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# DEATH CAMP FUKUSHIMA CHERNOBYL



**EVIDENCE FROM SCIENTISTS & DOCTORS  
PERSECUTED FOR TELLING THE TRUTH**

## Contents

Nuclear Shutdown

Chernobyl Deaths Top  
a Million Based on Real  
Evidence

Truth about Fukushima

Fukushima Fallout Rivals  
Chernobyl

Bystander Effects Amplify  
Dose and Harm from  
Ionizing Radiation

Apple Pectin for  
Radioprotection

The Pectin Controversy

Green Tea Compound for  
Radioprotection

WHO Report on Fukushima a  
Travesty

UK's Nuclear Illusion

ISIS special report by Dr. Mae-Wan Ho,  
Susie Greaves and Prof. Peter Saunders



Dr. Mae-Wan Ho and Prof. Peter Saunders

Now or never

"We lost Japan," said Rie Inomata, who works as an interpreter [1].

"I feel guilty and sorry for the children. They did not choose nuclear power plants, they did not choose to be born; but it is them that have to suffer in the future."

"By not protesting against nuclear power I allowed this accident to happen. If we go in the same direction, I don't see any future."

"If we [are to] make a difference, we must decide now, it is now or never."

Potential future of Fukushima children  
written in Chernobyl

The potential future for the Fukushima children victims is written starkly in the government birth and death registries of the heavily contaminated regions in the Chernobyl fallout; dedicated doctors, scientists, and ordinary citizens are bearing witness to the humanitarian disaster still unfolding.

There have been close to a million excess deaths, with general mortality rates doubled or tripled [2] (Chernobyl Deaths Top a Million Based on Real Evidence, SiS 55). A diversity of illnesses continue to claim lives including those of children: birth abnormalities, cancers, cardiovascular malfunction, premature aging, defects affecting practically every organ system, often multiple illnesses in the same individual, all associated with exposure to radioactivity in the body either inhaled or ingested in contaminated food. The number of children in Belarus has fallen by more than 27% since 2000, despite increasing birth rates. The horrific health impacts of the nuclear accident are still emerging more than 26 years later because the land is still contaminated, and the genetic/epigenetic legacy is just as long lasting.

Many of the deaths and sicknesses could have been avoided had governments not done their best to suppress the evidence from the start, even to the point of persecuting doctors and scientists - who put their lives and careers at risk in trying to save the children - including cutting off major funding for a simple treatment that would have reduced the children's radioactive burden [3, 4] (Apple Pectin for Radioprotection, The Pectin Controversy, SiS 55).

Fukushima fallout as big as Chernobyl  
Chernobyl was generally recognized as the biggest nuclear accident in history. Within days of the first explosion, Fukushima was reclassified by the International Atomic Energy Agency to the highest grade 7 - with "widespread health and environmental effects" - the same as Chernobyl [5] (Fukushima Nuclear Crisis, SiS 50).

But as in Chernobyl, the government has withheld vital information from people, the international regulators are downplaying the health impacts, and to this day, the total radioactivity released from the stricken Fukushima Dai-ichi nuclear power plant is still unknown [6] (Truth about Fukushima, SiS 55).

The most authoritative estimates based on measurements carried out by the Comprehensive Test Ban Treaty monitoring stations around the globe indicate that the total radioactivity released from the Fukushima accident is at least as great as from Chernobyl; some 15 times the official estimate, and much more global in reach [7] (Fukushima Fallout Rivals Chernobyl, SiS 55). The radioactivity in the waste water discharged into the Pacific Ocean is already the single largest release into the ocean in history.

The Japanese government's own measurements show widespread contamination, with levels of radioactivity outside the official evacuation zone so high that **within a matter of weeks, people would have been exposed to 10-200 times the legal limit dose for a whole year [6]. Evacuation especially of children from those areas is a matter of the utmost urgency. Yet the Japanese government is still refusing to do that.**

Nuclear reactors to restart despite lag in crisis plan

On 16 June 2012, Japanese premier Noda ordered the restart of two nuclear reactors amid widespread protest, and new crisis plans drafted after the Fukushima disaster are still to be implemented by any local community living near the nuclear power reactors. The Ohi nuclear reactors to be restarted are a case in point.

If a Fukushima-style meltdown were to happen, the only route for escape or sending help is [8] "a winding, cliff-hugging road often closed by snow in winter or clogged by beachgoers in summer." Radioactivity from the meltdown could contaminate Lake Biwa, the country's biggest freshwater source serving 14 million people. The reactors sit on Wakasa Bay, a region home to 13 commercial reactors. Some of the crucial measures designed to protect residents in the new crisis plans are not ready, such as a raised seawall in 2013 and an onsite command centre by March 2016. And filter vents that could reduce radiation leaks to the environment won't be ready for three more years.

The Fukui provincial government only started a survey in June 2012 for a multibillion dollar project to repair the sole route to the Ohi nuclear plant and to add a new alternative evacuation road.

Governor Yukuko Kada of neighbouring



Death Camp Fukushima Chernobyl 2012

Shiga province accuses the central government of still ignoring the residents, and says it has still refused to provide radiation simulation data she has asked for in order to compile an evacuation map and to study the impact on Lake Biwa, as another Fukushima-class crisis could “instantly make the lake water undrinkable.”

Public opposition to resuming operations remains high because of the Fukushima disaster and a lingering distrust of the nuclear industry as well as the pro-nuclear regulators and governments.

But the public have good reason on their side.

Big nuclear accidents 200 times more often than previous estimates

Scientists at the Max Planck Institute for Chemistry in Mainz have calculated that catastrophic nuclear accidents such as Chernobyl and Fukushima may occur once every 10 to 20 years, based on the operating hours of all civil nuclear reactors and the number of nuclear meltdowns that have occurred [9]. This is more than 200 times as often than estimated in the past. The research team also determined that in the event of such a major accident, half of the long-lived radioactive caesium-137 would be spread over an area extending more than 1 000 km away from the reactor. Western Europe in particular is likely to be contaminated about once in 50 years by more than 40kBq of Cs-137 per square metre, a level upwards that the International Atomic Energy Agency (IAEA) defines as ‘contaminated’.

Their calculations showed that if a single nuclear meltdown were to occur in Western Europe, ~ 28 million people would be affected by contamination of more than 40 kBq per square metre. In southern Asia, the dense population would put the number of people affected by a major nuclear accident at ~34 million, while in the eastern USA and in East Asia this would be 14 to 21 million.

Fukushima has triggered Germany’s exit from their nuclear power programme. It is to close down all 17 nuclear reactors and replace them with renewable energies, mostly wind and solar, and has invested €200 billion (8 % of the country’s GDP) towards that end [10]. “Germany’s exit from the nuclear energy program will reduce the national risk of radioactive contamination,” said Director and lead author of the Max Planck study Jos Lelieveld, an atmosphere chemist [9]. “However, an even stronger reduction would result if Germany’s neighbours were to switch off their reactors. Not only do we need an in-depth and public analysis of the actual risks of nuclear accidents. In light of our findings I believe an internationally coordinated phasing out of nuclear energy should also be considered.”

Some governments have too cosy a relationship with the nuclear industry. The UK government is chief among those countries with nuclear ambitions undaunted by the Fukushima disaster. It is still deter-

mined to go ahead with the construction of at least 10 new reactors, despite plenty of counter-evidence available to it, which include evidence that an adequate supply of low carbon energy could be produced without it, to the point of misleading Parliament by omission of the evidence in order to get the decision through [11] (UK’s Nuclear Illusion, SiS 55), and with a huge public subsidy. Why?

The most likely explanation is a too-cosy relationship between the government and the nuclear industry, which applies in other countries like France [12] (The True Costs of French Nuclear Power, SiS 53) with close links to nuclear weaponry. But times have changed, the nuclear option is a dinosaur, both as far as energy supply and defence is concerned, and it is time to end the nuclear illusion once and for all.

WHO cannot be trusted

The World Health Organisation (WHO), which should have been an independent regulator of nuclear safety, has long abandoned this obligation. In 1959, the WHO signed an agreement (WHA 12-40) with IAEA that effectively gave the IAEA responsibility for health issues arising from the civilian use of nuclear power. The terms of the agreement are freely available to the public [13] but they are still not widely known, with the result that most people are unaware that reports and other documents that purport to have major input from the WHO, the agency set up by the UN in 1948 to deal with international health issues, are actually from the IAEA, the body whose mission is to promote the nuclear industry. The WHO has put its name on documents such as the 2003-2005 report of the Chernobyl Forum [14] that it had little to do with; it could not have because it has no department for nuclear health and no experts in the field. Its report on Fukushima, similarly, cannot be trusted [15] (WHO Report on Fukushima a Travesty, SiS 55)

IndependentWHO, an organisation concerned about the dangers of nuclear power in general and the consequences of Chernobyl and Fukushima in particular, demands the revision of agreement WHA 12/40, and has held a vigil outside WHO headquarters in Geneva every working day since April 2007 to draw attention to the crime of non-assistance to the victims of Chernobyl and now Fukushima. (For more, see its web site: <http://independentwho.org/en/>)

Thanks to the IndependentWHO, the editors of SiS were invited to the Scientific and Citizen Forum on Radioprotection – From Chernobyl to Fukushima, 11-13 May 2012, Geneva, which the group organized. This led to the series of articles that has been collected into the present report, *Death Camp Fukushima Chernobyl*.

Death Camp Fukushima Chernobyl

*Death Camp Fukushima Chernobyl* is a concise summary of scientific evidence on:

- The devastating health consequences of

the Chernobyl radioactivity fallout suppressed by governments and pro-nuclear regulatory authorities

- The real extent of the Fukushima fallout and health hazards faced by victims, both downplayed by the Japanese government and the regulatory authorities
- New findings on the amplified health impacts of low dose ionizing radiation
- Simple radioprotection measures.

It also shows why the official picture presented by organisations such as the WHO is highly misleading, and why countries still determined to go nuclear are clinging to obsolete energy and defence policies.

The report makes clear that children living in the highly contaminated areas outside the official evacuation zone around Fukushima Dai-ichi nuclear plants must be evacuated promptly in order to avert a humanitarian disaster on the scale of Chernobyl. Concerted international effort is needed to provide help for evacuating the children and to continue health monitoring and research on radioprotection. Finally, a global phase out of nuclear power is in order given that a combination of renewable energy options can provide all our energy needs safely, sustainably and at much more affordable costs for all, as we made the case thoroughly in ([16] Green Energies - 100% Renewable by 2050, ISIS Report).

## References

1. Stories from Fukushima, Message in a Bottle, From the kids of Fukushima to the World, accessed 20 June 2012, [http://message.in.a.bottle.over-blog.com/pages/STORIES\\_FROM\\_FUKUSHIMA\\_ENGLISH-6985709.html](http://message.in.a.bottle.over-blog.com/pages/STORIES_FROM_FUKUSHIMA_ENGLISH-6985709.html)
2. Ho MW. Chernobyl deaths top a million. *Science in Society* 55, 14-17, 2012.
3. Ho MW. Apple pectin for radioprotection. *Science in Society* 55, 32-33, 2012.
4. Greaves S. The pectin controversy. *Science in Society* 55, 34-36, 2012.
5. Ho MW. Fukushima nuclear crisis. *Science in Society* 50 4-9, 2011.
6. Ho MW. Truth about Fukushima. *Science in Society* 55, 18-23, 2012.
7. Ho MW. Fukushima fallout rivals Chernobyl. *Science in Society* 55, 24-27, 2012.
8. “Crisis plans lag even as Japan’s reactors restart”, Mari Yamaguchi, Associated Press, *chron.com*, 21 June 2012, <http://www.chron.com/business/article/Crisis-plans-lag-even-as-Japan-s-reactors-restart-3650896.php#page-1>
9. “Probability of contamination from nuclear accidents is higher than expected” Max-Planck-Gesellschaft, 22 May 2012, [http://www.mpg.de/5809418/reactor\\_accidents](http://www.mpg.de/5809418/reactor_accidents)
10. “Germany swaps nuclear for solar and wind power”, Oliver Lazenby, *Truthout*, 22 June 2012, <http://truth-out.org/news/item/9932-germany-swaps-nuclear-for-solar-and-wind-power>
11. Saunders PT. UK’s nuclear illusion. *Science in Society* 55, 40-42, 2012.
12. Greaves S. The true costs of French nuclear power. *Science in Society* 53, 8-11, 2012.
13. Agreement between the International Atomic Energy Agency and the World Health Organisation, IAEA/WHO, 1959, [http://www.iaea.org/Publications/Documents/Inf-circs/0thers/inf20.shtml#note\\_c](http://www.iaea.org/Publications/Documents/Inf-circs/0thers/inf20.shtml#note_c)
14. Chernobyl’s Legacy: Health Environmental and Socio-Economic Impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine. IAEA Division of Public Information. Vienna, IAEA, 2006, <http://www.iaea.org/Publications/Booklets/Chernobyl/chernobyl.pdf>
15. Greaves S. WHO report on Fukushima a travesty. *Science in Society* 55, 38-39, 2012.
16. Ho MW, Brett C, Burcher S and Saunders PT. Green Energies, 100 % Renewables by 2050, ISIS/TWN, London/ Penang, 2009, <http://www.i-sis.org.uk/GreenEnergies.php>

# Chernobyl Deaths Top a Million Based on Real Evidence

*Medical records from contaminated areas speak for themselves; doctors, scientists and citizens bear witness to the devastating health impacts of radioactive fallout from nuclear accidents*

**Dr. Mae-Wan Ho**

## Official denial by nuclear lobby

The Chernobyl disaster occurred on 26 April 1986 at the Chernobyl Nuclear Power Plant near the city of Prypiat in Ukraine, then part of the Soviet Union, and close to the administrative border with Belarus. A sudden power output surge prompted an attempt at emergency shutdown; but a more extreme spike in power output led to the rupture of a reactor vessel and a series of explosions. The graphite moderator was exposed, causing it to ignite, and the resulting fire sent a plume of highly radioactive fallout over large parts of the western Soviet Union and Europe. From 1986 to 2000, 350 400 people were evacuated and resettled from the most contaminated areas of Belarus, Russia and Ukraine. According to official post-Soviet data, about 57 % of the fallout landed in Belarus [1]. Chernobyl is widely considered to have been the worst nuclear accident in history and one of only two classified as a level 7 event on the International Nuclear Event Scale, the other being the Fukushima Daiichi nuclear meltdown in 2011 (see [2] Fukushima Nuclear Crisis, SiS 50).

From the beginning, the official nuclear safety experts were at pains to minimise the projected health impacts, as they are doing now for the Fukushima accident.

The UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) estimated a “global collective dose” of radiation exposure from the accident “equivalent on average to 21 additional days of world exposure to natural background radiation”. Successive studies reported by the IAEA (International Atomic Energy Agency) continued to underestimate the level of exposure and to understate health impacts other than [3] “psychosocial effects, believed to be unrelated to radiation exposure” resulting from the lack of information immediately after the accident, “the stress and trauma of compulsory relocation to less contaminated areas, the breaking of social ties and the fear that radiation exposure could cause health damage in the future.”

The number of deaths attributed to Chernobyl varies widely [1]. Thirty-one deaths are directly attributed to the accident, all among the reactor staff and emergency workers. An UNSCEAR report plac-

es the total confirmed deaths from radiation at 64 as of 2008. The Chernobyl Forum [4] founded in February 2003 at the IAEA Headquarters in

Vienna with representatives from IAEA and UN agencies including UNSCEAR, WHO, the World Bank, and Belarus, Russia and Ukraine, estimates that the eventual death toll could reach 4 000 among those exposed to the highest levels of radiation (200 000 emergency workers, 115 000 evacuees and 270 000 residents of the most contaminated areas); the figure includes some 50 emergency workers who died of acute radiation syndrome, 9 children who died of thyroid cancer and an estimated total of 3950 deaths from radiation-induced cancer and leukemia. The Union of Concerned Scientists based in Washington in the United States estimates another 50 000 excess cancer cases among people living in areas outside the most contaminated, and 25 000 excess deaths. A Greenpeace report puts the figure at 200 000 or more. The Russian publication, *Chernobyl*, by scientists Alexey V. Yablokov, Vassily B Nesterenko, and Alexey V. Nesterenko, translated and published by the New York Academy of Sciences in 2009, concludes that among the billions of people worldwide who were exposed to radioactive contamination from the disaster, nearly a million deaths had already occurred between 1986 and 2004. Most of the deaths were in Russia, Belarus and Ukraine [5] (see Truth about Chernobyl, SiS 47). The report drew on thousands of published papers and internet and printed publications. Those publications and papers, written by leading Eastern authorities, were downplayed or ignored by the IAEA and UNSCEAR. These agencies minimised their estimates by several plays including [6]:



Dr. Alexey Yablokov



- Underestimating the level of radiation by averaging exposure over a large regions, such as an entire country; so high exposure doses and health statistics of the most contaminated areas are lumped together with the less and least exposed
- Ignoring internal sources of radiation due to inhalation and ingestion of radioactive material from fallout
- Using an obsolete and erroneous

model of linear energy transfer due to external sources of ionising radiation

- Not counting diseases and conditions other than cancers
- Overestimating the natural background radiation; today's 'background' has been greatly increased by discharges from nuclear activities including tests of nuclear weapons, use of depleted uranium, and uranium mining
- Suppressing and withholding information from the public.

Nevertheless, the devastating health impacts did not escape the notice of the hundreds of doctors, scientists and other citizens who had to bear witness to the deformities, sicknesses and deaths of exposed babies, children and adults in their care.

#### Diversity of health impacts and their global extent over generations to come

Alexei Yablokov, distinguished academician of the Russian Academy of Sciences in Moscow, spoke at the Scientific and Citizen Forum on Radioprotection – From Chernobyl to Fukushima, 11-13 May 2012 in Geneva [7]. He is adamant that the consequences of the Chernobyl disaster can be clearly demonstrated by comparing the states of people's health in areas receiving different amounts of additional radiation following the accident, instead of one based on average effective dose calculated by the ICRP and UNSCEAR which underestimates the true levels of irradiation. For example, there is a clear difference in mortality rates between highly contaminated provinces and less contaminated provinces of Russia (see Figure 1). Yablokov is lead author of a massive report, now in its third enlarged 2011 edition [8], which has collated all the available evidence.

The evidence that emerged is also striking for the diversity of deformities and illnesses observed apart from cancers; and this is documented in more than 10 000 studies published in different countries, mainly Russia, Ukraine and Belarus, in the 25 years since the disaster. Contrary to the figures given out by UNSCEAR, IAEA and the World Health Organization (WHO), even reports published by the governments of Belarus and Ukraine recognise that there has been a significant increase in levels of illness and deaths everywhere: various forms of cancer (not only of the thyroid), cataracts, cardiovascular diseases, diseases of the respiratory and digestive systems, immunological and neuropsychiatric effects, birth defects, and alterations in reproductive function, and premature aging. Death rate among the liquidators (recovery workers) remained high even four years after the disaster, despite the fact that most of them were young and in good health. Twenty years later, 115 000 (out of 830 000) are dead.

Yablokov emphasized that the fallout from Chernobyl is global, as 57 % of the radioactive material fell outside the former Soviet Union. Consequently, many countries in the Northern hemisphere particularly Europe and Western Asia would also be affected. A significant increase in birth defects was observed in many European countries and in Turkey. Particularly telling are the higher infant mortality rates above a long-term decreasing trend recorded simultaneously in four different European countries between 1986 and 1992 (see Figure 2).

Another impact of fallout from Chernobyl is the increase in cancer, death rates and marked deterioration in educational achievement in schoolchildren in the most contaminated areas of Sweden compared with less contaminated areas. Even after 26 years, there

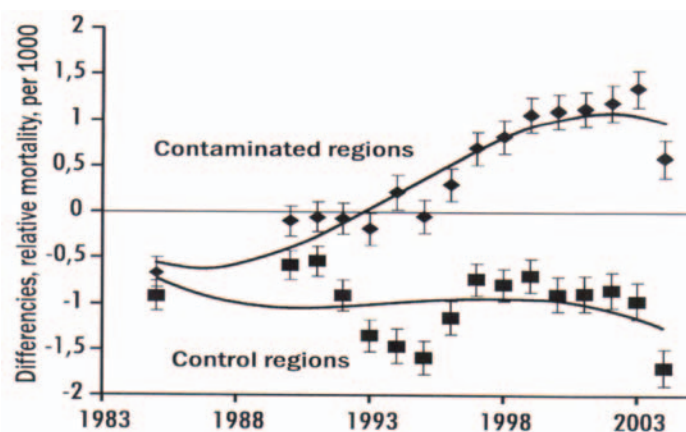


Figure 1 Relative death rates in 6 highly contaminated provinces compared with 6 less contaminated provinces in Russia; zero represents no difference from Russia as a whole

are places in Norway, Germany, Switzerland, France and other European countries where deer, boar, fish and mushrooms are still contaminated by caesium 137 at dangerous levels [8].

The health legacy from Chernobyl is long lasting. The genetic damage in terms of chromosomal breaks and other mutations will affect the health of millions over several generations yet to come. "The full picture of deteriorating health in the contaminated territories is far from complete," Yablokov said. More research is needed; instead, research on the health impacts of Chernobyl has been cut back in Russia, Ukraine, and Belarus.

#### Overview of the evidence

Evidence of the devastating health impacts from the radioactive fallout of Chernobyl is still to be found long after the accident. Seventeen years later, areas contaminated at levels above 40 kBq/m<sup>2</sup> in Belarus, Ukraine and Russia, have seen an increase in total average mortality of 3.8 to 4 % (an excess of 237 000 people) compared with neighbouring regions that were less contaminated [9]. (A Bq, becquerel, is a radioactive disintegration rate of one per second.) A conservative extrapolation from these figures led to the conclusion that over the 20 years following the accident, Chernobyl has caused an additional million deaths (about 0.1 of total mortality).

Some general effects of the Chernobyl accident that began to appear in the 3rd to 4th year and have continued over the following 10 to 15 years; these are as follows.

- Two to three times the general morbidity rate in the most contaminated territories (including children)
  - Increase in primary illness
  - Increase in the number of low birth-weight babies and birth defects
  - Premature ageing (biological age 5-7 years higher than chronological age)
  - Poly-morbidity, the presence of a number of illnesses in one individual.
- Specific health problems linked to radiation from Chernobyl affect practically all organ systems.
- The circulatory system (radiological lesions of the endothelium, the interior walls of the blood vessels)
  - Heart disease
  - The endocrine system (including non-cancerous diseases of the thyroid gland);
  - The immune system
  - The respiratory system (including lesions of the upper airways)
  - The genito-urinary system and reproductive processes
  - The skeleton (osteopenia and osteoporosis, low density or fragile bone)
  - The central nervous and neuropsychiatric system (associated with organic modifications of the post-frontal, temporal and parieto-occipital lobes of the brain cortex and other deeper structures)
  - The visual apparatus (including radiation cataracts)

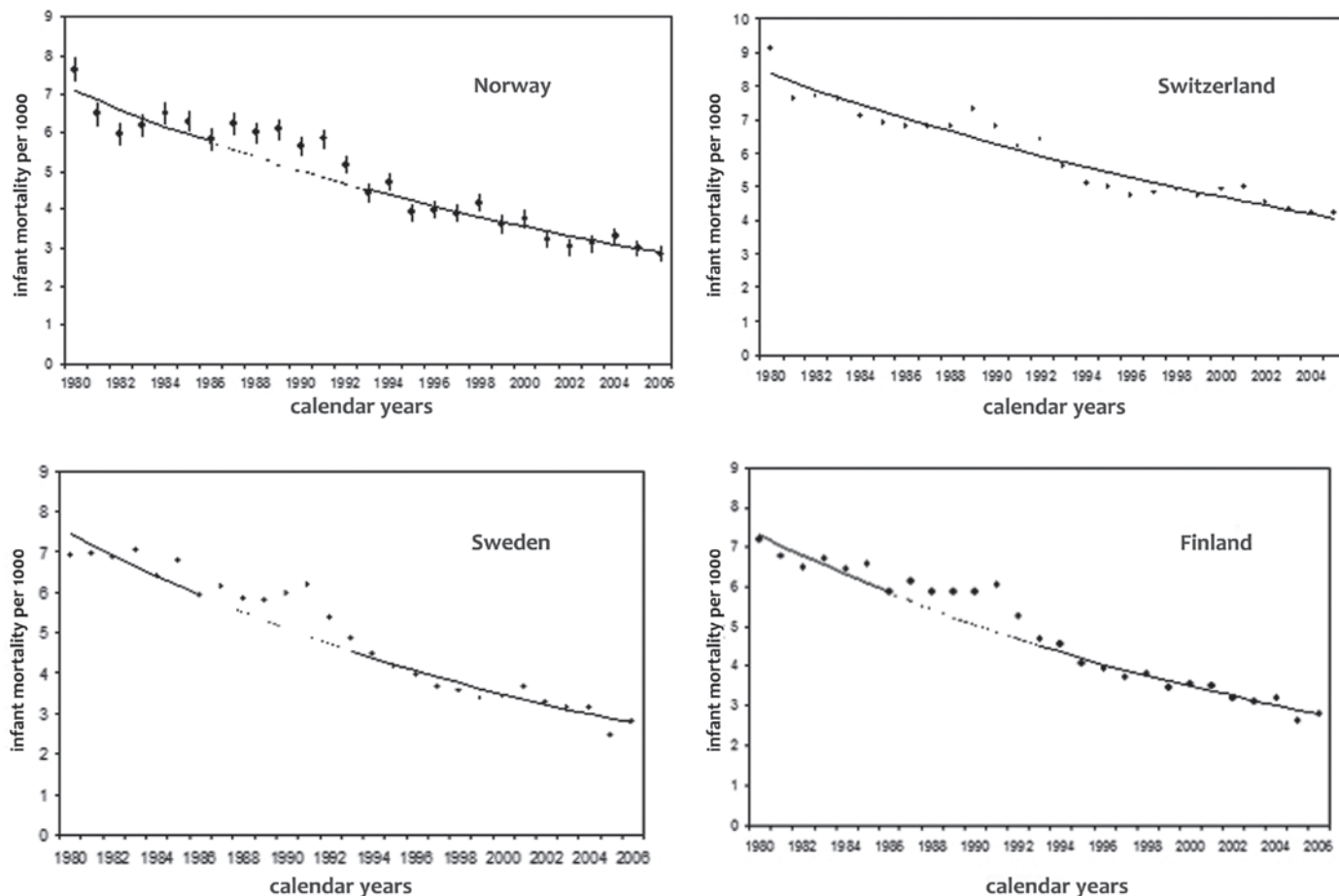


Figure 2 Infant mortality in four different European countries

- The digestive system
- Birth defects and developmental anomalies
- Thyroid cancer (not only in children but also in adults) and other malignant tumours.

