Supplementary information requested of the Medical Association for Prevention of War (Australia) at Inquiry public hearing, 19 Aug 2005

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Inquiry into developing Australia's non-fossil fuel energy industry Case study: The strategic importance of Australia's uranium resources

House of Representatives Standing Committee on Industry and Resources

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Introduction

At the Committee's public hearing in Melbourne on 19 Aug 2005, Associate Professor Tilman Ruff was requested by the Committee to provide:

1. Further information and references regarding the health consequences of the Chernobyl disaster; and
2. A reference to the most recent Carnegie Endowment for International Peace report on nuclear, biological and chemical threats, which discusses the situation regarding laser enrichment of uranium in various countries, and related proliferation concerns

This information is provided here, and a further paper written recently for the Association by Professor Frank Barnaby, is enclosed. Entitled 'Safeguards and plutonium reprocessing', this provides further background on the matter of plutonium and reprocessing of spent nuclear fuel, discussed with the Committee during its 19 August hearing.

Health consequences of the Chernobyl disaster

Introduction

During representatives of MAPW's appearance before the Committee hearing on 19 Aug 05, the Chair invited A/Prof Ruff to explain the discrepancy between a United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) assessment he cited of 31 immediate deaths and an increase of some 800 cases of thyroid cancer diagnosed in children, only about 10 of which had been fatal, and the higher numbers, at least 6000 deaths (and a documented up to a 34-fold increase in thyroid cancer rates) A/Prof Ruff described in his submission.

The figure of 6000 deaths cited and referenced is a low-end figure very likely to substantially underestimate the scale of the health consequences of the disaster.

Since the hearing, a major multi-agency UN report was released on 5 Sep 2005, by the International Atomic Agency (IAEA), World Health Organisation (WHO) and United Nations Development Programme (UNDP). This 600 page report is the work of the Chernobyl Forum, made up of 8 agencies – IAEA, WHO, UNDP, Food and Agriculture Organisation (FAO), United Nations Environment Programme (UNEP), United Nations Office for the Coordination of Humanitarian Affairs (UN-OCHA), UNSCEAR, the World Bank, and the governments of Belarus, Russia and Ukraine. Its (conservative) estimate is 4000 deaths attributable to the disaster over the lifetime of emergency workers and local residents in the most contaminated areas – quite similar to the estimate cited in the MAPW submission.

The Committee Chair's suggestion of about 40 total deaths caused by the Chernobyl disaster is quite inaccurate and a misleading interpretation of the evidence.

A summary of the key findings of the recent Chernobyl Forum report, and a review of its strengths and weaknesses are presented to the Committee to provide a framework to understand the consequences of the world's worst civilian nuclear disaster.

'Chernobyl's legacy: health, environmental and socio-economic impacts' - the Sept 2005 Chernobyl Forum Report[1]

Major findings

The summary of major findings is contained in the Press release announcing the Report[2].

Radiological and health

[1] Available at: http://www.who.int/ionizing_radiation/a_e/chernobyl/-EGH%20Master%20file%202005.08.24.pdf

[2] IAEA, WHO, UNDP. Chernobyl: the true scale of the accident. 20 years later a UN report provides definitive answers and ways to repair lives. (Press release). 5 Sep 2005, 11 pp.

- Major releases of radionuclides continued for 10 days after the core meltdown on 26 April 1986 and contaminated more than 200,000 square km of Europe
- Strontium-90 and cesium-137, with half-lives of around 30 years, persist and will remain a concern for decades to come. Cesium, present especially in milk, meat, fish and some plant foods, remains the most significant concern for internal human exposure
- About 100,000 people of the 5 million living in the most contaminated areas received more than the recommended maximum radiation dose limit of more than 1mSv annually
- Although plutonium isotopes and americium-241 will persist for thousands of years, their contribution to human exposure is thought to be low
- A total of about 4000 deaths attributable to the disaster are expected over the lifetime of emergency workers and local residents in the most contaminated areas, including:
    - Some 50 emergency workers who died of acute radiation syndrome
    - 9 children who have died of thyroid cancer
    - An estimated 3940 deaths from radiation-induced cancer (a 3% increased incidence in overall cancer deaths), including leukemia among the following 600,000 people:
        - 200,000 emergency workers exposed over the period 1986-7
        - 116,000 people evacuated
        - 270,000 residents of the most contaminated areas
- Among emergency and recovery operation workers ('liquidators'), an increase in leukemia, solid cancers and cardiovascular diseases has already been identified

Social

- Relocation proved a 'deeply traumatic experience' for some 350,000 people
- Poverty and lifestyle diseases are severe and persistent, the effects of the disaster compounding adverse social and economic consequences following the break-up of the former Soviet Union. Poverty is especially acute in affected areas
- Adverse mental health consequences including depression, 'paralysing fatalism', reckless risk-taking behavior and substance abuse have been extensive and persistent in affected communities
- Anxiety over health effects of radiation shows no signs of diminishing and may even be spreading

Environment

- Increased mortality in conifers, invertebrates and mammals and reproductive losses in plants and animals were seen in areas up to 20-30 km distant from the reactor
- Agriculture was hard hit, with 784,320 hectares taken from production. Countermeasures applied on more than 3 billion ha of agricultural land in Belarus, Russia and Ukraine were needed to minimize the amount of products with radionuclide concentrations above action levels. Some agricultural lands in Belarus, Ukraine and Russia are still out of use and will need to remain so until remediation can be undertaken
- In Western Europe, a range of countermeasures are still being used for animal products from uplands and forests
- Timber production was halted in 694,200 ha of forest

- Restrictions on harvesting of firewood and food products such as game, fish, berries and mushrooms are still needed in some areas though they are often disregarded by the population, especially in low-income areas

Economic losses

- A variety of estimates from the 1990s placed the costs over 2 decades at hundreds of billions of dollars [These are not further developed, elaborated upon or updated in the Report.]

