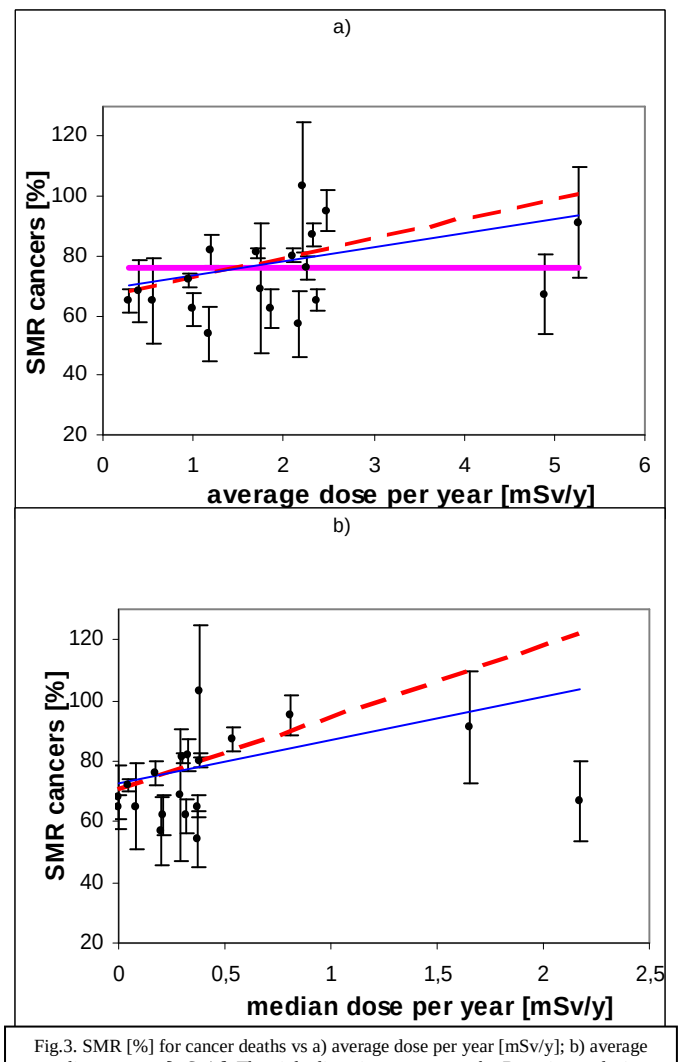

Fig.3. SMR [%] for cancer deaths vs a) average dose per year [mSv/y]; b) average median per year [mSv/y]. The violet line gives an average by Bayesian analysis, dashed line with a slope is a Bayesian fit and the thin line is a standard χ^2 fit

Linear dose-effect relationship fitted to the data

The fits were carried out by conventional least-square (χ^2) method, and by means of the Bayesian analysis [14,15]. In the latter, the accuracies of the data allowed to vary in the way described in [15].

Relative risk (RR, Fig. 5) set to a constant,: $\langle RR \rangle = 1.001 \pm 0.004$ with $\chi^2 = 11.2$.

Treating the point at 175 mSv as an "outlier" , $\langle RR \rangle$ changes to 0.994 ± 0.005 with $\chi^2 = 2.1$. Thus almost all misfit calculated and shown in the first result relies on this single point. All other points lie almost perfectly on the line RR=1.

For $RR = a\langle D \rangle + b$, where $\langle D \rangle$ is the average annual dose, one gets: $a = (5.5 \pm 4.2) \cdot 10^{-4}$/mSv, $b = 0.990 \pm 0.022$ with $\chi^2 = 9.5$ for cancer deaths.

From the Bayesian analysis [14]: $a = (2.9 \pm 16.7) \cdot 10^{-4}$, $b = 1.05 \pm 0.24$ with $\chi^2 = 1.04$.

