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# Jacobs Journal of Epidemiology and Preventive Medicine

Research Article

## Breast Cancer Mortality in Estuary Wards near Bradwell Nuclear Power Station, Essex, UK 2001-1995

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Received: 04-28-2015

Accepted: 05-06-2015

Published:



### Abstract

Ecological studies near point sources of risk are generally modelled by distance bands involving data from small areas fitted into convenient radial area divisions. In contradistinction, this study examines risk of dying of breast cancer between 1995 and 2001 in wards adjoining the estuary of the River Blackwater in Essex, UK where measured radionuclide contamination exists in muddy sediment and other material, derived from discharges from the Bradwell Nuclear Power station. Estuary wards are compared with inland wards using Social Class adjusted expected numbers based on national mortality rates for the period. Results show a significant effect with relative risk for the River Blackwater Estuary vs. other wards with Relative Risk RR = 1.7 (CI 1.22, 2.34; p = 0.0015) based on 144 breast cancer deaths in 42,579 women. In addition, the contaminated Blackwater wards are compared with the wards of the River Crouch, a similar muddy estuary to the south but separated by a large sandbank, and therefore not contaminated. For this comparison, involving 84 deaths, RR = 2.1 (CI 1.12, 3.98; p = 0.018). Finally, two towns, Maldon, on the Blackwater and Burnham on the River Crouch were compared using 44 deaths, the results gave RR = 2.1 (1.02, 4.15; p = 0.04).

Use of the concentric circle radial approach and employing 4km and 17km radii gave no effect, RR = 1.06 (0.47, 2.38; p = 0.89), showing that the choice of ecological dispersion is critical to the result.

**Keywords:** Radiation; Nuclear; Estuary; Sea-To-Land; Sediment; Breast Cancer; Leukemia

### Introduction

#### Epidemiological aspects of Nuclear Site risk studies.

Nuclear site effects on health are generally examined by ecological epidemiology of childhood leukemia, thought to be the most sensitive indicator [1]. Whilst it may be true that child leukemia in the 0-4 age group is a sensitive indicator, its utility for such studies is far outweighed by the extremely low background rate and the age range restriction to a single 5-year group. Additionally, for obvious reasons, nuclear sites are located in low population areas and in the UK anyway, near the sea. Thus for child leukemia, statistical power is limited, and only large scale studies aggregating many nuclear sites and long time periods can hope to provide answers. Such a study has been carried out in Germany and has shown that there is an approximate doubling of risk for child leukemia inside 5km [2]. This study employed the usual method of defining populations in concentric rings around a point source and comparing such radial populations by distance. Such an approach ignores the real dispersion of the radioactive discharges, downwind and to local land and bodies of water (rivers, estuaries, the sea). One of the main nuclear site childhood leukemia clusters in Germany is the Elbemarsch cluster which is associated with communities living on a contaminated river estuary [3]. The first nuclear site child leukemia cluster to be discovered, the Sellafield cluster in Cumbria was in fact in Seascale, a coastal village with a radioactively contaminated foreshore [1,4] and the same is true for the La Hague study where playing on the beach emerged as a risk factor [5]. Alexander et al, 1990, found a positive association between estuary wards and leukemia risk [6]. Later attempts to follow this coastal estuary effect up were confounded by Chernobyl [7].

Breast cancer is also caused by exposure to ionizing radiation, but as an indicator of effect it is superior as an indicator to child leukemia because the background rates are much higher (150 per 100,000 in UK) and the effective population at risk (45-75) is six times greater. An association between breast cancer and exposure from nuclear sites has been found for two other nuclear sites in the UK, Hinkley Point in Somerset [8] and Trawsfynydd in Gwynedd [9]. Associations have also been found in studies in the USA [10]. The results reported here are essentially those from an epidemiological exercise proposed and discussed but finally cancelled in the Committee Examining Radiation Risks from Internal Emitters (CERRIE) 2001-2004 [11,12].

