Chernobyl: the health consequences

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This presentation will focus initially on selected aspects of the health impact of the accident, and then go on to discuss some of the pitfalls involved in trying to assess the health detriment in isolation and without regard for the context in which it occurs.

The accident on 26 April 1986 was unique. Two explosions, followed by a graphite fire in the destroyed reactor, not only dispersed radionuclides high into the atmosphere, but the fire was instrumental in ensuring the continued dispersion for about ten days. This prolonged discharge into the atmosphere combined with changes in wind direction ensured that radionuclides were widely distributed over Europe and were even detected throughout the Northern Hemisphere (1,2). The actual ground deposition was very variable, depending on many factors such as coincident rainfall during the passage of the plume, wind speed and direction, and the topography of the terrain. The mosaic distribution of ground deposition became much more variable with distance from the site, and is responsible for the wide range of individual doses that characterises this accident.

Following the accident, a large number of people were involved in the clean-up of the site and other contaminated areas. Within seven months of the accident an immense concrete structure, known as the "Sarcophagus", was erected to envelope the ruined reactor.

I Dose Estimates

The main sources of exposure of the population were thyroid exposure from radioiodines inhaled or ingested in food, and whole body exposure from externally and internally deposited radiocaesiums. However, there were special groups whose exposure was higher than that of the general public, and involved other radionuclides. Among these were:

a) The evacuees from the 30-km zone

Soon after the accident it became clear that doses in Pripyat and the area around the site would be high and that evacuation was required. The next day about 49,000 people were hurriedly evacuated from Pripyat, and during the next few weeks about another 75,000 were evacuated from the 30-km zone. The average whole body dose of people evacuated from the Ukrainian part of the 30-km zone (3) was estimated to be 15 mSv, but the range was extremely wide. The collective dose was calculated to be 1300 person.sievert. The average thyroid doses of the Pripyat evacuees ranged from about 70 mSv for those over 16 years, to 1.4 Sv for children up to the age of three years. Table 1 summarises these doses. It was very clear, even at this early stage, that the thyroid was the organ in the very young which was most exposed.

b) The early "Liquidators"

At the time of the accident, the initial responders at the site or those called in to combat the immediate effects at the reactor numbered about 400 in all (1). Later in the accident clean-up, many more individuals were recruited for decontamination and other activities. These people are often referred to as "Liquidators", but it is convenient to divide them into two groups. The first group consisted of the initial responders, and included the firemen and others involved in rescue operations. These people were exposed to external gamma and beta radiation from exposure in the plume, to core fragments scattered about the site, and to radioactive deposits on the skin and clothing. They also inhaled radioactive gases and particles. The dosimeters used at the time were too few and all were overexposed, so that they can not be used to establish dose levels. However, biological indicators of dose in the persons hospitalised at the time showed that a large number of people received very high doses. The thyroid dose for these workers tended to be high but very variable, ranging from zero to 20 Gy, with the majority less than about 1 Gy. It was in this group that all the major early health effects were seen.

Table 1
Doses to Evacuees in Ukraine

		Individual Dose (mSv)	Collective Dose (p.Sv)
Thyroid	> 16 y	70	2600
	< 4 y	1400	3300
Whole Body		15	1300

The second group of workers classified as "Liquidators" were those between the ages of 20 and 45 recruited from the Armed Forces and elsewhere to assist in the clean-up activities. The then Soviet government established a national dose register, called the All-Union Dose Registry (AUDR), in Obninsk in order to follow these and other highly exposed groups. The clean-up activities continued for many years, and it is interesting to note that the average individual dose fell from about 170 mSv for those recruited in 1986 to 130 mSv in 1987, 30 mSv in 1988 and to 15 mSv in 1989 (4). Since the break-up of the Soviet Union, each Republic has taken over the responsibility for its own nationals in the AUDR. The result is a fragmentation of the data which leads to difficulty in access, especially for foreigners. The most readily available data is in the Russian National Medical Dosimetric Registry (RNMDR), which replaced the original AUDR (4).

c) People living in the contaminated regions

Early in the course of the accident, it became obvious that the radioiodines were contributing significant thyroid doses (5), especially to children, and the Soviet authorities made every effort not only to minimize doses, but also to record the thyroid doses as accurately as possible. The results of this measured and reconstructive dosimetry indicated that some groups in the population, notably children in the more contaminated regions, received high doses to their thyroids, and that an increase in thyroid abnormalities including cancer was a very real possibility in the future. WHO (6) reported that, in the Ukraine, most children received less than one gray to the thyroid, although several thousand received more than two gray. Of this last group, a few hundred children received doses of over 10 gray, and more than two hundred received a dose of 15 gray or more. In Belarus about 1,000 children received over 5 gray and several had doses in the range of 30 to 40 gray. It was known from previous studies that an increase in thyroid tumours tended to appear six to eight years following irradiation, and continue for more than twenty years after exposure. At the same time, the current conventional wisdom is that internal radioiodine exposure is less carcinogenic than external irradiation of the thyroid.