Other health impacts include the following.

- Alterations in the health of children born to irradiated parents (including the liquidators and also people who left the contaminated areas), and in particular those children who were irradiated *in utero*;
- Genetic alterations (frequent mutations of the somatic and germ tissues, changes in the secondary sex ratio).

One specific effect of the radioactive contamination from Chernobyl is the change in the secondary sex ratio (ratio of male/female births). After 1987, there was a statistically significant decrease in the number of girls born in some European countries [10]. In 2008, there was a deficit of female births worldwide of around a million [11].

Yablokov (and other speakers at the conference) blamed the lack of clear understanding of the negative impact of the Chernobyl disaster first of all on the secrecy and falsification of the USSR medi-

cal statistics for the first three and a half years after the catastrophe, on the difficulties in estimating absorbed doses by individuals, the inability to determine the impact of each of the radionuclides (fission products are notoriously heterogeneous) [7], and most of all, the agreement signed between the WHO and the IAEA in 1959, whereby the WHO needs the consent of the IAEA to publish the results of studies on ionising radiation [12]. That has resulted in crucial data being concealed.

#### The children of Belarus

Thyroid cancer is practically the only health impact admitted by the UNSCEAR assessment to be linked to Chernobyl [13]. It recognized more than 6 000 cases of thyroid cancer reported in children and adolescents up to 2005 who were exposed at the time of the accident, and "more cases to be expected during the next decades." In fact, 8 700 additional thyroid cancer cases occurred in Belarus alone between 1990 and 2006, according to M.V. Malko of the Belarus National Academy of Sciences [14]. The number of thyroid cancer cases registered during this period was about 13 300 as against 4 600 expected. The situation has got worse, as populations are living in areas still highly contaminated. Since 2005, malignant tumours of the thyroid in both adults and children had jumped again, from 10.8 per 100 000 inhabitants to more than 11.8 or more in 2008 and 2009.

Galina Bandajevskaya, a paediatrician in Belarus, is witnessing the continuing impact on the children in her country. Since 2000, the number of children under 18 in Belarus has decreased by 27.4 % (see Figure 3), despite the fact that birth rate has been increasing since 2003, from 9 per 1 000 to 11.4 per 1 000 in 2010.

"To-day, paediatricians like myself are seeing, in the course of our clinical examinations, an increase in the number of illnesses and a general deterioration in children's health in Belarus." Bandajevskaya said. According to the data, out of a total of more than 1 million school children in Belarus in 2009, only 26.7 % were considered in good health, 58.1 % had functional deficiencies and were at risk of developing chronic illnesses, while 13.8 % already suffered from

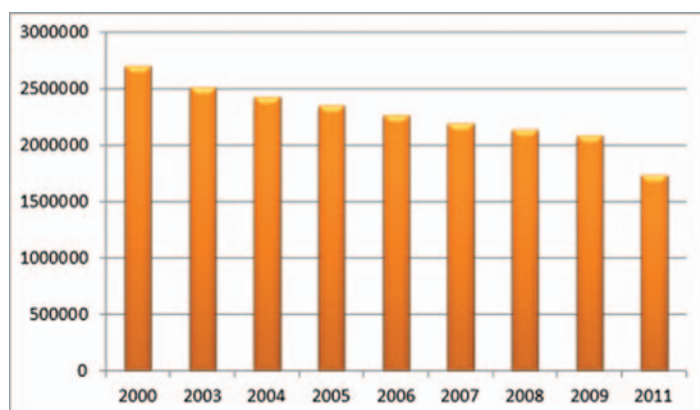


Figure 3 Population trend in children of Belarus

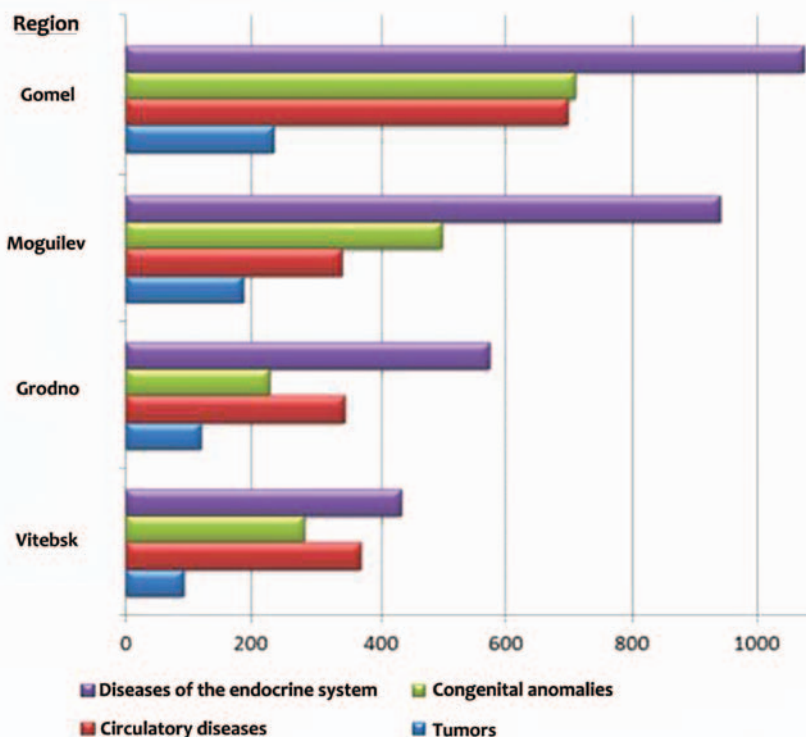


Figure 4 Primary diseases in children of Belarus by regions

chronic illness.

In 2010, a high incidence of primary diseases of the endocrine system, the blood and circulatory system and tumours were seen especially in the Gomel and Mogilev regions, which are the most highly contaminated (see Figure 4)

Bandajevskaya's speciality is cardiovascular disease. The diagnosis of heart problems in children is very straight forward. Every paediatric clinic has a cardiac monitor to measure heart rhythm, and in maternity wards, every new born baby is given an electrocardiogram and a Doppler ultrasound test. And here, paediatricians have been baffled by what they found, because they are unable to explain the cause of the problem. The official sources present a list of risk factors such as arterial hypertension, overweight, obesity, smoking, and family history; but just as important a risk factor is living in areas that have been contaminated by Chernobyl radioactivity, and that has been completely ignored. In the official preventative care programmes, the health authorities see no need to include measurement of radionuclides in the bodies of children affected by the Chernobyl accident, and clinics and hospitals in urban areas do not have human radiation spectrometers to do the job.

Cardiovascular disease in children from contaminated regions of Belarus was found to increase in the first few years after the accident. Today, the incidence of the disease continues to climb (Figure 5).

The frequency of congenital heart malformations has also increased. Estimates vary between 0.8 and 1.2 % of all new born babies,

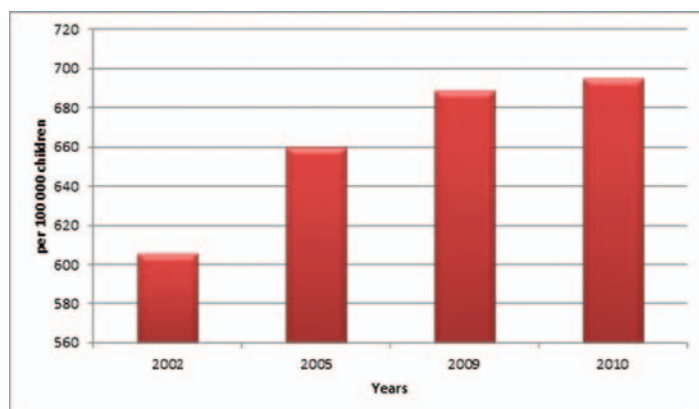


Figure 5 Cardiovascular disease in children of Belarus

constituting 30 % of all birth defects observed. Congenital heart malformations represent a large and heterogeneous group that includes relatively minor forms to serious conditions incompatible with life.

Paediatric cardiologists are very concerned about problems of heart arrhythmia (abnormal irregular heartbeat) and electrical conduction, both of which are increasing. Arrhythmia has a tendency to become chronic and increases the risk of sudden death. Children in apparent "good health" can also experience certain problems of arrhythmia and conductivity. Between 2004 and 2011, children with cardiovascular disease have more than doubled, mainly due to increases in congenital heart malformations and heart arrhythmias.

Public health specialists working in the areas contaminated by the accident note that diseases of the eye and related visual apparatus has more than tripled in children.

Bandajevskaya called on government authorities to take concrete action to stem the rapidly deteriorating health of children in contaminated areas, and for the concerted efforts of radioprotection experts to give practical advice and scientists to develop and introduce prophylactic measures and treatment. This cannot happen until governments and the regulatory authorities stop suppressing and concealing information on the health impacts of ionising radiation in general and of nuclear accidents like Chernobyl and Fukushima in particular.

The health impacts of the Fukushima disaster are already emerging, thanks to the concerted efforts of Japanese doctors, scientists and citizens in the face of government disinformation (see [16] Truth about Fukushima, SiS 55).

Meanwhile new research is exposing how the health impacts of ionizing radiation has been greatly underestimated by the conventional model used by IAEA, UNSCEAR and the ICRP (International) (see [17] Bystander Effects Multiply Dose & Harm from Ionizing Radiation, SiS 55); and more importantly, which treatments and prophylactic measures may be effective.

#### References

1. Chernobyl disaster, Wikipedia, 20 May 2012,
2. Ho MW. Fukushima nuclear crisis. *Science in Society* 50m 4-9, 2011.
3. Assessing the Chernobyl Consequences, IAEA, accessed 21 May 2012, [http://en.wikipedia.org/wiki/Chernobyl\\_disaster#Assessing\\_the\\_disaster.27s\\_effects\\_on\\_human\\_health](http://en.wikipedia.org/wiki/Chernobyl_disaster#Assessing_the_disaster.27s_effects_on_human_health)<http://www.iaea.org/Publications/Magazines/Bulletin/Bull383/boxp6.html>
4. Chernobyl Forum, IAEA.org, accessed 21 May 2012, [http://www-ns.iaea.org/meetings/rw-summaries/chernobyl\\_forum.asp](http://www-ns.iaea.org/meetings/rw-summaries/chernobyl_forum.asp)
5. Saunders PT. Truth about Chernobyl. *Science in Society* 47, 40-41, 2010.
6. Many presentations at Scientific and Citizen Forum on Radioprotection – From Chernobyl to Fukushima, 11-13 May 2012, Geneva
7. Yablokov A. The diversity of biomedical consequences of the Chernobyl disaster. Presentation at Scientific and Citizen Forum on Radioprotection – From Chernobyl to Fukushima, 11-13 May 2012, Geneva.
8. Yablokov AV, Nesterenko VB, Nesterenko AV. and Preobrazhenskaya NE. *Chernobyl: Consequences of the Catastrophe for People and the Nature*, 3<sup>rd</sup> Enlarged Edition (in Russian), Kiev, Universarium Publ., 2011.
9. Khudoley VV, Blokov IP, Sadovnichik T and, Bisaro S. An attempt to evaluate the effects of the accident at Chernobyl on the population living in the radioactively contaminated territories in Russia: estimation and prognosis of excess mortality and cases of cancer. Moscow, Centre for Independent Ecological Expertise at the Russian Academy of Science, OMNNO "Greenpeace Council", 2006, p.3 to 19.
10. ScherbH, K.Voigt, 2011. The human sex odds at birth after the atmospheric atomic bomb tests, after Chernobyl, and in the vicinity of nuclear facilities. *Environ Sci Pollut Res*. vol. 18, # 5, pp. 697 - 707.
11. Scherb H and Voigt K. Adverse genetic effects induced by chemical or physical environmental pollution. *Environ Sci Pollut Res* 2010, DOI 10.1007/s11356-010-0332-0.
12. World Health Organization. Controversies. IAEA – Agreement WHA 12–40 .Wikipedia ([http://en.wikipedia.org/wiki/World\\_Health\\_Organization](http://en.wikipedia.org/wiki/World_Health_Organization)).
13. The Chernobyl accident, UNSCEAR's assessment of the radiation effects. UNSCEAR, accessed 22 May 2012, <http://www.unscear.org/unscear/en/chernobyl.html>
14. Malko MV. Risk assessment of radiation-induced thyroid cancer in population of Belarus. In *ECRR Proceedings Lesvos 2009* (Busby C, Busby J Rietuma D and de Messiere M, eds.), Green Audit, 2011.
15. Bandajevskaya GS. The state of children's health in Belarus following the accident at the Chernobyl nuclear power station. Presentation at Scientific and Citizen Forum on Radioprotection – From Chernobyl to Fukushima, 11-13 May 2012, Geneva.
16. Ho MW. Truth about Fukushima. *Science in Society* 55, 18-23, 2012.
17. Ho MW. Bystander effects multiply ionizing radiation dose and illnesses. *Science in Society* 55, 28-31, 2012.

# Truth about Fukushima



Image courtesy enformable.com

*The release of radioactivity from Fukushima is at least as great as from Chernobyl, and a humanitarian disaster on the scale of Chernobyl needs to be averted by acknowledging the truth and taking responsibility for mitigating measures* **Dr. Mae-Wan Ho**

Regulators seriously economical with the truth  
 “Few people will develop cancer as a consequence of being exposed to the radioactive material that spewed from Japan’s Fukushima Dai-ichi nuclear power plant... and those who do will never know for sure what caused their disease.” These conclusions, published in the journal *Nature* [1] are based on two “comprehensive, independent assessments” from UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) and WHO (World Health Organisation), both notorious for downplaying and denying the devastating health impacts of the Chernobyl accident [2] (see Chernobyl Deaths Top a Million Based on Real Evidence, SiS 55). They are now using the same tactics to rule out, *a priori*, potential health impacts from Fukushima radioactive releases.

According to the draft UNSCEAR report seen by *Nature* [1], 167 workers at the plant received radiation doses that “slightly raise their risk of developing cancer.” Actually, six former reactor workers have died since the catastrophe, but UNSCEAR ruled they were unrelated to the accident [3].

“There may be some increase in cancer risk that may not be detectable statistically,” Kiuohiko Mabuchi, head of Chernobyl studies at the National Cancer Institute in Rockville, Maryland, told *Nature*. He said that in Chernobyl, where clean-up workers were exposed to much higher dose, 0.1 % of the 110 000 workers surveyed have so far developed leukaemia, although not all of those cases resulted from the accident. In fact, the death rate of the “clean-up workers” at Chernobyl remained high even four years after the accident, and 20 years later, 115 000 (out of 830 000) are dead [2].

WHO, for its part, estimates that most residents of Fukushima and neighbouring Japanese prefectures received absorbed doses below 10 mSv [1]. Residents of Namie town and Iitate village, not evacuated until months after the accident, received 10-50 mSv, though infants in Namie may have been exposed to enough I-131 to have received 100-200 mSv. The government aims to keep public exposure from the accident below 20 mSv, but in the longer term, it wants to decontaminate the region so residents will receive no more than 1 mSv per year from the accident. **Thus, people have been exposed within a matter of weeks, 10 to 200 times the legal limit dose for a whole year.**

Yet, WHO’s conclusion for Fukushima is the same as for Chernobyl [1]: “A greater health risk may come from the psychological stress created.”

A day later..

A day later, Tokyo Electric Power Company (TEPCO) announced that the amount of radioactive material released during the first days of the Fukushima nuclear disaster was almost two and a half times the initial estimate by Japanese safety regulators [4]. The operator said the meltdowns at the three reactors released about 900 000 Terabecquerels ( $10^{12}$  Bq) of radioactive substances into the air during

March 2011.

The later estimate was based on measurements suggesting the amount of radioactive iodine I-131 released was much larger than previous estimates. TEPCO said it had initially been unable to accurately judge the amount of radioactive materials released because radiation sensors closest to the plant were disabled in the disaster.

Several days later, ex-Prime Minister Naoto Ken apologized for his role in the Fukushima nuclear crisis [5]. His government’s push for nuclear energy was largely to blame. Ken had stepped down in September 2011 when the government faced fierce criticism over its handling of the crisis and for providing too little information to the public. It was Ken, however, who ordered TEPCO to keep the men on site; otherwise Fukushima would have spiralled out of control, according to a private panel probing the accident.

But the threat remains. Experts are now worried about the state of the spent fuel pool in unit 4, which is unlikely to withstand another earthquake [6]. The severely damaged unit 4 building houses a spent nuclear fuel pool that contains 10 times the amount of Cs-137 released at Chernobyl. Nearly all of the 10 893 spent fuel assemblies at the Fukushima Daiichi plant sit in pools vulnerable to future earthquakes, with altogether 85 times the long-lived radioactivity released at Chernobyl. A letter was sent by 72 Japanese NGOs to the United Nations with an urgent request for immediate action to stabilize unit 4’s spent nuclear fuel. The letter was endorsed by nuclear experts from both Japan and abroad.

Andrew DeWit, professor of political economy at Rikkyo University told Al Jazeera that transparency on the issues of nuclear energy was paramount. And that is precisely what’s lacking, in Japan, and in the world at large.



Miwa Chiwaki

“We heard it first from the internet”

Miwa Chiwaki from Kodomo Fukushima (Fukushima network to protect children from radiation) said [7] it was in a BBC programme via the internet that people first saw pictures of the explosions at the power station. The Japanese government had information from SPEEDI (System for Prediction of Environment Emergency Dose Information) and they passed the information first to the US government on 14 March and to the Japanese people only on 23 March.

The day after the tsunami struck the Fukushima nuclear plant, thousands of residents at the nearby town of Namie gathered to evacuate. In the absence of guidance from Tokyo, the town officials led the residents north, in the belief that the winter winds would blow south and carry away the radioactive plume. They stayed in the

Tsushima district for three nights where the children played outside and some parents used the water from a mountain stream to cook rice [8]. But the ill winds from Fukushima had been blowing directly towards them in Tsushima, as it would transpire two months later. SPEEDI had predicted that. But bureaucrats in Tokyo had not seen it their responsibility to make that information public. Japan's political leaders did not know about the system, and later downplayed the data, fearful of having to enlarge the evacuation zone and acknowledge the severity of the accident.

Tamotsu Baba, the mayor of Namie, now living with thousands in temporary housing in another town, condemned the withholding of information as being akin to "murder".

The true level of contamination is also hidden from people, Chiwaki said [7]. Many mothers queued up with their children in the rain for several hours to receive water rations (while radioactivity was being washed down over them with the rain), in litate, villagers were left in very high levels of contamination for a whole month.

"Advisers on radiation control from Fukushima prefecture flocked to the villages," Chiwaki said, "and, with broad smiles on their faces, told the people that 'there is nothing to worry about, you can let your children play outside.'" Three days later, the village was classified "planned evacuation zone".

The circumstances of the accident and the real levels of contamination were only revealed piecemeal. A "safety campaign" was initiated on 20 March. Professor Shunichi Yamashita of Nagasaki University was sent around the country, smiling and say things like: "100 mSv? No problem!" "Radiation is only a threat to people who worry

**Experts are now worried about the state of the spent fuel pool in unit 4, which is unlikely to withstand another earthquake. The severely damaged unit 4 building houses a spent nuclear fuel pool that contains 10 times the amount of Cs-137 released at Chernobyl**

about it." "Smile and you won't be affected by the radiation."

Radioactivity, dose and general exposure limits  
A great deal of confusion and anxiety is created by the different units used in announcements to the popular media. The unit of radioactivity is a Becquerel, Bq, equal to 1 radioactive disintegration per second, coming directly from a source, a radionuclide in contaminated food or drink, soil or air. Larger units are the kBq (1 000), MBq (10<sup>6</sup>), (GBq (10<sup>9</sup>), TBq (10<sup>12</sup>), PBq (10<sup>15</sup>), and EBq (10<sup>18</sup>).

The unit of *absorbed dose* (amount of energy absorbed by a unit of material) is the Gray, Gy, equal to 1 Joule/kg. The *equivalent* or *effective dose* is the Sievert, Sv (also in units of Joule/kg) which is the absorbed dose modified to represent the presumed biological effect. Note that 1 Joule is a very small amount of energy. But unlike

ordinary chemical energy, where typically kJ quantities are needed before anything can happen, the energy in ionizing radiation exists in extremely concentrated quanta or packets; hence 1 J of energy would already contain many of these energetic missiles (typically a billion) that target atoms and molecules. This is the major difference between ionizing radiation and ordinary chemical energy.

The Becquerel and the Sievert are not directly convertible, because it depends on the radionuclide involved, which particles or photons it produces per disintegration, and how much energy each of the photons or particles carries. There is a website that tells you how the calculation is done and actually does it for you [9] (<http://www.radprocalculator.com/Gamma.aspx>). Some useful approximate correspondences are:

1 mSv of I-131 = 2.06525 x 10<sup>6</sup> Bq

1 mSv of Cs-137 = 1.30878 x 10<sup>6</sup> Bq

Radiation exposure considers how long a period over which the dose is absorbed, usually in mSv/year.

The exposure limit in Europe is 1 mSv/year for the public, and the occupational exposure, 20 mSv/year [10]. For USA, the occupational exposure limit is 50 mSv, reduced to 10 % for pregnant women. Dose limit for the public is 1 mSv/year, in addition to a background of 0.3 mSv and 0.05 mSv from sources such as medical X-ray [11].

To put these exposure limits in perspective, it is generally recognized that a dose of 1 000 mSi will kill an adult. A whole body dose of 400 mSv will kill about 50 % of people within 60 days of the exposure, mostly from infection, as their immune systems are destroyed [12]. At very low doses, such as what most of us receive every day from background radiation, the cells are able to repair the damage, though the recent discovery of bystander effects indicate that doses as low as tens of mSi are harmful [3]. At higher doses (up to 100 mSi), the cells may not be able to repair the damage, and may either be changed permanently, or die. Most cells that die are replaced with few consequences. Cells changed permanently may give rise to diseases, they may go on to produce abnormal cells when they divide, and may become cancerous.

A comment submitted to the ICRP (International Commission on Radiological Protection) by the Sierra Club in 2006 stated [13]: "Numerous academic researchers, independent scholars, and governmental bodies, such as the U.S. National Academies of Science and National Research Council, have now concluded that the linear no-threshold hypothesis is valid and that there is no "safe" level of radiation exposure."

Exposure limits and exposure levels in Japan post-Fukushima

The pre-Fukushima legal exposure limit for the public in Japan was 10 mSv/y and 50 mSv/y for occupational exposure [14]. The occupational legal limits were soon scrapped after the accident. At the end of April 2011, the Japanese government released a map based on air surveys done by MEXT (Japan's Ministry of Education, Culture, Sports, Science and Technology), which revealed that people living in areas not being evacuated will receive radiation doses up to 23.5 times their annual legal limit over the course of the next year [15].

It is important to note that all the exposure limits and projected exposure mentioned so far are for external sources. As the French expert body, Institut de Radioprotection et de Sûreté Nucléaire (IRSN) pointed out, they take no account of [15, p. 4] "exposure from other pathways such as immersion within the plume and inhalation of particles in the plume during the accident nor the doses already received or to be received from ingestion of contaminated foodstuffs. The total effective doses to be received (external + internal) could be much higher according to the type of deposit (dry or wet), diet and source of food."