## Method

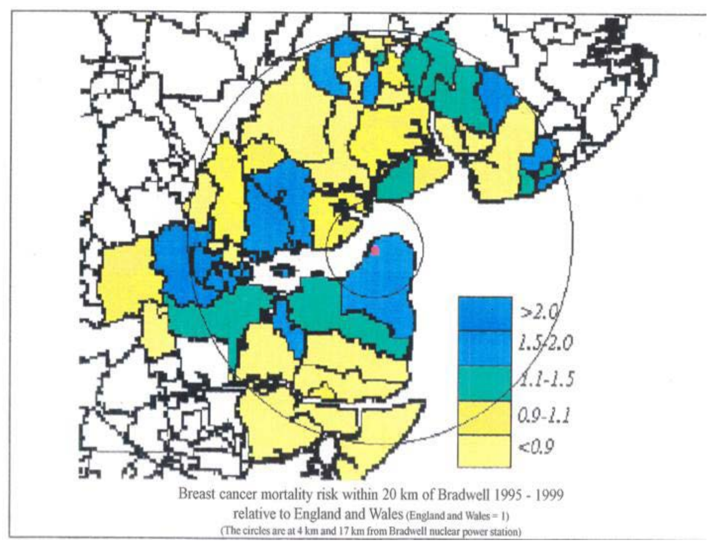
### The study area

Bradwell nuclear power station is sited on the remote eastern tip of the south side of the River Blackwater in Essex. The estuary of the River Blackwater is a tidal muddy inlet on the East Coast of England which is not really a river but is a sea inlet which fills up and dries out daily to reveal large areas of muddy sediment. The mud banks in the estuary are extended out to sea to the south by large offshore drying banks, St Peters Flats, the Buxey and Ray Sands and to the north by Mersea Flats and the Bench Head. Liquid discharges from the nuclear plant to the sea are thus trapped in the estuary moving backwards and forwards on the tide and precipitating to the mud banks. They have accumulated there since the station was commissioned in 1962 and stopped operation in 2002 and levels in sediment are routinely measured and reported in MAFF and RIFE [13]. As expected, levels of measured radioactivity are highest at the head of the estuary at Maldon. To the south of Bradwell but separated from it by extensive offshore drying sand and mud banks is a similar estuary, that of the River Crouch. Wards on the River Crouch form a control for exposures to radioactive contamination since the tidal streams and offshore drying banks isolate the two estuaries from each other. The area is shown in Fig 1 where wards are painted according to the SMR results obtained in an earlier study for the period 1995-1999.

### The population

England and Wales ward level populations were obtained from the Office for Population Census and Surveys (OPCS) for 26 wards surrounding and up to 20km from the nuclear power station at Bradwell, Essex. Deaths from Breast Cancer to ward level are tabulated annually from 1995 to 2001 in Vital Statistics outputs which were purchased from OPCS. Ward level Social Class data was also obtained from census tables. The census wards are those at the 1991 census as are the populations. In the 2001 census, there were significant boundary changes with the 26 wards in the area being reduced to 17 wards. Thus the 2001 census data cannot be used for a base population. Expected numbers of Deaths were obtained by multiplying each 5-year age group population in each ward by the 1998 England and Wales national mortality rates for the same age group and then further adjusting by the mean Social Class of the ward using the relationship between Social Class and Breast Cancer given in the 1988 England and Wales longitudinal study [14]. Standardised Mortality Ratios were generated as Observed/Expected and statistical tests between groups of wards were carried out using simple contingency tables to obtain Relative Risks, 95% confidence intervals and p-values.

**Figure 1.** Study area showing location of Bradwell nuclear power station (red), surrounding 1991 census wards employed in the study and SMR levels in each ward for the period 1995-1999. Concentric circles are drawn at 4km and 17km illustrating the problem of the concentric areas approach.




## Results

Table 1 gives the Social Class and age standardised SMRs for the 26 wards in the study area together with ward populations in 1991 and the Blackwater estuary/non Blackwater estuary dichotomy. Table 2 compares Blackwater Estuary with non-Blackwater estuary for the period. Table 3 compares the Blackwater estuary wards with the Crouch estuary wards and Table 4 compares the 3 wards in the town of Maldon at