The damaged reactor

- The protective shelter or sarcophagus built over the damaged reactor was erected quickly and imperfectly and did not allow collection of complete data on the stability of the damaged reactor
- Some structural parts of the shelter have corroded, and the main potential hazard posed by the shelter is the possible collapse of its top structures, with further release of radioactivity
- Strengthening of those unstable structures has been performed recently, and construction of a new structure covering the existing shelter that should serve for more than 100 years is planned to start in the near future. It will hopefully allow dismantlement of the current shelter, removal of the radioactive fuel mass, and eventually, decommissioning of the damaged reactor
- A comprehensive strategy is still to be developed for dealing with the high level and long-lived radioactive waste from past remediation activities. Much of this waste was placed in temporary storage in trenches and landfills that do not meet current waste safety requirements. For example, they are without engineered barriers, proper design documentation, or hydro-geological investigation.
- The other 3 RBMK reactors (Units 1-3) at the site are shutdown with a view to being decommissioned, and 2 additional reactors (Units 5 and 6) that had been near completion were abandoned in 1986 following the disaster. Thus major radioactive waste management tasks remain at the site.

Report of the UN Chernobyl Forum Expert Group 'Health': Health effects of the Chernobyl accident and special health care programmes. Working Draft 31 Aug 2005[3].

Key findings of this section of the Chernobyl Forum report are presented with some comment.

Most affected populations

- 30 immediate deaths among power plant employees and firemen occurred with days–weeks, 28 due to high radiation exposure
- About 240,000 recovery operation or clean-up workers (also called liquidators) undertook mitigation activities at the reactor and in the 30 km surrounding 'exclusion zone' in 1986-7; and these activities continued on a large scale until 1990, involving 600,000 identified personnel in the 3 most affected

[3] Available at: http://www.who.int/ionizing_radiation/a_e/chernobyl/-EGH%20Master%20file%202005.08.24.pdf

countries [Other estimates which include personnel from other countries of the former USSR suggest that such personnel number in total around 800,000 eg in the background material for a forthcoming conference on the health of liquidators to be held in Switzerland[4]]

- About 116,000 residents of highly contaminated areas were evacuated in 1986 and a further 220,000 after this time, across the 3 republics of Belarus, Russia and Ukraine
- Iodine blockade with stable iodine to reduce thyroid radiation doses from ingested iodine-131 (I-131) must be given immediately after exposure to be effective – this was effectively implemented in Poland, but not for the majority of the affected population in the former Soviet Union. Indeed, high doses of stable iodine administered too late to block radioactive iodine uptake may have increased radiation doses (p 68)
- 'Contaminated areas', defined as those where cesium-137 (Cs-137) deposition was more than 37 kBq per square meter (m^2), (or 1 microcurie per $m^{2)}$ are variably described as containing 5 million (p 4), 6 million (p 27) or 6.8 million (p 144) residents in different places in the report.

Dose estimations

- Much uncertainty and inconsistency exists in relation to assessments of thyroid radiation doses in the 3 most affected republics (p 17)
- Doses to recovery operation workers estimated by different methods involve uncertainties of between 10% and a factor of 5 (p 23)
- National registry data in the 3 most affected countries cover less than half of the recovery operation workers, and do not contain information on affiliation or type of work carried out (p 25)
- Falsification of Registry data is thought to have occurred for about 10% of the military workers (p 25); and for the remainder of the military workers, the doses are thought to have been systematically overestimated by about a factor of 2.[This would tend to underestimate dose-related health effects]. Doses from internal irradiation 'have not been given much attention' and limited information is available on beta radiation to the skin and eye (p 25)
- Internal doses from strontium-90 and plutonium-239 have received limited attention (p 28)

Thyroid cancer

- An unexpectedly early and marked, dose-related rise in incidence of thyroid cancer in children and also in liquidators has unequivocally been observed in all 3 most affected republics, with odds ratios in exposed children up to over 100 (p 38)
- There is also evidence that in territories with severe iodine deficiency, the increased risk of thyroid cancer was further increased by a factor of between 2 and 3.2 (p 38, 46)
- Pooled analysis of groups exposed to external radiation during childhood and adolescence in various parts of the world show thyroid cancer risk still increased at the longest period of observation, about 45 years, with the greatest risk at about 15-30 years after exposure. More than 15 years after

[4] 'Health of liquidators (clean-up workers), 20 years after the Chernobyl explosion' is a conference to be held on 12 November 2005 at University Hospital, Bern, Switzerland, organized by Physicians for Social Responsibility/International Physicians for the Prevention of Nuclear War Switzerland and the Faculty of Medicine of the University of Bern. For further information see: www.ippnw.ch

the Chernobyl disaster, thyroid cancer incidence is still highly elevated, and it is likely that it will continue at this current high rate for at least the next decade (p 44)

