JACOBS PUBLISHERS

OPEN ACCESS

Jacobs Journal of Epidemiology and Preventive Medicine

Research Article

Infant and Perinatal Mortality and Stillbirths near Hinkley Point Nuclear Power Station in Somerset, 2005-1993; an Epidemiological Investigation of Causation

Christopher Busby[1*], Mireille de Messieres[2], Saoirse Morgan[3]

[1]*Environmental Research SIA, 1117 Latvian Academy of Sciences, Riga, Latvia, LV-1050*

[2]*Green Audit, No1 Sea View Place, Aberystwyth, SY23 1DZ, UK*

[3]*Green Audit, No1 Sea View Place, Aberystwyth, SY23 1DZ, UK*

**Corresponding author:* *Dr. Christopher Busby, Environmental Research SIA, 1117 Latvian Academy of Sciences, Riga, LV-1050; Tel: +371 29419511; Email: christo@greenaudit.org*

Received: *07-29-2015*

Accepted: *08-20-2015*

Published:

Abstract

Data from the UK Office for National Statistics for 1993-2005 was employed to examine infant and perinatal mortality, birth sex-ratio and breast cancer mortality rate as indicators of genotoxic effects in populations living both downwind of the Hinkley Point nuclear power station in Somerset UK and adjacent to coastal estuary mud flats which accumulate radioactivity from historic releases of radioactivity. We defined the center of the local contaminated mud bank, as the source of risk. For 1993-98, Trend in Relative Risks (33 infant deaths in 29 wards in 6km rings to 18km from the source) were 1.9, 1.54, 0.81 compared with 0.9 in the rest of 103 wards in the study area. Using Poisson regression with both Distance and Deprivation as covariates, Distance was significant (p = 0.015) but not Deprivation (p = 0.3). For perinatal mortality a similar result appeared (63 stillbirths in the 18km ring) with trend for 6km bands from the source of 1.24, 1.35, 1.1 with 0.9 in 103 inland wards. For the later period 1999-2005 there was no significant effect with distance either from the putative source or from the Power Station. Examination of the downwind town of Burnham-on-Sea 1993-98 showed excess risk for infant mortality RR = 4.3; p = 0.01, and neonatal mortality RR = 6.7 ;p = 0.003 based on 4 deaths. Sex-ratio at birth was anomalous with 1175 (boys to 1000 girls) over the whole period 1993-2005, expected rate 1055. There was also an excess risk of breast cancer deaths in Burnham-on-Sea North, for 1997-2005 RR = 1.7 p = 0.001 (41 deaths observed and 24 expected). In the whole period 1993-2005 there was an excess of infant deaths in the 11 estuary wards (24 deaths in 3866 livebirths) compared with 138 deaths in the 34005 livebirths in the rest of the area (OR = 1.53, 0.99<OR<2.35; p = 0.053). This was driven by a sudden peak in infant mortality which occurred in 1996 when there were 5 deaths in the 295 livebirths in the estuary wards compared with 9 deaths in the 2800 births inland (OR = 5.27 (1.53, 17.31; p = 0.0009). This followed accidental radioactivity releases from the plant for which the operators were fined. The trend with time shows an increase in the infant mortality in the estuary area which persisted until 2001 giving for the period 1996-2001 an Odds Ratio of 2.74 (1.61<OR<4.65) p = 0.0001) estuary vs. inland.

Keywords: Radiation; Nuclear; Estuary; Sea-to-Land; Sediment; Infant Mortality; Perinatal; Breast Cancer

Introduction

Political decisions about the development of nuclear energy options should at minimum be based on cost and benefit (although it is arguable that there are human rights issues that transcend the utilitarian approach) [1]. One of the costs which should naturally be examined is the possible effect of licensed and accidental releases on local populations. Nuclear site effects on health are generally examined by ecological epidemiology of childhood leukemia, thought to be the most sensitive indicator [2-9]. However, since it is now generally conceded that both childhood leukemia and also adult cancers are caused in part by genetic or genomic damage, and since the numbers of cases of adult cancers which are known to be radiogenic are far greater, the study of adult cancer near nuclear sites has been shown to provide useful information, particularly in the case of breast cancer. Recent studies of breast cancer in estuary wards near the Bradwell nuclear power station in Essex [10] and downwind of the Trawsfynydd nuclear power station in Gwynedd, Wales [11] both reported excess risk associated with adult populations exposed to historic releases. The question of the best methodology for conducting such studies was discussed, and the suggestion was made that it was best to focus on those groups living near the contamination rather than the hitherto accepted epidemiological approach which was to study effects in concentric distance rings around the putative source [12].

If it is true that cancer originates in somatic genetic mutations, then it is likely that another indicator of effects of releases of radioactivity from nuclear plants would be birth data. Since these are generally available in developed societies to small area levels, infant mortality and stillbirth might provide a probe for the possible damaging effects of releases from nuclear sites. The foetus appears to be exquisitely susceptible to the effects of radiation [13]. Increases in infant, neonatal and perinatal mortality were apparent at the time of the atmospheric weapons testing [14,15]. More recently the ratio of boys born to girls, the sex-ratio, has been shown to be perturbed in populations exposed to releases from Chernobyl, and other radioactive exposure events [16]. The authors even showed a trend in sex ratio by distance from nuclear plants in Germany [16]. Infant leukemia was significantly increased after Chernobyl in 5 countries of Europe [17].

The Bradwell study [10] found elevated risk of dying of breast cancer in populations living near the contaminated intertidal sediment of the River Blackwater. The Trawsfynydd study [11] found excess risk of breast cancer in the downwind town of Llan Ffestiniog. Hinkley Point in Somerset UK, also a Carbon Dioxide Graphite Moderated MAGNOX station like Bradwell and Trawsfynydd, discharges to the shallow but extensive estuary of the River Parratt which is tidal for much of its length and faces the prevailing winds. Elevated levels of discharged radionuclides including enriched Uranium are annually measured in the estuary and particularly in the sediment of the large mud bank called Steart Flats to the north east of the plant. The town of Burnham-on-Sea lies alongside these mud flats and is also downwind from the power station. Thus it is not unreasonable to expect similar effects in the area to those reported at the other two nuclear plants. Indeed, earlier studies also found an excess risk of breast cancer mortality [18-20] and incidence [21] in the ward of Burnham-on-Sea North, downwind from Hinkley Point, though the questionnaire study was criticized by the official radiation protection committee [22]. The criticisms focused on the methodology of the incidence questionnaire study [21] but failed to address the fact that official mortality data from 1995 continuously showed a doubling in risk of dying from breast cancer in the ward, an excess risk which persists. The present study avoids the arguments about breast cancer incidence and follows up the issue by switching the focus from cancer to effects on infant and perinatal mortality and sex ratio in populations living close to the contaminated mud flats and downwind from the plant.