**Table 1.** Wards in the study area with Social Class and age standardised SMRs for 1995-2001 in 26 wards near Bradwell Nuclear Power Station. Estuary wards are identified in **bold** type *(*) in Column 6 means Cumulative Poisson p<0.05, ** for p<0.01.*

| **Ward[a]** | **Female census Ward Population** | **Black water Estuary = 1** | **Expect 7 yrs** | **Observe** | **RR** |
|---|---|---|---|---|---|
| Althorne | 1143 | 0 | 3.27 | 1 | 0.31 |
| Burnham on Crouch North | 1324 | 0 | 4.02 | 2 | 0.5 |
| Burnham on Crouch South | 2281 | 0 | 7.47 | 8 | 1.07 |
| Goldhanger | 792 | 0 | 2.47 | 4 | 1.62 |
| Great Totham | 1527 | 0 | 3.99 | 5 | 1.25 |
| **Heybridge East** | **1854** | **1** | **2.78** | **3** | **1.08** |
| Heybridge West | 1405 | 0 | 3.92 | 6 | 1.53 |
| Little Baddow, Danbury, S'don | 4145 | 0 | 11.67 | 9 | 0.77 |
| **Maldon East** | **1352** | **1** | **5.73** | **7** | **1.22** |
| **Maldon North West** | **2019** | **1** | **8.17** | **16** | **1.96**** |
| **Maldon South** | **2200** | **1** | **5.12** | **11** | **2.15**** |
| Purleigh | 783 | 0 | 1.99 | 2 | 1.01 |
| **St Lawrence** | **708** | **1** | **2.14** | **3** | **1.41** |
| Southminster | 1701 | 0 | 4.46 | 5 | 1.12 |
| **The Maylands** | **1659** | **1** | **3.30** | **5** | **1.52** |
| **Tillingham** | **873** | **1** | **2.51** | **3** | **1.20** |
| **Tollesbury** | **1300** | **1** | **3.68** | **7** | **1.90** |
| Tolleshunt D'Arcy | 933 | 0 | 2.80 | 5 | 1.79 |
| Wickham Bishops | 1054 | 0 | 3.01 | 4 | 1.33 |
| Woodham | 792 | 0 | 2.07 | 3 | 1.45 |
| Woodham Ferrers and Bickn. | 1546 | 0 | 3.05 | 0 | 0 |
| Birch M'ing and Copford | 1533 | 0 | 5.31 | 4 | 0.75 |
| Pyefleet | 1130 | 0 | 3.85 | 4 | 1.04 |
| Tiptree | 3918 | 0 | 10.01 | 8 | 0.80 |
| **West Mersea** | **3451** | **1** | **12.87** | **18** | **1.40** |
| Winstree | 1159 | 0 | 2.66 | 1 | 0.38 |

the head of the Blackwater with the two Burnham on Crouch wards are those 1991 census small areas for which the cancer mortality numbers were given by the Vital Statistics outputs of the Office for Population Census and Surveys. There were significant boundary changes at the 2001 census when the area was reduced from 26 wards to 17.

**Table 2.** Comparing Blackwater Estuary wards with non-Blackwater Estuary wards 1995-2001.

| | deaths | Population | Relative Risk (95% Confidence Interval; p-value) |
|---|---|---|---|
| Blackwater | 73 | 15413 | 1.7 (1.22<RR<2.34; p = 0.0015) |
| Non Blackwater | 71 | 27166 | |

**Table 3.** Comparing Blackwater Estuary wards with Crouch Estuary wards 1995-2001.

| | deaths | Population | Relative Risk (95% Confidence Interval; p-value) |
|---|---|---|---|
| Blackwater | 73 | 15413 | 2.1 (1.12<RR<3.98; p = 0.018) |
| Crouch | 11 | 4748 | |

**Table 4.** Comparing Maldon (Blackwater) wards with Burnham on Crouch Estuary wards 1995-2001.

| | deaths | Population | Relative Risk (95% Confidence Interval; p-value) |
|---|---|---|---|
| Maldon 3 wards | 34 | 5571 | 2.1 (1.02<RR<4.15; p = 0.04) |
| Crouch 2 wards | 10 | 3364 | |

## Discussion

The effect of exposures to licensed releases from nuclear plants is increasingly of interest. Recently, the US Nuclear Regulatory Commission asked the National Academy of Sciences to perform a "state of the art" study on cancer risk in populations surrounding NRC licenses nuclear facilities to allay fears in these populations. As the NRC writes:

*Nuclear facilities licensed by the US Nuclear Regulatory Commission (NRC) sometimes release very small amounts of radioactivity during normal operations. NRC regulations ensure plant operators monitor and control these releases to meet very strict radiation dose limits, and plants must publicly report these releases to the agency. Some communities are concerned about these releases' potential impact on the health of those living near those nuclear facilities.* [15]