Matsui Eisuke

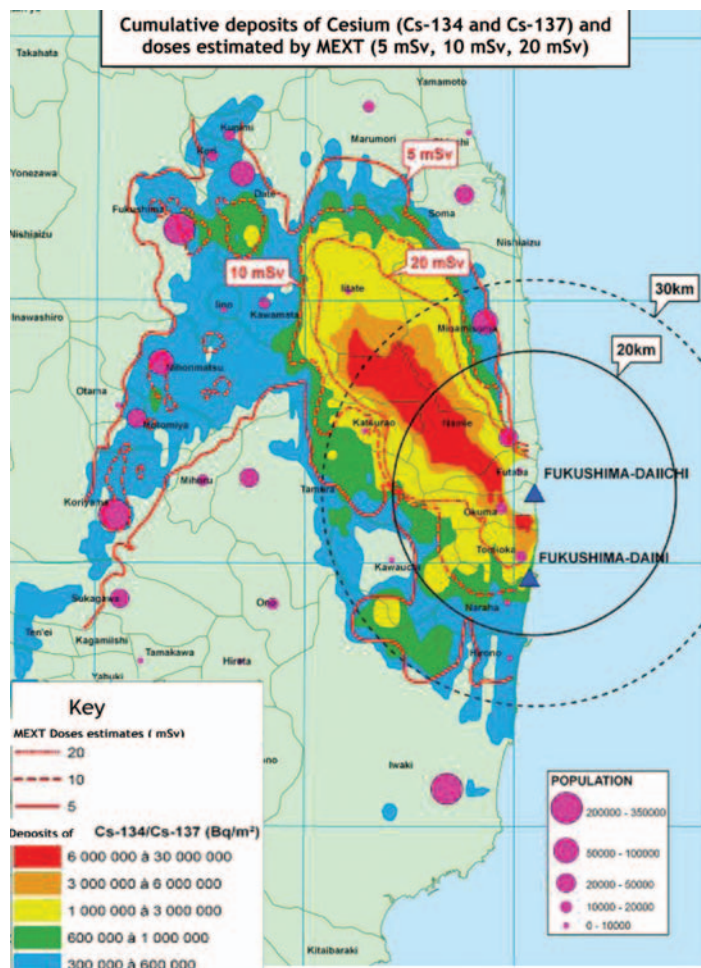


Figure 1 Map of caesium 137 + 134 deposits (Figure 7) superimposed on the map of projected doses for the 1st year (Figure 4) for 3 dose levels only (5, 10 and 20 mSv)

In addition, as Director of the Medical Institute of Environment at Gifu in Japan Matsui Eisuke pointed out [16], the government and its professional advisors in measuring exposure have relied mainly on  $\gamma$ -rays that are easy to detect. But, in terms of internal radiation exposure,  $\beta$  and  $\alpha$ - particles have a far more serious effect. "The government and TEPCO hardly measure such isotopes as  $\beta$ -emitting strontium-90 or  $\alpha$ -emitting plutonium-239."

Exposure due to ingested or inhaled radionuclide is a major problem in radioactive fallout, particularly when prompt evacuation, radioactive monitoring, and remediation have all failed to be carried out, as was the case for both Chernobyl and Fukushima.

IRS's assessment of projected doses based on the Japanese map released (see Figure 1), estimated that some 70 000 people including 9 500 children are living in the most contaminated areas outside the initial 20 km evacuation zone projected to receive further doses up to 200 mSv or more. This clearly calls for further evacuation beyond the initial 20 km zone. Under Japanese Food Sanitation Law, 5 000 Bq/kg of radioactive Cs is considered the safe limit in soil [17]. Consequently, large areas of Japan may no longer be suitable for agriculture.

The Japanese government at first raised the legal exposure limit to 20 mSv a year for the public, including children, thereby leaving them in areas from which they would have been barred under the old standard [7]. The limit for children was later scaled back to 1 mSv/y but only applies while they are *inside* school buildings.

In March 2012, the Japanese government announced a new standard limit for radionuclides in foods to 1 mSv/y, reducing from a previous provisional limit of 5 mSv/y. This translates into a maximum of 100 Bq/kg for regular food items such as meat, vegetables and fish (revised down from 500 Bq just after the Fukushima meltdown), 50 Bq/l for milk and infant food and 10 Bq for drinking water (revised down from 200) [18]. As shown above, this still means an accumula-

tion of internal exposure up to 1 million Bq a year, depending on how fast the radionuclides are cleared from the body. We already know that much lower levels have proven deadly for the children of Belarus (see [19] Apple Pectin for Radioprotection, SiS 55).

According to the German Society for Radiation Protection, a person is normally exposed to about 0.3 mSv per year through ingestion of food and drink; and this should be considered the permissible level of ingested radioactivity. In order not to go beyond this level, the amount of radioactive caesium-137 should not exceed 8 Bq/kg in milk and baby formula and 16 Bq/kg in all other foodstuff. Radioactive iodine with its short half-life should not be permitted in food at all [20].

How much radioactivity was released by the stricken Fukushima nuclear plant?

Although a picture of the radioactivity deposited on land is emerging, the actual levels of radioactivity to which people have been exposed are impossible to tell because there is a lot of uncertainty as to how much radioactivity has been released in the series of explosions in the Fukushima nuclear plant thus far.

TEPCO's latest press release [21] gave the amounts of radionuclides released between 12 and 31 March 2011 as follows.

#### Releases into the air:

Noble gas: Approx.  $5 \times 10^{17}$  Bq

Iodine 131: Approx.  $5 \times 10^{17}$  Bq

Caesium 134: Approx.  $1 \times 10^{16}$  Bq

Caesium 137: Approx.  $1 \times 10^{16}$  Bq

#### Releases into the ocean:

Iodine-131: Approx.  $1.1 \times 10^{16}$  Bq

Cesium-134: Approx.  $3.5 \times 10^{15}$  Bq

Cesium-137: Approx.  $3.6 \times 10^{15}$  Bq

These add up to a total of  $1.038.1 \times 10^{15}$  Bq or 1 038.1 PBq released.

TEPCO admits that the radioactivity measuring equipment were "unavailable due to the accident," so "further data still need to be collected to review the validity of the evaluation result." These reported radioactive releases from Fukushima are less than one-tenth those from the Chernobyl accident, a total of some 14 EBq ( $14 \times 10^{18}$  Bq), over half of it in noble gases [22].

How reliable are the latest TEPCO results?

Using data from radioactivity measuring posts set up under the Comprehensive Test Ban Treaty (CTBT), the Austrian Central Institute for Meteorology and Geodynamics (ZAMG) gave estimates of between 360-390 PBq iodine-131 and about 50 PBq of caesium-137 for the period of 12-14 March [23]. According to their calculations, the iodine-131 emissions from Fukushima in those three days amounted to 20 % of the total iodine-131 emissions from Chernobyl (1 760 PBq), while the emissions of caesium-137 in those three days amounted to about 60 % of the total caesium-137 emissions from Chernobyl (85 PBq).

A study led by the Norwegian Institute for Air Research (NILU) found about 16 700 PBq of xenon-133 (250% of the amount released at Chernobyl) emitted by the Fukushima power plant between 12 and 19 March 2011, the largest release of radioactive Xenon in history [24]. In addition, 35.8 PBq of caesium-137 (42% of the amount released at Chernobyl) was emitted in the same period. The study found that radioactive emissions were first measured right after the earthquake and before the tsunami struck the plant, indicating that the quake itself had already caused substantial damage to the reactors. The NILU report also suggests that the fire in the spent fuel pond of reactor 4 may have been the major contributor to airborne emissions, as emissions decreased significantly after the fire had been brought under control.

The same team of researchers updated their estimates in a paper published online giving estimates of 15 300 PBq of Xenon-133 and 36.6 PBq Cs-137 released into the atmosphere [25], not counting iodine-131 or Cs-134 (which was as much as Cs-137), nor releases into the ocean. But already, this is nearly 15 times the latest TEPCO estimate for total releases. I shall report separately in detail on this latest independent estimate, which gives a global picture of

contamination from the fallout (see [26] Fukushima Fallout Rivals Chernobyl, SiS 55).

#### Contamination of soil [27]

MEXT conducted soil surveys in 100 locations within 80 km of the Fukushima power plant in June and July of 2011. They found contamination with various radionuclides; the main ones were strontium-90, iodine-131, and caesium-137. Strontium-90, with a half-life of 28 years, is similar to calcium, and is therefore incorporated into bone where it can remain for decades, emitting  $\beta$ -particles and irradiating the bone-marrow, causing leukaemia and other cancers. Strontium-90 was found at concentrations of 1.8-32 Bq/kg at sites outside the 30 km evacuation zone in Nishigou, Motomiya, Ootama and Ono.

Iodine-131 has a half-life of 8 days. When ingested, it is incorporated like ordinary iodine in the thyroid gland, where it emits  $\beta$ - and  $\alpha$ -radiation, causing thyroid cancer especially in children. I-131 was found in milk, drinking water, vegetables and water around Northern Japan. According to the IAEA (International Atomic Energy Agency), iodine-131 deposition in Tokyo reached 36 000 Bq/m<sup>2</sup> between 22 and 23 March 2011. Soil samples in the municipalities of Nishigou, Izumizaki, Ootama, Shirakawa, Nihonmatsu, Date, Iwaki, Iitate, Ono, Minamisoma and Tamura showed concentrations of I-131 between 2 000 and 1 170 000 Bq/kg. In the municipality of Ono, 40 km southwest of the Fukushima plant, MEXT scientists found up to 7 440 Bq/kg of I-131 in rainwater samples. In August 2011, MEXT scientists still found I-131 concentrations of more than 200 Bq/kg in most of the municipalities, with maximum in Namie and Iitate of 1 300 and 1 100 Bq/kg respectively. Given its short half-life, this high level detected 145 days after the initial fallout on 15 March suggests extremely high initial contamination of the soil > 288 MBq/kg, or additional contamination of the area after the initial fallout. To convert from Bq/kg to Bq/m<sup>2</sup>, the convention is to multiply by 20 or 65, depending on the depth to which the soil is sampled. A conservative multiplier of 20 would give a value of > 5760 MBq/kg, going way off the top of the scale shown in the map of Fig. 1, which only gives radioactivity due to Cs-137 and Cs-134.

Cs-137 has a half-life of 30 years. It is similar to potassium, so its distribution is fairly even throughout the body if ingested. It is mainly a  $\beta$ -emitter, but its decay product barium-137 also produces  $\gamma$ -radiation. It can cause solid tumours in virtually all organs. Cs-137 has a biological half-life of 70 days and is excreted through urine like potassium. It therefore accumulates in the bladder and irradiates the adjacent uterus and foetus in pregnant women. IRSN states that around 874 km<sup>2</sup> of the area outside the 20 km evacuation zone must be considered highly contaminated with Cs-137, to an estimated concentration >6MBq/m<sup>2</sup>, similar to the evacuation zone around the Chernobyl power plant [15] (see Figure 1). In fact, Cs-137 in the



Image courtesy 2.bp.blogspot

**some 70 000 people including 9 500 children are living in the most contaminated areas outside the initial 20 km evacuation zone projected to receive further doses up to 200 mSv or more**

Fukushima prefecture even reached up to 30 MBq/m<sup>2</sup> north-west of the plant, and up to 10 MBq/m<sup>2</sup> in neighbouring prefectures. Soil sample with Cs-137 between 20 000 and 220 000 Bq/kg were found by MEXT scientists in the municipalities of Iitate, Kawamata, Name, Katsurao and Nihonmatsu in April 2011. Even higher values up to 420 000 Bq/kg were recorded later in August 2011. According to IAEA, Cs-137 deposition in Tokyo reached 340 Bq/m<sup>2</sup> 22-23 March 2011. Radioactive caesium was also found in large quantities in beef, rice, milk, fish, drinking water and other foodstuff.

#### Contamination of the marine environment

Massive amounts of radioactive waste water used in cooling the reactors and spent fuel ponds were discharged into the sea, seeped into the soil or ground water or evaporated into the atmosphere [27]. Between 4 and 10 April 2011, TEPCO deliberately released 10 393 tonnes of radioactive water. It constituted the single largest radioactive discharge into the oceans in history. A 1-2 week pulse of radioactivity peaked in the water around the Fukushima plant on 6 April 2011, with ocean concentrations of 68 MBq/m<sup>3</sup>, and an estimated total release of up to 22 PBq [28, 29]; TEPCO admits 18.1 PBq [21]. After considerable dilution 2-3 months following the peak, surface concentrations were still higher than previously existing by as much as 10 000-fold in coastal waters and as much as 1 000-fold over a 150 000 km<sup>2</sup> area of the Pacific up to 600 km east of Japan. Radioactive Cs was detected in all species of marine organisms ranging from phytoplankton to fish.

The waters northeast of the Fukushima plant are among the major fishing zones in the world, responsible for half of Japan's sea-food. But catch from the Ibaraki prefecture showed such high levels of radioactive isotopes that it had to be discarded as radioactive waste [27]. Radioactive contamination in the ocean does not get diluted away, like other pollutants it gets accumulated in the marine food chain, up to fish consumed by humans. Radioactive caesium in sea bass caught in the North Pacific continually rose from March till September, with a maximum found on 15 September of 670 Bq/kg. Radioactivity not only disperses passively in the ocean by currents



Image courtesy 2.bp.blogspot



and mixing, but is also spread by fish and mammals. The Pacific Bluefin tuna was found to transport Fukushima-derived radionuclides from Japan to California. Fifteen Pacific Bluefin tuna sampled in August 2011 had elevated levels of Cs-134 ( $4.0 \pm 1.4$  Bq/kg) and Cs-137 ( $6.3 \pm 1.5$  Bq/kg).

#### Contamination of food and drinking water

Extensive contamination of food and drinking water was documented in the months after the disaster [27].

Outside the evacuation zone in Fukushima prefecture, MEXT survey one week after the earthquake found contaminated vegetables in the municipalities of Iitate, Kawamata, Tamura, Ono, Minamisoma, Iwaki, Tshukidate, Nihonmatsu, Sirakawa, Sukagawa, Ootama, Izumizaki and Saigou. I-131 concentrations were as high as 2.54 MBq/kg and Cs-137 up to 2.65 MBq/kg. One month after meltdown, radioactivity was still above 100 000 Bq/kg for I-131, and 900 000 Bq/kg for Cs-137 in some regions. In Ibaraki prefecture ~100 km south of the Fukushima plant, spinach was found with I-131 up to 54 100 Bq/kg and Cs-137 up to 1 931 Bq/kg. Other highly contaminated vegetables included mustard, parsley, and Shitake mushrooms, and lesser amounts of radiation were detected in lettuce, onions, tomatoes, strawberries, wheat and barley.

Milk, beef, rice and drinking water were also contaminated. The IAEA warned that levels of I-131 exceeded permissible limits between 17 and 23 March. Even in the northern district of Tokyo, tap water contained 210 Bq/l of I-131.

Seafood and fish caught close to the nuclear plant reached 500 – 1 000 Bq/kg. In April 2011, the Japanese Fishing Ministry found radioactive iodine and caesium in sand lance from Fukushima prefecture each with an activity up to 12 000 Bq/kg. The independent French radioactivity laboratory ACRO found readings of more than 10 000 Bq/kg in algae harvested outside the 20 km evacuation zone. One sample showed levels of 127 000 Bq/kg of I-131, 800 Bq/kg of Cs-134 and 840 Bq/kg of Cs-137.

In the prefecture of Shizuoka ~400 km from Fukushima, local tea leaves were found contaminated with 670 Bq/kg Cs-137, and radioactive Japanese green tea was discovered in France in June 2011.

#### Emerging health impacts [27]

Employees of the stricken Fukushima nuclear plant, rescue- and clean-up workers are the most acutely exposed group. According to the Japanese Atomic Information Forum, radiation levels inside the plant peaked at around 1 000 mSv/h, a dose fatal to humans exposed for more than an hour. While airborne emissions decreased gradually, massive amounts of radiation still remained on site through wash-out in water continually pumped into the plant to cool the reactors. By 1 August 2011, radiation of 10 Sv/h was still detected around the premises. A total of 8 300 workers have been deployed in rescue and clean-up since March. In July, TEPCO announced that 111 workers had been exposed to radiation of more than 100 mSv, some as high as

678 mSv. That did not take into account effects of internal radiation through ingested or inhaled radioisotopes.

An under-cover report broadcast on 4 October 2011 on German TV ZDF revealed radiation levels as high as 10 Sv/h, and new hotspots were still being discovered [30]. The exposure badges given to the workers routinely registered an error message as the radioactivity went way off-scale. The workers, paid €80-100 a day, were forbidden by contract to talk to reporters and given little information on the radiation levels in the plant. They only discovered that on TV. Some 18 000 workers had gone through the plant by then.

Following the nuclear meltdowns, the Japanese government ordered the evacuation of 200 000 people in an area of about 600 km<sup>2</sup>. As mentioned above, 70 000 people including 9 500 children were still living in highly contaminated areas outside this evacuation zone 2 months after the accident [15]. IAEA measured radiation levels 16-115 µSv/h (i.e., up to 140-1 007 mSv/y) outside the 20 km evacuation zone. MEXT scientists confirmed these levels in their soil surveys of April 2011. Dose rates recorded in several cities outside the evacuation zone were 2 µSv/h in Nihonmatsu, Tamura, Souma, Minamisoma and Date; more than 5 µSv/h in Namie, and more than 100 µSv/h in Iitate. Four months later in August 2011, MEXT scientists still detected radiation doses up to 34 µSv/h in Namie, up to 16 µSv/h

**According to the German Society for Radiation Protection, a person is normally exposed to about 0.3 mSv per year through ingestion of food and drink. In order not to go beyond this level, the amount of radioactive caesium-137 should not exceed 8 Bq/kg in milk and baby formula and 16 Bq/kg in all other foodstuff. Radioactive iodine with its short half-life should not be permitted in food at all**

in Iitate, and up to 17.5 µSv/h in Katsurao.

IRSN projected the external exposure of the 70 000 living in the highly contaminated areas outside the 20 km evacuation zone to reach 200 mSv/y or more in the first year [15]. The external collective dose over 4 years of this population was calculated to be 4 400

person-Sv, amounting to 60 % of the collective dose received by the population in the highly contaminated regions around Chernobyl.

MEXT's calculations confirm those exposure levels. The estimated doses over the course of a year are up to 235.4 mSv in the town of Namie, 61.7 mSv in Iitate, 24.2 mSv in Kawamata, 21.2 mSv in Date, 18 mSv in Katsurao, 15.6 mSv in Minamisoma and more than 10 mSv in Fukushima city and Koriyama – both more than 55 km away from the plant. The natural (pre-existing) background radiation level in Japan is 1.48 mSv/y.

These high external sources of exposure have been and will continue to be internalized in food and drink. The devastating impacts of chronic exposure have been documented especially in the multiple diseases and deaths of hundreds of thousands of children as the result of the Chernobyl catastrophe, exacerbated by official denial, suppression, and disinformation [2].

I-131 is one of the most acute causes of cancer in children after a nuclear meltdown. Uptake of radioactive iodine can be prevented by a timely supply of iodine tablets. While such iodine tablets were supplied to the municipalities and evacuation centres during the first few days of the disaster, the order to distribute them was never issued, and hence, with very few exceptions, **no iodine tablets were taken by people exposed to radioactive iodine** [27]. This may lead to a large number of cases of thyroid cancer, as in the case of Chernobyl [2]. And the signs are ominous.

At the end of March 2011, a group of researchers around Hiroshima professor Satoshi Tashiro tested 1 149 children aged 0 to 15 from Iwaki city Kawamata town and Iitate village. Some 44.5 % showed radioactive contamination of up to 35 mSv in their thyroid gland. In October 2011, the University of Fukushima began with thyroid examinations on 360 000 children living in the regions affected by radioactive contamination. Matsui Eisuke reported some of the results so far [16]. Between October 2011 and 31 March 2012, 38 114 children 1-18 y in Fukushima prefecture were examined by ultrasonography of the thyroid gland. Cysts were found in more than 35 % of the children. In comparison, in Nagasaki where 250 children 7-14 y had been examined since 2000, only 2 (0.8 %) had cysts in their thyroid gland.

Chiwaki reports that today, centres for measuring levels of

radioactivity in food are opening one after another all over Japan, and not just in Fukushima [7]. Parents have banded together to set up organic cafes to stock non-contaminated organic vegetables, and also to demand that school canteens use only uncontaminated ingredients. "It is mainly thanks to independent networks that people have been able to go somewhere else temporarily to take care of their health."

Evacuation from highly contaminated areas still refused. The government still refuses to evacuate people from the highly contaminated regions [7]. The city of Fukushima organized a planning meeting in the Ōnami district that had been recommended for evacuation, and the opening words were: "Evacuation reduces economic activity, so we would opt for decontamination," in other words, "We won't let you leave." The city has designated zones measuring >2 µSv/h for decontamination, and wanted volunteers; but when asked about their decontamination plans, said they have none. In February 2012, an estimated 62 000 people left Fukushima prefecture to seek refuge elsewhere.

In June 2011, pupils from 14 primary and secondary schools from the town of Kōriyama formally demanded that the local authority respect their right to be evacuated and to continue their education in a less contaminated area. But six months later, the demand has been refused.

"We have launched an appeal," Chiwaki said. Refugees from the evacuation zones leave however they can, sometimes the whole family and sometimes the mother leaves with the children, and the husband stays behind to work and look after the house. Sharp divisions of opinion end in divorce and break up families.

"We have learnt lessons from the experience of Chernobyl and will never give up in our efforts to protect the lives of our children and everyone else. We ask the whole world to give us their support."