Leukemia and non-thyroid solid cancers

- Data with considerable methodological limitations and lacking dose information for children exposed in utero are nevertheless suggestive of an increase in leukemia (p 84), and a case-control study in Ukraine suggested an increase in leukemia in exposed children (p 86)
- Recent data suggest a 2-fold increase in leukemia (other than chronic lymphocytic leukemia) among Russian liquidation workers exposed to estimated total external doses of 150-300mGy (p 87)
- As noted in the report (p 91), solid cancers from Chernobyl radiation exposure would be expected to only now begin to appear, following a typical minimal latent period of 10-15 years. [Thus, most cancers that will be caused by Chernobyl radiation are yet to occur, and long-term, high-quality disease surveillance will be required.]
- To date, there has been relatively little study of solid cancers other than thyroid cancer in Chernobyl-exposed populations, however at least 2 significant studies have been reported. Cited in the report (p 92) is a descriptive epidemiological study in Belarus and Ukraine undertaken in collaboration with the International Agency for Research on Cancer (IARC) and the Finnish Cancer Registry. The results indicate a significant increase in incidence of pre-menopausal breast cancer incidence among women exposed before the age of 45 y in the most contaminated compared with less contaminated districts.
- An important study not referred to in the Report, despite having been published in October 2004, almost a year before the release of the draft Report, is an assessment of data from the Belarus national Cancer Registry, which compares baseline incidence rates for various cancers and overall cancer in 1976-85, with rates observed in 1990-2000[5]. Data are disaggregated by sex and region, allowing comparison between high and low exposure regions; and linkage with a national registry of those most affected by Chernobyl – liquidators (about 120,000), evacuated persons, and those still living in contaminated territories.
  A statistically significant increase in cancer incidence, averaging 39.8%, was observed in all regions, but was most pronounced in Gomel region, the most contaminated region, with an increase between the 2 time periods of 55.9%. Compared with adults in the least contaminated region (Vitebsk), in the period 1997-2000 (an anticipated 11-15 year latency period), male liquidators had statistically significantly raised risk of cancers of all sites, and for colon, lung and bladder cancer, with relative risks shown in Table 1.

[5] Okeanov AE, Sosnovskaya EY, Priatkina OP. A national cancer registry to assess trends after the Chernobyl accident. Swiss Med Wkly 2004;134:645-9.

Table 1. Relative risk (RR) in cancer incidence (truncated age-standardised rate for ages 20-85 per 100,000 population) in liquidators, 1997-2000, compared with control adults in least contaminated area (Vitebsk), Belarus Source: Okeanov et al 2004

	Incidence in controls	Incidence in liquidators	RR	95% confidence interval
All sites	373.3	449.3	1.20*	1.14 - 1.27
Breast (female)	58.6	61.3	1.05	0.81 - 1.35
Lung	52.4	67.3	1.28*	1.13 - 1.46
Stomach	41.7	44.9	1.08	0.92 - 1.26
Colon	17.0	22.3	1.31*	1.03 - 1.67
Rectum	19.0	18.4	0.97	0.77 - 1.23
Kidney	14.8	17.9	1.21	0.97 - 1.50
Bladder	10.9	17.0	1.55*	1.21 - 1.99

*Statistically significant differences

Even though thyroid cancer represents only 0.4% of the total cancers recorded, an increase in the exposed adult population is clearly discernible, with a standardized incidence among the adult population aged over 30 years of 1.24 per 100,000 population in 1980, 1.96 in 1990, and 5.67 in 2000. Among liquidators, the rate was 24.4 per 100,000 for the period 1993-2000. While longer follow-up and data from additional populations will be useful, and controlling for confounding factors such as smoking would be desirable, these data are biologically highly plausible and indicate an increase in a diverse range of solid tumours among the most exposed populations, especially liquidators

- As noted in the Report, even if effects due to low and moderate radiation doses may be difficult to detect given the high incidence of cancer overall, and its multiple causes other than ionizing radiation, even a small increase in relative risk can result in a substantial number of cases when applied to a large population

Non-cancer diseases

- **The eye**

- Several studies in Ukraine among liquidators and exposed children show an association of posterior subcapsular cataracts with Chernobyl radiation exposure, consistent with other evidence, at relatively low doses, of the order of 250 mGy (p 107)

- **Cardiovascular diseases**

- In Ukraine and Belarus, there are no large epidemiological studies on radiation and cardiovascular disease, however in Russia, data are available on 4995 deaths among a cohort of 60,910 emergency workers, which demonstrated a significant dose-related excess relative risk (RR) for death from cardiovascular disease, with an excess RR coefficient per Sv of 0.54 (95% CI 0.18-0.91) (p 111). Despite the known inaccuracies and limitations of radiation dose data recorded in Chernobyl State Registers, these findings are consistent with the published data for Japanese atomic bomb survivors (p 112)

- **Cytogenetic markers**

- A variety of types of chromosomal abnormalities in circulating blood lymphocytes have been shown to serve as biological dosimeters for assessing radiation doses received, either immediately following exposure or retrospectively. While a number of studies have been conducted, primarily to estimate absorbed radiation doses, in liquidators and residents in highly contaminated communities, these have not been systematically used on a large scale and have not been coordinated with data on health outcomes (p 116).

- **Infant mortality**

- Considerable uncertainty and unexplained fluctuations and changes are noted in a range of observed reproductive and child health outcomes. Cases of Down's syndrome in Belarus have fluctuated widely over time (p 123-6). A steady increase over time in 9 types of congenital malformations has been reported in both low and high contamination areas in Belarus since the disaster (p 123-4). The birth rate in Ukraine has declined by about 30% during the 1990s, apparently as a result of induced abortions – in 2000, there were 113 induced abortions per 100 live births and this ratio continues to increase (p 123).
- The most significant finding is probably the high infant mortality rates, which the Report notes have generally decreased in non-contaminated areas, and less so in highly contaminated areas (pp 125,127, 129). The reasons for this remain unexplained. Though the Report states that the increase in infant mortality in most heavily contaminated areas is not statistically significant, an upward trend in those areas during 1990-7, while the rate elsewhere is declining, is strongly suggestive of an adverse effect on infant mortality in the most contaminated areas in the period 4-11 years after the disaster, and aggregated data in a larger population may be more definitive. The causes of the high infant mortality in the 3 most affected countries are not elucidated in the Report.