Background

That there may be sea coast effect on cancer was first suggested by a study of leukemia in coastal and estuary populations which was published in 1990 [23]. A large study of cancer in populations living near the Irish Sea in Wales and examination of cancer in small areas of Ireland, funded by the Irish State in connection with a court case, and conducted from 1998-2001 demonstrated the existence of a sea coast/ estuary effect, with a 30% excess risk of most cancer sites in populations living close to estuaries and coastal areas where there was measured radioactively contaminated intertidal sediment [24]. The effect was a very local one, and affected those living within 1km of the coast. Owing to legal constraints the study was not published, but when the case collapsed, the results were published in 2006 as a book, Wolves of Water [24]. It is intended that these results will be submitted for peer-review in the future. The suggested exposure route was by inhalation of radioactive nano-particles [24]. These were resuspended and blown ashore by a well described phenomenon, sea-to-land transfer. The trend in cancer risk was similar to the trend in measured Plutonium concentration in air by distance from the coast [24]. These discoveries in Wales were then, later, supported by the finding of excess breast cancer mortality risk in those living near the estuary of the River Blackwater in Essex where sediment was contaminated from releases from the Bradwell nuclear power station. [10]. They were also supported by a study of breast and other cancer trends near Hinkley Point [18-21].

Hinkley Point nuclear power station is located on the West coast of the county of Somerset in South West England. It was built with two MAGNOX Carbon Dioxide graphite moderated gas cooled reactors (Hinkley A) in 1957; these are the same reactor type as Trawsfynydd and Bradwell, the subject of earlier studies [10,11] Later in 1967 a new type of Advanced

Gas Cooled Reactor Hinkley B was built. The location is on the southern end of a wide muddy estuary, the River Parratt, which is tidal for much of its length. There is a large tidal range (about 6 metres from high tide to low tide) and this has created a large area of mud which is revealed when the tide is out and which borders the town of Burnham on Sea to the north of the estuary mouth (Fig 1).

In England and Wales, the smallest administrative areas (for which census data and health data are collected) are called "Wards". Different wards have different populations but in general the overall ward populations are around 2000 to 5000 individuals. In England and Wales, health data, including birth outcomes, although collected, have not been made available to small areas. But in 1997 the then Office for Population Census and Surveys OPCS (now called the Office for National Statistics ONS) began to sell certain ward data. This included cancer mortality for 5 major cancer sites, and also infant mortality and stillbirth. In 2001 stillbirth data was removed, and in the last few years, the datasets have been made confidential once again. Nevertheless, we (Green Audit) have purchased all the ward level data that was available since it became available and this has enabled us to look for cancer mortality effects near putative point sources of pollution anywhere in England and Wales between 1995 and 2007.

Medical services in England and Wales are free. Local doctors (General Practitioners) are the first point of contact and patients are referred to hospitals and specialists if necessary. Cancer incidence and mortality data has been collected by law since 1974; mortality data is available nationwide back to before the 1939-45 war. Cancer incidence data for small areas (like wards) has never been made available for independent research but County level data can be obtained from the larger area administration, in the case of Somerset, the South West Cancer Intelligence Agency, which is independent of central government but funded by it.

Results of our analysis of the wards in the county of Somerset indicated that there was increased risk of all cancers combined, prostate cancer, lung cancer and breast cancer with a trend by distance from the main source of respirable radioactive particles, the large offshore mud bank known as the Steart Flats, west of the coastal town of Burnham-on-Sea and north east of the Hinkley Point site and its liquid radioactive waste outfall pipe. The location of the power station and its relation to the estuary, the mud flats and the town are shown in **Fig 1**.

The mud flats at the mouth of the River Parratt become the cumulative depository of all the liquid and most of the airborne releases (due to washout from the atmosphere) from the power station. The hypothesis, which followed from the Irish Sea study findings [19] was that radioactive particles move up the tidal river Parratt and are resuspended, with the result that local proximal estuary wards would carry excess cancer risk following inhalation.

By 2007, using the official data from the UK Office for National Statistics, we were able to look at breast cancer mortality in Burnham North in the whole period. Between 1995 and 2005 there were 41 deaths from breast cancer in Burnham North whilst 24 were predicted on the basis of the age breakdown of the population, the ward level socioeconomic status and national rates. This represents a 70% excess risk with a cumulative Poisson p-value of 0.001.

Figure 1. The Estuary of the River Parratt in Somerset, South West England. Hinkley Point Nuclear Power Station is on the coast and ringed in red. The town of Burnham on Sea is 10km downwind and ringed in green. At low tide, the contaminated mud labelled " Steart Flats" and "Berrow Flats", is exposed for several miles offshore.

Since cancer is a genetic disease expressed at the cellular level, areas which have a true causal increase in cancer risk due to the presence of some mutagenic agent might also be expected to show a high risk of other health conditions associated with mutagenic stress. We were therefore interested in examining the levels of infant and perinatal mortality and stillbirth in Burnham North to see if these end points are also raised, and at the same time to examine the same area of Somerset in which we had previously looked at cancer risk. The hypothesis we are testing is that there is an increased risk of infant mortality, perinatal mortality, stillbirth and sex ratio effects in estuary wards near the Steart Flats with contaminated sediment we proposed as the source of exposures which caused the excess cancer we found in the earlier studies.

Method

The area we examined was the same area of Somerset we used to examine the cancer mortality trends [18-20]. The data were split into 2 periods since after 1999 there were ward boundary and ward name changes. We examined the post-1999 set of wards separately, in addition to combining them with the pre-1999 wards for an overall examination of trend. Wards are listed in the Appendix. Annual numbers of total births by census ward were purchased from the Office for National Statistics (ONS) together with tables of infant and neonatal (0-28day) mortality by year and ward for the appropriate periods. Stillbirth data were also obtained from ONS up to 2001, after which the data were no longer released owing to a new decision by ONS about confidentiality. In order to examine the relation between dis advantagement and infant mortality in the area, deprivation quotients were obtained from ONS for the pre-1999 wards.

First, ward level Relative Risk was examined on the basis of the rate for the appropriate period for the whole of the study area, some 100 wards. This defined an expected number of infant deaths, neonatal, and stillbirths in any ward or aggregate of wards, and comparison of the observed number with this expected number gave a Relative Risk, RR = O/E. We examined the effect of the contaminated mud bank and the estuary of the Parratt in a number of different ways. First we determined the distance in km of the centroid of the wards from (a) Hinkley Point and (b) the center of the Steart Flats. Then:

1. We aggregated wards into roughly equal numbers at annular bands with distances from the two possible point sources (a) and (b) of 0-6km, 6-12km, 12-18km, all the other wards in the area. We then compared rates for the various end points in these distance bands for the two separate periods 1993-98 and (without the stillbirths) 1999-2005 and (without the stillbirths) for the whole period.

2. We examined the rates and Relative Risks in Burnham-on-Sea.

3. We constructed risk maps for the two periods and two sets of wards.

4. We looked at wards which were proximal to the estuary or the sea and compared these with those which were not.

5. We examined the trend for infant mortality from the two putative point sources using a General Linear Poisson Regression model of Numbers of cases divided by Numbers of Births versus both Distance and Deprivation for the two periods and for the whole period:

$$\text{Log}(N/B) = a\log(\text{Distance}) + b\log(\text{Deprivation}) + \text{Intercept}$$

6. We compared the trend in infant mortality risk over the whole period by estuary and inland wards.

Results

The whole study area

The whole area was the same as that used in the earlier cancer mortality study and consisted of the wards listed in Appendix A. Details of the total numbers of births and the various rates for infant mortality, neonatal mortality and stillbirths are given in Table 1.