Although many hundreds of thousands of measurements of radioiodine in the thyroid were made, there is considerable uncertainty about the early thyroid dose estimates. Some of the best estimates come from later dose reconstruction, which confirmed the widespread belief that the thyroid doses were high, especially in children. Again a wide variation in geographic distribution of thyroid dose was clearly demonstrated. In Belarus, the collective dose to the thyroid in children aged 0 - 14 years at the time of the accident has been estimated to be about 170,000 person.sievert and for the same age group in the Ukraine, about 60,000 person.sievert.

In the Ukraine (7), more than 150,000 examinations were conducted by special dosimetric teams, and a realistic estimate of the collective thyroid dose of 64,000 person.gray has been made, leading to a projection of 300 additional thyroid cancers. In the contaminated regions of Russia, Bryansk, Tula and Orel, a collective thyroid dose of 105,000 person.sievert was estimated (8), with a predicted excess cancer total of 349 in a population of 4.3 million. This represents an increase of 3 - 6% above the spontaneous rate. Table 2 summarises this information.

Table 2
Collective dose to thyroid in contaminated areas (p.Sv)

	BELARUS	**UKRAINE**	**RUSSIA**
0 - 14 y	170,000	60,000	
Total Population		200,000	100,000

For the whole Ukrainian population, the collective dose to the thyroid has been estimated to be 200,000 p.Sv, and 100,000 p.Sv for Russia. These are large collective thyroid doses and even with the wide individual dose variation and the lack of accuracy of many of the dose estimates, it is clear that the thyroid is the organ which is most likely to show effects.

Table 3 shows that of the approximately 270,000 people living in areas with contamination of > 555 kBq m^{-2} ^{137}Cs, it has been estimated that the external collective dose amounted to 7,300 p.Sv out of a total collective dose of 9,700 p.Sv.

Table 3
Doses to inhabitants of contaminated
areas > 555 kBq m^{-2} of ^{137}Cs (1986 - 1989)

No of Persons	**External Collective Dose (p.Sv)**	**Total Collective Dose (p.Sv)**
~270,000	7,300	9,700

However, Zvonova et al. (9) cast doubt on simplified models to convert ground deposition to dose, when they failed to demonstrate any correlation between Cs whole-body content and Cs soil contamination. This was attributed to a large variation in the Cs to plant transfer, dependent on the soil characteristics. They also go on to point out that the public response to the suggested countermeasures also influenced the whole body uptake of caesium. Where these tended to be followed, body burdens of radiocaesium were 2 - 3 times lower than in those areas where the local population did not heed the countermeasures and continued to eat locally grown produce. It is also interesting to note that clean food became much less available due to the deterioration of the economic situation in Russia, forcing dependence on local and forest products. This increased the average whole-body content of Cs significantly, especially in Bryansk where in 1993, this coincided with a bumper crop of wild mushrooms. During the period 1991 to 1994, the authors estimate the internal dose to range from 0.1 to 2.4 mSv per year. This paper illustrates well the influence of confounding physical and sociological factors in determining the dose from ingested radionuclides.

d) Doses outside the Soviet Union

As the pattern of ground deposition of radionuclides in Europe followed a similar patchy distribution, the resulting individual doses were extremely variable, with a wide range. Nevertheless, the average dose in Europe was low. As shown in Table 4, the average 50 year Committed Dose was estimated to be between 0.17 and 0.49 mSv. This may be compared with the average dose from background of about 120 mSv over the same period.

Table 4
Comparison of average 50 y dose estimates in Europe

US Dept of Energy	0.49 mGy
UKAEA	0.21 mSv
CEC	0.17 mSv
UNSCEAR	0.38 mSv
Average background (50y)	**120 mSv**

While this may not accurately reflect the risk to specific individuals, the collective dose and its corresponding risk to the population are very low. Outside Europe in the rest of the Northern Hemisphere, the doses were so low as to be inconsequential. It should be remembered that the major part of the dose inside and outside the former Soviet Union has already been received, and that any effort to reduce it still further is unlikely to be cost effective.

