Nuclear Free Local Authorities RADIOACTIVE WASTE POLICY Briefing No. 37 – FSA Monitoring radioactivity in food

Prepared for NFLA member authorities, March 2013

Submission by the Nuclear Free Local Authorities (NFLA) to the Food Standards Agency (FSA) on its consultation around monitoring radioactivity in food

Introduction to Briefing

This Policy Briefing provides member authorities with the submission made by the Nuclear Free Local Authorities (NFLA) to the Food Standards Agency (FSA) public consultation on the monitoring regime to test for radioactivity levels in food. The response has been developed for the NFLA by the independent marine pollution consultant Tim Deere-Jones. The response follows on from many relevant comments that the NFLA have made to the Environment Agency on environmental permits for a new nuclear reactor at Hinkley Point (see NFLA New Nuclear Monitor 29 on the NFLA website). It provides a thorough and detailed analysis of NFLA concerns over the radioactive sampling regime in the UK. The FSA consultation closed on March 6th 2013 – details of it can be found at the website - http://www.food.gov.uk/news-updates/consultations/consultations-england/2012/radioactivity-consult.

FOOD STANDARDS AGENCY CONSULTATION - MONITORING RADIOACTIVITY IN FOOD Consultation Submission Response of the NUCLEAR FREE LOCAL AUTHORITIES (NFLA)

A. EXECUTIVE SUMMARY

i. The Food Standards Agency Press release of 12 December states that "An annual monitoring programme has been in place for more than 25 years and no food safety risks have been identified during this period". The FSA is asking stakeholders to submit their views on plans to update and improve the existing monitoring programme.

ii. In respect of marine radioactivity, the FSA statement is based on the outcomes of dose assessment modelling of the received dietary dose, from a range of foodstuff thought to be representative of dietary exposure pathways. This Submission from the UK Nuclear Free Local Authorities has reviewed the volume and quality of the data inputs upon which such modelling relies for its accuracy and relevance.

iii. On the basis of the review conclusions (see below) the NFLA concludes that the current programme for monitoring doses of marine derived radioactivity in food is not fit for purpose, in that it can not provide sufficient data to justify the FSA claim that there is a "low risk from radioactivity in food" and that "no food safety risks have been identified".

iv. The NFLA does not believe that the FSA proposal to "optimise" the monitoring programme by "reducing background monitoring away from nuclear sites" while continuing to monitor food around all licensed nuclear sites", would offer the best or most effective programme for monitoring marine radioactivity in foodstuffs. On the contrary, the NFLA believe that the FSA preferred option is not a viable proposal for monitoring in the context of the current poor data and the large proposed future expansion of nuclear power, and radioactive waste discharges to sea, in the UK.

v. This Submission therefore urges the FSA to adopt a more stringent and intense monitoring programme, which must consist of:

a: a higher number of sampling observations;

b: analysis for a greater number of representative isotopes;

c: a more intensive study of “far field” sites (such as island and coastal communities)

d: a more intensive link between sample gathering and the “peaks” of pulsed discharges (especially in the case of Tritium);

e: a more intense research effort into the potential dietary impacts of the sea to land transfer of a range of radio-nuclides and the contribution of marine radioactivity to coastal zone terrestrial diets;

f: a more intense research effort into the dietary implications of Americium “in growth” (due to Pu 241 decay).

B. MAJOR CONCLUSIONS OF THIS SUBMISSION BY SECTION

Sections 1, 2 &3

This Submission concludes that the monitoring of foodstuffs for their marine radioactivity content is based upon an early and very simplistic hypothesis for the behaviour and fate of radioactive wastes discharged into the UK’s coastal environment. In this context this Submission concludes that the major focus on “near field” monitoring of marine foodstuffs sampled in the close vicinity of nuclear sites is misplaced.

This Submission concludes that the monitoring and analytical programmes currently operated cannot prove appropriately detailed descriptions of the potential doses of dietary marine radioactivity because:

a: Statements that fish and shellfish samples are “indicator species” which “essentially sample the local water and consume other organisms are imprecise and lack the appropriate scientific rigour and have little empirical evidential support;

b: the number of sampling observations at UK nuclear power stations (NPS) (fin fish and shellfish) is generally less than 4 and most often just 1 or 2;

c: no details are provided of time of year, sate of tide, ambient weather and water column parameters (all factors having close relevance to ambient radioactivity concentrations in the marine environment being sampled.

