A SURVEY OF CANCER IN THE VICINITY OF TRAWSFYNYDD NUCLEAR POWER STATION IN NORTH WALES

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Introduction

The question of high cancer rates in north Wales has been one of significant debate since one of us called attention to high levels of cancer in Wales (Busby 1994). Since then a study funded by the Irish State of the Wales Cancer Registry small area database which was released to Green Audit in 1996 has revealed high levels of all cancers in adults and children in the period 1974 to 1989. Highest levels were found close to parts of the Irish Sea coast which were contaminated with radioactive material from Sellafield. These included the Menai Strait and northern coastal towns. The rates of cancer were found to be increasing toward the end of this period, particularly in children (Busby 2002). The Wales Cancer Registry was dissolved in 1996 and replaced in 1997 by the Wales Cancer Intelligence and Surveillance Unit (WCISU) which has consistently denied claims that there are any excess cancer rates in north Wales. The denials followed a BBC documentary TV programme, *Sea of Troubles,* broadcast in February 1998 which drew attention to the findings of increases in child leukaemia near the coast. The levels of cancer were examined by the WCISU who published a report claiming that the levels of childhood cancer were normal. This report was endorsed by the government Committee on Medical Aspects of Radiation in the Environment, COMARE, which had been set up in the wake of the Sellafield child leukaemia cluster enquiry under Sir Douglas Black in 1884.

However, examination of the report by WCISU revealed that 18% of the child cancer cases had been removed from the WCR database, and the original files supplied to Green Audit had been wiped from the computer system and so could not be examined to see where the children had been taken from. The claims of high levels of cancer in adults had not been examined by WCISU or by COMARE. Welsh Assembly Government accepted the claims of COMARE and WCISU and made official statements that there was no excess cancer in north Wales, and that the WCR dataset Green Audit had used was corrupt.

The matter was re-examined in 2001-2004 by the Committee Examining Radiation Risk from Internal Emitters (CERRIE), which was set up by the then Environment Minister, the Rt. Hon. Michael Meacher. However, the Minister was sacked in 2003 and the CERRIE committee was split on the issue and produced two separate reports (CERRIE 2004 a and b). There was a significant development in early 2004 due to the involvement of reporters from HTV Bangor. An investigation by HTV reporters resulted in the identification of over 40 children suffering with cancer in North Wales. Calculations by Green Audit using the results of this research defined the existence of childhood leukaemia and brain tumour cluster in the Menai Strait coastal area of north-west Wales more serious and more highly statistically significant that the famous Sellafield (Seascale) 10-fold excess child leukaemia cluster discovered in 1983 by Yorkshire TV. The Green Audit report showed the presence of a 20-fold excess of child leukaemia (0-4) in Caernarfon over the period 2000-2003 (3 cases, 0.1 expected, RR = 20; $p < 0.0000$) with at least 5 cases of brain and spinal tumours in the same town since 1996 in 0-14 year olds, a Relative Risk of 18-times the national average (RR = 18; $p<0.00005$). In the 34 wards surrounding the radioactively contaminated Menai Strait there were 6 cases of leukaemia 0-4 from 2000-2003; RR = 7.8, $p = 0.0005$ and between

1996 and 2003 there were 9 cases of brain and spinal cancer RR = 5.4; p = 0.0004. The results were presented at the International Conference on childhood leukaemia organised by the charity Children with Leukaemia (CwL) in Westminster in September 2004.

WCISU again responded by arguing that the finding was alarmist and incorrect, and that there was no need to worry. By 2005 WCISU had reported to the Welsh Assembly Government that Green Audit had made errors in its analysis and had used incorrect populations for the areas involved in the childhood cancer excess. By 2006, Green Audit had responded to this in a short report (Busby, Bramhall 2005) which was able to show unequivocally that it was WCISU that had made major and elementary errors in its own population estimates. A letter (Busby and Howard 2006) was published in the Journal of Public Health demanding that WCISU retract its analysis. In the same issue of JPH a letter from WCISU admitted their mistake, though without changing their conclusions. The Royal College of Physicians began conducting an enquiry into the WCISU analysis and COMARE also set up an enquiry. This background sets the stage for the most recent study of radiation and cancer in north Wales which is presented here.