**For more information and especially if you can offer help, please contact <http://fukushima-evacuation-e.blogspot.co.uk/2012/04/take-action-to-help-children-in.html>**

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#### References

1. "Fukushima's doses tallied", Geoff Brumfiel, *Nature* 2012, 423-4, 24 May 2012, <http://www.nature.com/news/fukushima-s-doses-tallied-1.10686>
2. Ho MW. Chernobyl deaths top one million based on real evidence. *Science in Society* 55, 14-17, 2012.
3. "Fukushima deaths not cause by radiation, UN says", George Jahn, *Huffington Post*, 23 May 2012, [http://www.huffingtonpost.com/2012/05/23/fukushima-deaths-radiation\\_n\\_1540397.html](http://www.huffingtonpost.com/2012/05/23/fukushima-deaths-radiation_n_1540397.html)
4. "Utility says it underestimated radiation released in Japan", *New York Times*, 24 May 2012, <http://www.nytimes.com/2012/05/25/world/asia/radioactive-release-at-fukushima-plant-was-underestimated.html>
5. "Japan ex-PM apologises for Fukushima failure", *Aljazeera*, 28 May 2012, <http://www.aljazeera.com/news/asia-pacific/2012/05/201252842649729894.html>
6. "Fukushima reactor 4 requires urgent intervention; coalition calls for emergency UN action to halt catastrophic release of radiation", Mike Adams, 6 May 2012, [http://www.naturalnews.com/035788\\_Fukushima\\_United\\_Nations\\_radiation.html](http://www.naturalnews.com/035788_Fukushima_United_Nations_radiation.html)
7. Chiwaki M. Our struggle for survival continues. Presentation at Scientific and Citizen Forum on Radioprotection – From Chernobyl to Fukushima, 11-13 May 2012, Geneva.
8. "Japan held nuclear data, leaving evacuees in peril" Norimitsu Onishi and Martin Fackler, *The New York Times*, 8 August 2011, [http://www.nytimes.com/2011/08/09/world/asia/09japan.html?pagewanted=all&\\_r=2](http://www.nytimes.com/2011/08/09/world/asia/09japan.html?pagewanted=all&_r=2)
9. Rad Pro Calculator Site Description and Details, accessed 1 June 2012, <http://www.radprocalculator.com/Gamma.aspx>
10. Radiation exposure, dose limits, European nuclear society, accessed 29 May 2012, <http://www.euronuclear.org/info/encyclopedia/r/radiation-exposure-dose-limit.htm>
11. Occupational dose limits, US Nuclear Regulatory Commission, accessed 29 May 2012, <http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1201.html>
12. Radiation and Risk, Idaho State University, accessed 30 May 2012, <http://www.physics.idaho.edu/radinf/risk.htm>
13. Johnsrud JH. Sierra Club, Radiation Committee, Commenting on behalf of the organisation on The Scope of Radiological Protection, ICRP Consultation, accessed 31 May 2012, [http://www.icrp.org/consultation\\_viewitem.asp?guid=%7B762C6A55-ECE0-41AB-A349-AB5E7FD56462%7D](http://www.icrp.org/consultation_viewitem.asp?guid=%7B762C6A55-ECE0-41AB-A349-AB5E7FD56462%7D)
14. "Japan forsee high radiation over the next year in areas not evacuated", Alexander Higgins, 28 April 2011, <http://blog.alexanderhiggins.com/2011/04/28/japan-forsees-high-radiation-year-areas-evacuated-20732/>
15. Assessment on the 66<sup>th</sup> day of projected external doses for populations living in the north-west fallout zone of the Fukushima nuclear accident, outcome of population evacuation measures, Report DRPH/2011-10, Directorate of Radiological Protection and Human Health, Institut de Radioprotection et de Sûreté Nucléaire, October 2011
16. Matsui E. Action taken by Japanese scientists and citizens concerned about low-
- doses internal radiation exposure in Japan. Presentation at Scientific and Citizen Forum on Radioprotection – From Chernobyl to Fukushima, 11-13 May 2012, Geneva.
17. Yasunari TJ, Stohl A, Hayano RS, Burkhart JF, Eckhardt S and Yssunari T. Cesium-137 deposition and contamination of Japanese soils due to the Fukushima nuclear accident. *PNAS* 2011, 108, 19530-4.
18. Food Safety Department, Pharmaceutical & Food Safety Bureau, MHLW, New Standard Limits for Radionuclides in Foods, Ministry of Health, Labour and Welfare, March 2012, [http://www.mhlw.go.jp/english/topics/2011eq/dl/new\\_standard.pdf](http://www.mhlw.go.jp/english/topics/2011eq/dl/new_standard.pdf)
19. Ho MW. Apple pectin for radioprotection. *Science in Society* 55, 32-33, 2012.
20. "Calculated Fatalities from Radiation", Study by the German Society for Radiation Protection and German IPPNW, Berlin, September 2011 [http://foodwatch.de/foodwatch/content/e10/e42688/e44884/e44993/CalculatedFatalitiesfromRadiation\\_Reportfoodwatch-IPPNW2011-09-20\\_ger.pdf](http://foodwatch.de/foodwatch/content/e10/e42688/e44884/e44993/CalculatedFatalitiesfromRadiation_Reportfoodwatch-IPPNW2011-09-20_ger.pdf)
21. Press release, Tokyo Electric Power Company, 24 May 2012, [http://www.tepco.co.jp/en/press/corp-com/release/2012/040659\\_1870.html](http://www.tepco.co.jp/en/press/corp-com/release/2012/040659_1870.html)
22. Chernobyl Accident 1986, World Nuclear Association, April 2012, <http://www.world-nuclear.org/info/chemobyl/info7.html>
23. Accident in the Japanese NPP Fukushima: Large emissions of Cesium-137 and Iodine-131. Austrian Central Institute for Meteorology and Geodynamics (ZAMG), March 24th, 2011, [www.zamg.ac.at/docs/aktuell/Japan2011-03-24\\_1600\\_E.pdf](http://www.zamg.ac.at/docs/aktuell/Japan2011-03-24_1600_E.pdf)
24. Stohl A et al. Xenon-133 and caesium-137 releases into the atmosphere from the Fukushima Daiichi nuclear power plant: determination of the source term, atmospheric dispersion, and deposition", *Atmos. Chem. Phys. Discuss.*, 11, 28319-28394, 2011, [www.atmos-chem-phys-discuss.net/11/28319/2011/acpd-11-28319-2011.html](http://www.atmos-chem-phys-discuss.net/11/28319/2011/acpd-11-28319-2011.html)
25. Stohl A, Seibert P, Wotawa G, Arnold D, Burkhart JF, Eckhardt S, Tapia C, Varga and Yasunari TJ. Xenon-133 and caesium-137 releases into the atmosphere from the Fukushima Dai-ichi nuclear power plant: determination of the source term, atmospheric dispersion, and deposition. *Atmos Chem Phys* 2012, 12, 2313-43.
26. Ho MW. Fukushima fallout rivals Chernobyl. *Science in Society* 55, 24-27, 2012.
27. Rosen A. Effects of the Fukushima nuclear meltdowns on environment and health, 9 March 2012, [http://www.ipnw.de/commonFiles/pdfs/Atomenergie/Effects\\_Fukushima\\_rosen.pdf](http://www.ipnw.de/commonFiles/pdfs/Atomenergie/Effects_Fukushima_rosen.pdf)
28. Buesseler K, Aoyama M and Fukasawa M. Impacts of the Fukushima nuclear power plants on Marine Radioactivity. *Environ Sci Technol* 2011, 45, 9931-5.
29. Buesseler KO, Jayne SR, Fisher NS, et al. Fukushima-derived radionuclides in the ocean and biota off Japan. *Proc Natl Acad Sci USA* 2012, 109:5984-8.
30. Fiske M. Research and activities of scientists and citizens in Japan who are concerned about low dose internal radiation exposures. Presentation at Scientific and Citizen Forum on Radioprotection – From Chernobyl to Fukushima, 11-13 May 2012, Geneva
31. "German TV-channel ZDF talks with workers at Fukushima Dai-ichi", YouTube, accessed 4 June 2012, <http://www.youtube.com/watch?v=V1T4Ac9nHeY>

# Fukushima Fallout Rivals Chernobyl

*State-of-the-art analysis based on the most inclusive datasets available reveals that radioactive fallout from the Fukushima meltdown is at least as big as Chernobyl and more global in reach*

*Dr. Mae-Wan Ho*

14 000 Americans already died from Fukushima fallout?

A paper published online December 2011 in a peer-reviewed journal estimated that nearly 14 000 have died in the United States in 14 weeks following the arrival of the radioactive fallout from the Fukushima meltdown [1]. It noted that the estimate is comparable to the 16 500 excess deaths in the 17 weeks after the Chernobyl disaster. The rise in reported deaths after Fukushima was greatest among infants less than one year of age.

health disaster still unfolding more than 25 years after the Chernobyl disaster (see [4] Chernobyl Deaths Top a Million Based on Real Evidence, SiS 55).

Comprehensive Test Ban Treaty Measurements

Withholding data, or not bothering collecting appropriate data, appear endemic to the nuclear industry and governments in general; and Fukushima is no exception ([5] Truth about Fukushima, SiS 55). But a

distribution and deposition of radionuclides and provide a more complete picture than the measurements alone. The simulations must be compared, and fit the measurement data. However, the single largest source of error in prediction is the source term, the rate of emissions into the atmosphere from the accident site. To this day, the time variation of emissions from Chernobyl is still uncertain.

The most comprehensive information on the events in the Fukushima disaster is

**A paper published online December 2011 in a peer-reviewed journal estimated that nearly 14 000 have died in the United States in 14 weeks following the arrival of the radioactive fallout from the Fukushima meltdown**

The authors' credentials appeared impeccable [2]. Joseph Mangano is a public health administrator and researcher who studies low-dose radiation exposure and subsequent risk of diseases such as cancer and damage to the newborn. He has published numerous articles and letters in medical and other journals as well as books, including *Low Level Radiation and Immune system Disorders: an Atomic Era Legacy*. Janette Sherman worked for the Atomic Energy Commission (precursor of the Nuclear Regulatory Commission) at University of California Berkeley, and for the US Navy Radiation Defense Laboratory in San Francisco. She specializes in internal medicine and toxicology, with an emphasis on chemicals and nuclear radiation, was an advisor to the National Cancer Institute, and served on the advisory board of the Environment Protection Agency for 6 years.

A major criticism of their work is that the authors claimed Fukushima fallout arrived just six days after the earthquake, tsunami, and meltdowns, but they provided no evidence for this assertion [3]. Another is the paucity of radioactive measurement data; but that is the responsibility of the US Environment Protection Agency (EPA), and is hardly the authors' fault. Indeed, the authors are themselves critical [1]: "The paucity of data from the U.S. EPA is unfortunate and will hamper future studies." The same paucity of data has indeed hampered studies that might have prevented the humanitarian

surprising source of observations is coming from radioactivity measuring stations set up under the Comprehensive Test Ban Treaty (CTBT), which foresees a global ban of all nuclear explosions. To verify compliance with the Treaty, a global monitoring system is being built, which includes measurements of radionuclides. Measurements of atmospheric concentrations of both Xe-133 and Cs-137 were available from CTBT stations to a high degree of sensitivity. Sixty monitoring stations are currently delivering data on Cs-137, and 25 stations delivering data on Xe-133 to the International Data Centre of the Preparatory Commission for the CTBT Organisation in Vienna. Cs-137, with a half-life of 30.17 years, comprises approximately half of the total radioactive caesium released, the other half being Cs-134 [6]. Xe-133, with a half-life of 5.25 days is the most abundant Xe isotope, comprising >97.3 % of xenon in emissions.

State of the art analysis on the most inclusive available datasets After the earthquake and Tsunami struck, elevated levels of radioactive emissions were measured in Japan and all over the Northern Hemisphere including the CTBT monitoring stations. But the point measurements are too sparse to determine the three-dimensional distribution of radionuclides in the atmosphere and their deposition on land and sea. Given accurate emissions data, dispersion models can simulate the atmospheric

a report released by the Japanese Government in June 2011 to the International Atomic Energy Agency (IAEA) [7], and its subsequent updates. Although the report contains estimates of the amounts of radioactivity released into the atmosphere for certain key radionuclides, the data are not reliable; as the releases did not take place through defined pathways and were not metered.

To make the best use of the available information and data, an international team led by Andreas Stohl at the Norwegian Institute for Air Research (NILU) applied state-of-the-art atmospheric dispersion models to optimise the fit between the model calculations (simulations) and the observed measurements, thereby to obtain the most reliable source term. This top-down approach, called inverse modelling, was earlier used to make estimates of the Chernobyl source term. And members of the team have previously developed an inverse modelling method for volcanic eruptions and greenhouse gas emissions.

A first guess of release rates were based on fuel inventories and documented accident events at the site based on information provided by the Japanese government's report [7]. The first guess was subsequently improved by inverse modelling, which combined the results of an atmospheric transport model, FLEXPART, and measurement data from several dozen stations in Japan, North America and other regions.

The simulation was driven with three-

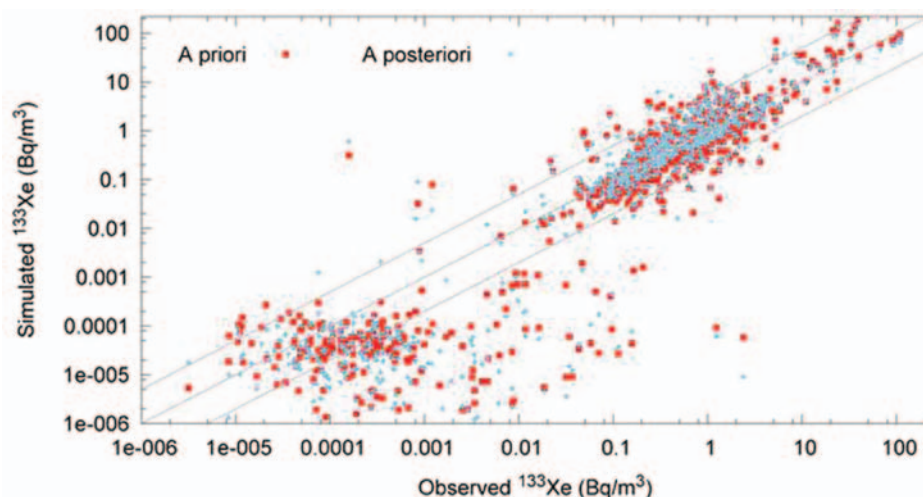


Figure 1 Scatter log/log plot of all Xe-133 data both *a priori* and *a posteriori* (see text)

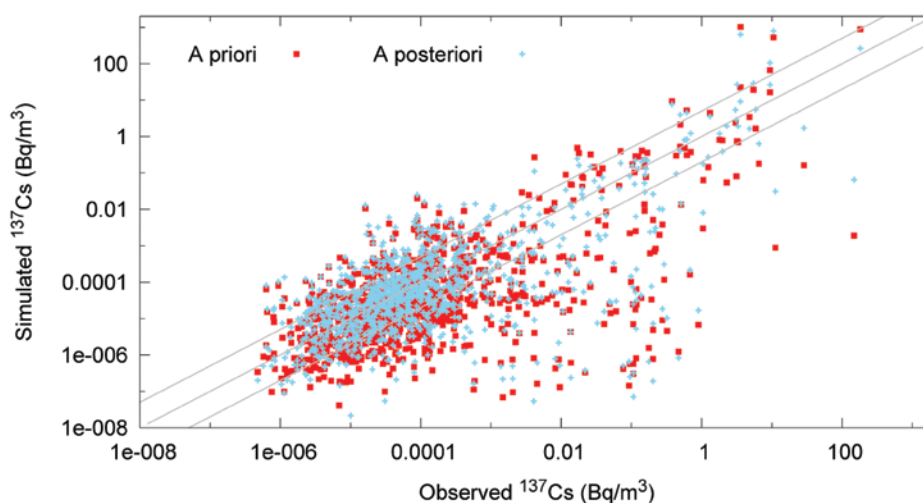


Figure 2

hourly operational meteorological data from two different sources: The European Centre for Medium-Range Weather Forecasts (ECMWF) analyses, and the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) analyses.

Total releases greater than Chernobyl  
The results obtained for the total release of Xe-133 was 15.3 EBq (uncertainty range 12.2-18.3, EBq – 1018 Bq), more than 2 x total release from Chernobyl (Chernobyl total was 5.2 EBq) and “likely the largest radioactive noble gas release in history”. This took place between 11 and 15 March 2011. In fact, the release is greater than the entire estimated Xe-133 inventory of the Fukushima Dai-ichi nuclear plant, and is explained by the decay of I-133 (half-life 20.8h) into Xe-133. There is strong evidence that Xe-133 release started before the first active venting was made, possibly from structural damage to reactor components and/or leaks due to excessive pressure inside the reactor.

For Cs-137, the inversion modelling results gave a total emission of 36.6 PBq (20.1-53.2, PBq =  $10^{15}$  Bq); 70 % more than first guess, and about 43 % of estimated Chernobyl emission. The results showed that Cs-137

emission peaked on 14-15 March but were generally high from 12 until 19 March, when they suddenly dropped by orders of magnitude at the time when spraying of water on the spent-fuel pool of unit 4 started. This indicates the emission may not have originated only from the damaged reactor cores, but also from the spent fuel pool of unit 4.

Altogether, an estimated 6.4 PBq of Cs-137, or 18 % of the total fallout until 20 April were deposited over Japanese land areas, while most of the rest fell over the North Pacific Ocean. Only 0.7 PBq or 1.9 % of the total fallout was deposited on land areas other than Japan.

Correspondence between simulated and observed results improved by inverse modelling

A scatter plot of all available Xe-137 observations versus simulation results, both *a priori* (from guess estimate of source) and *a posteriori* (source values optimised to fit the data) is given in Figure 1.

The straight line in the middle is where the correspondence is 1:1 between measured and simulated values, the lines above and below represent respectively overestimates and underestimates by a factor of 5. There

is a background emission of Xe-133 from nuclear facilities, which is highly variable, and this is allowed for by adding a value of  $1 \times 10^{-4}$  Bq/m<sup>3</sup> to every simulated concentration; consequently, one cannot expect correlation between measured and simulated values at the low end (lower left quadrant). Many of the data points there represent enhanced background observed. Data point in the upper right quadrant all reflect emissions from the Fukushima fallout, and for those data points, the modelled and observed values show a tight correlation, with most simulated points falling within a factor of 5 of the observed values. While the model results using the first guess emissions are already well correlated with the measurements, applying the inversion simulation clearly improves the correspondence, with most of the data points falling closer to the 1:1 line.

The scatter plot of the measured and simulated Cs-137 concentrations is given in Figure 2, where again, a background of normally distributed random concentration was added to every simulated concentration value.

The fit between simulated and observed data are not as good for Cs-137 as it is for Xe-133. One reason is the added complexity of modelling wet and dry removal of the particles carrying Cs-137 from the atmosphere. Nevertheless, there is still a clear correlation between simulated and observed concentrations.

Time series of simulated and observed measurements made at key stations in Japan, Oahu (Hawaii), Richland (Washington State), and Stockholm were also produced, as well as the amount of radioactivity deposited on the ground. The fit between simulated and observed tend to be better outside Japan, possibly due to contamination of monitoring stations in Japan.

Deposition of radioactivity on land

It may have seemed fortunate that westerly winds prevailed during most of the accident to carry the radioactive plume offshore. But exactly during and following the period of the strongest Cs-137 releases on 14 and 15 March, as well as after another period with strong emissions on 19 March, the radioactive plume was carried over Eastern Honshu Island, where rain deposited a large fraction of Cs-137 on the land.

Radioactive clouds reached North America on 15 March and Europe on 22 March. By mid-April, Xe-133 was fairly uniformly distributed in the mid-latitudes of the entire Northern Hemisphere and was for the first time also measured in the Southern Hemisphere (Darwin Station, Australia). In general, simulated and observed concentrations of Xe-133 and Cs-137 both at Japanese as well as distant sites were in good quantitative agreement.

The dispersion of radionuclides from the Fukushima fallout was simulated based on GFS meteorological analyses. The first releases associated with the venting and ex-

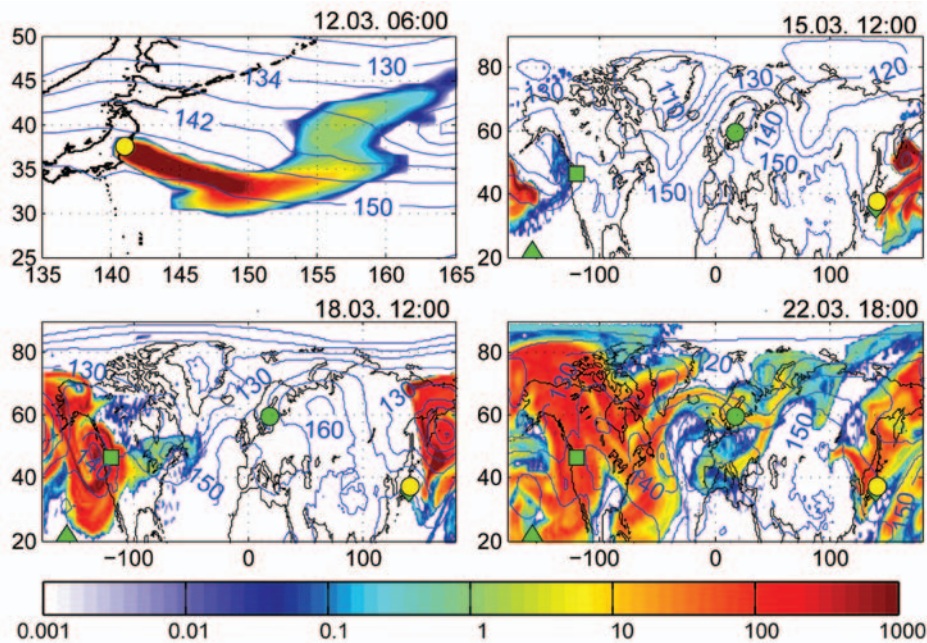


Figure 3 Simulated total atmospheric columns of Xe-133 (colour shading) in  $\text{kBq/m}^2$  and geopotential (height adjusted for pressure, blue isolines) at four different time points from 12 March (upper left) to 22 March 2011 (lower right); Fukushima Dai-ichi Power plant, yellow circle; air sampling site at Tokai-mura, green square; deposition monitoring site in Tokyo, green diamond; air sampling station on Oahu (Hawaii), green triangle; Stockholm, green circle.

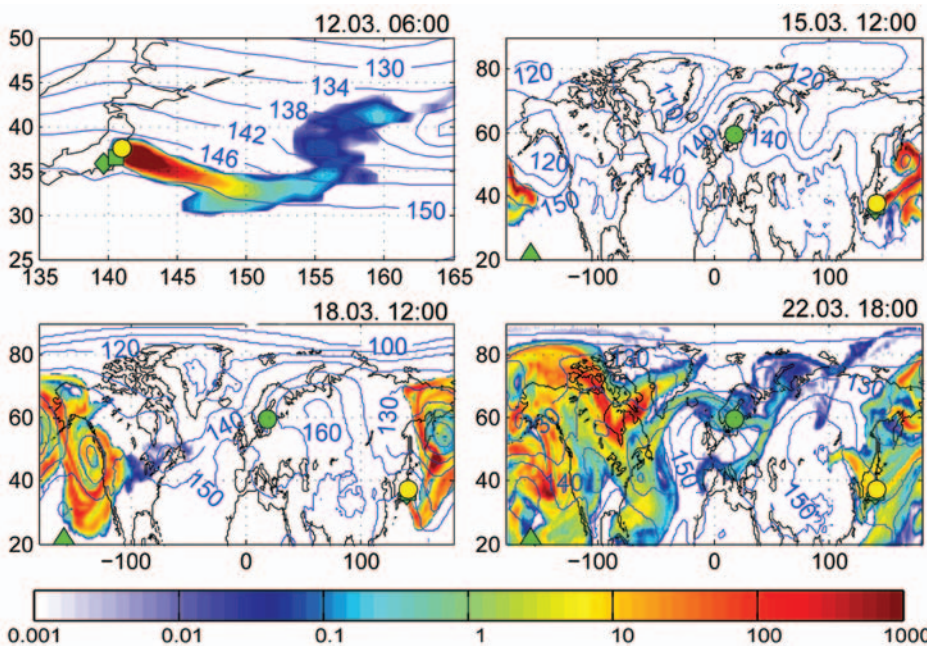


Figure 4 Simulated total atmospheric columns of Cs-137 (colour shading) in  $\text{Bq/m}^2$  and geopotential (height adjusted for pressure, blue isolines); other details as in Figure 3

plosion of Fukushima Daichi Nuclear Power Plant unit 1 reactor on 11 and 12 March 2011 was blown mainly offshore and transported eastsoutheast over the North Pacific Ocean,

though a change in wind direction on 12 March blew the plume over the coastal areas north of the power plant. There was no precipitation, and the magnitude of the

release was an order of magnitude lower than on 13 and 14 March, associated with the venting and explosions in the other units. On 14 March, a cyclone developed over southern Japan, and this coincided with a period of very high emissions from ventings and explosions of unit 2, unit 3 and in the spent-fuel pool of unit 4. (Details of the release events are given in an Appendix of the paper [4].)

During the accident events, Xe-133 and Cs-137 from the Fukushima fallout dispersed throughout the Northern Hemisphere and eventually also reached the Southern Hemisphere. A first radionuclide cloud ahead of the main plume containing only Xe-133 was transported rapidly across the North Pacific at low altitudes and arrived in western North America on 15 March (Figure 3). The first radioactive cloud skimmed along the North American seaboard because a large cyclone over the Eastern Pacific produced a southerly flow along the coastline. It was nevertheless detected at Richland, Washington State in USA. The main part of the radioactive cloud entered western North America on 17-18 March and could be detected by monitoring sites there (see Figure 4). A comparison of the top left panels in Figure 3 and 4 shows that the lead part of the Xe-133 plume is much stronger than the Cs-137 plume, resulting mainly from the earlier start of Xe-133 emissions. On 18 March, high levels of both Xe-133 and Cs-137 can be found over the eastern Pacific Ocean and western North America. This part of the cloud was still close to the surface south of  $50^\circ$ . The high altitude head of the cloud with lower levels of Cs-137 had already arrived over the North Atlantic. At the same time, the radioactive cloud penetrated the subtropics and arrived at Hawaii on 19 March.

From the Xe-133 maps (Figure 3), it can be seen that already, by 18 March, the highly radioactive plume had engulfed much of western and central North America from Canada to the USA, with radioactivity ranging well over 1 000 to 100 000  $\text{Bq}$  or more. Some of this could be easily have been inhaled by the inhabitants.