The "state of the art", is to employ various parameters or algorithms of risk based on assumption about exposures involving radial distance. Stone in 1988 pointed out that whilst the true pattern of risk with distance might be unknown, causation required that risk in increasing areas in annular radial circles should diminish continuously, at least in rank [16]. Others have employed various functions involving diminished risk with distance e.g the KiKK study in Germany of childhood leukemia and the Viel and Poubel study of La Hague [17]. Unfortunately, none of these inverse distance models truly track the exposures and may give incorrect results, especially if there is diversity of population types. For example, many nuclear sites are in underpopulated areas but have a large urban population in a city or large town in the peripheral exposure ring, and this confounds any risk trend with distance since urban and rural populations have different baseline risks for cancer and leukemia. If the plant is sited on a river, or the sea, then any radial effect will be confounded since the length of the coast, estuary or river bank will confer high risk to those living in all the distance bands. This is clearly the case in the Bradwell situation.

Then there is a prevailing wind effect which ensures that those downwind are more exposed to aerial discharges than those upwind, so at minimum the risk ratios in the rings are substantially diluted. Further, as in this instance, the major releases are sometimes to the sea, and the radioactivity concentrates in the estuarine sediment where it may be resuspended by sea-to-land transfer and become available for inhalation. Sea to land transfer is a well described and understood phenomenon, and has been validated by measurements made in the Irish Sea near the Sellafield plant in Cumbria [18]. When the tide recedes the shallow Blackwater estuary reveals large areas of soft mud consisting of fine particulates which can be carried on the wind as dust particles, available for inhalation. Measurements made by the UK Ministry of Agriculture Fisheries and Food and more recently, the Environment Agency and CEFAS have recorded excess levels of radioactivity in sediment on the Blackwater since the 1970s. The concentrations are highest at the innermost part of the estuary because the fine sediments which carry the radioactivity precipitate out at the head of tide [19-22]. Thus in 2009, for Caesium-137, the most usual measured yardstick of contamination, concentrations were highest at at Maldon at the western end at 36Bq/kg , with 14Bq/kg on the north side of the estuary, 8.8 at West Mersea and 7.7Bq/kg at the Bradwell pipeline itself [22]. Other radionuclides are released, including Plutonium, Uranium, Strontium-90, Tritium and Carbon14. There are elevated levels of Carbon-14 in local produce and in 2009 measurements showed 79Bq/kg C-14 in a wild rabbit. Fish and shellfish are also contaminated.

It will be argued by the radiation protection agencies that these levels are very low, and confer very small "doses" as calculated by the current radiation risk model, that of the International Commission on Radiological Protection (ICRP). But that model also cannot predict or explain the childhood leukemia findings by similar orders of magnitude to those necessary to explain the findings of this breast cancer study, or the findings of the Trawsfynydd study (this Journal, this issue). It is arguable that the reason for this is that the ICRP model is unsafe when applied to certain internal chronic exposures since its methodology is based on the concept of "dose", a measure of average energy per unit mass. The predictions of the ICRP model are based on external acute exposures of the Japanese A-Bomb life span study. There are persuasive reasons to abandon this approach for internal chronic exposures to certain radionuclides, including those released by Bradwell [23].

The results presented here seem unequivocal. First, the Blackwater wards have significantly greater breast cancer mortality than the non-Blackwater wards. Second, this is a radioactivity effect because the comparison of the two estuaries, contaminated Blackwater and uncontaminated Crouch show that there is a doubling of risk associated with the contamination. And in case there might be concerns about rural and urban populations, where there could, in principle, be a differential town effect, there is significantly higher risk in the main Blackwater town of Maldon, versus the main Crouch town of Burnham.

To demonstrate the importance of the assumptions about dispersion, use of the concentric circle radial approach and employing 4km and 17km radii gave no effect, RR = 1.06 (0.47, 2.38; p = 0.89). Superficial examination of the risk map in Fig 1 shows why this is. Thus it is clear that for an ecological study to succeed, it is critically important to place the exposed study group where the exposure really is and not employ an unrealistic and simplistic approach.