II Health Effects

a) Acute

All the acute health effects occurred among the personnel of the plant, or in those persons brought in for fire fighting and clean-up operations. Two immediate deaths were associated with the accident. A third person died early the morning of the accident. Twenty-eight other persons died later in the treatment centres, bringing the total to 31 deaths in the first weeks after the accident (1,2).

Over 200 persons were placed in hospital within the first twenty-four hours. The severity and rapidity of onset of their symptoms depended on their dose. The initial early signs and symptoms of radiation sickness from high doses, included diarrhoea, vomiting, fever and erythema. Patients were allocated to four categories of radiation sickness according to the severity of their symptoms, signs and dose estimates. The differential white blood cell count showed reduced circulating lymphocytes (lymphocytopenia) which was the initial indicator of the severity of the exposure and became evident in the first 24-36 hours for those most severely irradiated.

Table 5
Outcome of treatment

DEGREE OF RADIATION SICKNESS	NUMBER OF PATIENTS	DEATHS	ESTIMATED DOSE (GRAY)
IV	21	20	6 - 16
III	21	7	4 - 6
II	55	1	2 - 4
I	140	0	1 - 2
Total	237	28	

No members of the general public received such high whole body doses as to induce Acute Radiation Sickness (2). Between May and June 1986, 11,600 people in Belarus were investigated without the discovery of any cases of acute radiation sickness.

In the highest exposure group (6 - 16 Gy), the first symptom was nausea, followed by vomiting, which usually occurred within 30 minutes of exposure. These patients were desperately ill; fever and intoxication as well as diarrhoea and vomiting, were prominent features. Mucous membranes were severely affected, becoming swollen, dry and ulcerated, making breathing and swallowing extremely painful and difficult. Extensive burns due to beta radiation often complicated the illness. Within the first two weeks white blood cells and platelets fell dramatically, indicating a very high dose which had compromised the production of blood cells in the bone marrow, making it virtually impossible for the patient to fight infection or to retain the natural clotting activity of the blood. Nearly all the patients with such high doses died (20 of 2), in spite of the intensive specialized medical treatment provided.

As the exposure decreased, the symptoms, signs and laboratory findings tended to improve. Vomiting began later, platelet and white cell counts did not drop so precipitously and the fever and toxaemia were less pronounced. Beta radiation burns to the skin were a major complicating factor and mucous membrane damage was difficult to treat, but survival improved markedly as the dose fell, so that no early deaths were noted in the 1 - 2 Gy exposure group.

b) Treatment

For high external radiation doses, treatment is directed at maintaining fluid and electrolyte balance, avoiding and treating infection, and treating other complications as they occur. Successful outcomes are dependent on maintaining life until the body recovers its own functions. Where other injuries are present, such as thermal or beta radiation skin burns, they may tip the scales against recovery unless vigorous supportive treatment is undertaken. The hospital treatment following the accident included replacement therapy with blood constituents, fluids and electrolytes; antibiotics; antifungal agents; barrier nursing and bone marrow transplantation.

The following are among the lessons learned in treating accidentally highly exposed patients:

1. Spontaneous haemorrhage was rare even when the platelet count fell below 1000 per µl.
2. Bone marrow transplantation is not as effective as expected in accidentally

exposed persons.

3. The oro-pharyngeal syndrome was most distressing to patients and difficult to treat.
4. The logistics of handling a large number of investigative tests and patients in specialised facilities had to be planned carefully before an effective therapeutic programme could be established.

c) Late Health Effects

While there have been reports of an increase in the incidence of some diseases as a result of the Chernobyl accident, many of these reports can not be verified and often refer to diseases which are not known to be associated with ionising radiation exposure. In the International Chernobyl Project (10), field studies were undertaken in the latter half of 1990 of the continuous residents of the rural settlements with a surface caesium contamination of greater than 555 kBq m^{-2}, and control settlements of 2,000 to 50,000 persons, using an age matched study design. Seven contaminated and six control settlements were chosen by the medical team. Since all persons could not be examined, representative samples were taken from various age groups. In all 1356 people were examined, and the aim was to examine about 250 from each of the larger settlements. Three medical teams each spent two weeks conducting medical examinations to provide the data for these assessments.