Conclusions

The data on deaths from all causes and cancer deaths among workers in nuclear industry are considered in light of the data published by IARC in 2007 [5-7]. The dose-effect relationship is assumed to be linear with arbitrary sign of the slope. Also zero effect of the dose is considered. Conventional and Bayesian analysis is used. It is shown that in spite of large cohort studied in [5-7], the data for overall mortality reveal so large scattering that arriving at definite conclusions is not possible. These data, however, are consistent with the earlier findings [8,9,12] that irradiated workers exhibit lower standardized mortality ratios (SMRs) than the control group. Similar situation is found in the case of cancer deaths. While no convincing support for Healthy Worker Survivor Effect (HWSE) is found, SMRs lowered by about 25% turn out to be not easily attributable to the Healthy Worker Effect (HWE).

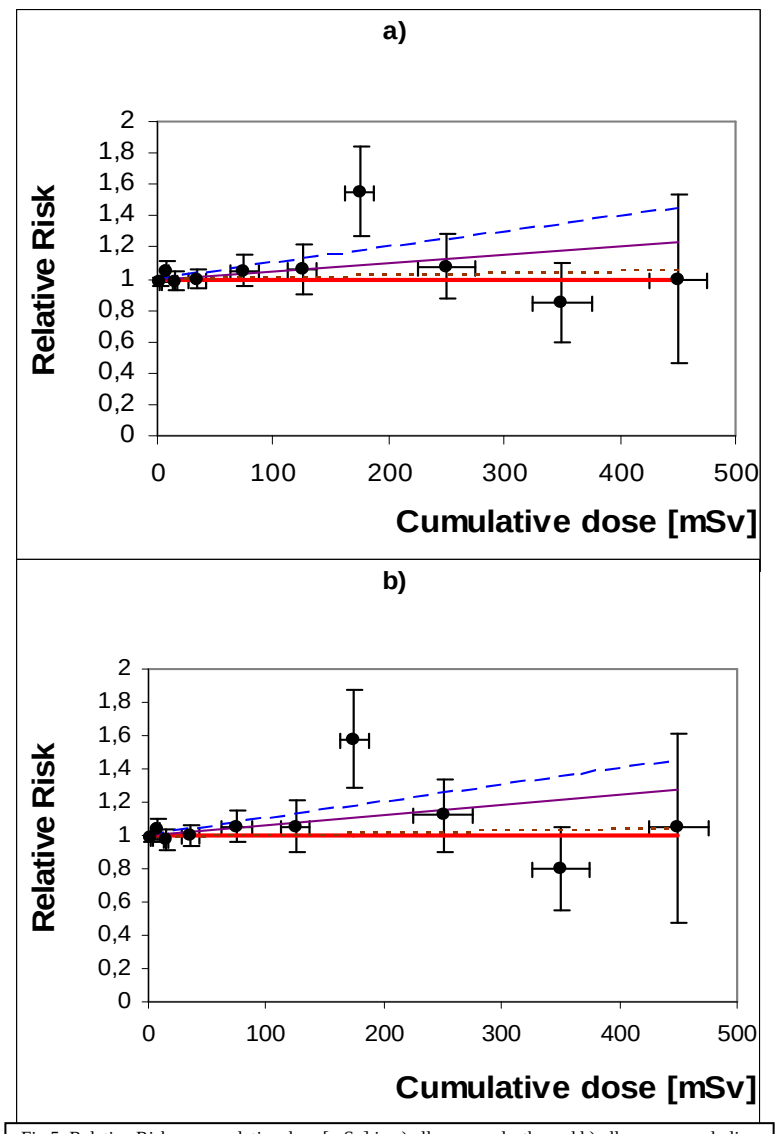

Fig.5. Relative Risk vs cumulative dose [mSv] in a) all cancers deaths and b) all cancers excluding leukemia. Solid red horizontal line corresponds to RR=1, dashed line is a fit as given in [6], solid line corresponds to the solution (3), and dotted line is a Bayesian fit, when the point for 175 mSv is not taken into account.