The excess risk of breast cancer in the areas surrounding the Blackwater was referred to in 1999 in the Essex sustainability report. That report examined a much larger area, the whole of Essex, but for the 14 County Districts of Essex, the County District around the Blackwater had the highest reported standardised mortality rates from breast cancer in the age groups 50-69. The Maldon County District had a standardised rate 109-148, 100 being the norm for the County of Essex [24]

We have also studied breast cancer mortality in the wards near the Hinkley Point nuclear site in Somerset, using the same approach as this study, and have found the same result, a doubling of risk [25]. In a separate questionnaire study of the town of Burnham on Sea downwind of Hinkley Point we have confirmed the excess risk in incidence. This study was followed up by the official South West Cancer Intelligence Agency which confirmed that the excess risk for incidence was real [8] but argued that it could not be due to the nuclear plant as the doses were too low. In a separate questionnaire study of downwinders of the Trawsfynydd nuclear power station in Wales, presented in this journal, we found a larger effect on breast cancer incidence especially in younger women below 60 where the risk relative to the national population was almost 5-fold.

Breast cancer and nuclear site exposures were extensively studied in the USA by the late Dr Jay Gould who presented his results in a book, *The Enemy Within* in 1996. He presented statistical evidence based on counties containing or downwind of nuclear sites which argued for an association. Yet official public health agencies and radiation risk agencies continue to focus on childhood leukemia and avoid examining adult cancers altogether. This Bradwell study and other studies carried out by our group demonstrate that breast cancer analysis by ecological analysis in which the most likely areas of dispersion are used as surrogates for exposure represent a useful method for examining the health effects of internal radionuclide exposures from nuclear sites.

Anecdotal evidence should not be ignored. The high rates of cancer in the Blackwater are clear to the locals. Increased risk of cancer in the area was bought to our attention by a local residents group in West Mersea, women who felt that there was too much breast cancer and referred to the 1999 Essex sustainability report which seemed to confirm the area as having the highest rates in the county. The fishermen, who had most contact with the contaminated mud also believed they were seeing effects. Mr B J R Wright, Secretary of the Maldon Oyster Fishermans Association wrote to the local paper, the Maldon and Burnham Standard published April 6th 2001:

*Trust the experts—what a joke. I find it more than a coincidence that in the last seven years four commercial fishermen who spent years working on the mud flats and fishing outside Bradwell Power Station have all had bone cancer. Three have died and I myself have survived owing to the brilliant staff at Broomfield hospital. I have also been told that commercial barge skippers who regularly plied our river are affected by bone cancer.*

The authorities too, though its approach was placatory: for example a headline in the Standard for June 7th 2001 was: *Council crackdown on breast cancer: residents urged to take up healthy eating and stop smoking*.

This study was originally carried out for the epidemiological sub-group project of the UK government Committee Examining Radiation Risk from Internal Emitters (CERRIE) [11,12] but was never published or incorporated in the final report as the epidemiological projects were cancelled by the Chair when the Environment Minister who set up CERRIE in 2001, the Rt Hon Michael Meacher, MP was dismissed and replaced by Mr Elliott Morley MP in 2004.

## Conclusion

Between 1995 and 2001 breast cancer mortality was significantly higher in wards adjacent to the River Blackwater in Essex than wards which were inland. The Blackwater wards which had measured radioactive contamination from the Bradwell nuclear power station had about twice the breast cancer mortality than a control group of wards on the uncontaminated river Crouch. Comparison of the Blackwater town of Maldon with the Crouch town of Burnham to the South showed the same doubling of risk. Official measurements show that there is radioactive contamination of intertidal sediment derived from historic discharges from the nuclear power station at Bradwell and confined to the estuary by local tidal conditions and topology. The exposure vector may be sea-to-land transfer and inhalation. The results show that breast cancer may be employed as a measure of harm from nuclear site releases and such an approach has much greater statistical power than employing childhood leukemia rates as a measure of health effect. Radial dispersion assumptions for the exposed populations showed no effect, indicating the dangers of making unrealistic assumptions about exposure groups in ecological epidemiology.

## Acknowledgements

I am grateful to Richard Bramhall for assistance with checking data and for other invaluable help. I acknowledge core funding support from the Joseph Rowntree Charitable Trust during the time of this study. The original study was commissioned by West Mersea Residents Association; the association paid £400 toward the costs.

## Conflict of Interest

There is no conflict of interest.

## References

1. Beral V, Bobrow M and Roman E (1993) Childhood cancer and nuclear installations*.* London: British Medical Journal

2 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.