Rates for all three end points in the overall study area were slightly lower than those of England and Wales. Risk maps for infant mortality are given in Fig 2 and Fig 3. Perinatal mortality risk (Neonatal and Stillbirths) is mapped for 1993-98 in Fig 4.

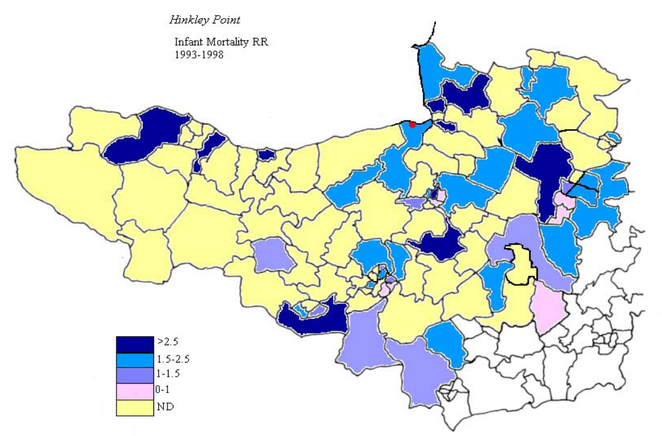

Figure 2. Infant mortality risk in area near Hinkley Point (red dot) 1993-1998.

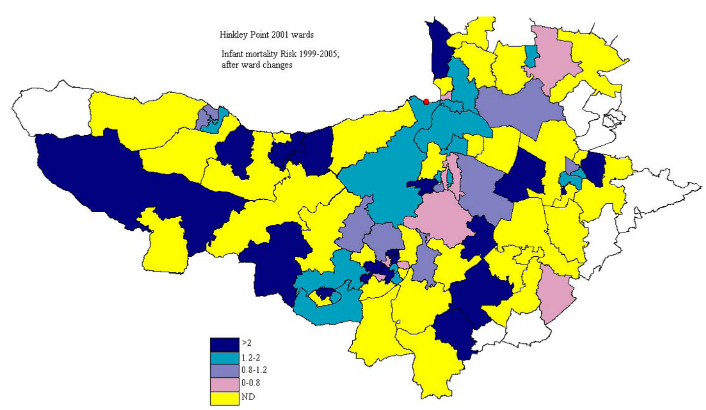

Figure 3. Infant mortality Risk near Hinkley Point (red dot) 1999-2005 . Note that the wards are slightly different after 1999.

Figure 4. Perinatal (0-28day + stillbirth) mortality risk in study area 1993-98.

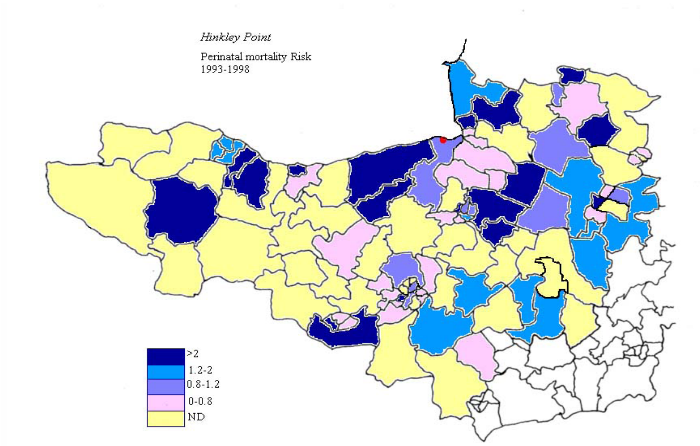

Table 1. Total births in the study area for the two periods 1993-98 and 1999-2005 with overall rates of infant and neonatal mortality and still births compared with England and Wales rates 1997.

	1993-1998 (6y)	Rate 93-98 Per 1000	1999-05 (7y)	Rate 99-05 Per 1000	E & W 1995 Rate/1000	E & W 2002 Rate/1000
Live Births	19097		21687			
Infant	79	4.13	96	4.42	6.1	5.3
Neonatal	51	2.67	71	3.27	4.1	NA
*Stillbirth	101	5.29	NA	NA	5.52	NA

*Stillbirth data not available after 2001. In 1995, the Infant Mortality Rate for all Somerset was 3.2/1000; in 2002 it was 4.2/1000

Burnham on Sea North

Overall results for the two periods are given in Tables 2 and 3 below. There was a significantly high level of neonatal (0-28days) mortality in the first period but no infant mortality in the second period.

Table 2 Total births, infant and neonatal mortality and stillbirths in Burnham-on-Sea North 1993-1998. Also given is the sex ratio, the number of boys born per 1000 girls.

	Number Persons	*Sex Ratio M/F	Rate/1000 livebirths	Relative Risk O/E	P-value (Poisson)
Live births	225	1163	-	-	-
Infant deaths	4	-	17.7	4.3	0.01
neonatal	4	-	17.7	6.7	0.003
stillbirths	0	-	0	-	-

*Sex ratio in England and Wales was 1055 in 1996 and is generally stated to be 1055 males per 1000 females with a Standard Deviation of 2.6

Table 3. Total births, infant and neonatal mortality in Burnham-on-Sea North 1999-2005. Also given is the sex ratio, the number of boys born per 1000 girls.

	Number Persons	*Sex Ratio M/F	Rate/1000 livebirths	Relative Risk O/E	P-value (Poisson)
Live births	304	1187	-	-	-
Infant deaths	0	-	0	0	0
neonatal	0	-	0	0	0

*Sex ratio in England and Wales was 1055 in 1996 and is generally stated to be 1055 males per 1000 females with a Standard Deviation of 2.6.

Comparison by distance bands from Steart Flats

The distances of the centroids of the wards from the centre of the Steart Flats were determined using the GIS program ARCVIEW. Then wards within 18km were aggregated into 3 groups according to these distances 0-6, 6-12 and 12-18km. Relative Risks were determined for each aggregated group. Results are shown in Table 4 for the period 1993-1998 and a plot with an exponential fit of the Relative Risks (based on the whole area rates for the period) in Fig 4.

The numbers of cases in the 18km study radius circle were too low for statistical significance of the trend line either using Chi-square for linear trend or Poisson regression ($p = 0.09$) but a Poisson regression analysis for the whole area for the period 1993-98 was carried out and showed a significant trend (see below).

In the period 1999-2005, the trend in infant mortality was flat (see Table 5) but stillbirths were not available after 2001.

Table 4. Births, Infant and Perinatal Mortality and Relative Risks in wards with centroids in radial band areas by distance from the centre of the Steart Flats near Hinkley Point Nuclear site 1993-1998.

Distance (N) wards	Obs: Inf (births)	Expect: Infant	RR inf. (p-value)	Obs: Perinatal	Exp: Perinatal	RR peri. (p-value)
0-6 (5)	11 (1415)	5.8	1.9 (0.03)	14	11.3	1.24 (NS)
6.1-12 (9)	10 (1580)	6.5	1.54 (NS)	17	12.6	1.35 (NS)
12.1-18 (15)	12 (3602)	14.9	0.81 (NS)	32	29	1.1 (NS)
18.1+ (74)	46 (12500)	51	0.9 (NS)	89	99	0.9 (NS)

Table 5. Births, and Infant Mortality and Relative Risk in wards with centroids in radial band areas by distance from the centre of the Steart Flats near Hinkley Point Nuclear site 1999-2005.