In all these studies, what has been significantly absent has been access to cancer registry small area data. People living in small areas close to radioactive contamination tend to be concerned that they may be affected by the exposures. In various studies of cancer mortality carried out in the late 1990s and early 2000s Green Audit has been able to show that there are significant excess risks of breast cancer in populations living near nuclear sites and particularly contaminated sediment Two such studies examined breast cancer near the Hinkley Point nuclear site in Somerset and near Bradwell Nuclear site in Essex, where 2-fold excesses of breast cancer mortality were found. (Busby et al 2001, 2002). In the case of the Hinkley Point site the refusal of the cancer registry to release incidence data led local people to conduct a survey of cancer in the town downwind on the nuclear plant, Burnham on Sea. The survey results (Busby and Rowe 2002) confirmed the breast cancer cluster found in the earlier mortality study (Busby et al 2002) and also drew attention to an excess of leukaemia.

The present study analyses data acquired by two of us (AG and EG) in an area downwind of the Trawsfynydd nuclear power station in north Wales.

The study

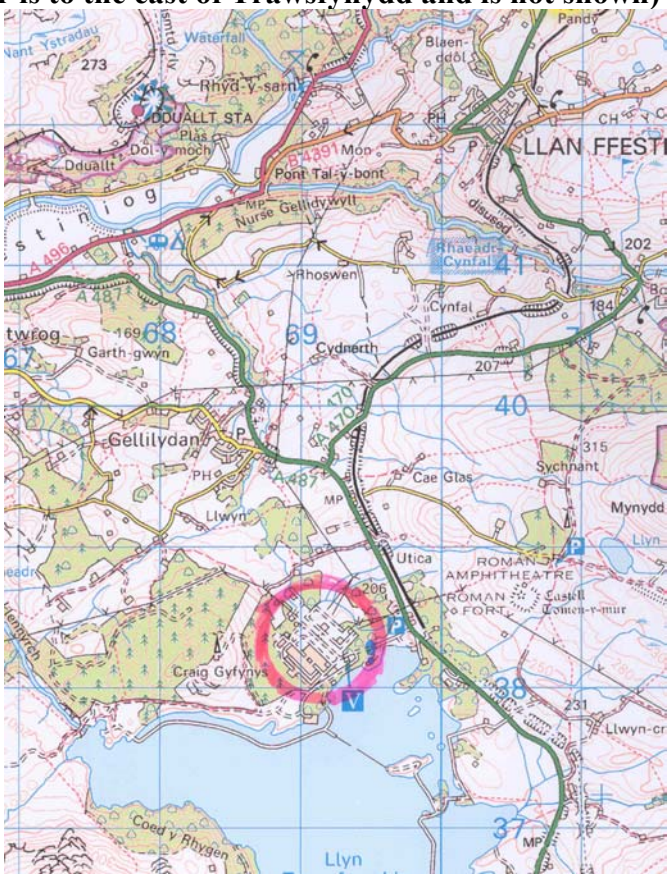
The study was broadly based upon the method of the Burnham on Sea cancer questionnaire study (Busby 2001) which in turn was piloted in Carlingford, County Louth, Ireland in 2000 (Busby and Rowe 2000).

Trawsfynydd nuclear power station is the only inland nuclear station to be built in the UK. The power station has two MAGNOX type CO2 cooled graphite moderated reactors and is situated on a lake, Llyn Trawsfynydd, which acts as a cooling water source and is also a sink for radioactivity released from the plant. Very large amounts of radioactive material exist in the lake bed sediment (Fern, Odell, Cobb 1988)) at concentrations which under UK legislation ought to require it to be controlled as Low Level Waste. There are also gaseous releases from the plant which is situated on the north shore of the lake (see map at Fig. 1). The power station ceased operation in 1993 but has yet to be fully decommissioned. The prevailing winds are south westerly. The study area was the area to the north and west of the plant. A small sample was also taken from Cwm Prysor (not shown on map). The town of Trawsfynydd itself, on the south east of the lake

shore was not examined for reasons of time and effort only. The question being addressed was whether there was an excess risk of cancer in the area. This followed anecdotal evidence from Llan Ffestiniog. A researcher went to each house in the town of Llan Ffestiniog to the north west of the Trawsfynydd site, the village and farms near Gellilydan to the north of the plant, and a few outlying farms in Cwm Prysor.

