The Nuclear Gamble:
Submission to the Planning Inspectorate over Wylfa B
John Urquhart, Zencity

https://infrastructure.planninginspectorate.gov.uk/projects/wales/wylfa-newydd-nuclear-power-station/

Executive Summary

The seas will rise

Based on the latest scientific findings it is estimated that the sea level rise by the end of the century will be between 6 metres and 19 metres. This has serious implications for the design and operation of the proposed Wylfa B Plant. In view of this possibility, it is recommended that in view of forecast increases sea levels, nuclear waste should not be stored on site.

Ice melt

The main cause of sea level rises in the future will be the acceleration of the melting of the polar ice caps due to the transfer of heat from the oceans.

300 K

An additional complication is the possible increase of water vapour in the upper troposphere where it acts as a potent greenhouse gas. According to latest findings, when sea level temperatures rise above 300 K this process would accelerate and even be part of a positive feedback loop.

The nuclear waste burden

If Wylfa B were to operate for 60 years it would add an estimated 33% to the existing UK radioactive waste inventory. This would have to be reflected in a larger waste storage facility, preferably well above sea level and the additional cost due to Wylfa B's nuclear waste alone is estimated to be a minimum of £15 billion.

Nuclear safety

New research on radiation effects

Most of these have been dealt with in the following video uploaded to YouTube: https://youtu.be/viNOlexO-pE. Graphs involving the impact of Chernobyl fall out on under-3 leukaemia rates and on increases in Down Syndrome in Wales are also included.

Radiation risks in women

The new research findings also point to the possibility that radiation risks to women are ten times that for men, including long-term genetic effects. For this reason, there should be a moratorium on all working in the nuclear industry by women of childbearing age until there is greater scientific understanding and agreement on these effects.

Radiological emergencies

The safety of the public from radiological emergencies appears to have been given low priority and this must be remedied forthwith particularly bearing in mind that fall out from nuclear accidents can travel large distances.

Monitoring the safety of nuclear power plants

Continuous monitoring of the site should include publicly-accessible alert mechanisms if levels at the site boundary above 180 nanograys per hour are recorded.

Health monitoring

The following health data should be made publicly available for receptors living within 5 kilometres, 10 kilometres of Wylfa B and for the total population of Anglesey for the following conditions: still births, birth defects, cancer and leukaemia in children and miscarriages.

Changing safety standards for the nuclear industry

If new scientific findings are acknowledged, this will have a major impact of setting new standards for exposure to radiation in the workforce. There is a possibility that such new standards would make the plant unviable.

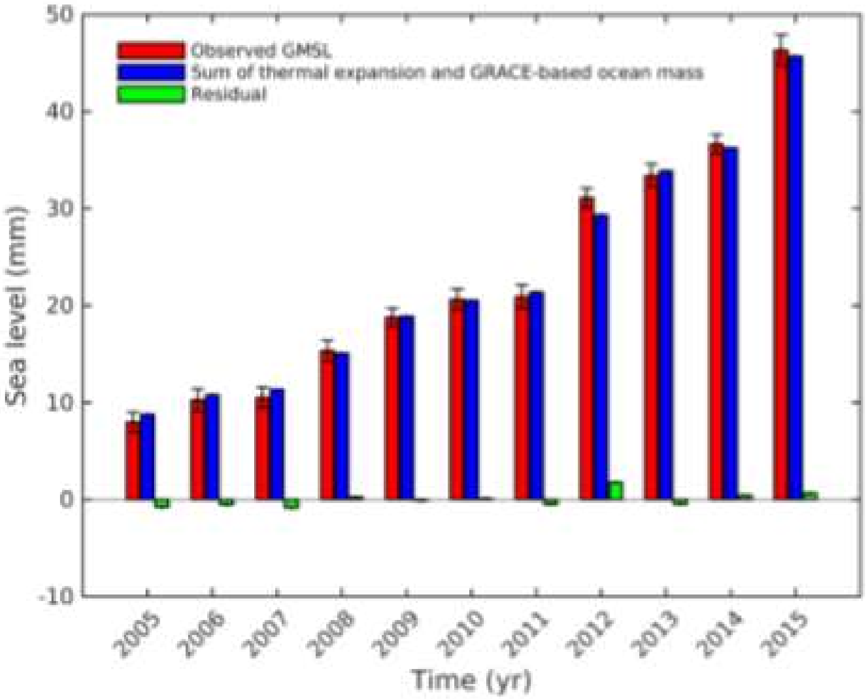
Thermal pollution

The part played by nuclear power plants in global warming has not been fully addressed taking into account associated CO_2 production and direct thermal pollution, which in the case of Wylfa B would be nearly 10% of thermal pollution from all UK transport. Finally, the fragmentation of decision making about the nuclear industry is noted and it is recommended that there should be a single authority to oversee all nuclear operations from the cradle to the grave.