By 22 March, contaminated air from Fukushima had circled the Northern Hemisphere and reached both the tropics as well as the polar regions (Figs. 3 and 4). Even though enhanced surface concentrations were still limited to small parts of the Northern Hemisphere, this changed quickly. In April, all measurement stations recorded an enhanced background of Xe-133. Even the

**By 22 March, contaminated air from Fukushima had circled the Northern Hemisphere and reached both the tropics as well as the polar regions. In April, all measurement stations recorded an enhanced background of Xe-133. Even the Australian station Darwin started registering enhanced Xe-133 in April**

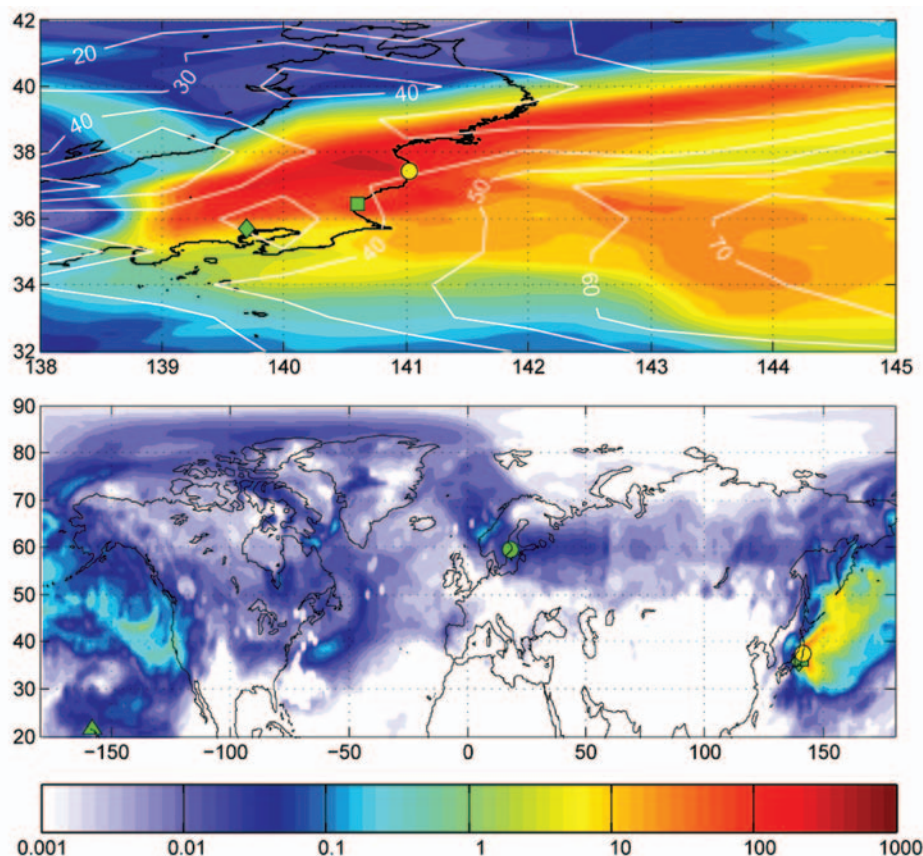


Figure 5 Maps of total deposition of Cs-137 until 20 April 2011 for Japan (upper panel) and globally (lower panel). The colour scale is in kBq/m<sup>2</sup>; other details as in Figure 3

Australian station Darwin started registering enhanced Xe-133 in April.

The maps of total deposition of Cs-137 in Japan and globally are shown in Figure 5. Note that the scale is in kBq/m<sup>2</sup>. The orientation of the simulated plume is exactly as found by aerial surveys of Cs-137 between 6 April and 26 May by MEXT. The airborne measurements show that along the main plume axis, Cs-137 deposition values greater than 1 000 kBq/m<sup>2</sup> extends about 50 km from the Fukushima plant (well outside the evacuation zone) [5].

In the Chernobyl disaster, Cs-137 deposition values exceeding 1 000 kBq/m<sup>2</sup> were observed in two areas: in the exclusion zone around Chernobyl Nuclear Power Plant and Prypjat, and north of the city of Gomel in Belarus. For the Fukushima accident, the land areas receiving such high deposition values are smaller, but still extensive. In the extratropical North Hemisphere, Cs-137 deposited from past nuclear testing is still present, raising the background to about 1-2 kBq/m<sup>2</sup>. That value is exceeded by deposition from Fukushima over large parts of Honshu Island and the western Pacific Ocean. However, deposition of Cs-137 over other parts of Asia, North America and Europe is minor compared to this pre-existing background.

The analysis accounts for more than 90 % of the Cs-137 emissions until 20 April, with the rest still residing in the atmosphere and small amounts lost by radioactive decay. Japan received 6.4 PBq or 18 % of total Cs-137 deposition until 20 April. This is quite similar

to a previous estimate of 22 % reported, although their absolute values are smaller because of lower source emissions used. Only 0.7 PBq or 1.9 % of total Cs-137 deposition occurred over land areas other than Japan, while the remaining 80 % (29.28 PBq) were deposited in the oceans. This is in addition to the deliberate releases of radioactivity that constituted “the largest radioactivity releases into the ocean in history” [5].

#### Central data repository and increased monitoring urgently needed

These results for only two of the main radionuclides already added up to nearly 15 times the total radioactivity in the latest TEPCO estimates [8] of just over 1 EBq. If we take the amount of Cs-134 as equal to 36.6 PBq (same as for Cs-137 when measured [6]), and add the value of 500 PBq for I-131 given by TEPCO for releases into the atmosphere, as well as the rest released into the ocean (18.1 PBq), we arrive at a total of 16.0532 EBq. This is certainly more than the estimated total of 14 EBq released in Chernobyl according to the World Nuclear Association [9].

The estimates are the best available based on still very incomplete information. In their closing remarks, the authors pointed out that the data collected for the analysis come from various sources, *none of which is available to the public* [4]. They speculated that more useful data sets were not even accessible to the research team; stating: “Institutions having produced relevant measurement data should make them freely

available,” and calling for a central data repository to be created. The analysis has only derived the source terms for two important radionuclides, and work needs to be done on others, notably I-131. This is absolutely necessary to address and mitigate the health impacts of the Fukushima catastrophe already unfolding.

The reluctance of officials to disclose information in the early days of the disaster has meant that iodine tablets were not distributed to people in the most highly contaminated areas, with the result that 44.5 % of the children showed radioactive contamination of up to 35 mSv in their thyroid gland; and an examination of more than 38 000 children in Fukushima prefecture found cysts in 35 % of the children’s thyroid gland (see [5]).

The excess deaths in the US observed by Mangano and Sherman in the 14 weeks following the accident do coincide with the arrival of high levels of radioactivity (in X-133) by day 5 (Figure 3), and by day 10 engulfed the whole of North America in both X-133 and Cs-137 (Figures 3 and 4). They wrote in the conclusion of *their* report [1]: “It is critical that research should proceed with all due haste, as answers are essential to early diagnosis and treatment for exposed people, particularly the children and the very young.”

The need for systematic monitoring, data-sharing, and research applies across the globe; as the available data already demonstrate, the disease burden will not be restricted to Japan.

#### References

1. Mangano JJ and Sherman JD. An unexpected mortality increase in the United States follows arrival of the radioactive plume from Fukushima: Is there a correlation? *International Journal of Health Services* 2012, 42, 47-64.
2. “Study: Fukushima radiation has already killed 14,000 Americans”, *WashingtonsBlog*, 24 December 2011, <http://www.washingtonsblog.com/2011/12/study-fukushima-radiation-has-already-killed-14000-americans.html>
3. “Researchers trumpet another flawed Fukushima death study”, *Micheal Moyer, Scientific American*, 20 December 2011, <http://blogs.scientificamerican.com/observations/2011/12/20/researchers-trumpet-another-flawed-fukushima-death-study/>
4. Stohl A, Seibert P, Wotawa G, Arnold D, Burkhardt JF, Eckhardt S, Tapia C, Varga and Yasunari TJ. Xenon-133 and caesium-137 releases into the atmosphere from the Fukushima Dai-ichi nuclear power plant: determination of the source term, atmospheric dispersion, and deposition. *Atmos Chem Phys* 2012, 12, 2313-43. Led by A. Stohl at Norwegian Institute for Air Research, Kjeller.
5. Ho MW. Truth about Fukushima. *Science in Society* 55, 18-23, 2012.
6. Assessment on the 66th day of projected external doses for populations living in the north-west fallout zone of the Fukushima nuclear accident, outcome of population evacuation measures, Report DRPH/2011-10, Directorate of Radiological Protection and Human Health, Institut de Radioprotection et de Sûreté Nucléaire, October 2011.
7. Nuclear Emergency Response Headquarters, Government of Japan: Report of the Japanese Government to the IAEA Ministerial Conference on Nuclear Safety – The Accident at TEPCO’s Fukushima Nuclear Power Stations, accessed 7 October 2011, <http://www.iaea.org/newscenter/focus/fukushima/japan-report/>
8. Press release, Tokyo Electric Power Company, 24 May 2012, [http://www.tepco.co.jp/en/press/corp-com/release/2012/1204659\\_1870.html](http://www.tepco.co.jp/en/press/corp-com/release/2012/1204659_1870.html)
9. Chernobyl Accident 1986, World Nuclear Association, April 2012, <http://www.world-nuclear.org/info/chnobyl/info7.html>

# Bystander Effects Multiply Dose & Harm from Ionizing Radiation

*Effects of radiation felt by non-irradiated neighbouring cells prompt a rethink of radiation risk, radiotherapy and radioprotection*

**Dr. Mae-Wan Ho**

## Low dose big effects

Linear dose response relationships are routinely used in risk assessments of exposure to environmental hazards, and ionizing radiation is no exception. Typically, effects at high doses that kill cells, cause gene mutations and cancers, are back extrapolated to obtain an exposure limit at which the harm caused is considered miniscule or acceptable in view of the benefits gained. Ionizing radiation was widely believed to cause mutations by directly breaking the bonds of DNA molecules in the nucleus.

In the early 1990s, Hatsumi Nagasawa and John Little at Harvard School of Public Health, Boston, Massachusetts, discovered, to their surprise, that while a linear relationship applies to high doses of  $\alpha$ -radiation (from 5cGy to 1.2 Gy, where cGy =  $10^{-2}$ Gy) (see Box), a much enhanced effect was obtained at very low doses of 0.03 cGy to 0.25 cGy, when 30 to 45 % of the cells in a population of Chinese hamster cells exhibited sister chromatid exchange (SCE involving double-stranded DNA breaks). At that low dose of radiation, only 0.07 to 0.6 % of the nuclei should have been directly hit by an alpha-particle. Yet the frequency of SCE rose rapidly at very low doses reaching a plateau below 1 cGy, after which no further increase occurred with increasing dose, though a decline occurred at higher doses. That was the first indication that damaging signals may be transmitted from irradiated to neighbouring non-irradiated cells in a population, and they called it "the bystander effect" [1].

In another experiment they looked at mutation frequency of a specific enzyme, and found the same enhanced effect at very low dose. At the lowest dose of 0.83 cGy, the efficiency with which the alpha-particle can induce a mutation increases nearly five-fold; the mutation frequency was the same as that due a dose 100 times as great (0.83 Gy).

Using the then newly developed microbeam of very low dose alpha particles to target individual cells, researchers at Columbia University, New York, showed that hitting the cytoplasm was sufficient to induce mutation in the nucleus [3]. They commented that low dose radiation is all the more dangerous because it does not kill the targeted cell, but allows its influence to spread widely to adjacent cells, thus multiplying the radiation effect (about 100 fold).

## Bystander effects now abundantly confirmed

Since then, a wide range of bystander effects in cells not directly exposed to ionizing radiation have been found, which are the same as or similar to those in the cells that were exposed [4], including cell death and chromosomal instability.

Actually, radiation induced bystander effects have been described as far back as 1954, when factors that cause damage to chromosomes could be detected in the blood of irradiated patients. Carmel Mothersill and Colin Seymour at McMaster University published a key paper in 1997 showing that filtered medium from irradiated human epithelial cells can reduce the survival of unirradiated cells, suggesting that soluble factors produced by the irradiated cells were involved in the bystander effects [5].

Indeed, serum from cancer patients treated with radiotherapy also causes cell death and chromosomal instability in unexposed cells in culture, and this has been shown as far back as 1968 [6].

In 2001, researchers at Columbia University, New York used microbeams to target single cells with exactly defined numbers of  $\alpha$ -particles (see Figure 1). They found that

hitting 10 % of the cells induced the same frequency of cancerous transformation as when every cell in the dish was targeted [7].

More recently, bystander DNA double-strand breaks were induced in a three-dimensional human tissue culture that is closer to *in vivo* conditions. The results obtained by the team led by Olga Sedelnikova at the National Cancer Institute, Bethesda, Maryland, were much more dramatic. In marked contrast to cultured cells in two-dimensions where maximal DSB occurred 30 minutes after irradiation, the incidence of DSBs in bystander cells reached a maximum between 12 to 48 hours after irradiation, gradually decreasing only over 7 days. At the maximum, 40 to 60 % of cells were affected [8]. These increases in

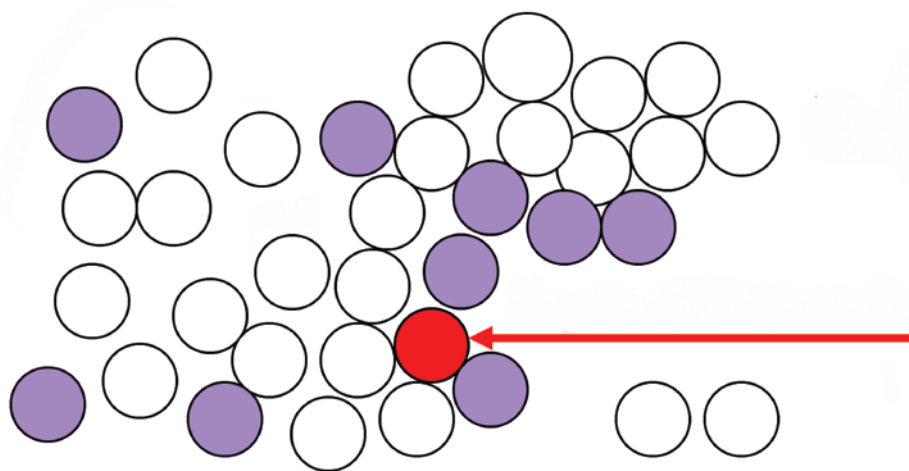


Figure 1 Microbeam shows up bystander effects in cells; red arrow microbeam, white cells normal, purple cells show bystander effects

bystander DSBs were followed by increased apoptosis and micronucleus formation, loss of nuclear DNA methylation and increased fractions of senescent cells. The authors commented that treatment of primary tumours with radiation therapy frequently results in the growth of a secondary malignancy of the same or different origin. They raised the question on whether bystander effects could introduce negative complications in radiation therapy, such as genomic instability in normal tissues. They concluded that induced senescence might be a protective mechanism. On the other hand, failure of these protective pathways can lead to the appearance of proliferating, damaged cells and to an increased probability of oncogenic transformation.

New research from the University of Pittsburgh Pennsylvania throws further light on the implications of bystander effects for radiotherapy. It is customary for patients receiving bone-marrow transplant to undergo whole body irradiation to kill the bone marrow cells of the host so as to encourage repopulation by transplanted cells. The researcher found that irradiated mouse recipients significantly impaired the long-term repopulating ability of transplanted mouse haematopoietic stem cells (HSCs) 17 hours after exposure to irradiated hosts, and before the cells began to divide. There was an increase in acute cell death associated with accelerated proliferation of the bystander HSCs. The effect was marked by a dramatic down-regulation of c-Kit (a proto-oncogene), apparently because of elevated reactive oxygen species (ROS). Administration of an antioxidant chemical or ectopically through over-expression of a ROS scavenging enzyme catalase improved the function of transplanted HSCs in the irradiated hosts [9]. This obviously has implications for protecting patients during radiotherapy as well as those receiving bone-marrow transplant.

### What causes the bystander effects?

The bystander effect is largely a low-dose phenomenon, appearing at doses below 10 cGy [10]. Higher doses often do not produce bystander effect possibly because the cells targeted are killed before they can influence non-targeted cells. As with the “war on cancer”, numerous attempts have been made to identify the genes or gene products involved in the bystander effects. And as in cancer, genes up-regulated or down-regulated are secondary to a state of electronic imbalance (see [11] Cancer a Redox Disease, SiS 54) created by the ionizing radiation, which breaks chemical bonds and generate free electrons (see Box 2).

When cells are irradiated, it is likely that ionization of one or more of the atoms on DNA molecules will occur in a direct hit, breaking the DNA chain or the links between chains. However, direct attack of radiation on the structure of DNA is not the only way radiation affect cells. The human body is about 70 % water; hence water is probably the most frequent target of ionizing radiation. Ionization of water leads to the formation of reactive oxygen species (ROS) (see Box 3) that damages DNA, lipids, proteins, carbohydrates, and other molecules. It is becoming increasingly clear that ROS is a major culprit in the bystander effect, as suggested by those who discovered the effect [1, 2]. This has been confirmed by more recent findings.

### ROS and oxidized extracellular DNA

A team led by Aleksei Ermakov at the Research Centre for Medical Genetics, Russian Academy of Medical Sciences in Moscow Researchers showed that an extracellular DNA (ecDNA) derived from the cell genome participates in the bystander effect induced by X-ray exposure in human lymphocytes and human umbilical-vein epithelial cells [15]. Their previous work suggested that radiation-sensitive cells undergoing apoptosis serve as a source of ecDNA fragments that diffuse in the medium and bind to DNA receptors on the surface of bystander cells. Bystander effects could be stimulated by ecDNA of irradiated cells but not by ecDNA produced by normal cells. In a new study, the team tested the idea that the difference between the two types of ecDNA is due to DNA oxidation events occurring during and after irradiation. They compared the production of NO (nitric oxide, a free radical and reactive oxygen species) and ROS in human endothelial cells that were irradiated at a low dose radiation, or exposed to the ecDNA<sup>R</sup> extracted from the media conditioned by irradiated cells, or exposed to the genomic DNA oxidized in vitro by treatment with H<sub>2</sub>O<sub>2</sub>, (DNA<sup>01</sup>), or H<sub>2</sub>O<sub>2</sub> plus uv light (DNA<sup>02</sup>; more strongly oxidizing). They found that all three treatments gave similar responses. The production of NO at 2h was suppressed at low doses of 0.03 Gy and 0.1 Gy but increased at 0.5 Gy or higher. Similarly, the ecDNA<sup>R</sup> extracted from media conditioned by irradiated cells decreased NO but not the extracellular DNA from non-irradiated cells; the oxidized DNA<sup>01</sup> and more so DNA<sup>02</sup> also reduced NO. ROS levels in general were increased in all three treatments by 1.2 to 1.8-times the controls with ecDNA<sup>R</sup> and oxidized DNA<sup>01</sup> and DNA<sup>02</sup> to larger extents than the direct radiation, or the bystander effect due from the conditioned medium.

Other researchers have shown that the major source of ROS in endothelial cells is the activity of NAD(P)H-oxidases, predominantly one

### Box 2

#### How ionizing radiation can impact on health

Ionizing radiation comes from radioactive decay of unstable chemical elements, which are generated in the nuclear fission process in nuclear power reactors, or in linear accelerators that produce X-rays and electron beams ( $\beta$ -particles) for radiotherapy [12, 13]. In general photons or particles with energy above 10 eV (electron volts) are ionizing.

Nuclear fission is the splitting of the nucleus of a large atom into two, along with a few neutrons and release of energy in the form of heat and  $\gamma$ -rays; about 0.2 to 0.4 % of fissions also produce  $\alpha$ -particles (nuclei of helium-4 with two protons and two neutrons), or nuclei of tritium (one proton and two neutrons). The fission products are often unstable and hence radioactive; they undergo  $\beta$ -decay giving out  $\beta$ -particles, antineutrinos, and additional  $\gamma$ -rays. Antineutrinos pass easily through ordinary matter; consequently, the major ionising radiations that can affect health are  $\alpha$ - and  $\beta$ -particles, X-rays,  $\gamma$ -rays and neutrons.

$\alpha$ - and  $\beta$ -particles are directly ionizing radiation; they interact directly with atoms, and if the energy is sufficient, knock outer electrons away to produce a free electron and a positively charged ion. A  $\beta$ -particle produces more than 100 ionizing events per cm in its track, whereas an  $\alpha$ -particle produces more than 10 000 ionizing events per cm. But while a  $\beta$ -particle can travel for centimetres through tissues,  $\alpha$ -particles travel for micrometres only. As the energy of each particle increases, so does the range. Consequently, external sources of  $\alpha$ -particles are stopped by the skin, while external  $\beta$ -particles can penetrate into the body. However, inhaled or ingested sources of  $\alpha$ -particles can do a lot more damage within the body.

X-rays and  $\gamma$ -rays induce ionization indirectly through 3 principal mechanisms: Compton scattering where they are scattered from the outer electrons of atoms, transferring energy to the electrons, and if enough energy is transferred, give rise to a free electron and a positively charged ion. In the photoelectric effect, one of the inner electrons of the atom absorbs the energy of the X-ray or  $\gamma$ -ray, and is ejected from the atom, again leaving a positively charged ion. Following this, one of the outer electrons ‘falls’ in to fill the vacancy, and X-ray is emitted from the atom. In pair formation, the x-ray or  $\gamma$ -ray interacts with the electric field of the nucleus, and is converted into an electron and a positron, the positron in travelling through the tissue material will usually react with another electron and become converted back to two X-rays or  $\gamma$ -rays.

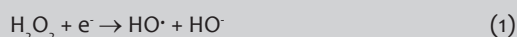
Neutrons are scattered directly from the atomic nuclei of atoms, resulting either in losing energy that is released as  $\gamma$ -rays or else it is absorbed by the nuclei resulting in a new nucleus (element) being formed. If the new nucleus is unstable, radioactive decay occurs creating  $\alpha$ -,  $\beta$ - or  $\gamma$ -rays. The second option can only occur if the neutron is sufficiently slow, and that is what happens in the nuclear fission process in nuclear power reactors.

Some of the free electrons generated by the ionizing radiation may be energetic enough to cause ionizations of their own; this is the secondary photoelectron effect of ionizing radiation.

## Box 3

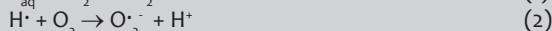
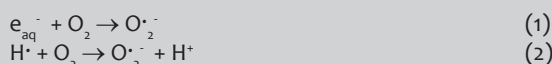
Reactive oxygen species generated from water [14]

Oxygen is the most important electron acceptor in the biosphere. It readily accepts unpaired electrons to give rise to a series of partially reduced species collectively known as reactive oxygen species (ROS). These include superoxide  $O_2^-$ , hydrogen peroxide  $H_2O_2$ , hydroxyl radical  $HO^\bullet$  and peroxy radical  $OO^\bullet$ , which may initiate and propagate free radical chain reactions damaging to cells. Hydroxyl radicals are generated by ionizing radiation either directly from water, or indirectly by the formation of secondary partial ROS that are subsequently converted to hydroxyl radicals by metabolic processes. Gamma rays, beta and alpha particles are all able to ionize water to produce hydroxyl radicals, the most reactive, and therefore potentially the most hazardous. Hydroxyl radicals have a very short persistence time, while hydrogen peroxide is the most long-lasting. Hydrogen peroxide can diffuse freely and can generate hydroxyl radicals by reacting with free electrons:

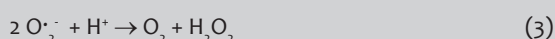


Oxidative attack on proteins destroys their enzyme, receptor and other biological function; damage to DNA causes mutations and chromosomal rearrangements; and peroxidation of lipids destroys membrane structure and function.

More than 80 % of energy of ionizing radiation deposited in cells results in the ejection of electrons from water. Subsequent reactions with surrounding water results in the formation of several reactive species:  $e_{aq}^-$  (hydrated free electron)  $HO^\bullet$  (hydroxyl radical, the most important reactive oxygen species),  $H^\bullet$  (hydrogen radical),  $H_2$  (hydrogen gas) and  $H_2O_2$  (hydrogen peroxide, a stable and diffusible reactive oxygen species). These products react rapidly with each other and with surrounding molecules. In the presence of  $O_2$ , superoxide radicals (another reactive oxygen species) are formed:

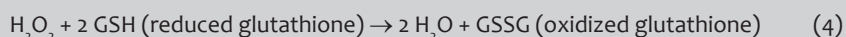


Superoxide generates hydrogen peroxide on a longer time scale:



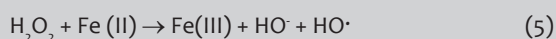
Because of their instability, most of the reactions generating the primary radical products will have taken place within 1 millisecond, but superoxide and  $H_2O_2$  will persist and diffuse to more distant sites.

Cellular damage by hydroxyl radical attack depends partly on the antioxidant status of the cell and partly on the availability of reducing systems capable of reducing or activating superoxide or hydrogen peroxide. The cellular antioxidant status determines the intracellular concentration of ROS. It has been shown that the effects of  $H_2O_2$  resemble those of ionizing radiation. Cells exhibiting high levels of SOD, catalase, and peroxidase activity are relatively less vulnerable to secondary effects of radiation. Glutathione peroxidase catalyses the reaction:



The activity of this peroxidase depends on the availability of reduced GSH. Regeneration of GSH from GSSG by glutathione reductase requires reduced nicotinamide adenine dinucleotide phosphate (NADPH) as electron donor.

The hydroxyl radical can be produced from more stable ROS via the participation of an electron donor, and many transition metal ions can act as electron donors:



Thus, hydroxyl radicals are generated from  $H_2O_2$  at sites where reduced transition metals are present.

encoded by the NOX4 gene. Irradiation with 0.1 Gy and treatment with ecDNA<sup>R</sup> led respectively to a 3-fold and 1.7 fold increase in NOX4 mRNA, while oxidized DNA stimulated transcription 5-15 fold compared with unoxidized DNA.

Also in previous work by the Russian team, the bystander effect involves DNA-binding to Toll-like receptor TLR9. This was confirmed by blocking the TLR9 response with chloroquine and oligonucleotide 2088, which suppressed the increase in ROS production and eliminated the effects of ecDNA<sup>R</sup>.

The team suggested that the bystander effect-like properties of ecDNA<sup>R</sup> and oxidized DNA may be used for the development of novel anti-tumour therapy that may stimulate cell death without actual irradiation, or synergistically with reduced irradiation doses.