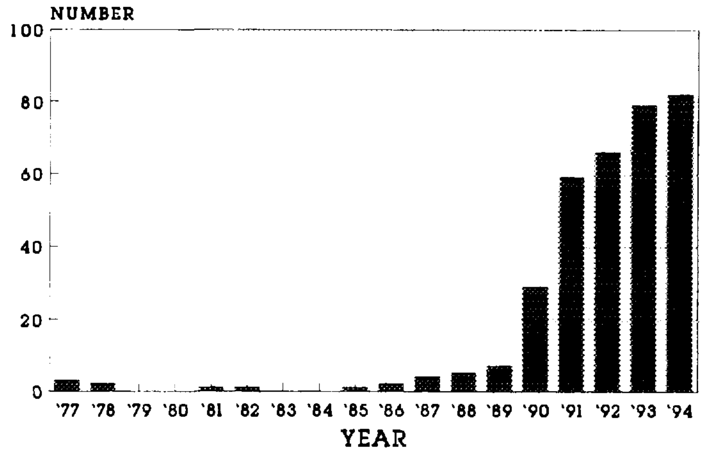
The medical examinations were quite comprehensive, and the general conclusions reached were that there were no health abnormalities which could be attributed to radiation exposure, but that there were significant non-radiation related health disorders which were similar in both contaminated and control settlements. The accident had substantial negative psychological consequences which were compounded by the socio-economic and political changes occurring in the then USSR.

Thyroid Cancer

The situation soon after the accident pointed to the thyroid (5) as the organ most likely to show radiation effects, especially for children and the authorities prepared as far as they could by establishing as accurate as possible individual dose records, and by identifying the most highly exposed groups in preparation for medical surveillance and epidemiological studies. It was felt that the delay in the appearance of radiation effects (six plus years) would allow sufficient time for the institution of a comprehensive diagnostic and therapeutic programme. What was not expected was that thyroid abnormalities would become detectable about four years after the accident.

The data that has been collected in Belarus is the most convincing and has been verified by international experts. It is for these reasons that most emphasis will be placed on these findings. In the course of this follow-up, it was noted latterly that the numbers of thyroid cancers in children were increasing in some areas. For Belarus as a whole (11,12), there has been a significantly increasing trend in childhood thyroid cancer incidence since 1990 (13). Moreover, this increase is confined to regions in the Gomel and Brest oblasts, and no significant increase has been noted in Mogilev, Minsk or Vitebsk where the radioiodine contamination is assessed to have been lower. Over 50% of all the cases are from the Gomel oblast. This increase is graphically illustrated in Fig. 1.

Fig. 1. Cases of Childhood Thyroid Cancer in Belarus



For the twenty years prior to 1986, only 13 cases of childhood thyroid cancer were seen in Minsk, which is the main Belarussian centre for thyroid cancer diagnosis and treatment in children. From 1986 to 1989, 2 to 6 cases of thyroid cancer in children were seen annually in Minsk. In 1990, the number jumped to 29, to 55 in 1991, then to 67 in 1992. By the end of 1994 the total had reached over 300 in Belarus.

The histology of the cancers since 1992 has shown that the vast majority were papillary carcinomata, and that they often presented with local invasion and distant metastases, usually to the lungs. This has made the treatment of these children extremely difficult, whether undertaken in Minsk or specialized centres in Europe.

This increase was confirmed by the final report of a CEC Expert Panel (14) convened in 1992 to investigate the reported data. These experts estimated that the incidence of childhood thyroid cancer (0-14 y) was between 0 and 0.14/100,000/y in Belarus prior to the accident, and was similar to that reported by other cancer registries in Europe and Scandinavia. This indicated that the data collection in Belarus was of similar adequacy. They noted that it jumped to 2.25/100,000/y in 1991, about a twenty-fold increase. In 1992 the incidence of childhood thyroid cancer in Belarus as a whole was estimated to be 2.77 per 100,000, whereas in the Gomel and Brest Oblasts it was 8.8 and 4.76/100,000/y respectively. Other data from the Ukraine and Russia show a similar, but not as dramatic, increase in the incidence of childhood thyroid cancer since 1987. This increased incidence is not confined to children, as a larger number of adult cases have been registered in Belarus and the Ukraine (15).

When this increase was first reported, it was very quickly pointed out (16) that any medical surveillance programme introduced would apparently increase the incidence by revealing occult disease and rectifying misdiagnoses. While this may account for a small proportion of the increase (17), it cannot possibly be the sole cause, as the increase is so large and many of the children presented not with occult disease, but with clinical evidence of thyroid and/or metastatic disease. In fact, only 12% of the childhood thyroid cancers were discovered by ultrasound screening alone in Belarus (18). In addition, subsequent examination by serial section of the thyroids of persons coming to autopsy in Belarus have confirmed that the occult thyroid cancer incidence is similar to that found in other studies (19) and showed none of the aggressive characteristics found in the childhood cancers presenting in life (20).