1. The seas will rise

1.1. Ice melt

Over the past 26 years, the sea level has risen by 40 mm due to ocean warming mainly caused by greenhouse gases, including carbon dioxide. This store of heat is beginning to melt the polar ice caps at an accelerating rate (see graph below 2003-2015)[1].



According to Keeling et al.[2], world sea levels rise by 1 mm for every 2.34 million terawatts of heat added to the oceans. But we have found via the ice melt route only 0.03255 million terawatts of heat are needed to raise sea levels by 1 mm, i.e. 72 times faster. This means if all the heat accumulated in the ocean to cause a 40 mm rise in sea level due to thermal expansion subsequently ended up as ice melt, this would entail a sea level rise of 2.88 metres (see Appendix A).

1.2. Simple physics – try this experiment with your children!

Half fill a large saucepan with cold tap water.
Measure the depth with a ruler.
Place on a hot stove with the lid upturned.
Empty the contents of an ice cube tray into the upturned lid.
The water in the pan will get hotter before the ice on top melts, but it will melt.
Then pour the melted water into the saucepan and measure the new level of water.

[1] Reference: Cazenave A et al. 2018: Global sea-level budget 1993-present EARTH SYSTEM SCIENCE DATA Volume: 10 Issue: 3 Pages: 1551-1590 DOI: 10.5194/essd-10-1551-2018 Published: AUG 28 2018

[2] Quantification of ocean heat uptake from changes in atmospheric O_2 and CO_2 composition, R. Keeling et al, *Nature volume 563, pages 105–108 (2018)*

Basically, this is what is happening to Planet Earth. At first seas rise slowly due to ocean warming then they rise much faster due the melting of the polar ice caps.

We cannot stop this ice melt time bomb but we can slow it down by acting NOW and switching to renewable energy.

1.3. How fast will the seas rise?

If we accept that there is a time delay between ocean thermal expansion and ice melt, then what does this imply for future years? The acceleration observed in the graph can be reduced to a set of numbers that can be extended using a geometric sequence.

If we apply a smooth curve to the histogram in the graph using the least squares method we arrive at the following sea level rises over the past 12 years:

2003-2007	12 mm
2007-2011	15 mm
2011-2015	20 mm

On this basis, we will reach an overall increase of 1.6 metres (5 feet) by 2047. This is less than 60% of the potential rise due to the transfer of heat from the ocean to ice melting. On this trajectory, we would anticipate that the total sea rise level by the end of the century would be 6 metres. But this may turn out to be a conservative estimate for the following reasons:

1. the take up of ice melt heat from the ocean may accelerate

2. the global rise in sea level temperature may accelerate. It should be noted that between 1991-2016 the average global temperature rose by 0.5°C and average sea surface temperatures (SST) would be commensurate with that figure. However, in a dramatic announcement on Radio 4 on Thursday 29th November 2018, the Meteorological Office claimed that by the end of the century global temperatures may increase by 5°C over the current temperature level. The implication of this statement needs to be expanded.

   Between 1991 and 2016 SST rose by 0.5°C in 26 years. If the sea temperatures continued to rise pro rata after a further 84 years – the end of the century – the further global temperature rise should only be 3.2 times that figure i.e. 1.6°C. But now the Met Office is claiming that the global temperature by the end of the century could be 5°C, three times greater than the pro rata rise. In other words, the Met Office is anticipating an acceleration of the rise in global temperatures.

   This has profound implications for estimating sea level rise this century. The 5°C rise means that the ocean thermal store could increase by 10 times the thermal store produced between 1991 and 2016. If only 60% of this century's thermal store resulted in ice melt then we are looking at a rise of 19 metres.

1.4. 300 K

However, the acceleration in global warming may be even greater. There is considerable concern about the increasing role played by water vapour as a greenhouse gas. In May of this year, PK Pal et al.[3] published their research findings based on satellite observations of water vapour concentrations in the upper troposphere compared to sea surface temperatures (SST). They found there was a direct association between increased water vapour concentrations and SST. More ominously they noted that, when the sea surface temperatures exceeded 300 K (i.e. 27°C), the rate of production of this water vapour in the upper troposphere increased by a factor of three. Already, SST in parts of the Tropics have reached 309°K.

They pointed out that water vapour in the upper troposphere acts as a potent greenhouse gas. In which case, we may already be observing a positive feedback loop, i.e. as SST increase, so too does water vapour concentration in the upper troposphere, which in turn heats up SST still further. This may be a runaway greenhouse effect which has already been alluded to by the IPCC. As the "chimneys" of clear water vapour increase in number and size over the tropical ocean surface, this too may be an exponential phenomenon.

[3] "Effect of Upper Tropospheric Humidity and Sea Surface Temperature on Greenhouse Factor in Tropical Region," by P.K. Pal, published online 24th May 2018, available via www.researchgate.net.