### Secondary photoelectron effects

Another way low dose ionization radiation can be amplified and appear as bystander effects is through scattering of photons through the tissues. Photons or particles can bounce off one target atom and strike another, generating a further free electron (see Box 2).

A research team at the Maria Skłodowska-Curie Memorial Cancer Centre and Institute of Oncology Gliwice Branch, Poland investigated direct and bystander effects induced by scattered radiation in two human cell lines – normal bronchial epithelial cells BEAS-2B and lung cancer epithelial cells A549 – placed in a bath of water at different depths and subjected to irradiation by 6 MeV photon beam or 22 MeV electron beam (5Gy maximum dose), and examined for apoptosis and micronucleated cells [16].

They found that for electron radiation both the numbers of apoptotic and micronucleated cells were greater than expected from the corresponding received dose, and the discrepancy between observed and expected becomes larger with increased medium depth. At a depth of 15-17 cm, the observed was ten times the expected, while micronucleated cells was about 2-3 fold. For photon radiation the biological effect did not differ significantly from expected value because photon radiation penetrates the medium better. When cells were placed outside the radiation field or under a shield, differences from expected dose were also found for both photon and electron, but no depth dependence was observed. For cells exposed outside the field of the photon beam, apoptosis was again about 7-10 fold the expected while micronuclei formation was 4-5 fold. For shielded cells under photon irradiation, apoptosis was about 3-fold while micronuclei was about 1.2-fold. For cells exposed outside the radiation field of the electron beam, again, a 10-fold difference from

the expected, and for micronucleated cells, 1.5 to 4-fold in BEAS cells, and 4-7 fold in A549 cells. All the irradiated cell medium, when added to non-irradiated A549 cells gave a 2-fold increase in micronucleated cells and a 2-fold increase in apoptotic cells, regardless of the dose of irradiation or whether it was inside the beam, outside the beam or shielded.

Apart from the bystander effects mediated through the exposed cell medium, these experiments indicate that secondary photoelectron scattering may be involved in the biological effects of low-dose radiation. This has been suggested by research published in the early 1990s [17]. Monte Carlo track structure methods were used to illustrate the importance of low-energy electrons produced by low linear-energy-transfer radiations. These low-energy secondary electrons contribute substantially to the dose in *all* low-LET irradiations, and account for up to nearly 50 % of the total dose imparted to a medium when irradiated with electrons or photons. Up to 50 % of secondary electrons themselves can also undergo further scattering and to generate more free electrons. For most ionizing radiations, nearly 50 % of all ionizations are due to secondary electrons with starting energies less than 1 keV.



Implications for risk assessment, radiotherapy and radioprotection  
Risk assessment and radiation protection have been based on extrapolation from known epidemiological data that mainly relate to high dose effects that assume a linear dose-response relationship even at very low doses [4]. This is clearly untenable in view of the bystander effects at low doses, which amplify the effective dose and harm caused.

The best available evidence suggests that bystander effects are mediated by ROS. ROS is well-known to be involved in general oxidative stress, with many downstream effects that mirror bystander effects: DNA breaks, genome instability, cell death, cancer, including cell senescence and aging [18], and cataracts [19]. *It is notable that these effects are appearing as significant health impacts linked to the Chernobyl fallout [20] (Chernobyl Deaths Top a Million Based on Real Evidence, SiS 55).* The pro-nuclear lobby and regulators should stop denying these impacts and governments

should devote much more resources to studying them instead, to prevent repeating the humanitarian disaster in the wake of the Fukushima meltdown (see [21] Truth about Fukushima, SiS 55).

The involvement of ROS also suggests that antioxidant interventions should be considered as a mitigation of bystander effects in those exposed or still being exposed to the Fukushima and Chernobyl fallouts. This is a matter of some urgency. Among the most promising findings are the well-known benefits of green tea in cancer prevention (see [22] Green Tea Against Cancers, SiS 33), and its many antioxidants polyphenols that probably account for reducing risks of heart disease, cancers, Alzheimer's disease, obesity, arthritis, diabetes, and a host of other conditions associated with oxidative stress (see [23] Green Tea, The Elixir of Life? SiS 33). New research from the Radiation and Cancer Therapeutics Lab at Jawaharlal Nehru University, New Delhi, and the Central University of Gujarat in India indeed shows that one of the main green tea polyphenols, EGCG (epigallocatechin-3-gallate) is most efficient at protecting DNA against  $\gamma$ -radiation induced breaks both inside and outside the cell, and also protects cells against radiation-induced cell death, lipid peroxidation and membrane damage (see [24] Green Tea Compound for Radioprotection, SiS 55).

As far as cancer radiotherapy is concerned, the bystander effects mean that the radiation beam will cover a wider area than the physical beam, and the potential harm may outweigh the presumed benefit. The same goes for diagnostic radiology, as it occurs at doses that might induce more harmful bystander effects than the potential benefit the procedure might deliver. It is also possible that antioxidants could offer radioprotection against these procedures.

SiS

## References

- Nagasawa H and Little JB. Induction of sister chromatid exchanges by extremely low doses of alpha particles. *Cancer Res* 1992, 52, 6394-6.
- Nagasawa H and Little JB. Unexpected sensitivity to the induction of mutations by very low doses of alpha-particle radiation: evidence for a bystander effect. *Radiation Research* 1999, 152, 552-7.
- Wu L-J, Randers-Pehrson G, Xu A, Waldren CA, Geard CR, Yu Z, and Hei TK. *PNAS* 1999, 96, 4959-64.
- Mothersill C and Seymour CB. Radiation-induced bystander effects – implications for cancer. *Nature Reviews Cancer* 2004, 4, 158-164.
- Mothersill C and Seymour CB. Medium from irradiated human epithelial cells but not human fibroblasts reduces the clonogenic survival of unirradiated cells. *Int J Radia Biol* 1997, 71, 421-7.
- Hollowell JG and Littlefield LG. Chromosome damage induced by plasma of X-rayed patient: an indirect effect of radiation. *Proc Soc Exp Biol Med* 1968, 129, 240-4.
- Sawant SG, Rander-Pehrson G, Geard CR, Brenner DJ and Hall EJ. The bystander effect in radiation oncogenesis: I. Transformation in CeH 10T1/2 cells in vitro can be initiated in the unirradiated neighbors of irradiated cells. *Radiation Research* 2001, 155, 397-401.
- Sedelnikova OA, Nakamura A, Kovalchuk O, Koturbash I, Mitchell SA, Marino SA, Brenner DH. And Bonner WM. DNA double-strand breaks form in bystander cells after microbeam irradiation of three-dimensional human tissue models. *Cancer Res* 2007, 67, 4295-302.
- Shen H, Yu H, Liang PH, Cheng H, XuFeng R, Yuan Y, Zhang P, Smithe CA and Cheng T. An acute negative bystander effect of g-irradiated recipients on transplanted hematopoietic stem cells. *Blood* 2012, 119, 3629-37.
- Hei TK, Zhou H, Ivanov VN, Hong M, Lieberman HB, Brenner DJ, Amundson SA and Geard CR. Mechanism of radiation-induced bystander effects: a unifying model *JPP* 2008, 60, 943-50.
- Ho MW. Cancer a redox disease. *Science in Society* 54, 12-17, 2012.
- Nuclear fission product, Wikipedia, 12 May 2012, [http://en.wikipedia.org/wiki/Nuclear\\_fission\\_product](http://en.wikipedia.org/wiki/Nuclear_fission_product)
- Kelly M. Effects of Radiation, accessed 23 May 2012, <http://www.marts100.com/Effects.htm>
- Kostyuk SV, Ermakov AV, Alekseeva AY, Smirnova TD, Glebova KV, Efremova V, Barampva A and Veiko NN. Role of extracellular DNA oxidative modification in radiation induced bystander effects in human endothelial cells. *Mutation Research* 2012, 729, 52-60.
- Kostyuk SV, Ermakov AV, Alekseeva AY, Smirnova TD, Glebova KV, Efremova V, Barampva A and Veiko NN. Role of extracellular DNA oxidative modification in radiation induced bystander effects in human endothelial cells. *Mutation Research* 2012, 729, 52-60.
- Konopacka M, Rogoliński J and Ślosarek K. Direct and bystander effects induced by scattered radiation generated during penetration or radiation inside a water phantom. *Mutation Research* 2011, 721, 6-14.
- Nikjoo H and Goodhead DT. Track structure analysis illustrating the prominent role of low-energy electrons in radiobiological effects of low-LET radiations, *Phys. Med. Biol.* 1991, 36, 229-238.
- Bonnefoy M, Drai J and Kostka T. Antioxidants to slow aging, facts and perspectives (in French) *Presse Med* 2002, 31, 1174-84.
- Babizhayev MA. Mitochondria induce oxidative stress, generation of reaction oxygen species and redox state unbalance of the eye lens leading to human cataract formation: disruption of redox lens organization by phospholipid hydroperoxides as a common basis for cataract disease. *Cell Biochem Funct* 2011, Apr;29(3):183-206. doi: 10.1002/cbf.1737. Epub 2011 Mar 7.
- Ho MW. Chernobyl deaths top a million based on real evidence. *Science in Society* 55, 14-17, 2012.
- Ho MW. Truth about Fukushima. *Science in Society* 55, 18-23, 2012.
- Ho MW. Green tea against cancer. *Science in Society* 33, 17-19, 2007.
- Ho MW. Green tea, the elixir of life? *Science in Society* 33, 12-16, 2007.
- Ho MW. Green tea compound for radioprotection. *Science in Society* 55, 36-37, 2012

# Apple Pectin for Radioprotection

*A group of doctors and scientists risked their lives and careers to help children living in the most contaminated areas of the Chernobyl fallout and discovered a simple treatment that clears the radionuclides from their bodies, offering hope for future generations of Chernobyl and Fukushima victims* **Dr. Mae-Wan Ho**

Vassili Nesterenko and Yuri Bandazhevsky, champions of the victims of Chernobyl

The radioactive fallout from Chernobyl contaminated vast areas of neighbouring Belarus to > 37 000 Bq/m<sup>2</sup>. Agricultural production was halted on 264 000 hectares, where 2 million people live, among them 500 000 children [1].

Vassili Nesterenko (1934-2008), a physician from Belarus and a former director of the Institute of Nuclear Energy at the National Academy of Sciences of Belarus, was one of the co-authors of a comprehensive report documenting the health impacts of Chernobyl (see [2] Chernobyl Deaths Top a Million Based on Real Evidence, SiS 55). Since 1990, he had been the director of the Belarusian independent Institute of Radiation Safety (BELRAD), created in 1989 with the help of Soviet physicist, dissident, and human rights activist Andrei Sakharov (Nobel Peace Award, 1975), Belarusian writer and critic, Ales Adamovich, and Russian chess grandmaster and former world champion Anatoly Karpov. The mission of BELRAD was to document and study the consequences of the Chernobyl disaster [3]. Because of his work on Chernobyl, Nesterenko lost his job and was threatened internment in a psychiatric asylum. He escaped two attempts on his life.

Nesterenko intervened personally during the accident at Chernobyl. As an expert on the subject and with his experience as a fire fighter, he threw liquid nitrogen containers from a helicopter in an attempt to cool the reactor core, risking his life in the radioactive smoke. He survived, but three of his 4 passengers in the helicopter died from the radiation and contamination.

Nesterenko was not alone in being persecuted for working on Chernobyl.

Yuri Bandazhevsky, former director of the Medical Institute in Gomel (Belarus) is a scientist also dedicated to understanding and mitigating the health consequences of the Chernobyl disaster. He created the Gomel Medical Institute, and was named its director in 1990. But in June 2001, Bandazhevsky was sentenced to 8 years imprisonment, as was the Deputy Director, Vladimir Ravkov. The imprisonment was widely believed to be due to his work on the consequences of Chernobyl, as his arrest came soon after he published reports critical of the official research being conducted into the Chernobyl incident [4].

Bandazhevsky was released on parole from prison in 2005, and prohibited from leaving Belarus for five months. He was afterwards invited by the mayor of Clermont-Ferrand in France to work at the university and at the hospital on the consequences of Chernobyl. Since 1977, Clermont Ferrand has been linked to Gomel. In France, Bandazhevsky is supported by the Commission de Recherche et d'Information Indépendantes sur la Radioactivité (CRIIRAD).

Chronic incorporation of Cs-137 into children's organs  
Bandazhevsky documented the chronic incorporation of Cs-137 in the organs of children living in contaminated areas. A paper published in 2003 examined the organs of 52 children up to the age of 10, who died in 1997. The highest accumulation was in the endocrine glands, in particular the thyroid, the adrenals and the pancreas. High levels were also found in the heart, the thymus and the spleen [5]. Children have a higher average burden of Cs-137 compared with adults living in the same community, typically 2 to 3 times.

The organs from 6 infants with very high levels of contamination in organs - thousands to >12 500 Bq/kg - all had severe symptoms: premature malformation, sepsis, cardiac abnormality, sepsis and

bleeding, and cerebral malformation.

Histological abnormalities were also demonstrated in the organ tissues and in animal models exposed to Cs-137 in their feed [6].

As these children were born after March 1987, they did not suffer from radioactive "iodine shock"; hence their illnesses and death was not due to short-lived I-131, but long-lived radionuclides especially Cs-137.

In the course of his work, Bandazhevsky found that Cs-137 over 20 Bq/kg leads to disturbance of electrophysiological processes in the heart muscle of children. Those born after 1986 and continuously living in contaminated areas with concentrations above 15 Ci/km<sup>2</sup> (Ci, Curie = 3.7 × 10<sup>10</sup> Bq) suffer serious pathological modifications of the cardiovascular system (see [2]).

Apple pectin reduces radioactivity in children's body

Meanwhile, the BELRAD, under the direction of Nesterenko, carried out radiation monitoring of the inhabitants of the Chernobyl contaminated zone and their foodstuffs, and developed measures for the maintenance of radiation safety and radioprotection. Nesterenko also pioneered a treatment with apple pectin for children living in highly contaminated areas and eating highly contaminated food.

As a complement to standard radioprotection measures, apple-pectin preparations have been given especially in Ukraine to reduce the Cs-137 uptake in children. Pectin acts by binding to the radionuclide in the gut to block its absorption. The question was raised as to whether pectin might also be useful in clearing it from tissues. Caesium is chemically similar to potassium, and therefore has a wide distribution in tissues and cells, and is also excreted in urine.

Researchers at BELRAD carried out a randomised, double-blind placebo-controlled trial to test the efficacy of dry, milled apple-extract containing 15-16 % pectin on 64 children from contaminated villages of the Gomel regions. The average Cs137 load in the group of children was about 30 Bq/kg body weight. The trial was conducted during a one-month stay in the sanatorium Silver Spring where only uncontaminated food was given to the children.

The results showed that Cs-137 counts in children given pectin-powder were reduced by an average of 62 %, whereas the average reduction in those children given only placebo powder was only 13.9 %. The difference was significant at less than 1 % level. The reduction was medically significant, as no child in the placebo group reached values below 20 Bq/kg body weight, which is considered by Bandazhevsky as potentially associated with specific pathological tissue damages.

Among the children living in the contaminated areas, 70 to 90 % of the children had Cs-137 exceeding 15-20 Bq/kg body weight. In many villages, the levels reached 200-400 Bq/kg; the highest values were measured in Narovlya district with 6 700-7 300 Bq/kg. As shown by Bandazhevsky, the chronic accumulation of Cs-137 contributed to progressive deterioration of health [7, 8].

In a second study published in 2007 carried out by the BELRAD and the Research Centre Jülich in Germany, a joint data-base was created to include all available data from previous measurements at both research institutes and evaluated to identify settlements with potentially enhanced radiation burdens. Serial measurements of the Cs body burden were then performed at those settlements. The new



Top: Vassili Nesterenko,  
bottom: Yuri Bandazhevsky

data for 17 000 children were used to evaluate the actual situation with special attention to the critical group – the 10 % in age group 1-19 y with the highest dose. These children were recruited into further investigations on the effectiveness of different treatments including apple pectin to reduce the Cs-137 burdens in the body.

Although total annual doses for most of nearly 17 000 children assessed in 2002-2003 were generally below 1 mSv (the international exposure limit, approximately equivalent to 1 308 780 Bq), there are still cases where the limit is exceeded merely due to a high ingestion dose. This calls for remedial measures for agricultural land and the use of clean food and control of food contamination.

A brand of pectin called Vitapect consists of apple pectins with added vitamins, mineral nutrient and flavouring. In a placebo controlled double-blind study, 8 groups of internally contaminated children were treated with Vitapect (5 g twice a day) for a two-week period during their stay in a sanatorium. An equal number of control groups were given a placebo preparation. Each group comprised 40-50 children. A total of 729 children participated in the study. The Cs-137 body count of each child was measured at the beginning and end of the treatment.

The relative reduction of specific activity was  $32.4 \pm 0.6$  % for the pectin groups compared with an average of  $14.2 \pm 0.5$  % for the control groups. The mechanism of action of pectin is assumed to be similar to that of Prussian Blue, a proven and recommended agent for removing Cs-137 from the body. It blocks the re-uptake of Cs-137 excreted into the gut, thereby reducing the biological half-life by a factor of 2.5 from 69 to 27 days, in good agreement with a theoretical model.

It is of interest that NASA (National Aeronautics and Space Administration) in the United States has suggested the following dietary countermeasures against ionizing radiation for astronauts [9]:

“Dietary countermeasures are drugs, that when ingested by an astronaut, may have the potential to reduce effects of ionizing radiation. These supplements can be broadly categorized into two groups. The first group includes specific nutrients that prevent the radiation damage. For example, antioxidants like vitamins C and A may help by soaking up radiation-produced free-radicals before they can do any harm. Research has also suggested that pectin fiber from fruits and vegetables, and omega-3-rich fish oils may be beneficial countermeasures to damage from long-term radiation exposure. Other studies have shown that diets rich in strawberries, blueberries, kale, and spinach prevent neurological damage due to radiation. In addition, drugs such as Radiogardase (also known as Prussian blue) that contain Ferric (III) hexacyanoferrate (II) are designed to increase the rate at which cesium-137 or thallium are eliminated from the body.”

BELRAD holds training seminars for parents and children, who receive the booklet, *How to Protect Yourself and Your Child from Radiation*, containing practical advice such as how to reduce the levels of radionuclides in wild fowl, mushrooms and fish, before they are cooked: by soaking them for two periods of 3-4 hours each in salted water (two tablespoons of salt with one tablespoon of vinegar in 1 litre of water) [10].

To-date, BELRAD has performed 433 000 whole body count measurement (WBC) in 300 villages in the provinces of Mogilyov, Brest, Grodno, Vitebsk, Minsk and Bryansk. In 2001, the WBC laboratory of the Institute was officially accredited and certified. The large scope of the work required the collation and evaluation of all the data received, which was then combined to produce *The Radio-ecological Atlas: Human Beings and Radiation*, a systematic analysis of whole body count measurements of Cs-137 performed on children in villages in 19 districts of the Chernobyl region of Belarus between 2001 and 2007. The Atlas is regularly updated as the Institute continues the radiation monitoring of children. It now includes measurements performed up to 2011, including additional results from two further provinces.

#### Seaweed alginate for radioprotection

Radioprotection is an urgent issue not just for the victims of Chernobyl but especially now for those living in highly contaminated areas

of Fukushima (see [11] Truth about Fukushima, SiS 55). A study carried out at the Institute of Radiation Medicine in Beijing China in 1991 demonstrated that sodium alginate prepared from seaweeds such as *Sargassum* sp. and kelp (*Laminaria* sp.) was able to block radioactive strontium uptake [12]. Na alginate from *S. siliquastrum* in particular, reduced the body burden of strontium 3.3-4.2 fold in rats, and by 78% ( $\pm 8.9$ ) in human subjects. No undesirable effects on gastrointestinal function was observed nor were Ca, Fe, Cu and Zn metabolism altered, both in the animal experiments and in human volunteers. A more recent study at the Institute of Radiation Protection, Ingolstadt, Germany, found that sodium alginate added to Sr-90 contaminated milk reduced the uptake of Sr-90 by a factor of 9 [13].

The seaweed Nori in the Japanese diet is also a rich source of alginate.

#### Hope

Bandazhevsky and the Gomel Medical Institute, and Nesterenko and BELRAD have made a real difference to the lives of villagers that they have been able to help. The levels of radionuclides have been reduced in comparison with the villages where the radiological contamination has remained the same or where the situation has got worse as the result of particular local conditions, such as, for example, an abundant crop of contaminated mushrooms. The importance of decontamination, continuing health surveillance and radioprotection cannot be over-emphasized.

BALRAD would have made much more progress had it not been for a scandalous disinformation campaign mounted against the apple pectin treatment, which stopped major funding from the European Parliament in the 1990s [14] (see also [15] The Pectin Controversy, SiS 55).

There is indeed hope for future generations to recover health and vitality, thanks to the work of these courageous doctors and scientists, who put their lives and careers on the line for the sake of learning the truth about the consequences of Chernobyl and helping the children affected. They deserve all our support.

For more information and especially if you would like to help, please contact *Enfants de Tchernobyl Belarus* (<http://enfants-tchernobyl-belarus.org>); [etb@enfants-tchernobyl-belarus.org](mailto:etb@enfants-tchernobyl-belarus.org); or the *Institute of Radioprotection “BELRAD”* (<http://belrad-institute.org>); [irs.belrad@gmail.com](mailto:irs.belrad@gmail.com); [etb@enfants-tchernobyl-belarus.org](mailto:etb@enfants-tchernobyl-belarus.org).

#### References

1. Nesterenko BV. Radioprotective measures for the Belarusian population after the Chernobyl accident. *Internat J Radiation Medicine* 2001, 3, 12.
2. Ho MW. Chernobyl deaths top a million based on real evidence. *Science in Society* 55, 14-17, 2012.
3. Vassili Nesterenko, Wikipedia, 6 March 2012, [http://en.wikipedia.org/wiki/Vassili\\_Nesterenko](http://en.wikipedia.org/wiki/Vassili_Nesterenko)
4. Yuri Bandazhevsky, Wikipedia, 27 Mar 2012, [http://en.wikipedia.org/wiki/Yuri\\_Bandazhevsky](http://en.wikipedia.org/wiki/Yuri_Bandazhevsky)
5. Bandazhevsky YI. Chronic Cs-137 incorporation in children's organs. *Swiss Med Wkly* 2003, 133, 488-90.
6. Bandazhevsky Y. From the syndrome of chronic incorporation of long lived radionuclides (SLIR) to the creation of programmes and radioprotection policies for populations, an example of an integrated model. Presentation at Scientific and Citizen Forum on Radioprotection – From Chernobyl to Fukushima, 11-13 May 2012, Geneva.
7. Bandazhevsky YL. Pathophysiology of incorporated radioactive emission. Gomel State Medical Institute, 1998, 57pp.
8. Bandazhevsky YL. Medical and biological effects of radiocaesium incorporated into the organism. Minsk 2000, 70 pp.
9. Space Faring, The Radiation Challenge, An Interdisciplinary Guide on Radiation Biology for grades 9 through 12, Module 3: Radiation Countermeasures, NASA, George C. Marshall Space Flight Center, Huntsville, AL 35812, p.5, [www.nasa.gov/pdf/284275main\\_Radiation\\_HS\\_Mod3.pdf](http://www.nasa.gov/pdf/284275main_Radiation_HS_Mod3.pdf)
10. Nesterenko VB, Nesterenko AV, Babenko VI, Kozyrenko MA, Krasnoporov IV and Vaida OA. Implementation of radioprotection for populations at local level. *Radio-ecological Atlas: human beings and radiation*. Presented by Alexei Nesterenko at Scientific and Citizen Forum on Radioprotection – From Chernobyl to Fukushima, 11-13 May 2012, Geneva.
11. Ho MW. Truth about Fukushima. *Science in Society* 55, 18-23, 2012.
12. Gong YF, Huan ZJ, Qiang MY, Lan FX, Bai GA, Mao YX, Ma XP and Zhang FG. Suppression of radioactive strontium absorption by sodium alginate in animals and human subjects. *Biomed Environ Sci* 1991, 4, 273-82.
13. Hollriegel V, Rohmuss M, Oeh U and Roth P. Strontium biokinetics in humans. Influence of alginate on the uptake of ingested strontium. *Health Physics* 2004, 86, 193-6.
14. Tcherkoff W. *Le Crime de Tchernobyl: Le Goulag Nucleaire*, Actes Sud, 2006.
15. Greaves S. The pectin controversy. *Science in Society* 55, 34-36, 2012.

# The Pectin Controversy

*How the government orchestrated attack on science and scientists to protect the nuclear industry* **Susie Greaves**

Chronic low level internal radiation from contaminated food  
The major health impacts in the last 26 years in areas contaminated by Chernobyl are due to chronic internal radiation from eating contaminated food. The rural areas are worst affected because the local population live off the land, eat fish from the rivers, hunt game and gather berries and mushrooms in the forest, all of which are contaminated with radionuclides.