- **Mental health**

- Increased levels of depression, anxiety, unexplained physical symptoms, subjective ill-health, and self-identification as 'invalid' and 'victim' have been documented in a range of Chernobyl-exposed populations (p 132-3). Suicide is reported as the leading cause of death in Estonian clean-up workers (p 133)
- The Consensus Expert Assessment in the Report concludes (p 134-5):

> *The mental health impact of Chernobyl is the largest public health problem caused by the accident to date. The magnitude and scope of the disaster, the size of the affected population, and the long-term consequences make it, by far, the worst industrial disaster on record. Chernobyl unleashed a complex of events and long-term difficulties, such as massive relocation, loss of economic stability, and long-term threats to health in current, and possibly, future generation, that resulted in an increased sense of anomie and diminished sense of physical and emotional balance..,.. the high levels of anxiety and medically unexplained physical symptoms continue to this day.*
>
> ...
>
> *The accident has had a serious impact on mental health and well-being in the general population. Importantly, however, it appears that this impact is demonstrable mainly at a subclinical level.'*

Mortality caused by ionizing radiation

As there is nothing that biologically unequivocally identifies cancers, cardiovascular events, or other stochastic (probabilistic) health outcomes - the probability of which is increased following radiation exposure - as being caused by radiation exposure, the Report states (p 137): 'In reality, the actual number of deaths caused by this accident is unlikely to ever be precisely known.' Indeed it cannot be any other way.

- **Acute radiation sickness (ARS)**
  - ARS was originally diagnosed in 237 emergency workers, later confirmed in detail in 134, of whom 28 died in 1986 and 19 more died between 1987 and 2004 (p 138)

- **Emergency workers**
  - National registries in the 3 most affected countries include dose and medical information for 550,000 emergency workers and more than 1.5 million people living in contaminated areas. Age-matched control and dose-response studies on liquidators have only been conducted in Russia (p 138) [but note published Belarus data referred to previously which is not included in the Report].
  - Evidence to date in this group indicates:
    - An increase in leukemia incidence with an excess relative risk per sievert (ERR/Sv) of 6.7 (95%CI 0.8 – 23.5)
    - An increase in mortality due to solid cancer, with an ERR/Sv of 2.11 (95%CI 1.3 - 2.9)
    - Increased mortality due to cardiovascular disease with ERR/Sv of 0.5 (95%CI 0.2 – 0.9)
  - The estimate of 4.6% of all deaths in the Russian liquidators being attributable to radiation-induced cancer and cardiovascular disease over the period 1991-8 underestimates the overall impact by:
    - Considering a period during which excess cancers have just started to occur
    - Considering only external and not internal radiation doses
    - Importantly, the relative risk assessment is based on an inappropriate baseline – the Russian general population. The Report shows (Figs 16.1 and 16.2, p 139) data which only begin in 1991 (rather than going back to 1986 as would be much more useful). In 1991 there was a substantial healthy worker effect – the standardized mortality ratio in these generally young (mostly between 20 and 40 years, p 163), healthy, (mostly male) workers was under 0.65 ie their mortality rate was 35% less than that of the general population. Over the period shown, till 1998, this healthy worker effect lessens and by 1997 almost disappears.
      The substantial diminution of the healthy worker effect 5-11 years after the disaster begs the question of whether it had already declined from 1986 to 1991, and in any case will substantially underestimate any adverse health effects. A more appropriate baseline would be age, sex and occupation-matched military, nuclear power and emergency service workers who were not exposed to significant Chernobyl radiation. There should be no technical reasons why such a more appropriate control group could not be utilised.
    - The number of deaths attributable to radiation exposure in the liquidators described in this section (Chapter 16) of the Report relates

to only approximately one-third of the Russian emergency workers (and less than 10% of the total number of liquidators), over a 7 year period 1991-8, an observation period extending only slightly longer than the recognized minimum latency period of about 10 years for many of the cancers.

- It is rather surprising (p 142) that the relatively simple task of applying the Russian mortality data to liquidators from the other countries is yet to be done

Populations of contaminated areas

- The conclusions presented in this section of the Report (16.2.3) do not reflect information in other sections of the report noted above, or other data which were available to the Report's authors well before its release in draft form (such as the published cancer registry data from Belarus outlined previously). This section of the Report states that the only malignancy which has shown a statistically significant increase to date is thyroid cancer in children and adolescents (p 143). This ignores evidence cited in the Report of increased incidence in leukemia in liquidators and probably in children, increase in thyroid cancer in adults, and increase of overall cancer and cancers of a range of other sites in adults in Belarus, especially in highly contaminated regions.
- Table 16.4 (p 145, adapted as Table 2 below) of the Report summarises predictions of excess deaths from solid cancers and leukemia in exposed populations. It contains errors as it is not clear which of 'solid cancer' and/or 'leukemia' applies to the 3 time periods listed for each group. The denominators included are not consistent with other sections of the report eg the number of evacuees is given as 135,000; elsewhere the figure of 116,000 is used. Similarly, residents of other contaminated areas other than the most contaminated zones (SCZs) are given here as numbering 6,800,000; elsewhere in the Report figures of 5 and 6 million are used for this (somewhat arbitrarily defined) group.
- Assuming that the first 2 periods for each population group refer to solid cancers and leukemia, respectively, over the lifetime of those alive at the time of the disaster, gives a total number of estimated deaths from malignancy of 3960 (not 3940 as quoted in the accompanying press release) for 200,000 liquidators who worked during 1986-7 (no more than 1/3 of the total number), evacuees and residents of the SCZs. However, another 4970 deaths are estimated in the residents of other contaminated areas.