2. The nuclear waste burden

2.1. What is nuclear waste?

Nuclear waste is created when a mixture of uranium 235 and 238 throws out neutrons and alpha particles which can create a chain reaction. A very rapid chain reaction is the basis of the nuclear bomb. A controlled chain reaction is the basis of nuclear power. However, in both cases the effect is to fulfil the famous law by Einstein; $E=mc^2$, i.e. if mass is annihilated when producing new radioactive isotopes this releases huge amounts of energy which can be utilised either as a bomb or in the production of electricity.

When this happens, the constituent elements produced are also radioactive and in turn create heat when they break down and the resulting porridge of isotopes is what we call nuclear waste. It should be noted that this process cannot be reversed, i.e. it is not possible to turn heat back into mass. In other words, nuclear waste is the ultimate entropy which, according to the second law of thermodynamics, always tends to increase. Nuclear power is an artificial way of dramatically increasing entropy, not only in the form of heat but also in the form of many radionuclides. It should also be noted that, by this principle, it is not possible to "burn up" nuclear waste in a nuclear reactor. Such a process simply begets more nuclear waste.

2.2. How much nuclear waste?

Generally speaking, the amount of nuclear waste created is proportional to the amount of electricity produced although certain reactors such as the AGR have been more efficient in converting heat into electricity. It is possible to calculate the amount of nuclear waste that Wylfa B could create by comparing its projected total electrical output over 60 years with the total amount already produced in the UK from nuclear power. In those terms, over 60 years the total radioactive waste inventory of Wylfa B will be 33% of the total existing UK radioactive nuclear waste inventory.

2.3. The implications of sea level rise on nuclear waste storage

There are already considerable difficulties in "disposing" of existing radioactive waste so it has been proposed in the development of Wylfa B that the used nuclear fuel rods should stay on site for up to 100 years after nuclear operations cease in about 2085, i.e. 2185. In view of the latest research findings on sea level rises, it would appear that storing nuclear waste on site would be extremely vulnerable to any significant sea level rise. The sea wall proposed of 14 or so metres would be totally inadequate for such a scenario. Rather than allowing this nuclear waste to accumulate on site with all the potential for a dramatic retreat, would it not be more sensible to arrange for the continuing disposal of the used fuel rods to a suitable designated site well above sea level? Such a decision would entail changing the design of the proposed Wylfa B plant as well as improving harbour facilities so that nuclear waste ships, which already exist, could transfer the used fuel rods from Anglesey to the Barrow in Furness port, which still handles nuclear waste. From there, the nuclear waste could be conveyed to a newly-developed site in Cumbria, preferably near the existing Sellafield facility. Over 40 years ago in the Windscale inquiry, it was proposed that used nuclear fuel rods could be stored in air-cooled facilities, as indeed is the case in other countries today.

2.4. The cost of nuclear waste storage

The current cost of a nuclear waste storage facility to handle existing nuclear waste is put at £45 billion. Clearly this would need to be extended if it was to hold the nuclear waste from newbuild reactors. It is assumed that the problem of sea level rises applies not only to Wylfa B but to all the new proposed nuclear sites in the UK including Hinkley Point C. The total radioactive waste inventory of such sites would amount to 220% of the existing total radioactive waste inventory suggesting that the size of the total eventual site will be 3.2 times larger than the existing proposed waste storage site. This in turn could raise the cost of such a site from £45 billion to £144 billion. This does not include the additional cost of cleaning up existing nuclear facilities, including Sellafield, which is estimated to be £162 billion.

Even if the cost of the nuclear waste from Wylfa B was confined simply to the cost of extending the long-term nuclear disposal site, this would add a further £15 billion to the cost of running Wylfa B over the next 60 years.

3. Nuclear safety

Nuclear safety rests on three main assumptions:

1. Radiation risks are mainly derived from cancer data for populations exposed to radiation from the Hiroshima and Nagasaki atomic bombs.
2. Health effects are linear with radiation dose and independent of the length of exposure.
3. The probability of another major nuclear accident in the future is vanishingly small.

3.1. New research on radiation effects

The first assumption ignores the fact that the systematic compilation of health data associated with the nuclear bombs on Japan did not start until five years after the explosions, i.e. 1950. This means that health effects that could have affected young children have not been recorded.

The systemic absence of health data has continued to this day concerning the possible health effects of radiation even though there has been ample opportunity in Britain, which has sophisticated systems of health recording. For example, no systematic study of still birth rates around British nuclear power plants has ever been carried out except for the work by Louise Parker and colleagues[4]. They examined still birth rates in the offspring of Sellafield radiation workers and found a 24% excess.

There is also a gap in our knowledge about the effects of radiation on the early stages of life. However, in 1983 Urquhart J.A. et al.[5] did find a 10-fold excess over a 30-year period in childhood leukaemia in Seascale, the village next to the Sellafield nuclear reprocessing plant. This study was followed up in Scotland when, in 1984, Urquhart J.D. and colleagues[6] found a 10-fold excess in young leukaemia rates near the Dounreay nuclear reprocessing plant.

These findings continue to cause controversy even today. The nuclear industry has dismissed these results on the grounds that the excess is probably due to a virus.