The people in these areas of Europe were abandoned to their fate, first by the Soviet government but soon after, by the West, as the nuclear lobby took over and persuaded governments that chronic low level radiation has no health effects. The nuclear lobby has only recently accepted that a distinction must be made between the effects of acute short lived external exposure to high levels of radiation as currently at Hiroshima and chronic low level internal radiation as in the case of Chernobyl victims [1].

Scientists from the three countries most affected - Belarus, Ukraine and Russia - battled from the start against this disinformation. Spurred on by the desperate plight of their people, they made unique discoveries about the effects of internally incorporated radionuclides, in particular caesium 137. Using this information, they developed a series of radioprotection measures, and one of these was the use of pectin as an adsorbent to aid the clearing of radionuclides from the body. The following account is based on an excellent book, *Le crime de Tchernobyl: le goulag nucleaire*, by journalist Wladimir Tchertkoff [2].

## *The major health impacts in the last 26 years in areas contaminated by Chernobyl are due to chronic internal radiation from eating contaminated food*

Vassili Nesterenko

Professor Vassili Nesterenko was the director of the Institute for Atomic Energy at the Academy of Sciences in Belarus from 1977 to 1987. When the accident occurred in 1986, he was called in by the Soviet government to assess the situation. He flew over the stricken reactor in a helicopter, receiving high levels of radiation that affected his health for the rest of his life. Nesterenko was a thorn in the flesh of the Soviet authorities from the start, insisting on iodine distribution, a wider evacuation, (neither of which were done soon enough) and producing his own reports of the contamination that challenged the official data. He received continual harassment and two attempts on his life. In 1989, unable to continue with his radioprotection work at the state institute, he set up the independent Belarussian Institute of Radiation Safety (BELRAD), with the support of Andrei Sakharov, another nuclear physicist, Ales Adamovitch, a writer, and Anatoli Karpov, the chess champion.

BELRAD measured the internal radiation in each individual child with a Human Radiation Spectrometer (HRS), and used this information to advise parents and teachers in the villages on how best to reduce the burden. It was vital to use HRS measurements rather than rely on abstract mathematical calculations, bordering on the absurd, of the total assumed radiation dose in one area. This method ignores the real situation in which there can be widely differing levels of radioactive contamination metres apart, and in any case, each child has a particular diet that is more or less contaminated.



Wladimir Tchertkoff, Wikimedia

By 1990, BELRAD had set up 370 local radioprotection centres for HRS measurements, and where samples of food can be monitored for radioactivity, and techniques introduced for reducing the level of caesium 137 in food. With help from charities abroad, some children went away on holiday for three weeks to reduce the radioactive burden in their bodies. BELRAD also introduced apple pectin cures.

Correlation between internal radioactivity and pathology established

In 1994, Nesterenko met Dr Yuri Bandajevsky, a pathologist and Rector of the Gomel Institute of Medicine. Yuri and his wife Galina Bandajevskaya, a paediatric cardiologist, had made two important discoveries. First that caesium 137, ingested through food, concentrates unevenly in the organs of the body. Thus, for an average of 50 Bq/kg in a child's body, there could be 1000 Bq/kg in the kidneys and over 2500 Bq/kg in the heart. Their second discovery was that irreversible lesions would occur in all vital organs of the body at levels above 50 Bq/kg. (This level was subsequently reduced to 20 Bq/kg, see [3] Apple Pectin for Radioprotection, SiS 55).

The importance of the discoveries cannot be overstated. The keystone of the nuclear lobby's insistence that Chernobyl cannot explain the increase in illness and death in the contaminated territories rests on the inability to correctly assess radiation dose and therefore correlate it with individual pathologies. This is precisely what Bandajevsky had done and it was extremely threatening to the nuclear lobby and to the Ministry of Health in Belarus.

Nesterenko and Bandajevsky, among others, had also severely criticised the 17 billion roubles spent in 1998 by the Belarus government supposedly on mitigating the consequences of the Chernobyl disaster. Instead, the money had been wasted on producing a faulty register of radiation doses that was abandoned a year later. The Ministry of Health in Belarus began to put obstacles in BELRAD's way. Throughout 1999, the Ministry of Health harassed the institute as to whether HRS (Human Radiation Spectrometer) measurements constituted a medical or a scientific procedure, and whether BELRAD needed a licence from the Ministry of Health. When the government lost this battle, they turned to the argument about the efficacy of pectin as an adsorbent.

Swiss Medical Weekly endorses apple pectin as effective adsor-

### bent for caesium 137

It has been known for decades that the use of adsorbents can enhance the elimination of heavy metals and radioactive materials from the body. The US Food and Drug Administration advise industry on the use of these adsorbents. What could possibly explain the controversy surrounding the use of apple pectin, a natural product that has no side effects, is cheap to produce and according to a study published by BELRAD in a reputable scientific journal, the *Swiss Medical Weekly*, has proven results in reducing levels of radioactive contamination in children's bodies? (The details are described in [3].)

### War against pectin or repression of science

It was clear that when the Ministry of Health in Belarus opposed BELRAD in its use of pectin, it was simply the nuclear lobby's continuing attempt to silence Bandajevsky and stop the work of BELRAD. If Bandajevsky's findings were to be admitted, the future of nuclear power would be under threat. Health effects from such low levels of radiation, contaminating enormous areas and endangering the health of millions of people, would have such devastating financial consequences, that *no government could consider nuclear power viable*.

The Ministry of Health in Belarus then enlisted Belarussian scientist Dr Jacob Kenigsberg, who worked (and continues to work!) for the International Atomic Energy Agency, and Professor Lengfelder, president of Deutscher Verbande für Tschernobyl-Hilfe (German Association for Aid to Chernobyl) to oppose Bandajevsky and the pectin therapy. Lengfelder and his vice-president Madame Frenzel conducted a smear campaign against Nesterenko and Bandajevsky, both of whom had brilliant careers as younger men before devoting themselves entirely to helping the victims of Chernobyl. The government-sponsored campaign against the two men culminated in Bandajevsky being sacked from his post at Gomel in 1999, arrested on trumped up charges and sentenced to eight years in prison [4]. He was adopted as a prisoner of conscience by Amnesty International and released in 2005.

### Unfounded claims against apple pectin

Lengfelder, Frenzel and Kenigsberg claimed that pectin had no useful properties. According to them, a study had been conducted by Herbstreith and Fox in Germany had proved that pectin was ineffective in decorporation (removing from body) of radionuclides. When a representative from Herbstreith and Fox was later interviewed, he said that only the effect of apple pectin on heavy metals had been studied, not the effect on radionuclide (p.137 of [1]).

But in a letter sent from the Ministry of Health of the Russian Federation in 2003 to local health authority directors, the pectin product Zosterine-Ultra was recommended as a "mass prophylactic in the atomic industry [with] the capacity to eliminate from the body the toxic components of lead, mercury, cadmium, zinc, manganese and other heavy metals as well as radionuclides including plutonium." It was "perfectly tolerated by patients and has no contra indications." The letter went on to say how important this product has been in the Chernobyl area in "lowering the levels of accumulation and concentration of toxic substances in the body, and reinforcing the body's own defence mechanisms." And the product has been "approved as a therapeutic and prophylactic food additive by various medical research institutes, hospitals and clinics, including the State Scientific Centre, Institute of Biophysics, the Institute of Research of the Academy of Medical Science of Russia, the Kirov Academy of Military Medicine, the Institute of Toxicology at the Ministry for Public Health in Russia, the Academy of Ongoing Medical Training (Saint Petersburg)." In short, it was a ringing endorsement from the Russian Ministry of Health.

### BELRAD refused European funding

But Lengfelder, Frenzel and Kenigsberg continued their campaign against the efficacy of pectin, with disastrous consequences. In spring 2005, the European Parliament refused to give financial backing to BELRAD through the programme TACIS (EU programme that

aims to help Eastern European countries make the transition to a market economy).

There was disagreement about the efficacy of pectin at the meeting of the TACIS approval board, and it was proposed that a study be commissioned to answer the question once and for all. According to the German Deputy Gila Altman, Lengfelder wielded his influence here too, and prevented the study being undertaken. Since then, BELRAD has survived only on donations from charitable bodies abroad and has great difficulty even paying the meagre wages of its staff. Vassili Nesterenko died in 2008, but his son Alexei continues the work and Belrad is now offering help and advice to Japanese radioprotection organisations.

Solange Fernex (1934-2006) European Deputy, wrote, in 2000, an impassioned plea to the French ambassador in Minsk to ask why Lengfelder "... is spending so much time attacking a fellow professor (Bandajevsky), who is defenceless, imprisoned, removed from his post and relegated to the status of a criminal. What could motivate him to destroy the BELRAD Institute, to condemn the work it undertakes and in particular its pectin cures?" (See page 319 of *Le crime de Tchernobyl* [1].)

Nesterenko answered this question as follows: "Because if pectin is administered three or four times a year, it really can lower, by a factor of two or three, the annual concentration of radionuclides in the child, in other words they will be less ill. Our food is contaminated. I think, I hope, that if such a terrible event were to happen in France or Germany, contaminated produce would be banned and everyone would eat clean food. But here, the State cannot provide it, and the people cannot afford to buy it. They eat what they grow... I think they didn't want to recognise that there had been mass contamination." (my italics)

Nesterenko added. "I don't think that pectin is a universal panacea. But it's an effective product that works, given that the population is not being evacuated from the contaminated territories." What would Nesterenko feel today, seeing not only the continuing plight of people in Belarus but now in Japan, and the arguments about whether or not to evacuate (see [5] Truth about Fukushima, SiS 55)?

### Ramifications for the nuclear industry worldwide

Here is the shameful truth. If the government in Belarus agreed that pectin was effective, they would have to agree that there was widespread radioactive contamination. Then they would have to agree that they (and the West) have allowed their people, 2 million, including 500,000 children, to eat contaminated food for 26 years, become ill, live miserable lives and die prematurely (90 % of children in Belarus were healthy in 1985. Now that figure is 20 %). The ramifications for the nuclear industry worldwide need hardly be stated. In 2000, Kofi Annan was asked to write the preface to the Office for the Coordination of Humanitarian Affairs report [6] *Chernobyl, A continuing catastrophe*. These were his final words.

"The most vulnerable victims were, in fact, young children and babies, unborn at the moment when the reactor exploded. Their adulthood- now fast approaching- is likely to be blighted by that moment, as their childhood has been. Many will die prematurely. Are we to let them live and die, believing the world indifferent to their plight?"

### Coda

Since this article was first circulated, an important missing chapter in the pectin controversy has opened up. The French nuclear lobby mounted a particularly insidious attack on BELRAD through the programme ETHOS in 1996 and its successor CORE (Cooperation pour la réhabilitation des conditions de vie dans les territoires de Belarus contaminé par l'accident de Tchernobyl). These programmes were financed by EDF (Electricité de France) and the CEA (Commissariat à l'Energie Atomique) and directed by Jacques Lochard, previously of the CEA. The philosophy behind these programmes, as expressed in a glossy brochure produced by the CEA in 2001 was that the people around Chernobyl needed to learn to "integrate the presence of radioactivity into their daily lives as a new part of existence."

Between 1996 and 1998, ETHOS worked alongside Nesterenko's system of local radio-protection centres, making use of the excellent database and dedicated staff. But soon after, ETHOS, together with the Belarus government, made sure that all the centres were removed from Nesterenko's control. With Nesterenko out of the way, effective radioprotection measures were abandoned and a new phase of rehabilitation was announced in the contaminated territories. Crucially, they refused to administer pectin to the children, with disastrous consequences.

In 2005, Nesterenko wrote in desperation to various ambassadors in Belarus, stating [2]: "It is highly regrettable that the proposal put forward by Belarusian scientists ... such as the introduction into the diet of pectin based adsorbents, was not accepted as part of the CORE project." Nesterenko found that under the CORE project between 2004 and 2005 when children had not been given pectin, the level of caesium-137 in their bodies remained unchanged. Yet between 2000 and 2001, when he had been in charge of radioprotection in the same villages, and the children had received courses of pectin, caesium-137 was reduced by 27 % in Braguine, 32 % in Bourki, Mikoulitchi and Khrakovitchi and 35 % in Komarine.

Unfortunately, ETHOS, with Lochard once more as director, is now in Japan advising the population in Japan on radioprotection. At public meetings in Fukushima city, Lochard speaks with pride of the radioprotection work done by ETHOS and CORE around Chernobyl. His message to the Japanese people is remarkably similar to the message given to the victims of Chernobyl. He says [7]: "... the fear of radiation is slowly vanishing outside the affected areas around Fukushima... there is really no objective reason for being scared taking into account the extremely low levels of exposure... a key issue will be to maintain strong links (social economic and cultural) between the affected areas and the rest of the country... the experience of Chernobyl has shown that over time the stigma of the territories and their inhabitants is a serious issue and it is important to take action against this risk."

In other words, psychological factors such as poor attitude, lack of determination, and fear are the real enemies, all part of a continuing propaganda war on behalf of the nuclear industry at the expense of genuine radioprotection.

#### Notes & References

1. By 2007, the ICRP was at least mentioning the words internal and external in their recommendations: "An important change is that doses from external and internal sources will be calculated using reference computational phantoms of the human body based on medical tomographic images, replacing the use of various mathematical models." ([http://www.icrp.org/docs/ICRP\\_Publication\\_103-Annals\\_of\\_the\\_ICRP\\_37\(2-4\)-Free\\_extract.pdf](http://www.icrp.org/docs/ICRP_Publication_103-Annals_of_the_ICRP_37(2-4)-Free_extract.pdf)).
2. Vladimir Tchertkoff. "Le crime de Tchernobyl: le goulag nucléaire", Actes Sud, 2006.
3. Ho MW. Apple pectin for radioprotection. *Science in Society* 55, 32-33, 2012.
4. Bertell R. Avoidable tragedy post-Chernobyl. *Journal of Humanitarian Medicine* 2002, Vol. II, No. 3, 21 - 28.
5. Ho MW. Truth about Fukushima. *Science in Society* 55 2012
6. United Nations Office for the Coordination of Humanitarian Affairs "Chernobyl: A continuing catastrophe", OCHA/99/20, 2000.



# Green Tea Compound for Radioprotection

*Green tea polyphenol antioxidant protects against bystander effects of low dose ionizing radiation that damage cells and cause numerous diseases including cancer* **Dr. Mae-Wan Ho**

The recent discovery of bystander effects from low levels of ionizing radiation has thrown risk assessment and radioprotection into disarray [1] (Bystander Effects Multiply Dose and Harm from Ionizing Radiation, *SiS* 55). However, it has also led to the discovery of potential mitigating measures against exposure to radioactivity, especially from nuclear accidents like Chernobyl (and Fukushima), the devastation health impacts of which are still surfacing 25 years later [2] (Chernobyl Deaths Top a Million Based on Real Evidence. *SiS* 55).

Ionizing radiation has been known to produce free radicals and reactive oxygen species (ROS), predominantly by ionizing water, the most abundant molecules in tissues and cells (see [1] for an explanation of ROS). ROS are responsible for oxidative damage to DNA, proteins, and lipids, initiating cell death, genomic instability and other consequences of radiation, both in cells that have been directly targeted, and in bystander cells that have not been irradiated [1]. There is evidence that various antioxidants can protect cells against bystander radiation damages, and new findings published online in *Mutation Research* appear particularly promising.

Ashu Tiku and Benila Richi at Jawaharlal Nehru University, New Delhi and Roasahb Kale at Central University of Gujarat in India may have found the ideal antioxidant for radioprotection [3].

#### Non-toxic compound needed for radioprotection

One main problem in radioprotection is to find compounds that are non-toxic or minimally so, and natural compounds fit the bill in being both non-toxic and easily available. Green tea is a rich source of polyphenols with strong antioxidant activities. Green tea extracts and its polyphenols have been shown to possess many health benefits attributed to their antioxidant and anti-inflammatory properties (see [4, 5] *Green Tea, The Elixir of Life?* and *Green Tea Against Cancers*, *SiS* 33). Most of the health benefits of green tea have been credited to the major polyphenol EGCG (epigallocatechin-3-gallate) (Figure 1), which constitutes 55 – 70 % of total polyphenols in green tea extract. Its antioxidant potential is believed to be far greater than vitamin E and vitamin C, the two main antioxidants among vitamins [6].

The team exposed both pBR322 plasmid DNA as well as spleen cells from mice to  $\gamma$ -radiation at different concentrations of EGCG. Preliminary experiments found that EGCG concentrations above 125  $\mu$ M were toxic to the cells, so the highest concentration used was restricted to 100  $\mu$ M. The effects of quercetin - another polyphenol found in fruits, vegetables, leaves and grains - and vitamin C were also investigated. The plasmid DNA and cells were incubated for 2 hours with EGCG at different concentrations or quercetin and vitamin C, both at 100  $\mu$ M, before being irradiated. Afterwards, the plasmid and cells were assessed for DNA damage, and the cells for viability, lipid peroxidation, membrane fluidity, and for activities of enzymes and cofactors involved in detoxification and scavenging of ROS.

#### Tea compound protects against DNA breaks and cell death

The intact plasmid is supercoiled in a compact form, while the cut plasmid is circular, and the two forms can be clearly distinguished and quantified by electrophoresis. The control (unexposed) sample is about 85% supercoiled. EGCG was found to protect plasmid DNA against breaks at high (50 Gy) or low (3 Gy) dose radiation: >82.5 % protection even at the lowest concentration of EGCG tested (10  $\mu$ M) and complete 100 % protection at 50  $\mu$ M. EGCG was better at protection against DNA breaks than

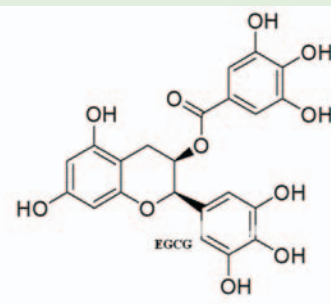


Figure 1 EGCG (epigallocatechin-3-gallate) from green tea



quercetin or vitamin C at the same concentration of 100  $\mu\text{M}$ .

The viability of cells was determined with a vital dye that depends on active mitochondria. At 3 to 7 Gy of  $\gamma$ -irradiation, cell viability was significantly decreased, and at the highest dose, to 53 % of unexposed controls; but pre-incubation with EGCG protected the cells and restored viability in a concentration dependent manner, at 100  $\mu\text{M}$ , viability was restored to >96 % of control.

Single cell comet assay was used to determine the extent of DNA degradation in the cells. In this assay, cells are trapped in agar gel on a microscope slide, lysed to expose their DNA for electrophoresis, and stained with a fluorescent dye. Cells with intact DNA will appear as a small compact bright spot, while cells with degraded DNA will appear as a diffuse spot with a tail, like a comet, hence the name of the assay. The bigger the tail, the greater is the extent of degradation, which can be quantified with computer software under a fluorescent microscope. Exposing the cells to 3 Gy led to substantial DNA degradation, which was reduced in a concentration dependent manner by EGCG. Quercetin and vitamin C also protected the cells against DNA damage, though not as effectively as EGCG.

#### Protection against lipid peroxidation

Peroxidation of membrane lipids by ROS destroys membrane structure and function. The results showed that lipid peroxidation increased with radiation dose from 0 to 7 Gy; and membrane fluidity also increased but more slowly. Pre-incubation with EGCG prevented lipid peroxidation and increase in membrane fluidity in a concentration dependent manner. Quercetin and vitamin C similarly protected against peroxidation and increase in membrane fluidity, but again, less efficiently than EGCG.

#### Key enzyme activities for antioxidant defence restored

Glutathione-S-transferase (GST) is a family of enzymes catalyzing the conjugation of reduced glutathione (GSH) to peroxidized lipids to detoxify them. Reduced glutathione GSH is a tripeptide antioxidant that takes part in reduction-oxidation reactions; in the process, it is oxidized into glutathione disulphide (GSSG). The ratio of reduced to oxidized glutathione is important in the cell's antioxidant defence. Superoxide dismutase (SOD) catalyses the conversion of superoxide (a reactive oxygen species) into oxygen and hydrogen peroxide and is an important ROS scavenger in cells. Lactate dehydrogenase (LDH) catalyzes the interconversion of pyruvate and lactic acid with simultaneous interconversion of NADH and NAD (reduced and oxidized nicotinamide adenine dinucleotide), which is

important in maintaining the cell's electronic balance and antioxidant defence.

$\gamma$ -irradiation reduced the activities of both GST and SOD. The reduction was countered by EGCG, and also by quercetin and vitamin C. The level of LDH, an indicator of damage was increased in  $\gamma$ -irradiated cells, while glutathione was decreased, as indicative of oxidative stress. EGCG was able to counteract those effects, and almost completely at 100  $\mu\text{M}$ . Quercetin was just as effective in reducing LDH and restoring GSH levels to those of controls, but vitamin C less so.

#### EGCG intercalates in DNA double helix

The authors suggest that EGCG can intercalate in the DNA double helix and protect it from free radical attack. EGCG binding to both DNA and RNA was documented for the first time by researchers at the Tokushima Bunri University and the Saitama Cancer Centre in Japan [7]. They found that EGCG binds to single-stranded DNA and RNA, as well as double-stranded DNA. Moreover, EGCG binding appears to stabilize double-stranded DNA.

Previous work has also demonstrated that due to the presence of abundant phenolic hydroxyl groups on aromatic rings (see Figure 1), EGCG is a highly efficient free radical scavenger, effectively disarming the free radicals and rendering harmless [8].

Most importantly, in the absence of  $\gamma$ -radiation, EGCG did not have any significant effect. Thus the innocuous habit of drinking two cups of green tea a day may indeed have surprisingly beneficial effects [4, 5] that include protecting against ionizing radiation.

#### References

1. Ho MW. Bystander effects amplify dose & harm of ionizing radiation. *Science in Society* 55, 28-31, 2012.
2. Ho MW. Chernobyl deaths top a million based on real evidence. *Science in Society* 55, 14-17, 2012.
3. Richi B, Kale RK and Tiku AB. Radio-modulatory effects of green tea catechin EGCG on pBR322 plasmid DNA and murine splenocytes against gamma-radiation induced damage. *Mutation Research, Genet. Toxicol. Environ. Mutagen.* 2012, <http://dx.doi.org/10.1016/j.mrgentox.2012.04.002>
4. Ho MW. Green tea against cancer. *Science in Society* 33, 17-19, 2007.
5. Ho MW. Green tea, the elixir of life? *Science in Society* 33, 12-16, 2007.
6. Rice-Evans C. Implications of the mechanisms of action of tea polyphenols as antioxidants in vitro for chemoprevention in humans. *Proc Soc Exp Biol Med* 1999, 220, 262-266.
7. Kuzuhara T, Sie Y, Yamaguchi K, Suganuma M and Fujiki H. DNA and RNA as new binding targets of green tea catechins. *J Biol Chem* 2006, 281, 17446-56.
8. Sang S, Cheng X, Stark RE, Rosen RT, Yang CS and Ho C-T. Chemical studies on antioxidant mechanism of tea catechins: analysis of radical reaction products of catechin and epicatechin with 2,2-diphenyl-1-picrylhydrazyl. *Bioorganic & Medicinal Chemistry* 2002, 10, 2233-7.

# WHO Report on Fu

*The World Health Organisation has failed in its obligation to protect the public and guilty of the crime of non-assistance* **Susie Greaves**

World Health Organisation subservient to nuclear lobby

The World Health Report (May 2012) entitled “Preliminary dose estimation from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami” [1] is a public relations exercise to reassure the world that WHO is fulfilling its role in the area of radiation and health. Following the preliminary dose estimation, WHO will complete a health risk assessment to “support the identification of needs and priorities for public health action.” But this report and the one to follow cannot help those people in Japan who should have been evacuated much sooner and who will certainly suffer health consequences of varying degrees from their exposure to radiation since March 2011.

This report bears all the hallmarks of WHO’s subservience to the IAEA. It was not written by WHO personnel but by an International Expert Panel convened by the WHO. A cursory glance at the list of contributors shows that all have ties to the nuclear industry, whether directly, as members of the IAEA or UNSCEAR, or as members of organisations like the UK Health Protection Agency (previously the National Radiological Protection Board). WHO has no department or expert in radiation and health [2]. It is entirely dependent on the IAEA for its information on the subject after signing the 1959 agreement WHA 12/40 between the two organisations [3].

## Unreliable or absent data

The report uses data supplied by the Japanese government, and makes no reference to alternative sources of information, for instance from independent Japanese citizen organisations [4], CRIIRAD (France) [5], Fairewinds (USA) [6] or Greenpeace international [7]. To rely only on Japanese government figures does a disservice to the people of Japan, many of whom no longer trust their own politicians. Independent Japanese scientists have criticised the methodology used by the Japanese government to measure the radioactive fallout from Fukushima. For example, Prof. Matsui Eisuke, a specialist in respiratory diseases and low dose radiation, and director of the Medical Institute of Environment at Gifu, says that [8] “The government and its professional advisors have relied mainly on gamma rays which are easy to detect. But, in terms of internal radiation exposure, beta and alpha rays have a far more serious effect than gamma rays. The government and TEPCO hardly measure such isotopes as beta emitting strontium 90 or alpha emitting plutonium 239. They have been deliberately ignoring the characteristics of internal exposure.”