Table 2. Predictions of excess deaths from solid cancers and leukemia over lifetime (up to 95 years) in populations exposed as a result of Chernobyl disaster (drawn from Report Table 16.4, p 145)

Population	Population size	Average dose	Predicted excess cancer deaths	Total predicted excess malignant deaths
Liquidators 1986-7	200,000	100 mSv	Solid 2000 Leukemia 200	2200
Evacuees from 30 km zone	135,000	10 mSv	Solid 150 Leukemia 10	160
Residents of SCZs	270,000	50 mSv	Solid 1500 Leukemia 100	1600
Subtotal				*3960*
Residents of other 'contaminated zones'	6,800,000	7 mSv	Solid 4600 Leukemia 370	4970
Total				8930

- These estimates are incomplete in a number of respects:
  - The number of liquidators included (200,000) is only a small fraction of the total number mentioned elsewhere in the report (600,000) in the 3 most affected countries. Yet even this number is incomplete, as liquidators are known to have come from other countries, such as Estonia and Lithuania, and elsewhere have been estimated to number around 800,000. These are generally the most exposed group.
  - The estimates omit Chernobyl radiation-attributed cardiovascular deaths (estimated in the Russian liquidators for the period 1986-1998, p 141) to comprise 2.0 % of all deaths, in comparison with 2.6% of all deaths estimated to be due to Chernobyl-related malignancy ie in this group, the excess of cardiovascular deaths is almost as large as the excess of cancer deaths. These data also omit other non-malignant causes of death such as suicide
  - These estimates omit the less exposed countries, particularly of Europe, which although generally involving quite low exposures, involve at least many tens of millions of people, so even small increased risks can be associated with a large number of attributable cases of disease
  - Internal exposures are not considered
  - Exposures for those born since 1986 and future generations are not considered
- These estimates are therefore quite incomplete and underestimate the health consequences of the disaster

Specific comments in relation to the Report and accompanying press release

The Health Effects report is designated as 'Working Draft, August 31, 2005', and is an incomplete, provisional document eg under 'Foreword' is written only 'to be inserted'. No overall summary or conclusions are presented.

The 11 page press release embargoed for 5 Sep 05, announcing the Chernobyl Forum's Report, was issued by IAEA, WHO and UNDP, titled 'Chernobyl: the true scale of the accident' and subtitled: '20 years later a UN report provides definitive answers and ways to repair lives'. This release rather than the Report itself seems to have been the basis for most of the media coverage of the Report. The first 2 paragraphs of the release state:

> *'A total of up to four thousand people could eventually die of radiation exposure from the Chernobyl nuclear power plant (NPP) accident nearly 20 years ago, an international team of more than 100 scientists has concluded.*
>
> *As of mid-2005, however, fewer than 50 deaths have been directly attributed to radiation from the disaster, almost all being highly exposed rescue workers, many of whom died within months of the accident but others who died as late as 2004.'*

From the above review of the Report's key findings in relation to health outcomes, it is apparent that these widely quoted statements are at odds with the findings of the Report and convey a misleading understatement of the effects of the disaster. The impression that *'As of mid-2005, however, fewer than 50 deaths had been directly attributed to radiation from the disaster...'* is in contrast to the Report's estimated 8930 deaths expected in the 3 most affected countries among 200,000 liquidators, 135,000 evacuees and 7,070,000 residents of the most contaminated areas, within the lifetime of those exposed. The figure of 50 deaths is highly selective, relating only to deaths from acute radiation sickness.

A more complete approach to total cancer deaths is reflected in a US Dept of Energy study which applied radiation risk estimates more conservative than those used today to the estimated collective exposure in the Northern Hemisphere of 930,000 person-gray over a 50 year period, on the basis of the total inventory of radionuclides released and their dispersal across the Northern Hemisphere[6]. In this study, ***17,400 excess cancer deaths over a 50 year period were estimated, with 63% of these occurring outside the (then) USSR, mostly elsewhere in Europe***. These estimates ignore non-cancer effects and those occurring over a longer timeframe.

WHO's lack of leadership in radiation health and the vexed relationship between WHO and the IAEA

An important contextual matter in relation to the Report and assessment of Chernobyl health consequences is the diminished independence and leadership of WHO in relation to radiation health matters in general and the health dimensions of the Chernobyl disaster in particular. These deficiencies have, in the absence of feasible alternative explanations, been attributed in large part to WHO's problematic and inherently contradictory relationship with the IAEA.

One expects that WHO, as the world's lead technical international health organization, acts with objective, independent, scientific rigour; and that it would take the lead on assessing health consequences of major international events. Unfortunately, in

[6] Anspaugh LR, Catlin RJ, Goldman M. The global impact of the Chernobyl reactor accident. Science 1988; 242:1514-9.

relation to radiation health matters, WHO has played a diminished role compared with its leadership and activity in other health areas. This applies in relation to the Chernobyl disaster, as evidenced by:

- WHO was not substantially involved in assessing or seeking to minimize the health consequences of the disaster in the first 5 years following it. A statement from WHO accompanying the Chernobyl Forum Health Report titled 'WHO's role in the assessment and mitigation of the health effects of the Chernbyl accident'[7] makes no mention of any WHO activities prior to 1991.
- The lead agency for essentially all major conferences and UN agency reports on the Chernobyl disaster has not been WHO, but the IAEA. A variety of other UN agencies such as UNSCEAR and the International Agency for Research on Cancer (IARC), as well as national and regional organizations, have often played a more important role than WHO.