The most recent published rates of childhood thyroid cancer (21) show unequivocal increases as seen in Table 6.

Table 6
Numbers and incidence of childhood thyroid cancer

AREA	1981-5		1986-90		1991-4	
	NO	RATE	NO	RATE	NO	RATE
Belarus	3	0.3	47	4	286	30.6
Gomel	1	0.5	21	10.5	143	96.4
Ukraine	25	0.5	60	1.1	149	3.4
Five North Regions	1	0.1	21	2	97	11.5
Russia Bryansk & Kaluga Reg.	0	0	3	1.2	20	10

Rates are for childhood thyroid cancer (0-14y) incidence expressed as average values per million children.

While there may be disquieting aspects of general data collection in the former Soviet Union, there is a real, and large, increase in the incidence of childhood thyroid cancer in Belarus and the Ukraine which is likely to be related to the Chernobyl accident. If this is so, one can expect the incidence of childhood thyroid cancer (0-14y) to revert back to the previous low levels once 14 years have elapsed since the accident and this cohort has aged. It is also clear that, as this exposed cohort ages, the incidence of adult thyroid cancer will continue to increase in it for the rest of its lifespan.

In any event, surveillance of the population at risk must be maintained for the lifetime of the exposed persons, and for this to be achieved, international support for surveillance and therapeutic programmes will need to be continued for the foreseeable future.

d) Psychosocial effects

The Chernobyl accident had widespread psychological effects not only inside the Soviet Union but also outside. I would like to concentrate on the effects within the Soviet Union, but the impact in the rest of the world cannot be completely ignored. The psychological effects were most pronounced in Europe where contamination was the highest. Here people reacted predictably, but in what may be regarded as extreme ways. Travel plans were cancelled, "clean" food was hoarded and abortions were sought, even when there was no scientific justification for these actions. People were reacting just to be on the safe side. Anti-nuclear sentiment became more prevalent (22), and official pronouncements mistrusted.

Within the Soviet Union, similar factors were present (24,25,26,27), but additional economic, social and political influences came into play. "Perestroika" and "Glaznost" had been introduced to try and change the face of the Soviet system, which was viewed by the people as being too autocratic, restrictive, centralised and oppressive, with no opportunity to voice a dissenting opinion. The Soviet authorities were gradually lifting restrictions, people were freer to speak more openly and even criticise the government, nationalism in the Republics was not repressed as much as it had been, and a new life was slowly emerging with fewer constraints, but still within the Communist system. This was the changing political scene when the accident happened, but the authorities reacted in the time honoured Soviet way. Information was deliberately withheld, and reassuring paternalistic advice was given when it was clearly inappropriate. The natural concerns of the people were dismissed by some as "Radiophobia", giving the impression that their fears and worries were somehow irrational. This of course, angered the population even more and polarised their response. At the same time, a new type of politician, spawned by the changing political circumstances, was emerging who capitalised on all the discontent and used it for his own ends which were usually anti-Soviet. This was particularly true of the nationalistic and anti-nuclear sentiments which appeared to coalesce around 1988 and 1989, so that all these elements had some influence on the development of opinions and movements at that time.

As an example I would like to show you a slide of a badge that I obtained in Kiev in 1989. It depicts an outline of the territory of the Ukraine, incorporating the colours of the national flag. On the map, the nuclear power stations are marked with black crosses, reminiscent of graveyard crosses and Chernobyl with a larger cross. The date of the accident is preceded by a funereal black bow, and the date itself uses the Ukrainian word for April rather than the Russian. So here is a subtle statement which embodies national fervour and independence, as well as nuclear opposition and resentment towards the centralised government which imposed its will on Ukrainians.

Another factor that enhanced the psychological effect of the accident was the difficulty people had in assessing the risks from the radiation. Here was an unseen hazard, imposed from outside, which polluted their land, their food and their person, which was very difficult to get rid of and would remain a hazard to them and their children for many years to come. It is not surprising that the people felt anxious and concerned, and that all their ills were due to radiation exposure. Widespread restrictions on everyday activities affecting work, schooling, diet and recreation have only served to reinforce their anxiety and stress.

The relocation of people whose families often have lived for generations in one small settlement has destroyed many of the established family and social networks, thereby increasing the stress of relocation itself. Relocation also produces home-sickness. This combined with economic hardship, shortages and the reluctance of the host communities to accept them, serves to magnify the stress of relocation. Such relocated people were sometimes viewed as contagious and avoided by the indigenous population who also resented the compensation paid to these "victims" as they were paying for it out of their tax money.