3. Hoffman W and Greiser E. Epidemiological evaluation of leukemia incidence in children and adults in the vicinity of the nuclear power plant at Krummel. In Schmitz-Feuerhake I and Schmidt M, Radiation Exposures by Nuclear acilities—Proceedings of an international workshop, GsF, Portsmouth, England, 1996. Bremen, Germany: GsF. 1998.

4. Gardner MJ. Follow-up Study of Leukemia and Lymphoma among Young People near Sellafield Nuclear Plant in West Cumbria. British Medical Journal. 1987, 295(6602): 822-827.

5. Viel JF, Poubel D. Case control study of leukemia among Young People near La Hague Nuclear Reprocessing Plant: The Environmental Hypothesis Revisited. British Medical Journal. 1997, 14: 101-106.

6. Alexander FE, Cartwright RA, McKinney PA, Ricketts TJ. Leukemia incidence, Social Class and Estuaries: an Ecological Analysis. Journal of Public Health Medicine. 1990, 12(2): 109-117.

7. Busby C. Is there a sea coast effect on childhood leukaemia in Dumfries and Galloway, Scotland, 1975-2002 ? Occupational and Environmental Medicine. 2008, 65(4): 286-287.

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

9. Busby C, deMessieres M (2015) Cancer near Trawsfynydd Nuclear Power Station in Wales, UK: a cross sectional cohort study. This journal this issue.

10. Gould Jay M. The enemy within; the high cost of living near nuclear reactors. Breast Cancer, low birth weights and other radiation induced immune deficiency effects. New York: Four Walls Eight Windows. 1996.

11. CERRIE. Report of the Committee Examining Radiation Risk from Internal Emitters (CERRIE) Chilton, UK: National Radiological Protection Board. 2004*.*

12. Busby CC, Bramhall R, Dorfman P. CERRIE Minority Report 2004: Minority Report of the UK Department of Health/ Department of Environment (DEFRA) Committee Examining Radiation Risk from Internal Emitters (CERRIE) Aberystwyth: Sosiumi Press. 2004.

13. Radioactivity in Food and the Environment, RIFE. Published annually from 1995. Earlier data from CEFAS Lowestoft UK.

14. Leon DA. Longitudinal Study: social distribution of cancer. OPCS Series LS No 3 London: HMSO. 1988.

15. Fact Sheet on Analysis of Cancer Risk in Populations Near Nuclear Facilities. USA Nuclear Regulatory Commission.

16. Stone RA. Investigations of environmental excess around putative sources: statistical problems and a proposed test. Statistics in Medicine. 1988, 7: 649-660.

17. Viel JF, Pobel D, Carré A. Incidence of leukemia in young people and the La Hague nuclear waste reprocessing plant: a sensitivity analysis. Statistics in Medicine. 1995, 14(21-22): 2459-2472.

18 Eakins JD, Lally AE. The transfer to land of actinide bearing sediments from the Irish Sea by spray. Science of the Total Environment. 1984, 35: 23-32.

19. Assinder D J. 'Behaviour of plutonium in the intertidal sediments of the eastern Irish sea', in Coughtrey, P. J., Bell, J. N. B., and Roberts, T. M. (eds.), Ecological Aspects of Radionuclide Release, Special Publication No. 3 of the British Ecological Society. 1983, 189-197.

20. Assinder DJ, Mudge SM, Bourne GS. Radiological assessment of the Ribble Estuary, 3. Redistribution of radionuclides. Journal of Environmental Radioactivity. 1997, 36: 43-67.

21. Assinder DJ, Mudge SM, Bourne GS. Radiological assessment of the Ribble Estuary, 1. Distribution of radionuclides in surface sediments. Journal of Environmental Radioactivity. 1997, 36(1): 1-19.

22. Assinder DJ, Robinson CD, Halsall J, Telford A. The distribution and behaviour of artificial radionuclides in sediments of the North Wales coast. Journal of Radioanalytical and Nuclear Chemistry. 1994, 182(2): 225-235.

23. Busby Christopher (2013). Aspects of DNA Damage from

Internal Radionuclides, New Research Directions in DNA Repair, Prof. Clark Chen (Ed.), ISBN: 978-953-51-1114-6, 2013.

24. Essex Sustainability Report 1999. Chelmsford: Essex County Council

25. Busby Chris, Rowe Helen. Cancer in Burnham on Sea North: Results of the PCAH questionnaire. Occasional Paper 2002/5 Green Audit: Aberystwyth. 2002.