A systematic study of childhood leukaemia around German nuclear power plants[7] found that under-5 leukaemia rates within 5 km of such plants were more than double the expected rate (O=37, E=17). Bithell et al[8] attempted to observe leukaemia rates around British nuclear power plants but, whereas the German study was able to pinpoint the location of cases within 25 metres, the Bithell study relied on ward data which made the placing of cases more problematic and therefore it is not surprising that no definite association was discovered.

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[4] Parker L 1999 Stillbirths among offspring of male radiation workers at Sellafield Nuclear Reprocessing Plant. Lancet 354:1407-1414 (Oct 23 1999).

[5] Urquhart J A 1984 Cancer in Cumbria; The Windscale Connection, Lancet 1i January 1984.

[6] Heasman M A Kemp I W Urquhart J D and Black R 1986 Childhood leukaemia in Northern Scotland. *Lancet,* 1, 266.

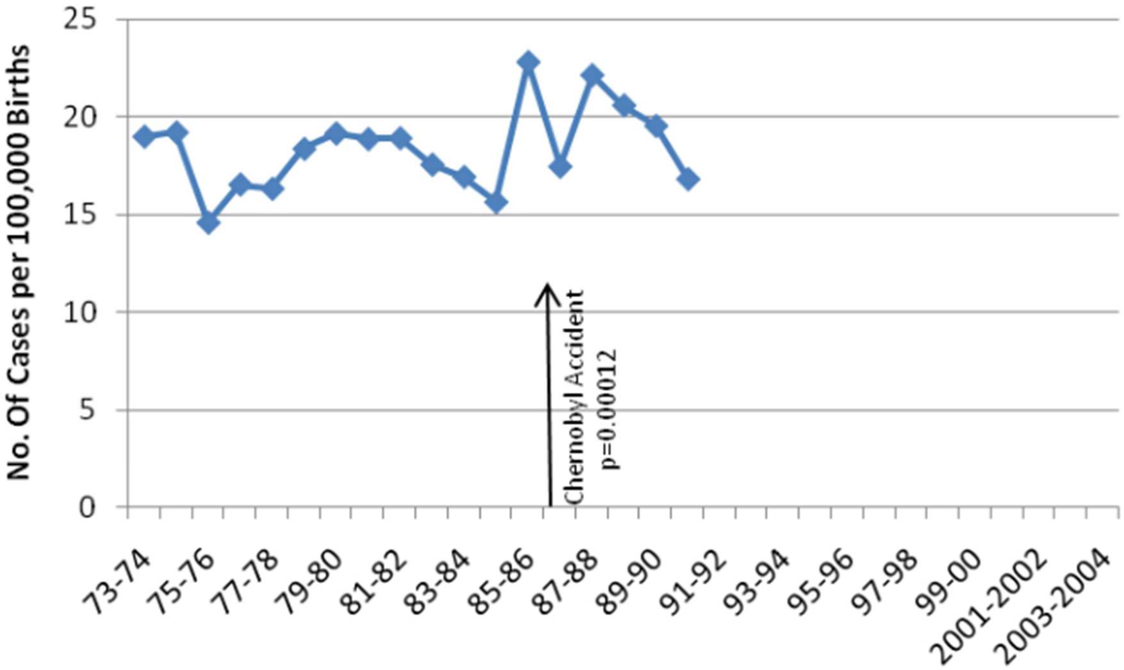
[7] Kaatsch P 2008 Leukaemia in Young Children Living in the Vicinity of German Nuclear Power Plants. Int J Cancer 1220: 721-726.

[8] Bithell J F 2008 Paper to Berlin Conference May 2008 on Childhood Leukaemia around British Nuclear Power plants.

The sensitivity of very young children to radiation effects was examined in two ways; first by a reassessment of Swedish data based on a study of the health effects of high levels of gamma radiation on babies under 12 months[9]. The reanalysis suggests that under-5 leukaemia in the Swedish study was underestimated by a factor of 10. A more important study was an examination of ONS cancer data, MB1CD-rom[10], which recorded national and regional rates of different cancers by age in single years at time of diagnosis and year of diagnosis between 1971-2000.

The further analysis of the findings was presented at the Stirling Low Level Radiation Conference on 26 June 2018 and can be viewed as video 8 ("The Welsh Connection") on YouTube[11].

The main conclusions of this study were that there was a 50% increase in under-3-year old cohorts by time of birth for the period 1985-86 and 1987-88 which was highly statistically significant. This graph is shown below:



It was concluded that these aberrant rates reflected two phenomena; exposure of under 12-month babies to Chernobyl fallout and also exposure of the male population to increased rates of fallout which created genomic instability effects.

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[9] Marie Lundell and Lars-Erik Holm (1996) Mortality from Leukemia after Irradiation in Infancy for Skin Hemangioma. Radiation Research: May 1996, Vol. 145, No. 5, pp. 595-601.

[10] Cancer Statistics Registrations various 1971-2000. MBI Table 2 OPCS then ONS HMSO London.