During times of stress the consumption of tobacco and alcohol increase, and this has been seen in the contaminated regions. It should also be remembered that the excessive consumption of these items carries with it well-established adverse health effects. The stress of relocation has been high enough to prompt some people, mostly elderly, to return to their abandoned homes and give up any benefits they might have obtained. The other side of the coin is illustrated by the polls which showed that about 70% of people living in contaminated areas wanted to be relocated (10). Apart from the avoidance of exposure, this may well have been prompted by the expected improvement in life style.

In essence, the psychological effects of the accident in the former Soviet Union may well constitute the greatest indirect health impact mediated through the induction of stress. I hope that I have convinced you that, to understand these mechanisms, the situation must be viewed within the context of the current political, social and economic conditions, and not in isolation. I will return to this theme in the next part of this presentation.

III Difficulties

There are two extreme groups who would like to see their opinions adopted by society. On the one hand, there are those organizations and groups who stand to gain from exaggerating the effects of the accident. At the other extreme, there are the apologists for Nuclear Power who wish to convince us that Chernobyl was a minor perturbation which should not influence the development of nuclear power technology. Each of these protagonists will often, consciously or unconsciously, present facts, usually incomplete or changed in emphasis, which are supportive of their own point of view. I would like to discuss some of the areas where there is inherent danger in the uncritical acceptance of conclusions and estimates which, at face value appear plausible, especially when one is not too familiar with the field in question. I would like to suggest, and this may appear to be excessively cynical, that you approach all reports, even those emanating from apparently reputable scientists, with a healthy scepticism. And, Yes, I include this presentation in that category, as most of us have some bias. Naturally, my bias is minimal!

a) Mortality and Morbidity Data

The methods of collection, collation and presentation of demographic data in the former Soviet Union left much to be desired; so much so that it is often very difficult to accept the validity of much of the early data. The International Chernobyl Report (10) noted that the comparison of data from different registers was not likely to be very useful, since data collection methods, verification, completeness, age/sex structure and social habits of the persons in the various registers were different. It went on to say that a uniform methodology for all tumour registries would be useful but that it would be difficult, if not impossible, to collect such data retrospectively in a uniform fashion. This then was the assessment by an international team of the state of data and data collection about four years after the accident. Nevertheless, even at this time it was noted that there had been an increasing incidence of cancers over the previous decade which began before the accident and continued after it. Thus any comparison of cancer incidence after the accident in a contaminated area cannot be viewed in isolation and must be compared with the increasing trend in the unexposed population.

What then, is happening to the disease morbidity and mortality incidence in the states of the former Soviet Union? Ellman (27) has looked at the volatile demographic indicators in Russia over the past few years. He notes that the crude death rate rose from a low of 10.4 per 1,000 in 1986 to 11.4 per 1,000 in 1991, an increase of some 9.6% in five years. Some of this rise was due to an aging population, because as it ages, more people enter the age-groups at the upper end of the lifespan and therefore are more likely to die. This effect can be eliminated by looking at age-specific death rates. This was done and Table 7 shows the results.

Table 7
Increase in annual crude death rate in Russian men: 1986 - 1991

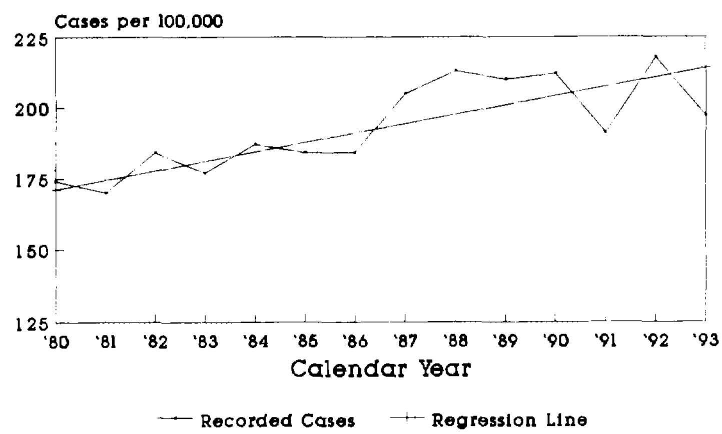
AGE GROUP	INCREASE
15 -19	31%
20 - 24	23%
25 - 29	35%
30 - 34	36%
35 - 39	34%