The questionnaire obtained the sex and ages of all persons living at each address where there were people living at the time of the survey, as shown on the electoral register. It also obtained the details of all cancers which had been diagnosed in the ten years from 1995, including the type of cancer (site), the age at diagnosis and the year of diagnosis. In addition it asked for whether the person smoked cigarettes, whether they had worked at Trawsfynydd, fished in the Trawsfynydd lake or eaten fish from the lake. These fish have been examined by the Ministry of Agriculture and shown to be contaminated with radioisotopes including Plutonium-239.

Figure 1. Map of Trawsfynydd Nuclear Power Station (ringed in red) and the study area (Cwm Prysor is to the east of Trawsfynydd and is not shown)



Results

Questionnaires were filled in from 260 addresses in Llan Ffestiniog, 21 farms and houses from Cwm Prysor and 121 addresses in or near Gellilydan. The numbers of persons in these areas represent the base population for the analysis of cancer expectation and these are given in Table 1.

Table 1 Questionnaire responses

Area	**No of questionnaires**	**Persons**
Llan Ffestiniog	260	640
Gellilydan	121	279
Cwm Prysor	21	59
Total area	402	978

The age and sex breakdown of the survey population is given in Table 2.

A proportion of houses were empty or were holiday homes. Two people refused to answer the questionnaire, one of these on the basis that there had been a cancer very recently and the person was too upset to discuss the issue. The survey included cancers that had been reported in people who were recently dead but who had lived at the address and were known to the occupants (relative). The number of these cases recorded in the cancers was 2.

The cancer risks for each site were calculated as Standardised Incidence Ratios (SIR) on the basis of England and Wales rates for 2002 (Office for National Statistics: Series MB1 No 33). Thus the national incidence rate per 100,000 for each 5-year sex and age group was applied to the number of individuals in that age group in the base population to obtain the expected number of cases per year. Two periods of time were examined. The first was the ten years 1996-2005. The second was the three years 2003-2005. For each period the expected number of cancer cases for the type of cancer being considered was calculated from the national rate and the Standardised Incidence Ratio SIR was calculated as:

$$\mathbf{SIR = O/tE}$$

Where O is the observed number of cases, E is the expected number of cases and t is the time period in years. This is a standard method used by ONS. The statistical significance of the result was obtained from cumulative Poisson tables as a p-value. A statistically significant result was taken to be any result that had a p-value lower than $p = 0.05$. The Poisson p-value represents the probability that the number of cancers found or less could have occurred as a result of chance alone.

Table 2. Sex and age breakdown of the survey base population recorded in the questionnaires returned.

Age group	Males	Females
0-4	16	18
5-9	36	29
10-14	39	32
15-19	48	42
20-24	13	11
25-29	20	23
30-34	33	21
35-39	30	31
40-44	43	38
45-49	38	35
50-54	21	32
55-59	34	44
60-64	33	28
65-69	22	21
70-74	29	35
75-79	22	20
80-84	11	14
85+	2	14

The observed numbers of cancer in the two periods chosen are given together with expected numbers, SIRs and p-values in Table 3. We have looked at cancer in all ages, but since there seemed to be many cancers in younger people we also examined the risks in the age group 0-60 and 0-50. It is clear from the results that there is a highly significant excess cancer risk at all ages in the last three years 2003-2005 and that this effect is even higher in the younger people. For people below the age of 50 we see 15 times more cancer in women than would be expected on the basis of national figures for England and Wales.

The questionnaire asked whether those who developed cancer worked at the nuclear power station, fished in the lake or ate the fish from the lake. These fish are known to be contaminated with radioisotopes. It was perhaps significant that of the women under the age of 60 who were registered with breast cancer between 2003 and 2005, three ate fish from Trawsfynydd lake; one did not and one is dead and we do not know if she did or not. Details of these women are given in Table 4.