[11] Science Line: Video 8 Low Level Radiation and Health Conference 2018 John Urquhart 'The Welsh Connection' https://youtu.be/viNOlexO-pE

3.2. Radiation risks in women

The following article appeared in **Radhealth** in July 2018[12]:

"Miscarriages and their causes are rarely discussed in public but for many women they are an unfortunate fact of life. To be more precise; for every 10,000 pregnancies, an estimated 3,000 end with a miscarriage. Very few people know that a significant proportion of these miscarriages is due to chromosome aberrations in the foetus, particularly Down Syndrome. Boué et al.[13], examined 1,500 foetuses that had naturally aborted. He found that 38% had Down Syndrome. So on that basis, for every 10,000 pregnancies, 1,114 miscarriages occur due to a Down Syndrome condition in the foetus. On the other hand, the actual number of children born with Down Syndrome is less than 10 in 10,000. Even allowing for therapeutic abortions, this implies that 99% of all foetuses with Down Syndrome are eliminated before reaching full term. A very comprehensive quality control system that must have developed over thousands of years through natural selection. The very high number of foetuses that start with Down Syndrome would suggest there is some omnipresent environmental factor to which humans are very sensitive. The Down Syndrome condition, along with other chromosome aberrations, together account for 50% of all natural miscarriages. The aberrations arise when genes on the chromosomes translocate and this is a form of genomic instability. We now know that one source of such instability is radiation. Could natural background radiation be a major cause of the Down Syndrome condition? We know that radiation levels can vary significantly at times. Gamma monitoring by the independent Argus Network over the last thirty years reveals that, under certain conditions, washout of radionuclides occurs which significantly increases radiation levels. A dramatic illustration of this phenomenon occurred several years ago when workers outside the Berkeley nuclear power station were caught in a rainstorm outside the plant and subsequently triggered radiation monitors on their way in! It was found that their clothes were covered with short-lived, naturally-occurring radionuclides including alpha and beta particles, which when breathed in, can penetrate deep into the body. So, is natural background radiation a major source of miscarriages in women? Hardly any research has been done in this area, particularly as miscarriages are not a notifiable condition and records are hardly ever kept. So, it is necessary to concentrate purely on the relationship between radiation and Down Syndrome. In the absence of any kind of research into the impact of Chernobyl and other low level radiation sources, the British government has recently announced their goal of increasing the percentage of women working in the nuclear industry to 40%. Could this have the effect of importing a genetic trojan horse into the British nation? Animal studies conducted before and after the Chernobyl nuclear accident show transgenerational effects due to radiation. Ryabokon et al. (2006)[14] showed that, in colonies of bank voles, these effects not only persisted but increased over twenty-two generations. Genomic instability does not stop at one generation. So women of child-bearing age should seriously consider whether to work in the nuclear industry. Not only for their own sake, but for the sake of their descendants."

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[12] http://electricityinfo.org/news/radhealth-23/

[13] Boue J 1975 Retrospective and prospective epidemiological studies of 1500 karyotype spontaneous human abortions. Teratology 12:11-26.

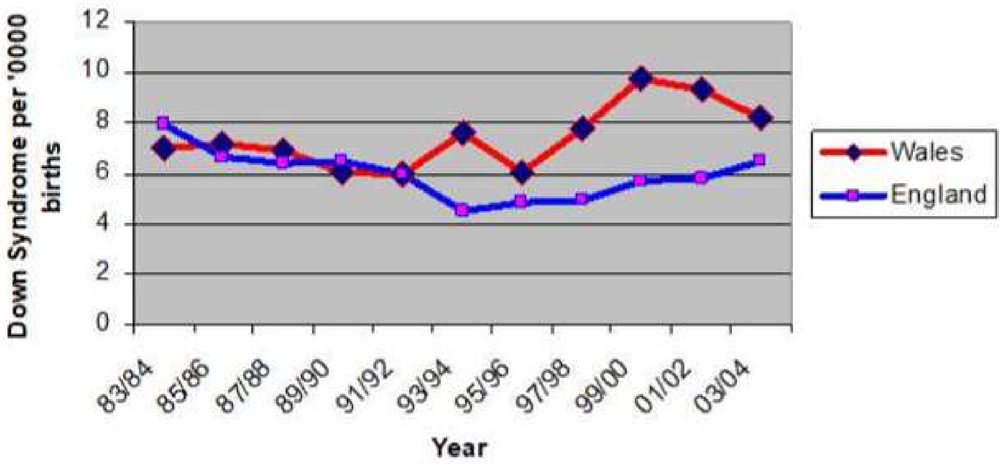
[14] Ryabokon N I 2006 Transgenerational accumulation of radiation damage in small mammals chronically exposed to Chernobyl fallout. Radiat Environ Biophys 45:167-177.

Additional research into Down Syndrome and radiation should be noted. In 1972, Eva Alberman[15] reported research findings which showed that exposure to x-rays of mothers to be increased the likelihood of giving birth to a Down Syndrome child, but only at least six years after exposure.