Ellman also points out that male life expectancy in Russia dropped by 1.5 years between 1987 and 1991. This he attributes to an increase in deaths from "external" causes (accidents, homicides etc.), often alcohol related, as these were markedly reduced in 1986 and 1987 during the anti-alcohol campaign. In 1993 the life expectancy of a Russian male was provisionally estimated to be 59 years. Further examination of mortality statistics in Russia since "Perestroika" shows that the crude death rate rose from 11.4 per 1,000 in 1991 to 12.2 in 1992 and 14.4 per 1,000 in 1993. This he attributes to the rapid deterioration of economic indices leading to impoverishment and poor quality food intake. He suggests that the social and economic changes resulting from the break-up of the former Soviet Union have had an adverse effect on the general health in Russia. Reduced funding for medical care, poor diet, stress and anxiety leading to excessive alcohol consumption, and the need to work longer hours to make ends meet, have all combined to reduce the general health and life expectancy of Russians. Ellman has adopted the word "Katastroika" to describe this phenomenon!

In an analysis of time trends of cancer incidence in Ukraine, Prisyazhniuk (29) noted a generally rising rate of cancer incidence which might be partly due to an actual increase or to an increased ascertainment. There was an increase in leukemia, mainly Chronic Lymphatic Leukemia in the oldest age group from 1987 to 1993. Since CLL is not associated with ionizing radiation exposure and such an exposure would have been expected to increase leukemia in the younger age groups and not the oldest, the accident can not be considered a cause of this increase.

Fig. 2 is re-drawn from the same author's data and shows the rising cancer incidence for men and women. Linear regressions fitted to the data before and after the accident do not show any significant difference in slope.

Fig. 2. Incidence Rate for all Cancers in Areas of Strict Control



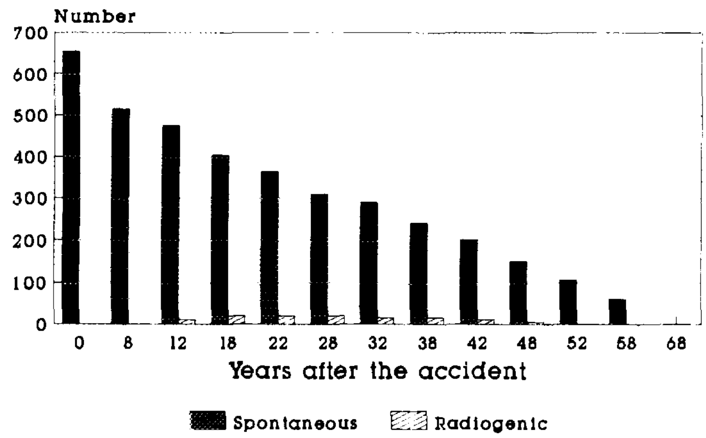
Whatever the cause, this increase can not be attributed to radiation exposure. As has been mentioned, only thyroid cancer has shown a statistically significant increase. Any apparent increases in adverse health effects which might be attributed to the Chernobyl accident need to be assessed against this volatile background of changing mortality and morbidity. Thus Tsyb and Ivanov (30) conclude that the data in the Russian National Medical Dosimetric Registry shows no excess cancer mortality among the Emergency Workers compared with controls. Having noted this, the usual caveat should be added here: ten years is a little early to assess the incidence of solid tumours, as the latent period for the appearance of these tumours can be considerably longer than this.

b) Implications for Public Health

Demin (31) has used dosimetric data from the Bryansk region of Russia to compare the number of cancer deaths predicted from the accident with the expected "spontaneous" number. Fig. 3 is redrawn from this data and shows the expected annual number of “spontaneous” cancer deaths at specific time intervals in a single population of 100,000 people aged >18 years at the time of the accident, and the annual number of predicted cancer deaths in the same population had it been exposed to the average dose in the Bryansk region.

It should be emphasized that this is a theoretical prediction, not an epidemiological study, of a single cohort that is followed for the specified time. This explains why the expected annual number of "spontaneous" cancer deaths is decreasing. It is clear that the annual number of "spontaneous" cancers far exceeds the number predicted from the accident in this population, leading to the conclusion that the radiation induced cancers will be indiscernible against this background.

Fig. 3. Annual Mortality from all Cancer in 100,000 Persons aged ⟩ 18 at accident



It has been suggested from time to time that the incidence of some diseases traditionally not known to be associated with radiation exposure have increased due to the Chernobyl accident. The more recent studies of the survivors of Hiroshima and Nagasaki are cited as convincing evidence of an association between some diseases such as myocardial infarction and chronic liver disease, and radiation exposure. However, closer examination of these allegations shows that this correlation is at best, weak and for myocardial infarction only occurs at very high doses above 1.5 - 2 Gy (32). Fig. 4 illustrates the association of dose with myocardial infarction among the A-Bomb survivors.