Distance (N) wards	Obs: Inf (births)	Expect: Infant	RR inf. (p-value)
0-6 (5)	7 (1555)	6.9	1.01 (NS)
6.1-12 (12)	14 (3695)	16.3	0.86 (NS)
12.1-18 (9)	11 (2237)	10	1.1 (NS)
18.1+ (67)	64 (13960)	62	1.03 (NS)

Coastal and estuary wards

We aggregated wards on the basis of their proximity both to the tidal River Parratt the estuary and to the sea coast and compared these wards with the inland ones. For the initial analysis we set up a coastal/ tidal category which had all the wards which were either adjacent with the sea or along the tidal section of the River Parratt as far as Bridge water. Infant mortality results are shown in Table 6. Interestingly, the clear effect present in the first period was missing in the second period. Table 7 gives these results. In order to further investigate these results and to examine what was driving the effect, we localized the examination to the outer estuary wards and compared the infant mortality trend in these wards with the trend in the inland wards. The trend in infant mortality in these two areas, represented as Relative Risk, based on Somerset rates, are shown in Fig 5 where we have also shown LOESS regression fits of the two datasets. The wards are given in Table 8, the numbers in Table 9 and the statistics in Table 10.

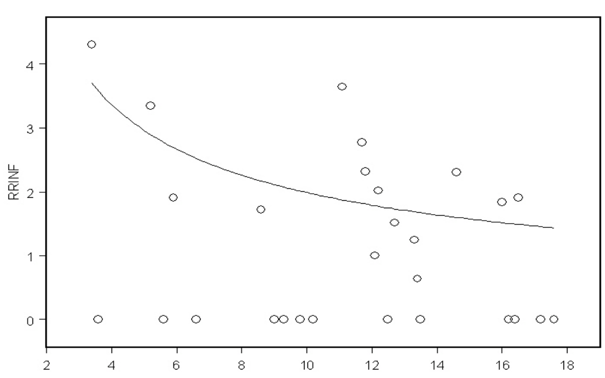

Figure 4. Exponential fitted line and Relative Risk of Infant Mortality by ward and distance from Steart Flats 1993-1998 in the restricted 18km radius area.

Table 6. Infant mortality in coastal/ estuary and inland wards 1993-1998.

	N wards	Births	Infant deaths	Expected	RR (p-) 95%CI
Coast	26	4859	33	21.5	1.53 (0.01)
Inland	77	14238	46	62.9	0.73
Test of Coast vs. Inland	OR = 2.1 P = 0.001; 95% C.I. is 1.34<OR<3.27 (Mantel Haenszel)				

Table 7. Infant mortality in coastal/ estuary and inland wards 1999-2005

	N wards	Births	Infant deaths	Expected	RR (p-)
Coast	24	5162	25	22.8	1.1 (NS)
Inland	69	16285	71	71.9	0.98
Test of coast vs. inland	Not significantly different				

Fig 5 Trend in infant mortality risk by years 1993-2005 comparing the estuary (blkue) wards near Hinkley Point (listed in Table 9) with all the inland (red) wards. Upper: LOESS fitted line. Note high value in 1996. (Estuary: circles and black line; inland: triangles and red line.)

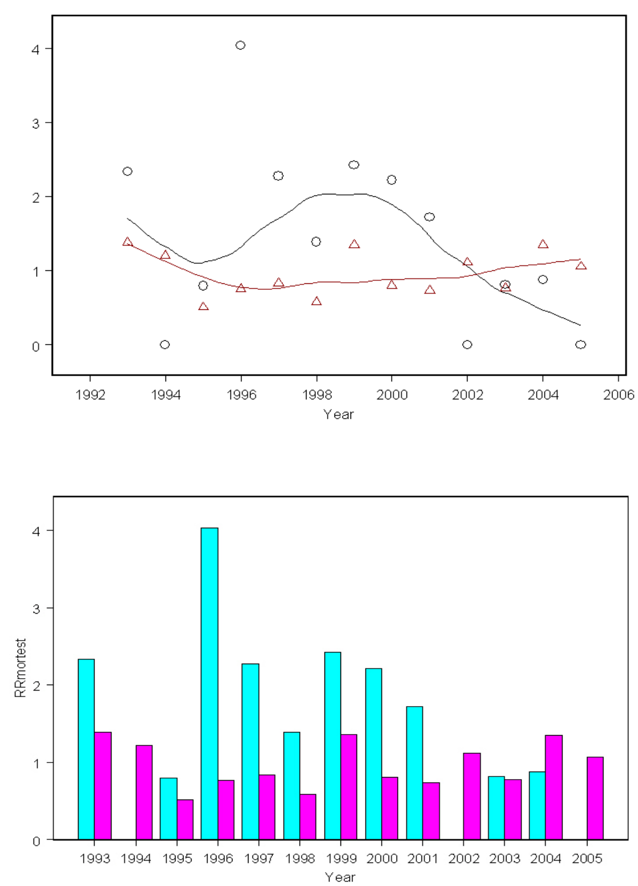

Table 8. Estuary wards. In period 2 (1999-2005) there were boundary changes and new wards were defined. We have employed these where this has occurred.

Ward	Period (1993-8 = 1)
Cannington and Combwich	1
Cannington and Quantocks	2
Huntspill	1
Huntspill and Pawlett	2
Highbridge	1, 2
Burnham North	1,2
Burnham South	1,2
Berrow	1,2
Brent	1
Brent North	2

Table 9. Infant mortality trend in estuary wards (Table 8) and inland wards by year. We should expect about 1.25 deaths per year in the estuary wards (on 300 births) and11.8 deaths inland on 2800 births.

Year	Estuary		Inland	
	Births	Infant deaths	Births	Infant deaths
93	306	3	3081	18
94	310	0	2932	15
95	300	1	2755	6
96	295	5	2800	9
97	314	3	2829	10
98	343	2	2832	7
99	295	3	2450	14
00	322	3	2363	8
01	277	2	2250	7
02	256	0	2337	11
03	292	1	2454	8
04	272	1	2463	14
05	284	0	2459	11

Table 10. Statistical test of Estuary vs Inland (Mantel Haenszel, Chi-square, 95% Confidence intervals and p-values).

Period	Odds Ratios, (95%CI), p-value
93-05	OR = 1.53 (0.99<OR<2.35) p = 0.053
96-01	OR = 2.74 (1.61<OR<4.65) p = 0.0001

Poisson regression and the effect of distance and also deprivation

Coefficients of overall deprivation are available from various sources. In the past we have employed Social Class by census ward as a weighting when examining cancer mortality risk [18-20]. In this study we use the more recent Index of Multiple Deprivation, which is available from ONS for each pre- 1999 census ward. Since it is generally found that infant mortality and deprivation are correlated, we ran Poisson Regression modeling infant mortality (DEATHS) on Deprivation (DEPP) and also on distance from the Steart Flats (FROMBAY) for the period 1993-98. Results, which showed a significant effect for distance from the Steart Flats (p= 0.015), but no effect for Deprivation are given in Table 11.

The regression equation was of the usual form:

Log (DEATHS/BIRTHS) = alog (FROMBAY) + blog (DEPP) + Intercept

Table 11. Poisson Regression results for analysis of infant mortality by distance from Steart Flats (BAYDIST) and Deprivation (DEPP) for all wards in the 1993-1998 period.