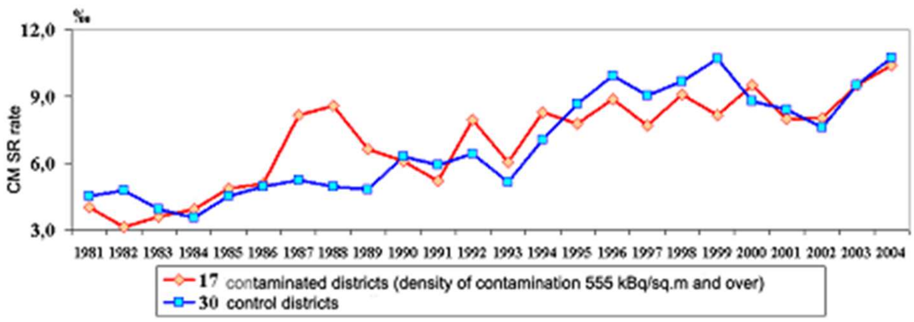
What happened when all mothers to be in Britain were exposed to an unexpected bout of radiation from the Chernobyl nuclear accident in early May 1986? Three large radioactive plumes from the accident swept south to north over the country and where they were intercepted by rain showers and significant amounts of radioactive debris were deposited[16].

One such area was Wales which it is generally agreed, had significantly higher levels of fallout.

The graph below is based on official figures for Down Syndrome comparing England and Wales between 1983 and 2004[17]. It can be seen immediately that exactly six years after the Chernobyl nuclear accident, Down Syndrome levels in Wales which previously had matched those in England, increased by about 45% over their English counterparts. This six-year delay effect exactly mirrors the findings of Eva Alberman.



What about other parts of Europe? This figure shows the annual birth defect rates in Belarus, which was heavily contaminated by fallout from Chernobyl[18].



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[15] Alberman E 1972 Parental exposure to X-irradiation and Downs Syndrome. Ann Hum Genet 36(2): 195-208.

[16] Smith F B 1989 The transport and deposition of airborne debris from the Chernobyl nuclear power plant accident and Smith F & Clarke M Met Office Scientific Paper No 42 HMSO London 1989 ISBN 011 400358 0.

[17] Congenital Anomalies Statistics DH3 1993-2004 Table 4 Welsh print out

[18] Belarussian National Report 2006 Strict hereditary disease analysis of births 1983-2001

It can be seen that in the most contaminated area, there was a significant jump in birth defects in 1987 and 1988, which could have been caused by exposure of male sperm to radioactive fallout. Levels then return almost to normal but in Belarus as a whole, six years after the Chernobyl nuclear accident the birth defect rate rose to four times the rate before the accident and continued to climb. The shape of the graph would suggest that the impact on the offspring due to parental exposure could be at least ten times higher via women than via men. Once again, there appears to be a six-year effect. These figures cover not only children born with Down Syndrome but all types of birth defects.

Clearly, there are many unresolved questions about the impact of radiation on the human female egg but the results from Wales and Belarus suggest that not only very low levels of man-made radiation may have an effect but that its genetic consequences are much higher in women than in men. These further findings reinforce the need for a moratorium on any women of childbearing age working in the nuclear industry, including the proposed Wylfa B plant until as such time that there is a clearer understanding of radiation risks for women from the nuclear industry.

4. Nuclear power operations

4.1. Radiological emergencies

A 74-page paper on radiological emergencies[19] has been put out by BEIS for consultation and has profound implications for the health and safety of the residents of Anglesey. The implies that much of the work for radiological safety standards should be devolved to local authorities. This seems to be entirely inappropriate given the present financial circumstances of many local authorities and their lack of scientific expertise. Rather like asking local authorities to negotiate with operators on the safety standards for cladding on buildings without proper oversight by national authorities.

The document proposes that the current emergency reference levels should be abolished and be subject to negotiation between the operator and local authorities but surely there has to be absolute standards for the rate of release of radioactivity from any nuclear site. For example, if monitors on the site boundary were recording one milligray per hour this would be 10,000 times the natural gamma background however there is nothing in the document that addresses this question of how unusual levels of radioactive emissions should be dealt with promptly, nor is there any mention of the essential role of the media in that situation.

In principle, the idea of a lead authority is sensible but it would be more appropriate to consider it at a regional level. For example in the case of Hinkley Point, West Somerset Council or any other councils it will amalgamate with, would not have the resources to carry out in-depth analysis of emergency plans. On the other hand Bristol, which is downwind of Hinkley Point, may have both the motivation and resources to deal with a comprehensive plan. By the same token, the Isle of Anglesey County Council could be designated as the frontline authority but it would need the back up of a large city-based lead authority downwind of the proposed Wylfa B site, for example Manchester. In any case, as we have seen in the pattern of radioactive fallout in the UK after the Chernobyl nuclear accident, there is no guarantee that the nearest authority to a nuclear power plant will be most adversely affected, particularly because of the significance of rainfall creating washout of radioactive debris.