Section 4

This Submission concludes that UK nuclear sites routinely discharge a complex cocktail of radio active wastes into the UK coastal waters (approx 65 nuclides in the case of proposed new build NPS) and that there is poor provision of access to the full/complete list of ALL radio nuclides discharged from UK nuclear sites, with many individual nuclides not being named or identified.

This Submission concludes that there is an absence of empirical evidence to demonstrate that un-named “very low level” or “lesser” radio nuclides has no detrimental health effect on human populations via the pathways of ingestion, and queries whether such evidence actually exists.

This Submission concludes that at no identified site is analysis for ALL radio nuclides in the discharge stream carried out.

This Submission concludes that its Review of RIFE reports demonstrates that at UK NPS and Naval bases, the monitoring/analytical programmes only investigate the concentration of 40% to 20% of the radio nuclides discharge.

This Submission, having reviewed the RIFE reports, concludes that not all of the nuclides listed/identified for monitoring/analysis (40% to 20% of total nuclides) are measured in all samples at UK NPS and Naval bases. Thus at some sites, some listed nuclides are only analysed for in 1 sample, others only analysed for in 2 or 3 samples.

This Submission further concludes that, given the complexity of radioactive waste discharges to UK coastal waters already reported to hold significant detectable quantities of a range of other (non-radioactive) marine pollutants posing a potential concern to public health via dietary pathways, the absence of strong data suites covering toxicological issues such as synergistic, antagonistic and cumulative effects between discrete radio nuclides and between radio nuclides and non-radioactive subjects) is a cause of concern.

Sections 5, 6, 7 and 8

This Submission concludes that the behaviour and fate of sea to land transferred of marine discharged radioactive wastes is poorly studied.

The Submission concludes that the research into the possible dietary radio logical impact of major coastal inundation events (storm surge etc) and their import of radioactively contaminated marine sediments does nor investigate the potential dietary impact by monitoring coastal soils and the crops grown upon them, in the wake of such events.

This Submission notes that, to date, only one such event has been studied (Towyn) and that that work was independent and not conducted by UK nuclear regulators of the nuclear industry.

This Submission notes that the dietary impact of some minor inundation impacts (tidal), in the immediate vicinity of nuclear sites, is investigated. However, this Submission concludes that such work is characterised by low numbers of sampling observations (1 or 2 samples only) and low numbers of nuclides being analysed for (1 or 2 nuclides only) and thus lacks scientific rigour.

This Submission concludes that monitoring to assess the dietary radiological impact of the use of marine organic material as a soil conditioner or fertiliser is also characterised by low numbers of sampling observations and the analysis of samples for less than 50% of the nuclides listed for site analysis.

This Submission concludes that although the nuclear regulators and the nuclear industry have carried out research on the sea to land transfer of marine radioactivity via marine aerosols and sea spray, the phenomenon cannot be accurately quantified because of the lack of appropriate technology.

However, studies have demonstrated large enrichments of concentrations of some nuclides during the process of sea to land transfer (Am 241 enrichments of up to 821 times), thus indicating the potential for dietary radioactivity pathways via consumption of coastal produce.

This Submission concludes that independent studies have shown that at sites distant from point sources of marine discharged radioactive wastes, mechanisms of sea to land transfer are shown to contribute at least as much (and almost certainly more) dietary radioactivity as is shown to occur in the immediate vicinity of nuclear sites.

This Submission concludes that the official policy of prioritisation of the monitoring effort on areas close to point sources of discharge does not take account of the evidence from more “distant” case studies (North Uist, Kingsbridge).

This Submission notes that in some ”distant site” cases (North Uist) the dietary dose (from 1 nuclide only) of marine radioactivity IN TERRESTRIAL FOODS is shown to be higher than the dietary dose (multiple nuclides) in sea foods from the near field vicinity adjacent to nuclear sites.

This Submission concludes that the historical, current and ongoing assumption that maximum dietary doses of marine radioactivity only occur in populations close to nuclear sites, is not supported by the available evidence.

This Submission concludes that, given the time scales since the production of the Towyn post inundation study and the North Uist and Kingsbridge dietary studies, there has been ample opportunity for regulators and the nuclear industry to initiate further research into such proven far field impacts and their implications, but that this opportunity has not been taken. Thus this Submission concludes that the research into dietary doses of sea to land transferred radioactivity lacks the appropriate level of scientific rigour.