Coefficients:	Value:	Std Error	t-value	ANOVA Pr (Chi)
(Intercept)	-5.22615206	0.43581618	-11.9916431	-
FROMBAY (a)	-0.02630337	0.01252011	-2.1008888	0.0156347
DEPP(b)	0.01204164	0.01222829	0.9847358	0.3290212

Discussion

Radiation and infant mortality

The association between increased infant mortality and exposure to internal fission product radionuclides at the time of atmospheric testing 1955-1965 was first pointed out by Sternglass [14] but has been disputed in that context by others [25, 26]. In 1992 the issue was reopened in a paper in the British Medical Journal by Robin Whyte [15] who argued that there was a real environmental effect in the period 1959-63 in the USA and also in England and Wales [15]. In rodents, exposure to Strontium-90, caused foetal death [27, 28]. More recently, infant mortality effects have been found in Germany and in the former Soviet Union following the radiation exposures of the Chernobyl accident [29-31]and the atmospheric nuclear tests [32]. The risk agencies e.g. UNSCEAR [33] do not consider infant mortality as a radiation effect either from exposure to weapons fallout nor the Chernobyl exposures. The ECRR on the other hand [1] has provisionally allowed for the effect of radiation on infant mortality and stillbirths and based its risk factor on a 14% increase per mSv (as calculated by the conventional ICRP risk model).

Infant mortality as an end point for mutagenic effect is of course epidemiogically difficult [34]. The reason is simple. The foetus can only sustain a certain level of damage, and high levels of damage cause miscarriages. Therefore the dose response has to be biphasic: increasing the dose beyond a certain point can cause a decrease in infant mortality. Of course this may also be accompanied by a decrease in birth rate, and this has been reported in the period 9 months following the Chernobyl accident [35]. With regard to nuclear sites, Mangano et al have shown effects in down winders and significantly also that these effects cease after the plants are shut [36]. Mangano et al's study is relevant to the present one. Subsequent to 1987, 8 U.S. nuclear plants located at least 113 km from other reactors ceased operations. Strontium-90 levels in local milk declined sharply after closings. But so did deaths among infants who had lived downwind and within 64 km of each plant. These reductions occurred during the first 2 yr that followed closing of the plants, were sustained for at least 6 yr, and were especially pronounced also for birth defects. Trends in infant deaths in proximate areas not downwind, and more than 64 km from the closed plants, were not different from the national patterns.

Hinkley Point and Cancer

As outlined in the introduction, we set out to examine infant and perinatal mortality near the Hinkley Point nuclear site because we had previously examined cancer rates in the same area of north Somerset and found a significant excess risk, particularly of breast cancer, in those living near the contaminated offshore intertidal sediment [18-21]. There was a decreasing (though non-statistically significant) trend in risk by distance from the mud bank known as the Steart Flats between 1995-1998 for 'All malignancy', Prostate, Lung and Breast cancer and the highest risk, for breast cancer, was found to be in the ward of Burnham North, downwind from the mud bank. Incidence statistics at the ward level are not made available for research and so a small area questionnaire study was carried out with a local group, Parents Concerned About Hinkley, PCAH. Results confirmed the breast cancer excess and showed also an excess in leukemia, cervical and kidney cancer [21]. The Somerset Coast Primary Care Trust commissioned the South West Cancer Intelligence Service (SWCIS) to follow this with their own examination of the cancer incidence in the area [37]. Despite the criticisms of COMARE [22] the SWCIS findings showed that the PCAH survey of Burnham North had accurately determined the rates of breast cancer and also leukemia, but the author of the SWCIS study, Dr Julia Verne, argued that the effect was one of chance and was not related to exposures from the plant or contaminated mud [37].

Nevertheless, there appeared to be an increased risk of cancer in those who lived near the contaminated estuary and offshore mudflats and the effect was greatest in Burnham North where it was statistically significant for breast cancer mortality. And it was also true that earlier studies of child leukemia in the area made by Somerset Health Authority had found that there was significantly high child leukemia near the Hinkley Point plant [38]. Also a study published by Alexander et al in 1990 had associated increased child leukemia with living near estuaries [23]. It is, of course, true that the mortality studies will have included a small number of individuals who had moved into the area over the period of the study or just before their death and that there was no way of adjusting for this. This also raises the question of the time lag between exposure and clinical expression of cancer. However, since the radiation exposures that cause cancer (by damaging genetic material) also causes infant deaths (by damaging genetic material) it is not unreasonable to want to see if there might be increased infant mortality in the same area where previously we and SWCIS found increased cancer risk. The exposures that cause infant mortality increases operate over less than a year, and so the question of whether the individuals had moved into the area is not an issue.

Infant mortality

We turn to the results. The sequence of investigation began with the largest area and then attempted to move forward a step at a time to see what was driving the effects we found. So having noted a significant effect by distance from the mud bank, we then looked to see if it was a general coastal effect or an estuary effect. After refining the study to look at the estuary we looked to see which wards carried the highest risk, and which years carried the highest risk. This sequence is summarized with the results in Table 12.

First, we were unable to examine stillbirths throughout the whole period since these data were no longer made available after 2001. We will examine each result of our study in turn. The study area consisted of 103 wards with 19097 births between 1993 and 1998 and 21697 births in 93 wards between 1999 and 2002. There were 79 infant deaths including 51 neonatal (0-28 day) deaths in 1993-98 and 96 infant including 71 neonatal deaths in 1999-2005. These define rates of 4.13 and 4.42 infant deaths per 1000 live births, slightly under the England and Wales mean for the period of 5.2 infant deaths per 1000 live births. The rate for stillbirths in the first period was 5.29 per 1000 live and dead births.

The infant and perinatal mortality results for the period 1993-1998, that is in the pre 1999 wards, were mapped by risk level (Figs 1 and 2). These maps suggest a clustering of risk near the coast, and this is confirmed in the case of infant mortality in this period by the aggregation of wards into radial distance bands of 6km depth. Table 4 shows that in the first period, based upon the rates for the whole area, there was a falling off of risk as we move away from the putative point source with the highest risk for infant mortality of 1.9 in the 5 wards which are within the 6km centroid band (a statistically significant effect with Poisson p = 0.03). The trend line is fitted to the individual ward risk points using an exponential regression in Fig 4. The overall trend was not significant however, probably because of the low numbers of deaths. Perinatal mortality risk was also higher in the 0-6km strip and lowest in the area outside the 18km radius chosen for the examination. In both cases the linear trend in proportions was not statistically significant.

We then examined Infant Mortality in the first period 1993-1998 by distance from the putative point source, the Steart Flats, using Poisson Regression. In this approach we also included deprivation as a covariate and used the whole of the area, rather than the restricted area near the point source, in order to bring in more cases. For this we employed the ONS Index of Multiple Deprivation (see www.ons.gov.uk). The result was that there was a significant correlation between distance from the point source (p = 0.016, Table 12) but no effect in relation to deprivation. It is quite interesting that in this location, infant mortality is not driven in any way by deprivation, or at least we can say that the main source of infant death is not deprivation.