The radiological impact of the Chernobyl nuclear accident in the UK was comprehensibly examined by the Met Office in their paper (see earlier reference 16 from the Met Office, which should be required reading for every emergency planning officer).

One of the curious features of nuclear accidents so far is that they always appear to be major accidents. This may be because minor accidents are brushed under the carpet or that inevitably a minor problem escalates into a major problem. In either case, it is difficult to see why a radiological emergency at a nuclear site should be of concern only to the neighbouring local authority.

[19] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/746272/revised-requirements-for-radiological-protection-emergency-preparedness-response-govtresponse.pdf

In 1990, there was general agreement between local authorities that the alert level on a nuclear facility site boundary should be not more than 1.8 times natural background, i.e. about 180 nanograys per hour. However in the radiological emergency document there is only reference to cumulative dose, which of course is difficult to predict.

The umbrella organisation that highlighted the question of safety standards was called LARRMACC (Local Authority Radiation and Radioactivity Monitoring Advice and Collation Centre), which can be Googled and it would seem that the revival of such a body representing local authorities but having its own independent source of finance would be advantageous to all parties. Bearing in mind that the proposed new build nuclear power plants are considered under major national infrastructure plans costing billions of pounds, the odd million or so to finance such a body on safety standards would not come amiss.

4.2. Monitoring the safety of nuclear power plants

It is clear that so far insufficient attention has been given to the variation in radiation from nuclear power plants. No real-time gamma monitor results are available near any nuclear power plant in Britain. The independent gamma monitoring network called Argus has had monitoring sites for the last thirty years in different parts of the UK but unfortunately none of these are close to nuclear power plants. It is recommended that the proposed Wylfa nuclear development must incorporate publicly-observable monitors connected to the internet. The ring of monitors around the nuclear power plant should report in real time every ten minutes as do the monitors attached to the Argus Program. If the normal levels are significantly breached, even for a short time, then public sirens should be activated. In any case, the public must be alerted in advance when refuelling will take place so that they have the opportunity to shelter from any possible radioactive atmospheric discharge.

It is recommended that houses and offices within ten kilometres have safe rooms where positive pressure can be maintained, so as not to draw in any radioactive gas, particularly tritium. Householders and businesses should be notified in advance as to when fuel changes are taking place so that the necessary precautions can be taken.

Such precautions would stand the community in good stead in the event of a nuclear accident at Wylfa. Contrary to assertions by the nuclear industry, the probability of major nuclear accidents is not vanishingly small. Bearing in mind that the probability of any event can be related to the frequency of past events, then on that basis we would expect a major nuclear accident somewhere in the world once every eighteen years. In the case of an individual nuclear power plant such as Wylfa, the probability of such an accident would be in the order of 1 in 9,000 per year, which over 60 years amounts to 1 in 150. This is still a significant level of risk in terms of the magnitude of the consequences.

The Isle of Anglesey would be particularly vulnerable to any attempt at evacuation, bearing in mind there are only two bridges out of the island with single carriageways.

4.3. Health monitoring

Continuous health monitoring around the proposed development should also be taking place. The Data Protection Act has done much to conceal from the public any health outcomes from living near a nuclear power plant. For example, the yearly number of still births by ward was removed from the public domain from 2000 onwards. The main reason given for concealing data is that it protects the privacy of individuals but the health of the community also has to be considered. Privacy would not be compromised if health results were published within certain distance bands. For example, within 5 kilometres, between 5 and 10 kilometres and greater than 10 kilometres from the plant on the Isle of Anglesey. This would also have the advantage that, if health data was omitted or concealed, an individual who had suffered an unrecorded health insult could complain. Public surveillance is the best way to protect health data.

The recommended categories for publication by zone and year are: number of still births; number of childhood cancers in five-year age groups; number of children born with birth defects and number of miscarriages. Hitherto, miscarriages have not been part of the public debate about the safety of nuclear power plants but since 30% of all pregnancies end in a natural miscarriage and it would appear that 50% of those are associated with chromosome aberrations, which may have been caused by radiation, then this is a parameter that must be included.

4.4. Changing safety standards for the nuclear industry

It is reasonable to ask whether the current safety standards in our nuclear industry are dictated by the need to preserve the nuclear industry even though the health risks are significant. It is anticipated that future research in this area will demonstrate that levels of exposure to radiation, particularly of workers, should be significantly reduced as they are the group that is most likely to transmit genomic instability to future generations. This effect at present cannot be quantified but any improvement in standards could make the plant non-viable in the same way that re-examination of health standards in the asbestos industry brought about its collapse.

