



Figure 1 Excess thyroid cancer risk in the period 1991–1995 among people born between 1971 and 1986. The dots indicate average values of settlements in the categories of dose 0.05–0.1, 0.1–0.2, 0.2–0.5, 0.5–1.0, and 1–2 Gy; the stars show results for cities with large collective doses; PY = person-year. The solid line is the best estimate of the excess absolute risk per unit dose. Broken and dotted lines indicate 95% confidence ranges.

Kiev) indicates that most of the cases would have become obvious independent of any screening.

In southern Ukraine, the thyroid cancer incidence rate in 1991 to 1995 among the birth cohort 1971 to 1986 was 4.2 per 10⁶ person-years⁹. Confidence intervals were derived from incidences in the period 1986 to 1988. In the northern part of Ukraine, the incidence differed by a factor of 1.5, and in Belarus and Bryansk by a factor of two from the incidence in southern Ukraine. The excess absolute risk shows no statistically significant deviation from a linear dose–response relationship (Fig. 1). A χ^2 -fit to data pooled for each of the three countries resulted in an excess absolute risk per unit dose of 2.3 (95% confidence interval: 1.4–3.8) per 10⁴ person-year Gy (grays: a unit of absorbed dose). This is a factor of two lower than the best estimate derived from a previous study of thyroid cancer after external exposures where the period of follow-up ranged from five years to several decades¹⁰. However, the result lies within the 95% confidence interval of that study. During the observation period of our study, the excess thyroid cancer incidence was rising. So the excess absolute risk per unit dose is expected to increase for longer observation periods.

The excess relative risk per unit dose ranges between 22 Gy⁻¹ (Zhytomyr oblast) and 90 Gy⁻¹ in the study area. These results are higher than those obtained from longer observation periods after external exposures¹⁰, possibly because the population we studied is still young and therefore has very low baseline rates.

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1. Kazakov, V. S., Demidchik, E. P. & Astakova, L. N. *Nature* 359, 21 (1992).
2. Likhtarev, I. A. *et al. Nature* 375, 365 (1995).
3. Goulko, G. M. *et al. Radiat. Environ. Biophys.* 36, 261–273 (1998).
4. Likhtarev, I. A. *et al. Health Phys.* 69, 6–15 (1995).
5. Drozdovitch, V. V. *et al. Radiat. Environ. Biophys.* 36, 17–23 (1997).
6. Gavrilin, Y. *et al. in The Radiological Consequences of the Chernobyl Accident*, 1011–1020 (EUR 16544, European Commission, 1996).
7. Zvonova, I. A. & Balonov, M. I. in *The Chernobyl Papers*, 71–126 (Research Enterprises Publishing Segment, Richland, Washington, 1993).
8. Williams, E. D. *et al. in The Radiological Consequences of the Chernobyl Accident* 699–714 (EUR 16544, European Commission, 1996).
9. Sobolev, B., Heidenreich, W. F., Kairo, I., Jacob, P., Goulko, G. & Likhtarev, I. *Radiat. Environ. Biophys.* 36, 195–199 (1997).
10. Ron, E. *et al. Radiat. Res.* 141, 259–277 (1995).

Sulphur isotope data consistency improved

The standard used for reporting relative sulphur isotope-abundance data has, historically, been troilite (FeS) derived from the Cañon Diablo meteorite, CDT. However, the isotopic inhomogeneity of this material — the variability in its sulphur-34/sulphur-32 isotope ratio is at least 0.4‰ — greatly exceeds the achievable analytical uncertainty of 0.05‰ (ref. 1). Accordingly, the International Union of Pure and Applied Chemistry (IUPAC) has recommended the setting up of a VCDT scale, which is expected to improve agreement between laboratories in measuring this ratio, $\delta^{34}\text{S}$.

Table 1 Examples of reference material

Name	NIST reference no.	$\delta^{34}\text{S}$
IAEA-S-1 silver sulphide	RM 8554	–0.3‰
IAEA-S-2 silver sulphide	RM 8555	~22‰
IAEA-S-3 silver sulphide		~32‰
NBS-123 sphalerite	RM 8556	~17‰
NBS-127 barium sulphate	RM 8557	~20‰
Soufre de Lacq elemental S	RM 8553	~16‰

A proposal that a VCDT scale be established was originally made in 1993, at the Consultants’ Meeting on Stable Isotope Standards and Intercomparison Materials, in Vienna, sponsored by the International Atomic Energy Agency (IAEA)². The scale is defined by assigning a $\delta^{34}\text{S}$ value of –0.3‰ exactly (relative to VCDT) to the internationally distributed silver sulphide reference material IAEA-S-1 (formerly called NZ1). This decision was based upon measurements of IAEA-S-1 in several laboratories using SO_2 ($\delta^{34}\text{S} = -0.25 \pm 0.31\text{‰}(2\sigma)$ for 17 laboratories³) and SF_6 ($\delta^{34}\text{S} = -0.3 \pm 0.1\text{‰}(2\sigma)$ for three laboratories³).

This recommendation by the IAEA consultants found favour with the Commission on Atomic Weights and Isotopic Abundances of IUPAC at a meeting in Guildford in the United Kingdom, in August 1995 (ref. 4). Accordingly, IUPAC recommended that:

- the use of meteoritic troilite and the reporting of $\delta^{34}\text{S}$ data relative to CDT be discontinued;
- relative sulphur isotopic abundance data be reported relative to VCDT; and
- the VCDT scale be established in laboratories through the use of IAEA-S-1 silver sulphide.

In addition, authors are encouraged to report $\delta^{34}\text{S}$ values for internationally distributed sulphur isotopic reference materials (Table 1) if they have been analysed. Sources of isotopic reference materials include:

- the National Institute of Standards and Technology, Standard Reference Materials Program, Room 204, Building 202, Gaithersburg, Maryland 20899-0001, United States. Tel: +1 301 975 6776; fax: +1 301 948 3730; e-mail: SRMINFO@enh.nist.gov and

- the International Atomic Energy Agency, Section of Isotope Hydrology, Wagramerstrasse 5, PO Box 100, A-1400 Vienna, Austria. Tel: +43 1 206021740; fax: +43 1 20607; e-mail: RIALIHL@iaea.org

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1. Beaudoin, G., Taylor, B. E., Rumble III, D., & Thiemens, M. *Geochim. Cosmochim. Acta* 58, 4253–4255 (1994).
2. *Reference and Intercomparison Materials for Stable Isotopes of Light Elements* (International Atomic Energy Agency, Vienna, TECDOC-825) 7–12 (1995).
3. Robinson, B. W. in *Reference and Intercomparison Materials for Stable Isotopes of Light Elements* (International Atomic Energy Agency, Vienna, TECDOC-825) 39–45 (1995).
4. Krouse, H. R., & Coplen, T. B. *Pure Appl. Chem.* 69, 293–295 (1997).