The IAEA spans inconsistent roles as both nuclear proliferation watchdog; and promoter of 'non-military' nuclear technology, including nuclear power, and involving largely the same materials, technology, and expertise as nuclear weapons development and production.

Article 1 of the Agreement between the IAEA and WHO (which came into force on 28 May 1959) established that the 2 organisations '...will act in close co-operation with each other and will consult each other regularly in regard to matters of common interest.' It appropriately asserts the independence of WHO's work by stating:

> ' ... it is recognized by the WHO that the IAEA has the primary responsibility for encouraging, assisting and coordinating research and development and practical application of atomic energy for peaceful purposes throughout the world *without prejudice to the right of the WHO to concern itself with promoting, developing, assisting and co-ordinating international health work, including research, in all its aspects.*'[emphasis added]

Article III.2 specifies: 'Subject to such arrangements as may be necessary for the safeguarding of confidential material, the Secretariat of the International Atomic Energy Agency and the Secretariat of the World Health Organisation shall keep each other fully informed concerning all projected activities and all programmes of work which may be of interest to both parties', and Article III.3 stipulates '...consultations regarding the provision by either party of such special information as may be of interest to the other party'. Such consultation and communication is appropriate for two UN agencies.

However, other parts of the Agreement inherently compromise WHO's independence in relation to nuclear and radiation matters:

> 'Whenever either organisation proposes to initiate a program or activity on a subject in which the other organization has or may have a substantial interest, the first party shall consult the other *with a view to adjusting the matter by mutual consent'* [Article I.3, emphasis added].

Further, Article III.1 outlines circumstances in which confidentiality may be exercised:

> ' The IAEA and the WHO recognize that they may find it necessary to apply certain limitations for the safeguarding of confidential information furnished to them. They therefore agree that nothing in this agreement shall be construed as requiring either of them to furnish such information as would, in the

[7] www.who.int/ionizing_radiation/a_e/chernobyl/en/print.html accessed 21.9.2005

> judgement of the party possessing the information, constitute a violation of the confidence of any of its Members or anyone from whom it has received such information or otherwise interfere with the orderly conduct of its operations.'

These provisions do not reinforce fundamental principles of accountability, transparency, or public provision of information; and do not justify confidentiality on the basis of public safety, as may temporarily be warranted, but on the basis of weaker, largely internal, organizational considerations.

The frequent deferral by WHO to IAEA as the lead agency in relation to Chernobyl consequences, the paucity and lateness of WHO involvement in evaluating and responding to the health consequences of the disaster, and the inappropriate downplaying of these consequences in the public communication around the recent Chernobyl Forum Report represent a compromised role of WHO, contrary to its global health leadership mandate.

Perhaps the most telling indicator of WHO's weak contribution and leadership on assessing Chernobyl disaster health consequences is the fact that I could only find 3 substantive WHO documents specific to Chernobyl included in the over 420 references in the Health Report.

Nor is the Chernobyl situation unique in this respect. It is germane to note that other highly radiation exposed populations in the former Soviet Union include those in the vicinity of Soviet nuclear test sites, particularly Semipalatinsk, in Kazakstan. Independent, rigorous, peer-reviewed, well-conducted and internationally-coordinated studies whose methods and findings should be promptly publicly available are needed in these populations, preferably led and co-ordinated by WHO. Yet again substantive WHO engagement and leadership appear to be absent.

General comments on the Report's context, strengths and limitations

Almost 20 years after the world's worst industrial disaster and worst non-military nuclear disaster, much of the available data on health consequences is weak, with a patchwork of different organizations utilizing different, non-standardised methodologies, and significant deficiencies exist in consistent and reliable radiation dose estimates, fundamental to accurate risk assessment. As outlined in this review, there is significant variation, both within the Report itself and between the Report and other sources, in the basic demography of population groups most affected.

Data on very few health outcomes, collected with sound and consistent methodology, are available for all the most affected areas. For example, the Report notes that information on liquidator mortality data are available mostly from Russia, on malformations mostly from Belarus, and on infant mortality mostly from Ukraine (p 105). Most data were collected in different ways in different places. This diminishes the ability of data to be pooled, its power to identify effects, the precision around estimates, and the reliability and strength of conclusions which can be drawn. The body of the Report, in contrast to the accompanying press release, highlights in some detail how incomplete and inconclusive the available data are, and highlights multiple ongoing research needs. It is in no way a definitive account of the health consequences of the disaster. The range of effects which have been already

demonstrated are therefore of even greater significance in terms of their likely true extent.

It is important to recognize (as the Report does), the fundamental principle that, particularly in relation to diseases which have multiple causes and changing epidemiology, lack of demonstration of an effect does not equate to absence of effect.

Particularly in the critical early days, weeks and years following the disaster, there existed strong elements of political cover-up and obfuscation which both hampered measures which could have protected people, and ongoing objective assessment of health consequences. A few examples will serve to underscore this:

- In the most affected countries, distribution of stable iodine, which could have minimized much of the harm from ingestion of short-lived I-131, was too late to be effective - indeed may have been harmful – and was not available at all to most of those who were significantly exposed
- The first reports of a major radioactive contamination event came not from Belarus, Ukraine or Russia, but from a nuclear power plant in Sweden, where contamination was detected on the clothing of incoming workers[8]
- Prof Yuri Bandashevsky, head of the Gomel State Medical Centre in one of the most contaminated regions of Belarus, paid for his work on the effects of internal radiation with an 8-year prison term, and was adopted by Amnesty International as a prisoner of conscience, believing that his conviction was 'related to his scientific research into the Chernobyl nuclear reactor catastrophe of 1986 and his open criticism of the state authorities'[9].