5. Thermal pollution

5.1. Nuclear power, thermal pollution and global warming

Nuclear power plants do not produce carbon dioxide directly but CO_2 is associated with the mining, transport and enrichment of uranium and also the eventual disposal of the nuclear waste. Nevertheless, direct thermal pollution, whether from fossil fuel burning or nuclear power plants, is still a significant player. In the case of Wylfa B, assuming a 30% efficiency in generating electricity, then the proposed 2.7 GW plant operating for 70% of the time would generate 54 TWh per year of thermal pollution. It should be noted that the total annual thermal pollution from all forms of transport in the UK is estimated to be 600 TWh.

5.2. Mitigation

In most planning applications, mitigating for the effect of a new development is an essential part of the planning process. For example, plans for a new housing estate on green belt which threatens wildlife corridors has to be mitigated for by increased biodiversity elsewhere. No such principle has been applied to mitigate for thermal pollution of the proposed Wylfa nuclear development. Just because it would be difficult, because under the second law of thermodynamics, that "heat cannot be destroyed," does not mean that it should not be built into the consultation process. This question becomes particularly acute if there is a "tipping point" for increased inputs into global warming.

If coal-fired power stations need to be replaced, then priority should be given to facilities which utilise renewable energy systems. One possibility that has been given scant attention is the use OTEC (Ocean Thermal Energy Conversion), which not only can generate electricity without thermal pollution but also provide benefits of desalination and the bringing to the surface of cooler waters which could contribute to reducing near-surface ocean temperatures, thus reversing in critical areas any positive feedback loop associated with water vapour.

This known technology could well provide 25% of current world electrical output and even contribute to the reversal of global warming.

6. Conclusions

The proposed Wylfa nuclear development involves huge investment of billions of pounds but the level of uncertainty still associated with nuclear energy means that such investment could well be vitiated if new scientific findings are acknowledged. In particular, the recent concern about rising sea levels means that a direct threat may emerge sooner rather than later to the operations of the plant and the storage of onsite nuclear waste.

The nuclear waste burden created by Wylfa B would be 33% of the existing total radioactive inventory and this has to be factored in to the cost of the ultimate storage and containment of nuclear waste.

There are also considerable question marks over health matters, impact of new knowledge on health and safety standards, the problem of exposing women workers, the long-term genetic implications for the workforce and their descendants and the possible increase of health effects in the local population, which have so far not been sufficiently considered.

Finally, concern should also be directed to what appears to be the fragmentation of decision-making on the nuclear lifecycle as a whole. For example, recently a member of a nuclear NGO asked the Office of Nuclear Regulation (ONR) what would be the impact of sea level rises on the proposed Wylfa B design, to which the reply was "the ONR does not consider matters beyond the shoreline." But judging by the latest scientific findings, Wylfa B itself might become "beyond the shoreline."

The lack of consideration of sea events on the Fukushima nuclear plant by the licensing authorities in Japan was a major factor in the Fukushima nuclear disaster.

Again, it also appears that the Department of Business, Energy & Industrial Strategy (BEIS) is attempting to offload its responsibilities on radiological protection. So, who is ultimately responsible for the safe working of the nuclear industry from the cradle to the grave? This is a crucial question that must be considered before any further nuclear development takes place.

Appendix A: Calculating sea level rises

The two main causes of sea level rise are thermal expansion due to the warming of the ocean and the melting of the polar ice caps.

1. Ocean thermal expansion

When water gets warmer it becomes less dense, so when the oceans become warmer their thermal expansion means that the sea level rises. The calculations here are based on that principle.

Over the past 200 years, the average surface temperature of Planet Earth has increased from 14°C to 15°C. This average also applies to the ocean's surface temperature. What happens when a column of water rises in temperature from 14°C to 15°C? On average, its density will reduce by 145 parts in one million. In other words, if we take a column of water 1 m^2 in area with a depth of 1,000 metres and heat it up from 14°C to 15°C, it will rise by 145 mm. By the same token, a column of water only 6.9 m deep will rise by 1 mm.

The heat needed to produce this rise of 1 mm in a column 1 m^2 is approximately 8 kilowatt hours (KWh). How much extra heat needs to be introduced into the ocean to cause a 1 mm rise? The total surface area of the world's oceans is about 350 million km^2 i.e. $350 \times 10^{12} m^2$. So, if 8 KWh for a surface area of 1 m^2 produces a 1 mm rise, this implies that the total global heat needed to raise all of the oceans by 1 mm is 2.8 million terawatt hours (TWh). This figure is reasonably close to the estimate based on Keeling's work of 2.34 million terawatt hours per mm rise.

2. Sea level rise due to melting ice

The amount of heat required to melt one tonne of polar ice is approximately 93 KWh. This assumes the mechanical equivalent of heat, a latent heat of fusion of 80 metres and that the original temperature of the ice is 0°C.

When land-based ice melts, the melted ice raises the sea level. It needs 350 billion tonnes of land-based ice to raise sea levels by 1 mm. The heat required to melt this amount of ice is equal to 0.03255 million TWh. In other words, the heat required to raise sea levels by the ocean thermal expansion route is 72 times that required to raise the sea by 1 mm via the ice melt route (2.34/0.03255=72).