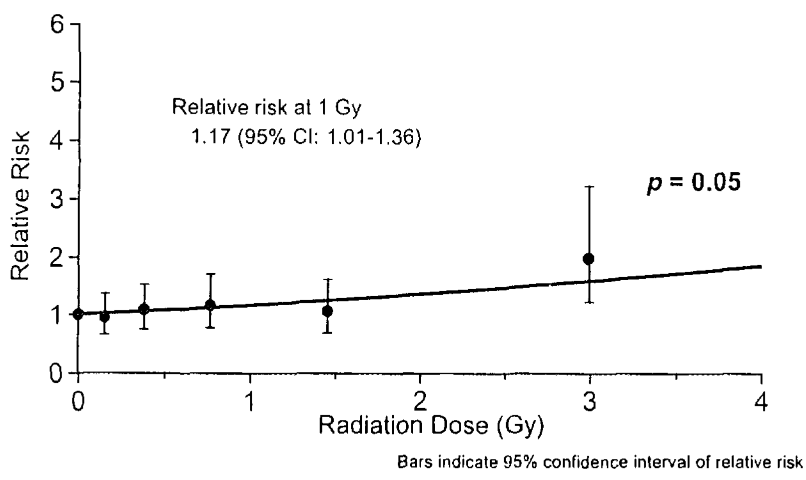


Fig. 4. Dose Response for Risk Factor Adjusted Incidence of Myocardial Infarction (Men and Women, 1958-90, AHS, Hiroshima and Nagasaki)

I don't know about you, but I need more convincing correlation especially with the dose range that we are concerned with in radiation protection. I should perhaps add that the evidence for a correlation between exposure and the risk of uterine myomata is more convincing. What then are the implications for public health ten years after the accident? What conclusions can be drawn? What sort of questions should we be discussing?

We have noted that the health effects in the inhabited contaminated regions are expected to be low, and that most of the dose has already been received, so that this cannot be influenced by remedial measures. Likhtariov et al. (33) have estimated the effective doses due to external irradiation of various population groups in the Ukraine. Their estimates, based on the ground contamination by ^{137}Cs, range from 1.7 µSv per kBq m^{-2} for young children to 4.4 µSv per kBq m^{-2} for agricultural workers. If an average population dose of 2 µSv is assumed, then the yearly dose from this component in the more heavily contaminated regions (500 kBq m^{-2}) amounts to about 1 mSv. While this is not the full story of the total exposure, the external exposure accounts for about 75% of the overall dose.

Data from (34), show the effects of decontamination on daily dose in Kirov (Belarus) in 1989. It is interesting to note that decontamination measures actually increased the dose to Forest Workers by about 13%. The most beneficial effect was on schoolchildren, where the dose was reduced by about 35%. It is clear that the benefit of decontamination varies widely among different groups within the population, but the average reduction from 4.8 to 4.4 mSv per year (about 8%) for the total population, is, to say the least, disappointing, especially when one considers that this was the result of the decontamination initiated when the dose was maximal. The structure of the exposed population may have a significant influence on the type and extent of land decontamination measures introduced in any future accident. Thus where the number of schoolchildren is maximal and the forest workers a small minority, land decontamination may be a viable option. As any further decontamination activities would only achieve minimal dose avoidance, is it reasonable to continue to expend large sums of money on land decontamination?

Table 8
The effect of decontamination
on external dose (Kirov 1989)

MEASURED MEAN DAILY DOSE (µGy d^{-1})

	Before	After	Ratio
Cattle breeders	12.3	11.9	0.97
Field Workers	17.5	13.2	0.75
Forest Workers	12.5	14.1	1.13
Office Workers	12.1	11.8	0.98
Pensioners, Housewives	12.9	12.8	0.99
School Children	15.0	9.7	0.65
Tractor Drivers	12.8	12.7	0.99
Average	**13.2**	**12.1**	**0.92**

The Ukraine is said to be expending one sixth of its budget on Chernobyl related remedial measures, and Belarus is also spending large amounts. Is this really cost-effective? Would this money be better spent improving the minimal and rudimentary health care services to try and reduce the impact of the real "spontaneous" cancer and other deaths, rather than the minimal number of theoretically predicted radiogenic cancer deaths?

Have we been seduced by humanitarian motives into precipitate actions which, in the cold light of day ten years later, may appear to be inappropriate and wasteful? Has the time come for a fundamental re-appraisal? If so, can such a re-appraisal be made in today's political and emotional environment?

I think it is the time to ask such questions. Whether there can be unbiased and unequivocal answers to such questions is another matter, but they should be asked.

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