The trends seen in the first period were not apparent in the second period after 1999 as we show in Table 4; Poisson regression for the second period also showed no significant effects on distance. Using Hinkley Point Nuclear Power Station as the centre of risk gave no significant result either by the concentric ring aggregation approach or by Poisson Regression. We have not recorded these negative results here but it should be borne in mind that we would not predict an effect centered in the nuclear power plant since the radioisotopes accumulate in the mud following their dispersion from the plant and in our hypothesis, it is the mud that is the source of risk.

To try and tease out the driver of these interesting results we looked at the wards which were proximal to the sea combined with those which were estuary wards. We included all the seaside wards and also those which bordered on the tidal section of the River Parratt as far inland as Bridgwater. Results showed a highly significant effect when these were tested against the inland wards for the first period 1993-1998 (Odds Ratio = 2.1 CI (1.34<OR<3.27) p = 0.001) Table 6. Again, there was no significant effect in the period 1999-2005.

The effect was clear in Burnham-on-Sea North, as we show in Table 2. The Relative Risk for Infant Mortality was 4.3 (p = 0.01 in the period 1993-98 and for neonatal mortality was 6.7 (p = 0.003). Again this effect did not persist into the later period 1999-2003 (Table 3). In order to follow up on whether there was a genetic effect on the birth outcomes we calculated the Sex Ratio (SR, the number of males born per 1000 females). The sex ratio SR is considered to be a good indicator of genetic damage from radiation. A discussion of its use in the Hiroshima survivors is given in reference [24], and Sherb et al [16] have shown variation in sex ratio with distance from the point source in a study of German nuclear power stations.

Table 12. Identifying the main driver for infant mortality risk in North Somerset wards 1993-2005 by distance from Steart Flats mud bank.

Area and period tested	Test and Result	Conclusion
1. All pre 1999 wards 93-99	Radial 6km rings show continuous reduction in risk; inner risk p = 0.03	1. Effect near the mud bank before 1999
2. All post 1999 wards: 99-05	Radial 6km rings do not show continuous reduction in risk	2 Effect not there after 1999
3. All pre 1999 wards 93-99 Poisson Regression on distance	Significant Regression line on distance p = 0.015; no effect for deprivation	3. Too few cases for significance in 18km ring but significant with all the wards using Poisson Regression
4. All post 1999 wards: 99-05	Regression not statistically significant; deprivation not available for wards	4. No effect in second period after 1999
5. Coastal and estuary wards vs. the rest pre 1999 wards	Statistically greater risk; OR = 2.1; (1.34, 3.27)	5. Effect increases if we look at coastal and estuary wards before 1999
6. Estuary wards only vs. the rest pre-1999	Statistically greater risk than for the coastal and estuary wards	6. Effect increases if we look at the estuary wards
7. Trend by year in estuary wards	Pinpoints increase in risk beginning in 1996 and ending in 2001	7. Effect is due to an increase in 1996 which falls off by 2001
8. Estuary wards only vs. the rest between 1996 and 2001	Effect is driven by the increase in the estuary wards between 1996 and 2001; OR = 2.74 (1.61, 4.65) p = 0.0001	
9. Burnham on Sea	Burnham on Sea shows the highest Risk in the period of high risk above; RR = 4.3 (vs whole of study area; p = 0.01)	8. Whatever is causing the effect is close to or upwind of Burnham on Sea and began in 1994/1995

The number of boys increases closer to the plants, as we find here. Sex ratio should not differ significantly from 1055. In Burnham it is as high as 1163 and this persists to the second period. More boys are being born: this is exactly what happened after Hiroshima in the city entrants (those who entered after the bomb) and it follows irradiation of the mothers by internal radioactivity and it is also what was found by Scherb et al near nuclear sites, after the weapons fallout and after Chernobyl [16].

To further examine the reason why there was a clear effect in the first but not second period we next focused on the estuary wards only. These 11 wards are given in Table 8. In Table 9 and 10 the infant mortality trend analysis suggests the explanation. As Fig 5 shows, the trend in infant mortality shows that levels increased sharply around 1996 and persisted until 2001. In 1996 there were 5 infant deaths in the 295 births in the estuary wards compared with 9 deaths in the 2800 births in the rest of the area (OR = 5.3 ($1.75<OR<15.4$) $p = 0.0009$). Taking the whole period 1996-2001 there were much higher risks in the estuary wards than the inland wards OR = 2.74 (1.61, 4.65) $p = 0.0001$. Thus it is these estuary wards rather than the coastal wards that drive the effect and Burnham-on-Sea where the effect is greatest. From the map it is clear that Burnham-on-Sea, and particularly the north ward has the largest population close to the mud flats and also directly downwind of the plant. The Hook of the south bank of the estuary funnels the wind directly to the Burnham North ward. We feel that this is the result which explains the other findings and possibly also the later increases in cancer which we discovered in the same ward areas in earlier studies. These results suggest that some radiation release from the nuclear plant occurred around 1995 which resulted in accumulation of radioactivity in the sediment of the Steart Flats and increased exposures to people living near the estuary wards and mainly those in Burnham North.

Conclusion: sources of radiation from the plant activities

Both infant mortality in the estuary wards and cancer rates in Burnham North remained high for some years. Again, it is hard to avoid the most likely explanation for all of these findings. That is that there was some exposure to a harmful mutagenic agent released around 1995 to the estuary of the River Parratt which affected individuals who lived in these wards. Since the only source of such an agent in the area known to us is the nuclear power station at Hinkley Point we tentatively conclude that there was a release of radioactivity in 1995, and that this is the cause both of the infant mortality and the subsequent cancer. Traces of such a release may yet remain in the environment e.g. in tree rings, mud cores, house dust etc.

There are three interesting possibilities in connection with Hinkley Point as a putative source.

(1) The period before 1999 when the main infant mortality effects were found also corresponds with the operation of the Hinkley Point A Magnox nuclear power station which reduced and finally halted operation in May 2000. Magnox stations have graphite cores cooled by Carbon Dioxide gas and release large amounts of radioactive noble gases, Krypton-85 and Argon-41. In fact the Hinkley A station released more radioactive noble gases in the period 1990-1997 than any other UK nuclear power station, roughly 3,000,000 GBq per annum (compare Hinkley B that releases about 40,000GBq/a) [39]. This is a large amount of radioactivity. These dense radioactive noble gases are released upwind of Burnham-on-Sea and roll along the mud flats toward the town, dissolving in the muddy silt and in any non-aqueous material to build up a reservoir. They will be inhaled as gases or adsorbed on particles. It may be significant that after the closure of Hinkley A the infant mortality rate downwind fell sharply and in Burnham on Sea there were no infant deaths after Hinkley A closed and there were no more exposures to the high local levels of radioactive noble gases. This is an effect similar to that reported by Mangano et al.[36] in the United States.

(2) Prior to 1995 there were three nuclear waste incinerators operating on the Hinkley site; they were "PUP" incinerators which had no filtration and were shut down in 1995 when activists were attempting to prevent a fourth large (filtered output) incinerator being built on the site to burn waste from Hinkley and also from the Trawsfynydd reactor in Wales which had just been closed down. At the time, (1995) one of the workers who was retiring contacted Jim Duffy of Stop Hinkley and told him that when waste was sent for burning at the PUP incinerators only the outer drums were monitored. The inner drums contained intermediate level waste which was burned with the low level waste in the outer drums. This operative refused to allow his name to be used as he was concerned about his pension and would not go public for the same reason: however he was concerned about what was being done.