We are told in the WHO report that no assessment can be made of the radiation received by people living within 20 km of the reactor because “precise data” were not available. Similarly we are told that no assessment can be made of the dose received by workers at the nuclear power plant because this requires a different “dosimetric approach”. Thus, two critical groups that have been exposed to very high levels of radiation are dismissed on page 15 of the report and never mentioned again.

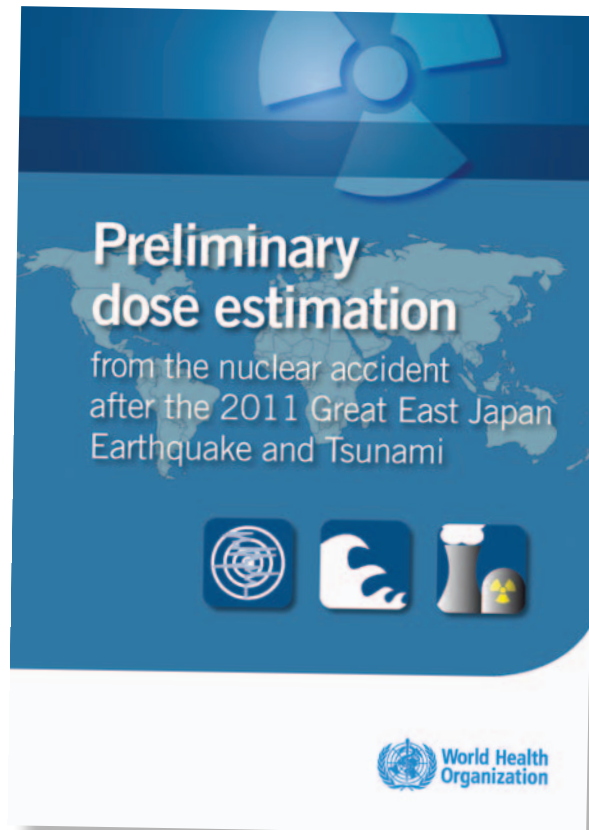
As regards estimates of the radiation dose in the rest of the world (page 28), we are told no measurements were available. Yet the 60 measuring stations worldwide belonging to the Comprehensive Test Ban Treaty Organisation [9] had been collecting crucial data, and could tell us exactly how much radiation was released on any day in many parts of the world since March 11th 2011. But though these stations are paid for by the people of the world, the measurements are only made available to pre-selected official organisations in each country and of course to WHO! Indeed, independent scientists have estimated even from a limited set of such data made available to them that the actual releases of radioactivity from the Fukushima accident has been at least 15 times as great as the official figures [10] (Fukushima Fallout Rivals Chernobyl, SiS 55)

Interestingly, in a meeting with the group IndependentWHO on 4 May 2011, Dr Chan, Director-General of the WHO confirmed that she receives these reports from the CTBTO and stated that she does not disseminate the information to the public because, in her view, there is no public health threat [11]. Yet earlier in the meeting, Chan admitted that she personally has no competence in radiation science and furthermore, there is no longer a department of radiation and health in WHO headquarters in Geneva.

Ten to 50 times annual dose limit as defined by International Commission on Radiological Protection

The report is padded out with an unnecessary amount of material justifying its methodology, so that we have to read as far as Page 63 before we are given some concrete figures about the actual radiation dose to which people have been exposed. It states that [1]: “In Fukushima prefecture, the estimated effective doses are within a dose band of 1–10 mSv, except in two of the example locations where the effective doses are estimated to be within a dose band of 10–50 mSv...”

These momentous figures are slipped into the text without any comment or interpretation by WHO. Two things should be borne in



# Fukushima a Travesty



*Vigil of IndependentWHO near WHO's head office in Geneva*

mind. First, the internationally accepted dose limit for members of the public is 1 mSv per year [12], so the 2 million inhabitants of Fukushima province have received up to ten times this limit, and the inhabitants of the worst affected areas (as an example the 75,000 people in Futaba county, and the 22,000 people in Namie county) have received between 10 and 50 times this limit.

As the WHO report makes no comment about the health implications of exposure to these amounts of radiation, we the public need to interpret the data ourselves, using other studies as a comparison. The largest study undertaken of nuclear industry workers in 2007, found increased cancer mortality among nuclear workers exposed to an average of 2 mSv/year, [13] and the latest BEIR report (Biological Effects of Ionising Radiation) from the United States Academy of Sciences indicates that children and especially girls are many times more vulnerable to the same radiation dose as adults [14].

## The crime of non-assistance

The objective of the World Health Organisation as stated in Article 1 of its Constitution, is “the attainment by all peoples of the highest possible level of health” and in Article 2, it states that it should “... assist in developing an informed public opinion among all peoples on matters of health” [15]. WHO ignores its own Constitution and is guilty of the crime of non-assistance, when it fails to point out that these levels of radiation are many times higher than accepted limits and leaves the task of interpreting these levels to the lay reader.

A full 14 months after the accident at Fukushima and WHO boasts that its report “provides timely and authoritative information” about the estimated radiation dose. It promises more detailed studies later and an assessment of the health impacts, but the tens of thousands of people, living in dangerously contaminated areas of Japan, cannot wait that long.

## Notes & References

1. Preliminary dose estimation from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami, World Health Organisation, May 2012. [http://whqlibdoc.who.int/publications/2012/9789241503662\\_eng.pdf](http://whqlibdoc.who.int/publications/2012/9789241503662_eng.pdf)
2. “On Tuesday, March 15, Maria Neira, Director of Public Health and Environment Department, acknowledged that the WHO had no experts on site. She said she was ready to respond to every request from Tokyo, adding that “this request should be made through the IAEA.” Agathe Duparc. Le Monde, 19.03.11 <http://philrr.blog.lemonde.fr/2011/03/>
3. IndependentWHO. The Agreement WHA 12-40 between WHO and IAEA. <http://>

[independentwho.org/en/who-and-iaea-aggreement/](http://independentwho.org/en/who-and-iaea-aggreement/)

4. Statement by Scientists and Engineers Concerning Fukushima Daiichi Nuclear Power Plant (no.3). 2011, Citizen's Nuclear Information Center, <http://www.cnrc.jp/english/topics/safety/earthquake/fukukk19may11.html>
5. Commission de Recherche et d'Information Indépendantes sur la Radioactivité. Consequences of the Fukushima Daiichi Accident in Japan : A substantial and long-lasting contamination. CRIIRAD, 2011. [http://www.criirad.org/actualites/dossier2011/japon\\_bis/en\\_anglais/11-07-07\\_cpciirad\\_eng.pdf](http://www.criirad.org/actualites/dossier2011/japon_bis/en_anglais/11-07-07_cpciirad_eng.pdf)
6. Fukushima Daiichi: The Truth and the Future, Fairewinds Energy Education, 2012 <http://fairewinds.com/content/fukushima-daiichi-truth-and-future>
7. Lessons from Fukushima, Greenpeace, 28 February, 2012, <http://www.greenpeace.org/international/en/publications/Campaign-reports/Nuclear-reports/Lessons-from-Fukushima/>
8. Eisuke M. Activities of Citizens and Scientists Concerned about Low Dose Internal Radiation Exposures in Japan. 201, [http://independentwho.org/media/Documents\\_IW/English\\_Abstracts\\_Forum\\_Radioprotection\\_IW\\_Geneva\\_2012.pdf](http://independentwho.org/media/Documents_IW/English_Abstracts_Forum_Radioprotection_IW_Geneva_2012.pdf)
9. Comprehensive Test Ban Treaty Organisation. Verification Regime. <http://www.ctbto.org/verification-regime/>
10. Ho MW. Fukushima fallout rivals Chernobyl. *Science in Society* 55, 24-27, 2012
11. Chronologie des échanges avec l'OMS (in French). IndependentWHO, 6 July 2011, <http://independentwho.org/fr/chronologie-echanges-avec-oms/>
12. Recommendations of the International Commission on Radiological Protection, International Commission on Radiological Protection. 2005, [http://www.icrp.org/docs/2005\\_recs\\_CONSULTATION\\_Draft1a.pdf](http://www.icrp.org/docs/2005_recs_CONSULTATION_Draft1a.pdf)
13. Fairewinds Energy Education. Cancer Risk To Young Children Near Fukushima Daiichi Underestimated. 2012. <http://fairewinds.com/content/cancer-risk-young-children-near-fukushima-daiichi-underestimated>
14. Using the BEIR risk models, girls are almost twice as vulnerable as same-aged boys, and a 5-year-old girl is 5 times and an infant female 7 times more vulnerable than a 30-year-old man. United States National Academy of Sciences. Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2. 2006. (page 311) [http://www.nap.edu/openbook.php?record\\_id=11340&page=311](http://www.nap.edu/openbook.php?record_id=11340&page=311)
15. The Constitution of the World Health Organisation. World Health Organisation, 2006, [http://www.who.int/governance/eb/who\\_constitution\\_en.pdf](http://www.who.int/governance/eb/who_constitution_en.pdf)

# UK's Nuclear Illusion

*UK Parliament's decision to authorise the construction of 10 new nuclear power plants was taken on the basis of misleading evidence* **Prof. Peter Saunders**

UK's commitment to nuclear

In early May 2012, Japan shut down its last nuclear power station for routine maintenance in a safety drive since the Fukushima meltdown, leaving the country nuclear free for the first time in more than 40 years [1]. Before the Fukushima disaster, Japan got 30 % of its power from nuclear energy. Hundreds marched through Tokyo to celebrate what they hope will be the end of nuclear power in Japan.

Most other countries are having second thoughts about nuclear power; some like Germany and Italy have already decided to do without it and others like Japan may follow [2] (Fukushima Fallout (SiS 51), but the UK government is still determined to go ahead with the construction of at least 10 new reactors. This is the only way we can fulfil our future energy needs and still meet our commitment to reduce carbon emissions, so we are told; besides, nuclear is the cheapest alternative to fossil fuels and is safer than coal. Every one of those claims is contradicted by evidence, as we have shown in numerous reports.

Nuclear power could only make a comparatively small contribution to our total energy needs and this could be supplied from renewable sources such as wind and solar (see [3] Green Energies - 100 % Renewable by 2050, ISIS publication). It is also very expensive; the government insisted there would be no subsidy for nuclear power even though no nuclear plant has ever been built without a subsidy and no one, least of all the companies that are expected to invest in them, seriously believes one ever will be. The government is already discussing with the industry what form the subsidy should take - probably a 'contract for difference' that will ensure a higher than market price - and how large it will be. It is also negotiating with the European Commission to ensure that the subsidy is permitted under EU rules [4].

*The government is already discussing with the industry what form the subsidy should take. It is also negotiating with the European Commission to ensure that the subsidy is permitted under EU rules*

Nuclear plants are notorious for coming in years late and hugely over budget and the two currently under construction in Europe at Olkiluoto in Finland and Flamanville in France, are no exceptions [5] (The Real Cost of Nuclear Power, SiS 47). And the danger of a major incident like Three Mile Island, Chernobyl or Fukushima is ever-present [6] (Lessons of Fukushima and Chernobyl, SiS 50). For the latest information, see [7, 8] Chernobyl Deaths Top a Million Based on Real Evidence and Truth about Fukushima, SiS 55.

There is a massive amount of evidence in the public domain against the nuclear option. Has the government somehow managed not to notice any of it? The recent report, *A Corruption of Governance?*, published jointly by the Association for the Conservation of Energy (ACE) and Unlock Democracy goes a long way towards answering this question [9]. By careful reading of Government documents and statements, especially the Draft Overarching National Policy Statement for Energy (EN-1) [10] and the Draft National Policy Statement for Nuclear Power Generation (EN-6) [11] the authors of the report, Ron Bailey and Lotte Blair, demonstrated that the government was well aware of the evidence against nuclear energy; but simply omitted to draw attention to it in Parliament when the decision was being taken.

How much electricity will we need?

Power stations take a long time to build, so if we want to have enough energy in 2025 or 2050, we need to start planning now. The first step, you would think, is to estimate how much energy we will be using, then work out how much of the different sources – fossil, solar, wind, biomass, nuclear, and so on – we could have in place by then. This will enable us to decide on a strategy taking into account factors such as cost, safety and the need to reduce carbon emissions.

That's not what the government did. Instead of analysing present consumption and trends, they asked a consulting firm Redpoint Energy to predict what the generating capacity would be in 2025, including both the proposed nuclear new build programme and the new renewables capacity that would be required to achieve the government's goal of about 29 % of electricity from renewables by that date [12]. Redpoint came up with the figure of 110 GW, which is a prediction of what the generating capacity will be if present policies are carried out. But the government is now using this as its estimate of the UK's need for energy in 2025, and a justification for the policies.

As for 2050, after they had spent much time and effort trying to get the government to supply information regarding demand up to and beyond that date, Bailey and Blair were told that there are no published assessments that extend that far. They then asked if there were any unpublished assessments or evidence and were told there were none. That hasn't stopped the Government from telling us over and over again that "electricity demand could double by 2050."

What will it cost?

When the Secretary of State was asked for an estimate of the relative costs of energy generation infrastructure, he provided a table that showed the levelised cost (i.e. the price at which the electricity must be sold to break even, averaged over the lifetime of the plant) of nuclear as 6.8p/kWh, lower than a selection of other options, such as modern coal and gas plants, onshore and offshore wind [13]. He did not include other sources, for example, biomass combined heat and power (CHP), gas CHP and landfill or sewage gas, all of which also appear in the Mott MacDonald (UK government) report [14] he was citing and are cheaper than nuclear, even according to the report. He also did



not remind MPs that renewable sources, such as solar and offshore wind, have a record of becoming considerably less expensive over time, whereas there is no prospect that nuclear will become cheaper in the foreseeable future because the lead time to employing new technology is so long. On the contrary, the cost of constructing nuclear plants generally rises considerably faster than inflation [3].

Bailey and Blair also noticed that the government assumed the nuclear plants would operate for 60 years, although experience shows that even 40 years is optimistic. In the first draft of the EN-1 document, the operating life is given as “in the region of 40-60” years. In the revised draft and in the final document, “40” has disappeared and the lifetime is given as 60 years. The Mott MacDonald analysis of costs assumes an operating lifetime of 60 years, but there is no reference given for that. The operating lifetime is especially important in considering nuclear power because so much of the total cost is in building the plants rather than in supplying them with fuel.

When the government announced that it was going ahead with 10 more nuclear power plants, it assured us that this would only happen if they could be built without subsidies. Anyone who looked at the evidence could see that this was impossible and indeed that was the view of the major investment bankers [4]. We can now be certain that the government knew that too.

The German company E.ON has pulled out of building nuclear reactors and the only companies left in the field, Electricité de France and Centrica, have made it clear that they will go ahead only if they are guaranteed a sufficiently high price for the electricity their nuclear plants produce [15]; a large subsidy, in other words.

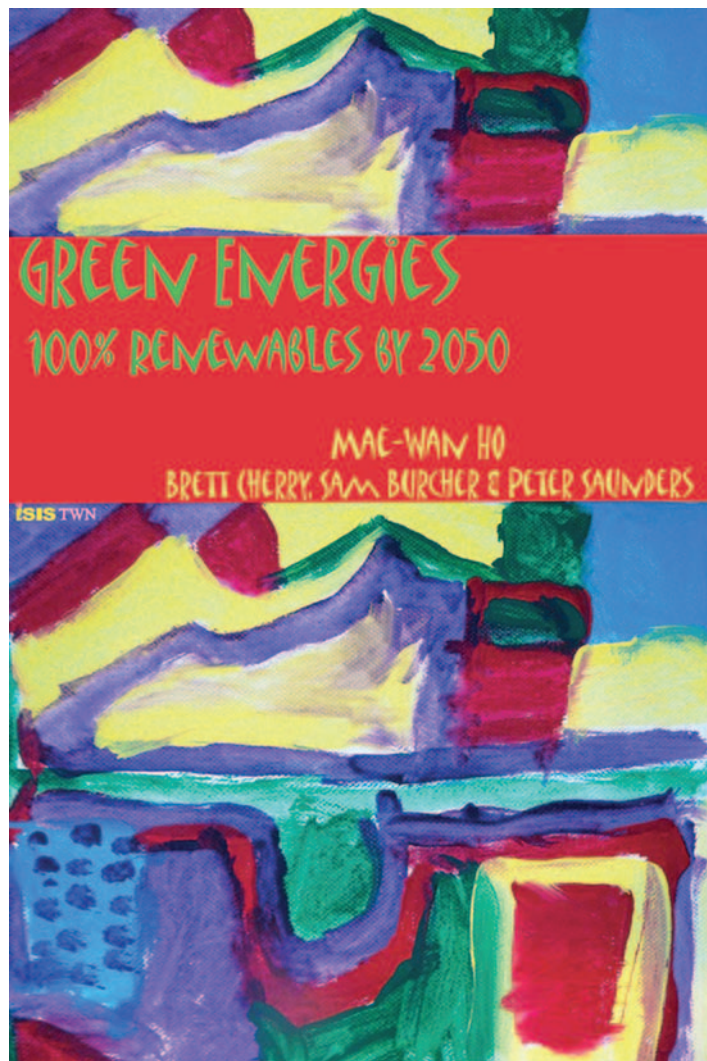
### Is nuclear necessary?

The report the government presented to Parliament greatly exaggerated our future energy needs and underestimated the cost of nuclear energy relative to other non-carbon sources. Despite this, it might – in principle – still be possible that we will not be able both to keep the lights on and meet our greenhouse gas reduction targets without it. That is far from the case. We have given details in our report [3] but perhaps the most convincing evidence is that the German government has already committed itself to closing down its existing nuclear facilities and not replacing them, and it is confident it can reach its targets without them.

The British government too knows that it is perfectly feasible to cope without nuclear. In 2010 and 2011 it published two “Pathways” reports [16]. Each included a number of scenarios that could achieve the required 80% reduction in emissions by 2050 and also satisfy the nation’s energy requirements. Of the 16 scenarios in the 2011 report, 6 involved no new nuclear build [5].

In the EN-1 and EN-6 National Policy Statements [NPSs] presented to Parliament, however, MPs were told that ‘failure to develop new nuclear power stations significantly earlier than the end of 2025 would increase the risk of the UK being locked into a higher carbon energy mix’ [17]. They were not told that more than one in three of the scenarios showed that an adequate supply of low carbon energy could be produced without nuclear.

The Director of ACE, Andrew Warren, wrote about this to Charles Hendry MP, the Minister responsible for nuclear power. A Department of Energy and Climate Change (DECC) official eventually replied [6] “you note that the overview of the Pathways 2050 analysis in EN-1 did not present the full information to MPs on all the possible options” and he justified this by saying “this is not, however, the purpose of the NPSs”.



ISIS Green Energy Report

The military situation is also different from before. Even those who believe it was nuclear weapons that kept the peace until the fall of the Soviet Union have been unable to suggest an even remotely plausible scenario in which they might be useful now. They certainly contributed nothing to our efforts in the Falklands, Bosnia, Iraq, Libya or Afghanistan. If anything, they only diverted expenditure from equipment that the soldiers who fought in those wars desperately needed.

Yet in the face of all the evidence, the government persists with its nuclear energy programme and uses policy-based evidence to justify it to Parliament. It is bound and determined to spend an estimated £20 billion on a replacement for Trident when no one has any idea what use it could possibly be.

The nuclear lobby see themselves as working at the cutting edge of science, promoting the most modern technologies for the defence of the realm and for supplying our energy needs. Successive governments have taken them at their word, and over the years their influence has grown. In fact, theirs is a mid-20<sup>th</sup> century vision. We are now in the 21<sup>st</sup> century and the energy of the future is renewables. As for defence, whatever the answer is, it is not Trident. It is time to end our fascination with the nuclear illusion.

ISIS

It seems a “national policy statement” is just that: a statement of government policy backed by arbitrary ‘evidence’ selected to justify what the government has decided to do. It is not an impartial presentation of the available evidence to help Parliament reach the best decision. It would be interesting to know whether our MPs understand this.

Why was it done?

Bailey and Blair believe that it was not government ministers who misled Parliament; that they themselves were given biased information. That’s not implausible. Ministers are busy and do not have the time to go through in detail every document they receive, still less to look up and read all the references. They rely heavily on summaries provided by their staff. We know that in real life, as in *Yes Minister*, civil servants and advisers are not above pushing their own agendas and keeping relevant information from their ministers.

All the same, we’re not convinced. We don’t recall hearing any former ministers complaining that they were misled about nuclear energy while they were in office. The real question is why a government should deliberately ignore evidence and choose an option that is going to be more expensive and less effective than the alternative. The most likely explanation is simply that over time, a close and comfortable relationship has grown up between governments on the one hand – ministers and civil servants alike – and the nuclear lobby on the other.

Sixty years ago, many people believed both that the UK needed its own atomic bomb and also that nuclear power would provide an unlimited supply of cheap electricity. The military and civilian projects have remained together ever since and have supported each other in many ways, as they have in other countries (see *The True Costs of French Nuclear Power* [18], SIS 53). For example, one of the advantages (from this point of view) of a pressurised water reactor is that it produces plutonium, which can be used in weapons. And much of the cost of research can be hidden in the defence budget, which tends not to be looked at with the same critical eye that other departments may experience.

Times have changed. We now know that nuclear power is neither cheap nor safe, and even though most people agree that we have to find alternatives to fossil fuels, we also know that nuclear is by no means best option for that.

#### References

1. “Tomari shutdown leaves Japan without nuclear power”, BBC News, 5 May 2012, <http://www.bbc.co.uk/news/world-asia-17967202>
2. Saunders PT (2011). Fukushima fallout. *Science in Society* 51, 22-23, 2011.
3. Ho MW, Cherry B, Burcher S and Saunders PT. Green Energies, 100% Renewables by 2050, ISIS/TWN, London/Penang, 2009, <http://www.i-sis.org.uk/GreenEnergies.php>
4. Hendry C. Reply to written question from M Horwood MP. *Hansard*, 18 April 2012. <http://www.publications.parliament.uk/pa/cm201212/cmhansrd/cm120418/text/120418w0001.htm#12041878000017>
5. Saunders PT. The real cost of nuclear power. *Science in Society* 47, 36-39, 2010.
6. Saunders PT (2011) Lessons of Fukushima and Chernobyl. *Science in Society* 50, 2-3, 2011.
7. Ho MW. Chernobyl deaths top a million. *Science in Society* 55, 14-17, 2012.
8. Ho MW. Truth about Fukushima. *Science in Society* 55, 18-23, 2012.
9. Bailey R and Blair L. A Corruption of Governance? Association for the Conservation of Energy and Unlock Democracy. <http://www.ukace.org/publications/ACE%20Campaigns%20282012-01%29%20-%20Corruption%20of%20Governance%20-%20Jan%2020123/05/12, 2012>.
10. Department for Energy and Climate Change (2009). Draft Overarching National Policy Statement for Energy (EN-1). <http://www.official-documents.gov.uk/document/other/9780108508493/9780108508493.pdf>
11. Department for Energy and Climate Change (2009). Draft National Policy Statement

- for Nuclear Power Generation (EN-6). <http://www.official-documents.gov.uk/document/other/9780108508332/9780108508332.pdf>
12. Redpoint Energy (2009). Implementation of the EU 2020 Renewables Target in the UK Electricity Sector: RO Reform’. [http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/renewable%20energy/renewable%20energy%20strategy/1\\_20090715120542\\_e\\_@\\_@\\_redpointimplementationoftheeu2020renewable-targetintheukelectricitysectorroreform.pdf](http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/renewable%20energy/renewable%20energy%20strategy/1_20090715120542_e_@_@_redpointimplementationoftheeu2020renewable-targetintheukelectricitysectorroreform.pdf)
13. Hendry C. Reply to written question from M Moon MP. *Hansard*, 8 March 2011. <http://www.publications.parliament.uk/pa/cm201011/cmhansrd/cm110308/text/110308w0002.htm>
14. Mott MacDonald, *UK Generation Costs Update*, June 2010, <http://www.decc.gov.uk/assets/decc/statistics/projections/71-uk-electricity-generation-costs-update-.pdf>
15. “Centrica threatens nuclear pullout” Guy Chazan and Jim Pickard. *Financial Times*, 20 April, 2012. <http://www.ft.com/cms/s/0/bb7f393c-8afo-11e1-912d-00144feab49a.html#axzz1tjoopUe3>
16. Department of Energy and Climate Change (2010). 2050 Pathways Analysis. <http://www.decc.gov.uk/assets/decc/what%20we%20do/a%20low%20carbon%20uk/2050/216-2050-pathways-analysis-report.pdf>
17. EN-6 (Ref. [6]), June 2011, p7 para 2.2.3
18. Greaves S. The true costs of French nuclear power. *Science in Society* 53, 8-11, 2012.