Table 3. Trawsfynydd survey study cancer risk table; not including non-melanoma skin cancer.

cancer	1996-2005; Obs/Expect	10 yrs SIR p-value	2003-2005 Obs/Expect	3 yrs SIR p-value
All ages				
All maligs M	40/34.5	1.16	22/10.5	2.13 (0.0007)
All maligs F	27/30.6	0.9	16/9.18	1.74 (0.03)
All maligs M+F	67/65	1.03	38/19.5	1.95 (0.0001)
F breast	10/7.7	1.3 (NS)	6/2.32	2.6 (0.03)
Prostate	8/6.79	1.2 (NS)	5/2.03	2.5 (0.05)
All leukaemia	3/1.28	2.34 (NS)	3/0.384	7.8 (0.007)
Leuk + lymph	4/2	2.0 (NS)	4/0.616	6.5 (0.003)
mesethelioma	3/0.37	8.1 (0.005)	2/ 0.111	18.0 (0.005)
pancreas	3/1.39	2.15 (NS)	2/0.417	4.8 (0.06)
larynx	4/0.425	9.4 (0.0008)	0	
colon	7/4.1	7/4.1 (1.7 (NS)	0	
0-60				
All maligs M	8/5.6	1.42 (NS)	3/1.68	1.8 (NS)
All maligs F	14/8.66	1.62 (0.05)	11/2.6	4.23 (0.0001)
All maligs M+F	22/14.3	1.54 (0.03)	14/4.28	3.3 (0.0002)
F Breast	6/3.42	1.75 (NS)	5/1.02	4.9 (0.004)
0-50				
All maligs M	2/0.7	2.9 (NS)	1/0.22	4.54
All maligs F	8/1.08	7.47 (0.0001)	5/0.324	15.4 (0.00005)
All maligs M+F	10/1.78	5.6 (0.00001)	6/0.544	11.3 (0.0001)

Table 4 The 5 women under the age of 60 yrs diagnosed with breast cancer between 2003 and 2005. Expected number is 1.02 in the three years (0.3415 per year). SIR = 4.9; p = 0.004

Case No	Age at diagnosis	Year of diagnosis	Area	Notes
41	36	2003	Ffestiniog	Dead
132	56	2003	Ffestiniog	Alive, smoked.
134	59	2003	Ffestiniog	Alive, smoked, ate lake fish
159	57	2005	Ffestinog	Alive, smoked, fished in lake, swam in lake, ate lake fish
329	57	2003	Gellilydan	Alive, non smoker, worked Traws visitor centre, ate lake fish

In addition to the cancers recorded in Table 3, there were other cancers diagnosed in the 10 year period. These included cancer of the lung, stomach, thymus, cervix, brain, uterus, ovary, liver, bladder, skin, kidney and myeloma.

The study also asked if anyone who had developed cancer ate fish from Trawsfynydd lake. The lake is used as a sports amenity and contains trout which are caught by fishermen and frequently are eaten. The trout are known to contain radionuclides and are regularly monitored by the authorities. Following the survey, when we had discovered that there seemed to be a significant proportion of people with cancer who had eaten fish from the lake, a new survey was carried out to examine the background rate of fish eating in the whole population. In 100 people sampled there were 10 who had at one time eaten fish from the lake. One has been included in the 10 although she said she was "not sure". Three people in the group said they had eaten fish but no longer did so. 38 people in the main survey were diagnosed with cancer between 2003 – 2005. Of these, 8 reported eating fish from the lake. If we use 10/100 as the background rate in the population then we would expect 3.8 of the cancer patients to be fish eaters. Using Cumulative Poisson tables we see that to find 8 or fewer fish eaters in this population, a relative rate of 2.1, has a probability of $p = 0.04$ and is therefore a statistically significant finding. It is interesting that one of the 8 cases was an 18-year-old with lymphoma who was said to be an avid angler, fishing the lake regularly.

Discussion

The main problem we have found with studies of this kind is population leakage. By this we mean that people who die of cancer in the past in the area may not appear in the observed cancer list since their relative or partner may have moved away or they had lived alone. But this means that the results obtained show levels of cancer which are lower than the real ones. We found in earlier surveys of this type that this was indeed the case, and that the rates of cancer fell off rapidly for periods more than 5 years before the survey. We call this the population leakage effect. It is particularly true of rapidly fatal cancers in older people, e.g lung cancer. However, it is a negative effect, and if we are looking for an increase in cancer due to some point source of pollution, we can assume that the most recent diagnoses represent the closest approximation to the real level of cancer risk. In the present analysis, we employ the three year period 2003-2005 to examine cancer risk.