(3) There was a release of 2 tons of radioactive carbon dioxide and radioiodine vented to the atmosphere in two separate accidents in October 1994 [40]. Nuclear Electric, the operators, were fined £220,000 in a case brought by Her Majesty's Inspectorate of Pollution. Exposures would thus have been to parents in October 1994, effects would have been seen in those born 9-12 months later (due to the delay in effects on sperm development). These children, born in Oct 1995 would have been aged 0-1 in 1996 when the peaks in infant mortality occurred in the estuary wards.

So any of these circumstances may be relevant, but the accidental release in late 1994 seems to line up with the increases in infant mortality in the area. We feel that it is not likely that both the infant mortality increases and cancer trends also both with time and with specific location, near a nuclear site and polluted environment are the result of chance, although this is conceivable.

Alternatively, it is fair to say that if there were evidence of some chemical exposure in 1995 which was severe enough to mainly affect Burnham on Sea but also cause problems in the other estuary wards, then this would have to be a possible explanation. There is, however, no evidence of such a major event, and indeed no large chemical site in the vicinity.

Infant mortality is a valuable indicator of environmental pollution, and these results imply that it may be used to signal possible unreported historical pollution events which could then also be investigated in other ways. Access to ward level cancer incidence data, and also stillbirth data, both of which are presently restricted, would make the matter of ascribing causes to such ill health more easy and would therefore make it more difficult for industry to discharge harmful substances into the environment. The Policy Information Network on Child Health and Environment PINCHE (www.pinche.org) concluded that a routine computer-based real time monitoring of all ward level health data would be straightforward and would enable rapid determination of risk from pollution sources [41]. Infant mortality would seem to be a valuable component of such a scheme.

Acknowledgements

The NGO Stop Hinkley contributed £1200 toward this study.

References

1. Scott Cato M, Busby C, Yablolov AV, Schmitz Feuerhake I, Bertell R. ECRR2010: The 2010 Recommendations of the European Committee on Radiation Risk. The Health Effects of Ionizing Radiation at Low Doses and Low Dose Rates. Brussels: ECRR; Aberystwyth Green Audit. 2010, 22-27.

2. Beral V, Bobrow M, Roman E. Childhood cancer and nuclear installations. London BMJ. 1993, 25(16).

3. Urquhart T D, Black R T, Muirhead M T, L Sharp, M Maxwell et al. Case-control study of leukaemia and non-Hodgkins lymphoma in children in Caithness near the Dounreay nuclear installation. British Medical Journal. 1991, 302(6778): 687-692.

4. Viel J-F, Poubel D, Carre A. Incidence of leukaemia in young people and the La Hague nuclear waste reprocessing plant: a sensitivity analysis. Statistics in Medicine. 1995, 14(21-22): 2459-2472.

5. Busby C, M Scott Cato. Death Rates from Leukemia are Higher than Expected in Areas around Nuclear Sites in Berkshire and Oxfordshire', British Medical Journal; 1997, 315(7103): 309

6. Gardner M J, Snee M P, Hall A J, Powell C A, Downes S, T et al. Results of Case Control Study of Leukemia and Lymphoma among Young People near Sellafield Nuclear Plant in West Cumbria. British Medical Journal. 1990, 300(6722): 423-429.

7. Bowie C, Ewings P D. Leukaemia incidence in Somerset with particular reference to Hinkley Point, Taunton Somerset Health Authority. 1988.

8. Kaatsch P, Spix C, Schulze-Rath R, Schmiedel S, Blettner M. Leukaemias in young children living in the vicinity of German nuclear power plants. Int J Cancer. 2008, 122(4): 721-726.

9. Sermage-Faure Claire, Laurier Dominique, Goujon-Bellec Stéphanie, Chartier Michel, Guyot-Goubin et al. Childhood leukemia around French nuclear power plants—The geocap study, 2002–2007. International Journal of Cancer Volume. 2012, 131(5): E769–E780.

10. Busby Christopher. Breast Cancer Mortality in Estuary Wards near Bradwell Nuclear Power Station, Essex, UK 2001-1995 . Jacobs Journal of Epidemiology and Preventive Medicine. 2015, 1(1): 005.

11. Busby, Christopher. de Messieres, Mireille. Cancer near Trawsfynydd Nuclear Power Station in Wales, UK: A Cross Sectional Cohort Study. Jacobs Journal of Epidemiology and Preventive Medicine. 2015, 1(1):07;

12. Busby Christopher. Epidemiology and the Effects of Radioactive Contamination: Time for a New Approach. Jacobs Journal of Epidemiology and Preventive Medicine. 2015, 1(1): 03.

13. Busby Chris, Lengfelder Edmund, Pflugbeil Sebastian, Schmitz Feuerhake Inge. The evidence of radiation effects in embryos and fetuses exposed by Chernobyl fallout and the question of dose response. Medicine, Conflict, Survival. 2009, 25(1): 18-39.

14. Sternglass EJ. Environmental Radiation and Human Health. In Proceedings of the 6th Berkeley Symposium on Mathematical Statistics and Probability Ed—Neyman J Berkeley California University of California Press. 1971, 6: 145-221.

15. Whyte R.K. First Day Neonatal Mortality since 1935: A Re-examination of the Cross Hypothesis. British Medical Journal. 1992, 304(6823): 343-346.

16. Scherb H, Voigt K. The human sex odds ratio at birth after the atmospheric Atomic Bomb tests, after Chernobyl and in the vicinity of nuclear facilities. Envir Sci Polllut Res. 2011, 18(5): 697-707.

17. Busby C.C. Very Low Dose Fetal Exposure to Chernobyl Contamination Resulted in Increases in Infant Leukemia in Europe and Raises Questions about Current Radiation Risk Models. International Journal of Environmental Research and Public Health. 2009, 6(12): 3105-3114.

18. Busby C, Dorfman P, Rowe H. Cancer mortality and proximity to Hinkley Point Nuclear Power Station in Somerset: Part 1 Breast Cancer. Occasional Paper 2000/2 Aberystwyth UK Green Audit. 2000.

19. Busby C, Dorfman P, Rowe H. Cancer mortality and proximity to Hinkley Point Nuclear Power Station in Somerset: Part 2 Prostate Cancer. Occasional Paper 2000/3 Aberystwyth UK Green Audit. 2000.

20. Busby C, Dorfman P, Rowe H. Cancer mortality and proximity to Hinkley Point Nuclear Power Station in Somerset: Part 3. All malignancy lung and stomach cancer Occasional Paper 2000/4 Summary Aberystwyth UK Green Audit. 2000.

21. Busby C, Rowe H. Cancer in Burnham on Sea North Results of the PCAH questionnaire. Occasional paper 2002/5 Aberystwyth UK. Green Audit. 2002.

22. Committee on Medical Aspects of Radiation n the Environment COMARE. Re-revised statement on Green Audit Occasional Paper 2002/5. Cancer in Burnham on Sea North Results of the PCAH (Parents Concerned about Hinkley) Questionnaire. 2004.

23. Alexander F E, Cartwright R A, McKinney P A, Ricketts T J. Leukemia Incidence, Social Class and Estuaries: an Ecological Analysis. Journal of Public Health Medicine. 1990, 12(2): 109-117.