Subsequently, and at the opposite extreme, there were some exaggerated claims of harm resulting from the disaster, in part probably driven by a desire to attract international resources to deal with its consequences, particularly in the context of the significant economic downturn resulting from the disaster, and the strains associated with break-up of the former USSR. As noted in the Report, there is 'some evidence from Belarus, Russia and Ukraine of the manipulation of diagnoses allowing persons to be recognized as a Chernobyl invalid without proper justification in order to obtain social benefits' (p 172).

The political, governmental, social and economic upheaval associated with the break-up of the former Soviet Union compounded the difficulties of conducting well-organised and long-term health studies and introduced a wide range of additional potentially confounding health effects, including an overall significant reduction in life expectancy, particularly among adult males – 6 years in Ukraine, 9 years in Russia - which would have the effect of shortening the period of older age when the risk of cancer is greatest and a radiation-related increase would be most evident, and therefore diminishing observed effects.

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[8] Anon. Chernobyl. Bulletin of the Atomic Scientists 1996;52(3):20.

[9] Schneider M. The Chernobyl disaster. A human tragedy for generations to come. In: International Physicians for the Prevention of Nuclear War, PSR/IPPNW-Switzerland. Rethinking nuclear energy and democracy after September 11, 2001. IPPNW Global Health Watch Report No. 4. Cambridge, MA; IPPNW, 2004:7.

In the survivors of Hiroshima and Nagasaki, an early peak of leukemia 5-10 years after the exposure was followed by a steady rise in solid cancers and non-cancer disease incidence which is still increasing. Children have a higher sensitivity to radiation than adults – the same radiation dose in boys in the first year of life produces 3-4 times the cancer risk as between the ages of 20 and 50 years; and infant girls have almost double the risk of boys[10]. For both these reasons, the greatest radiation-related increase in cancer and other diseases in those exposed following the Chernobyl disaster is yet to occur, and cancer cases among those exposed to Chernobyl fallout as children can be expected to continue to accrue till the 2060s and 2070s.

Health assessment of the long-term impacts of the disaster also needs to take into account potential exposures, especially internal exposures, from long-lived isotopes such as Cs-137, Sr-90, Pu-239 and Am-240, in future generations living in contaminated regions, particularly given recycling of radionuclides within the biosphere, and bioaccumulation of some, such as Cs-137. Such long-term exposure pathways have scarcely been investigated and the Chernobyl Forum report does not address them.

The Report also does not address the health consequences of the disaster outside the most affected countries. Even though exposures of the large populations of Europe generally involved low radiation doses and therefore the incremental risk of adverse health effects is small, because they affect a very large number of people, the total number of excess cases, eg of cancer, attributable to Chernobyl exposure, even though not directly measurable, is considerable, as demonstrated in the US DOE study cited.

The limitations of the Report can perhaps best be illustrated if one adds to the Report's estimated number of **8930** excess cancer-related deaths over the lifetime of those most exposed in the 3 most affected countries (but involving no more than one-third of the total liquidators) (Table 2), some conservative estimates for other groups:

- As many cancer deaths in the 400,000–600,000 additional liquidators for whom risk estimates have not yet been made (p 142) as in the Russian cohort for which they have: 2200 x 2-3 **= 4400 - 6600**
- The Report (p 141) estimates that in Russian liquidators 2.0% of radiation-related deaths were due to cardiovascular disease and 2.6% to cancers. If one applies this ratio to the whole cohort of 600,000-800,000 liquidators, as above in relation to cancers, one can estimate 2200 x 3-4 x 2.0/2.6 cardiovascular deaths among all the liquidators: **5077 - 6769**
- The same number of cancer deaths outside the 3 most affected countries as in the 1988 US DOE report (based on 50 year dose commitment): **10,920**
- An additional 20% of cancer deaths related to exposures occurring in future generations: 0.2 x (8930+(4400-6600)+10,920)= **4850-5290**

This yields an estimate (rounded to 3 figures) of **34,200 – 38,500 deaths**. This does not include any non-cancer effects other than in liquidators, and even in this group includes only cardiovascular deaths, and not those due to suicide, other mental health problems, substance abuse or any other causes; or any possible genetic effects.

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[10] The National Academies. BEIR VII: health risks from exposure to low levels of ionizing radiation. Washington DC; National Academies Press, 2005.

And of course in addition to the burden of excess mortality is the substantial and long-term burden of illness and ill-health. As noted in the WHO statement accompanying the draft Health Effects Report[11]:

> *'The Chernobyl disaster was a human tragedy, resulting in large-scale displacement of populations, the contamination of vast areas of land, the loss of livelihood and the mental trauma suffered by people who had to be evacuated because of severing links with their home and social networks. The victims of the tragedy were confronted by situations they could not understand and against which they had no means of defense.'*

Conclusions

Despite the considerable limitations in quality and extent of data available on health outcomes of the Chernobyl disaster, multiple confounding factors, lack of leadership by WHO, and the fact that most health consequences beyond the acute phase of the disaster are still to occur, the Report documents numerous health consequences of the disaster, and estimates that about 9000 excess deaths can be expected only in the most affected areas among those alive at the time of the disaster. This estimate includes only 200,000 of the 600,000 to 800,000 liquidators, who were the most heavily exposed group.

A conference on 'Health of liquidators (clean-up workers), 20 years after the Chernobyl explosion' organized MAPW's Swiss sister organization Physicians for Social Responsibility/ International Physicians for the Prevention of Nuclear War Switzerland is being held on 12 Nov 05 at the University Hospital in Bern, Switzerland.