The results speak for themselves. The levels of cancer in the area in this period are significantly and alarmingly high. The main increases are in female breast cancer, prostate cancer, leukaemia, mesothelioma and pancreatic cancer. Mesothelioma is a cancer of the pleura which in 80% of cases has been associated with exposure to asbestos in the work place. It may be of interest that the *Oxford Textbook of Pathology* (p. 487) ascribed the remaining 20% to radiation exposure. The other finding was that there seems to be a higher level of cancer risk in the younger people, particularly the women. Table 3 shows that in the under 60s, the relative risk of all cancer in women in the recent 3- year period was 4-fold, in the under 50s it was 15.4-fold ($p = 0.00005$) based on 5 cancers. Table 6 dissects out these cases.

Table 6 Cancer in people less than 50 years of age. The skin cancer was not included in the all malignancy analysis

Sex M=1; F=2	age	diagnosed	Cancer
2	46	2004	Myeloma
2	40	2003	Thymus
2	36	2003	Breast
2	37	2005	Cervix
2	42	2003	Larynx
1	18	2005	Lymphoma
2	22	2005	Skin

These results show that there is some cause of cancer in the area of the study. Cancer is a genetic disease expressed at the cellular level. The cause is environmental and involves prior exposure to a mutagen or carcinogen (see e.g. Cairns 1978, Doll and Peto 1981, Busby 1995). There are two possible causes here. They are not mutually exclusive and both involve exposure to internal radioactive isotopes. The first and most obvious is the radioactive pollution from Trawsfynydd. The nuclear plant released radioactivity into the air for the whole period of its operation and the study area is almost entirely downwind of the plant (see maps). The mountainous nature of the area to the north and east of the plant ensures that any releases would be deposited mainly in the towns and villages and farms in the area containing the homes we have surveyed. Contamination via the fish eating route should also be taken seriously since it is seen, on the basis of the small sample, to involve a statistically significant correlation; three of the recent breast cancer victims under the age of 60 ate radioactively contaminated fish from Trawsfynydd lake.

The other obvious source of radiation exposure is Chernobyl. The area around Trawsfynydd was seriously contaminated by radioactivity which fell with the rain in May 1986. The internal contamination from inhalation or ingestion of radioisotopes will have added to any contamination from Trawsfynydd. Clearly to dissect out the components of the causes of these increases will require further epidemiological work in small area analysis. But such work is not possible at present. The data are not released. In addition we have significant concerns about those whose job it is to monitor cancer in Wales. The WCISU has consistently refused to release data and when analyses of questionnaire data show high levels of cancer or leukaemia the WCISU responds with denials and poor, biased epidemiological studies. An example is to be seen in their 1999 submission to COMARE in which, affecting to replicate the methodology of reports showing elevated cancer rates along the contaminated Irish Sea coast, they employed a range of statistical techniques to diminish the findings. Most recently their study of the child leukaemias on the Menai and in Wales between 1982 and 1990 (White, Steward, Wade 2005) has been shown to contain serious mathematical and conceptual errors (Busby and Howard 2006). The director of WCISU Dr John Steward admitted to one of us that he was involved in an earlier study of cancer near Trawsfynydd published by the Welsh Office in 1994 (Welsh Office 1994). This 1994 study used an inappropriate method to show that there was no leukaemia excess near Trawsfynydd and was criticised by one of us in 1994 (see Busby 1995). The Trawsfynydd lake sediment contains serious contamination from Plutonium,

Caesium Americium, Strontium and other radioactive isotopes. Astonishingly, it has been advertised as a tourist amenity with people swimming and fishing in the contaminated lake. The safety of these activities has been underpinned by a report from the National Radiological Protection Board, but the basis for the calculations made by NRPB has been undermined by the new findings and discussions over risks from internal irradiation published by the European Committee on Radiation Risk in 2003 (ECRR2003) and the reports of the CERRIE committee. These new findings, that internal radioactive exposures are hundreds of times more dangerous than have been hitherto assumed, are borne out by reports from Chernobyl affected territories (see ECRR2006, Tondel et al. 2004, Okeanov et al. 2004). A comprehensive independent epidemiological small area study of Wales is long overdue and might be designed to show the components of radiological causes of cancer in Wales, which include the two nuclear sites Wylfa and Trawsfynydd, the Chernobyl fallout, and finally the coastal contamination from Sellafield. We recommend the replacement of the WCISU with a more open and truly independent body and the release of small area cancer data. The cancer rate in the study area is alarmingly high. The most likely cause is radiation from the plant. A full scale investigation would have access to cancer incidence data and would take samples from the town and measure radiation levels in these samples and in the local inhabitants.

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