24. Busby Chris. Wolves of Water A Study Constructed from Atomic Radiation, Morality, Epidemiology, Science, Bias, Philosophy and Death. Aberystwyth Green Audit 2006.

25. Lindop P, Rotblat J. Strontium-90 and infant mortality. Nature. 1969, 224(5226): 1257-1264.

26. Nishiwaki Y, Yamashita H, Honda Y, Kimara Y, Fujimori H. Effects of radioactive fallout on the pregnant woman and Fetus. International Journal of Environmental Studies. 1972, 2(1-4): 277-289.

27. Luning K G, Frolen H, Nelson A, Roennbaeck C. Genetic Effects of Strontium-90 injected into male mice. Nature. 1963, 197: 304-305.

28. Smirnova E I, Lyaginska A M. Heart Development of Sr-90 Injured Rats, in Y I Moskalev and Y I Izd (eds) Radioaktiv Izotopy Organizs (Moscow: Medizina). 1969, 348.

29. Petrova A, Gnedko T, Maistrova I, Zafranskaya M, Dainiak N. Morbidity in a large cohort study of children born to mothers exposed to radiation. Chernobyl Stem cells. 1997, 15(Suppl 2): 141-150.

30. Grosche B, Irl C, Schoetzau A, van Santen E.Perinatal mortality in Bavaria, Germany, after the Chernobyl reactor accident.Radiat Environ Biophys. 1997, 36(2):129-36.

31. Korblein A. Perinatal mortality in West Germany following atmospheric nuclear weapons tests. Arch Environ Health. 2004, 59(11): 604-609.

32. Scherb H, Weigelt E, Bruske-Hohlfeld I. Regression analysis of time trends in perinatal mortality in Germany 1980-1993. Environ.Health Perspect. 2000, 108(2): 159-165.

33. UNSCEAR. Sources and Effects of Ionizing Radiation Vol 1 Sources. New York United Nations. 2000.

34. Doll R. Hazards of the first nine months: an epidemiologist's nightmare. J Ir Med Assoc. 1973, 66(5): 117-126.

35. Bentham G. Chernobyl Fallout and Perinatal Mortality in England and Wales. Social Science Medicine. 1991, 33(4): 429-434.

36. Mangano J J, Gould J M, Sternglass E J, Sherman J D, Brown J et al. Infant death and childhood cancer reductions after nuclear plant closings in the United States. Arch Environ Health 2002, 57(1): 23-31.

37. SWCIS. Cancer incidence in Burnham North, Burnham South, Highbridge and Berrow, 1990-1999. by Julia Verne Taunton: SWCIS. 2003.

38. Ewings PD, Bowie C, Phillips MJ, Johnson SA. Incidence of leukemia in young people in the vicinity of Hinkley Point Nuclear Power station 1959-86. BMJ Clinical Research. 1989, 299(6694): 289-283.

39. UNSCEAR. 2000.

40. Burnham and Highbridge Weekly News 20 Oct 1995.

41. Van den Hazel P, Zuurbier M, Bistrup M L, Busby C, Fucic A, Koppe JG. Policy and science in children's health and environment: Recommendations from the PINCHE project. Acta Paediatrica S. 2006, 95(453): 114-119.

APPENDIX A.

Wards used in the analysis.

1993-1998	1999-2005
Cannington and Combwich	2Cannington and Quantocks
Central	2East Poldens
Dowsborough	2Bridgwater Eastover
East Poldens	2Bridgwater Hamp
Eastern Quantocks	2Huntspill and Pawlett
Eastover	2North Petherton
Hamp	2Puriton
Huntspill	2Bridgwater Quantock
Newton Green	2Sandford
North Petherton	2Bridgwater Sydenham
Parchey	2Bridgwater Victoria
Pawlett and Puriton	2West Poldens
Quantock	2Woolavington
Sandford	2Alcombe East
Sowey	2Alcombe West
Sydenham	2Aville Vale
Victoria	2Carhampton and Withycombe
West Poldens	2Crowcombe and Stogumber
Westonzoyland	2Dulverton and Brushford
Woolavington	2Minehead North
Alcombe	2Minehead South
Aville Vale	2Old Cleeve
Carhampton and Withycombe	2Porlock and District
Crowcombe and Stogumber	2Quantock Vale
Dulverton and Brushford	2Watchet
Dunster	2West Quantock
Holnicote	2Williton
Minehead North	2Burrow Hill
Minehead South	2Curry Rivel
Old Cleeve	2Islemoor
Porlock And Oare	2Langport and Huish
Quantock Vale	2Martock
Watchet	2Turn Hill
West Quantock	2Wessex
Williton	2Blackdown
Burrow Hill	2Neroche
Curry Rivel	2Dulverton and Brushford
Islemoor	2Quarme
Langport and Huish	2Bishop's Hull
Martock	2Bishop's Lydeard
Turn Hill	2Bradford-on-Tone
Wessex	2Comeytrowe
Blackdown	2Milverton and North Deane
Neroche	2Monument
Dulverton and Brushford	2Neroche
Exmoor	2Blackdown
Haddon	2North Curry
Quarme	2Norton Fitzwarren
Bishop's Hull	2Ruishton and Creech
Bishop's Lydeard	2Staplegrove
Bradford-on-Tone	2Stoke St. Gregory
Comeytrowe	2Taunton Fairwater
Milverton	2Taunton Halcon
Monument	2Taunton Blackbrook and Holway
Neroche	2Taunton Lyngford
Blackdown	2Taunton Manor and Wilton
North Curry	2Taunton Pyrland and Rowbarton
North Deane	2Trull
Norton Fitzwarren	2Wellington North
Ruishton and Creech	2Wellington Rockwell Green and
Staplegrove	2Wiveliscombe and West Deane
Stoke St. Gregory	2West Monkton
Taunton Fairwater	2Axbridge
Taunton Halcon	2Axe Vale
Taunton Holway	2Berrow
Taunton Lyngford	2Brent North
Taunton Manor	2Burnham North
Taunton Priory and Wilton	2Burnham South
Taunton Pyrland	2Cheddar and Shipham
Taunton Rowbarton	2Highbridge
Taunton Trinity	2Wedmore and Mark
Trull	2Avalon
Wellington North	2Glastonbury St Benedict's
Wellington Rockwell Green	2Glastonbury St Edmund's
Wellington South	2Glastonbury St John's
West Deane	2Glastonbury St Mary's
West Monkton	2Moor
Wiveliscombe	2Rodney and Priddy
Axbridge	2Street North
Axe Vale	2Street South
Berrow	2Wells Central

Brent	2Wells St Cuthbert's
Burnham North	2Wells St Thomas'
Burnham South	2Bridgewater bower
Cheddar	2Knoll
Highbridge	2Taunton killams and mountfield
Mark	2Wellington east
Shipham	2Illminster
Wedmore	2Knowle
Avalon	2Kings isle
Ebbor	2Street west
Glastonbury St. Benedict's	2St Cuthberts out N and West
Glastonbury St. Edmund's	2Hutton and Locking
Glastonbury St. John's	
Glastonbury St. Mary's	
Moor	
Rodney	
Sheppey	
Street North	
Street South	
Wells Central	
Wells St. Cuthbert's	
Wells St. Thomas	