By any standard, as the report notes, the Chernobyl disaster was the world's worst industrial disaster, with serious economic, social, environmental and health consequences which will continue to accrue over many years hence.

[11] WHO. WHO's role in the assessment and mitigation of the health effects of the Chernobyl accident. www.who.int/ionizing_radiation/a_e/chernobyl/en/print.html. Accessed 21 Sep 2005.

Laser enrichment of uranium – proliferation concerns documented in recent Carnegie Endowment for International Peace Report: 'Deadly Arsenals'

As presented in the Association's submission to the current Inquiry and discussed by A/Prof Ruff during the public hearing on 19 Aug 2005, in the context of research into laser enrichment of uranium being undertaken by Silex Systems at the Lucas Heights facility in Sydney, laser enrichment of uranium poses significant proliferation concerns.

Committee members requested further information on these issues from a major new report from the Carnegie Endowment which was referred to by A/Prof Ruff[12]. Key points in this report relating to laser enrichment of uranium will be presented here.

In their review of global trends, the authors note that 'The NPT has already been severely threatened by the development in several states of facilities for enriching uranium and reprocessing plutonium.' (p 17), that proliferation problems have grown worse since 2000 (p 21), and that it is not clear if the international nuclear black market involving over 30 countries and headed by Pakistan's AQ Khan 'has shut down or merely gone underground' (p21). Indeed, they cite 'growing concern that the entire nonproliferation regime is in danger of catastrophic collapse' (p 22).

The authors note that even the IAEA Additional Protocol 'cannot prevent a determined state from acquiring a nuclear weapons capability' (p 32), and underscore the fundamental problem that 'The same technologies that can enrich uranium to low levels for reactor fuel can enrich it to high levels for nuclear weapons' (p 32). This recognition explains much of the current concern about Iran's nuclear activities, and President George W Bush's proposal for a moratorium on additional countries acquiring uranium enrichment or reprocessing capacity[13].

The Report makes the important points that 'acquiring a supply of nuclear material (as opposed to making the weapon itself) remains the most difficult challenge for a terrorist group' (p 16) and that 'the most likely sources of nuclear weapons and materials for terrorists are storage areas in the former states of the Soviet Union and Pakistan, and ***fissile material kept at dozens of civilian sites around the world'*** [emphasis added] (p 16). And the authors state that 'Because uranium can be used in the simpler gun design [rather than requiring an implosion design], ***highly enriched uranium is considered a particularly attractive material for terrorists seeking to acquire nuclear weapons***' [emphasis added] (p 48).

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[12] Cirincione J, Wolfsthal JB, Rajkumar M. Deadly arsenals. Nuclear, chemical and biological threats. 2nd edition. Washington DC; Carnegie Endowment for International Peace, 2005.

[13] The White House. President announces new measures to counter the threat of WMD – remarks by the President on weapons of mass destruction proliferation. http://www.whitehouse.gov/news/releases/2004/02/

Pakistan relies primarily on highly enriched uranium (rather than plutonium) for its nuclear weapons program (p 50).

Because light water-moderated reactors require low-enriched uranium (whereas heavy-water and graphite-moderated reactors use natural uranium as fuel), access to enrichment capacity is required to run such reactors (p 53).

In relation to uranium enrichment, the Report finds that: 'Considerable research and development has been conducted on several chemical and laser isotope-separation technologies, but none of these is yet efficient enough to use in the commercial production of enriched uranium. ***Iran and South Korea have recently been found to have conducted uranium enrichment activities using lasers, causing increased concern about control of this technology***' [emphasis added] (p 49).

Iran

Iran has pursued at least 2 different methods for enriching uranium: gas centrifuges and lasers – work on the latter began under the Shah in the 1970s (p 299). The program is based on 2 technologies: atomic vapour laser isotope separation (AVLIS) and molecular isotope separation (MLIS). Iran established a pilot laser enrichment plant at a site known as Lashkar Ab'ad in 2000. The IAEA has completed a review of the AVLIS program and concluded that the levels of enrichment achieved matched Iran's description of the activity (up to 15% U-235 enrichment); but determined that the equipment could have been used for the production of highly enriched uranium (p 301).

South Korea

South Korea's laser uranium enrichment activities, though not detailed in the Carnegie report, should be discussed in this context. An excellent analysis is presented in the Stockholm International Peace Research Institute's 2005 Yearbook[14]. These activities came to light in connection with South Korea's initial expanded declaration under the NPT Additional Safeguards Protocol. Laboratory laser uranium enrichment experiments using the AVLIS method were conducted in 2000. The failure to report them was a violation of South Korea's safeguards agreement. IAEA inspectors learned of additional violations: undeclared uranium conversion activities and a plutonium separation experiment.

In the tense situation on the Korean peninsula, these disclosures impeded efforts to restart the Six-Party Talks on North Korea's nuclear weapon program and complicated South Korea's efforts to engage and improve relations with the North. At its November 2004 meeting, the IAEA Board of Governors concluded that South Korea's failure to declare the experiments was 'a matter of serious concern'.

[14] Kile SN. Nuclear arms control and non-proliferation. In: Stockholm International Peace Research Institute. SIPRI Yearbook 2005. SIPRI; Oxford University Press, 2005:568-70.

Other states

Efforts to develop laser uranium enrichment have been part of past nuclear weapons programs in a number of other countries, including:

- Iraq (p 338)
- Brazil (p 396)
- South Africa (an MLIS program developed jointly with the French nuclear firm Cogema)

Conclusion

It is clear that laser enrichment of uranium has been a part of numerous nuclear weapons development programs and constitutes a significant proliferation concern.