Literature

1. UNSCEAR (1994) Annex B: *Adaptive responses to radiation in cells and organisms*. In *Sources and Effects of Ionizing Radiation. Report of the United Nations Svcientific Committee on the Effects of Atomic Radiation*, United Nations, 185-272 (1994)
2. T.D.Luckey, *Radiation Hormesis*, Boca Raton: CRC Press (1991)
3. E.Cardis et al., *Effects of Low Doses and Low Dose Rates of External Ionizing Radiation: Cancer Mortality Among Nuclear Industry Workers in Three Countries*, Radiat. Res. 142 (1995) 117-132
4. T.D.Luckey, Nuclear law stands on thin ice, Int. J. Nuclear Law 2 (2008) 33-65
5. M.Vrijheid et al., *The 15-Country Collaborative Study of Cancer Risk among Radiation Workers in the Nuclear IndustryDesign, Epidemiological Methods and Descriptive Results*, Rad. Res. 167 (2007) 396-416
6. I.Thierry-Chef et al., *The 15-Country Collaborative Study of Cancer Risk among Radiation Workers in the Nuclear Industry: Study of Errors in Dosimetry*, Rad. Res. 167 (2007) 396-416
7. E.Cardis et al., *The 15-Country Collaborative Study of Cancer Risk among Radiation Workers in the Nuclear Industry: Estimates of Radiation-Related Cancer Risks*, Rad. Res. 167 (2007) 396-416
8. T.D.Luckey, *Radiation Hormesis Overview*, RSO Magazine 8 (2008) 22-39
9. T.D.Luckey, *Documented optimum and threshold for ionizing radiation*, Int.J.Nuclear Law, 1 (2007) 378-409
10. W.L.Chen et al., *Is chronic radiation an effective prophylaxis against cancer*, J.Amer.Physicians and Surg. 9 (2004) 6-10
11. Hwang, S.-L. et al., *Estimates of Relative Risks for Cancers in a Population after Prolonged Low-Dose-Rate Radiation Exposure: A Follow-up Assessment from 1983 to 2005*, Radiat. Res. 170 (2008) 143-148
12. T.Rockwell, J.Muckerheide, *Testimony to the Nuclear Regulatory Commission's Advisory Committee on Nuclear Waste&Materials*, Radiation, Science & Health, April 8 (2008)
13. R.Sponsler and J.Cameron, *Nuclear Shipyard Worker Study*, Int. J. Low Radiation 1 (2005) 463-478
14. D.S.Sivia, J.Skilling, *Data Analysis. A Bayesian Tutorial*, Oxford University Press (2006)
15. D.S.Sivia, *Dealing with Duff Data*, in *MaxEnt 96: Proc. Maximum Entropy Conf.* M.Sears, V.Nedeljkovic, N.E.Pendock, S.Sibisi, Eds., Univ. Witwatersrand, Johannesburg, South Africa (1996) 131-137
16. HBRRG (High Background Radiation Research Group), *Aspects of environmental radiation and dosimetry concerning the high background radiation areas in China*, J.Rad.Res. (Tokyo) 22 (1981) 88-90; Science 209 (1981) 877-879
17. C.-Y. Li, F.-C. Sung, *A review of the healthy worker effect in occupational epsiemiology*, Occup. Med. 49/4 (1999) 225-229
18. R.R. Monson, *Observations on the healthy worker effect*, J.Occup.Med 28 (1986) 425-433
19. B.L. Cohen, *Cancer Risk from Low-Level Radiation*, A.J.R. 179 (November 2002)
20. B.L.Cohen, *The Linear No-Threshold Theory of Radiation Carcinogenesis Should be rejected*, J.A.Phys.Surg. 13 (2008) 70-76
21. K.Sakamoto, *Radiobiological basis for cancer therapy by total or half-body irradiation*, Nonlinearity in Biology, Toxicology and Medicine 2 (2004) 293-316
22. B.E.Leonard, A review: development of microdose model for analysis of adaptive response and bystander dose response behavior, Dose-Response 6 (2008) 113-183