Section 9

This Submission reviews some of the latest scientific research into the behaviour and fate of the soluble radio nuclide tritium in marine environments and reports a 2009 study which strongly implies that the historical and current understanding of tritium in marine environments and biota has been deeply flawed because it has been based on a number of assumptions now shown to be mistaken.

This Submission notes that recent research now describes a number of characteristics “not… reported previously” for tritium and plainly implies that previously modelled hypothetical calculations are flawed and in need of revision.

This Submission notes the intention to discharge tritium from proposed new build PWR NPS on a “pulsed” and intermittent basis and concludes that the current monitoring and sampling strategies dictate that tritium dietary analysis is based on only 1 or 2 sampling observations per annum. This Submission further concludes that (given the reported very rapid incorporation of tritium into marine and coastal wetland organisms) such a strategy is not fit for purpose in the context of pulsed discharges and therefore lacks scientific rigour and relevance.

This Submission further concludes that the monitoring and analysis of tritium in marine and coastal zone foodstuffs is not consistent and is characterised by both low numbers of sampling observations and a limited number of foodstuffs sampled and a failure to monitor coastal zone wetland foodstuffs such as wildfowl which are shown to have among the highest body concentrations of tritium.

Section 10

This Submission draws attention to the problem of Am 241 “in growth” in UK waters as a result of the decay of un-quantified historical discharges of Pu 24, and notes that by the end of this century Americium production is expected to peak at an annual rate of about 48 TBq per year.

This Submission concludes that, in the context of issues raised in earlier sections, the current level of research into the dietary doses of sea to land transferred Am 241 (and also a number of Pu nuclides) is incomplete and insufficiently rigorous.

Section 11

This Submission draws attention to the fact that, in the context of the issues set out in the preceding sections, the various modelling programmes concerning the environmental behaviour and fate of marine discharges radioactive wastes, pathways of exposure and the subsequent doses of radioactivity to the public are not informed by the most recently identified, accurate, reliable and up-to-date data and understanding of all relevant parameters.

This Submission draws attention to the fact that although hypothetical models are generally calibrated against observed data, in this case much of the existing observed data is deeply flawed because it is based on the flaws and weaknesses set out in preceding sections of this Submission.

This Submission therefore concludes that the entire suite of hypothetical models, upon which the assessment of doses of dietary radioactivity derived from marine discharges is based, are significantly flawed and that their use by the Regulating agencies has very limited evidential justification.

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1. Monitoring at UK Nuclear sites

1.1 The monitoring and sampling of radioactivity in marine samples has been reported for many years. The current reporting series is the RIFE (Radioactivity in Food and the Environment) Reports, which have been published since RIFE 1 was published in 1996 (presenting the results for the year 1995). The RIFE Reports are currently produced on a collaborative basis by the environment agencies and the Food Standards Agency.

1.2 Prior to this, the monitoring and sampling of marine samples was reported in the annual Aquatic Environment Monitoring Reports (AEMRs) produced by the Fisheries and Food Directorate of Fisheries Research of the Ministry of Agriculture Fisheries and Food.

1.3 Typical examples of the long standing monitoring practices employed in the UK are presented in the annual RIFE Reports. The contents of these reports contain significant sections describing the Food Standards Agency monitoring of radioactivity in foodstuffs of terrestrial and marine origin.

2. Sampling and monitoring of fin fish, shellfish, and seaweeds

2.1 The annual monitoring programmes carried out by government agencies appear to remain rooted on the simplistic hypothesis that discharged radioactive wastes will either disperse and dilute in the marine environment or remain bound to immobile marine sediments relatively close to the point source of the discharge. Thus, the major investigative effort is focussed on “near field” impacts close to the point source of discharge where, according to the hypothesis, radioactivity concentrations are likely to be at their highest and exposure of the public at its greatest.

2.2 Adherence to this policy is not necessarily the choice of the FSA, but, given the operation of this policy and the collaborative set up of the RIFE reporting it must be assumed that the FSA supports that policy and has accepted the hypothesis of the behaviour and fate of marine radioactivity that the policy encapsulates.

2.3 Thus, the RIFE reports confirm this hypothesis and also explain that:

a: “Most of the monitoring carried out and presented in this report concerns the local effects of discharges from nuclear licensed sites in the UK.” (section 1.1 of RIFE reports);

b: there is “some ongoing monitoring of Chernobyl impacts” (section 1.1 of RIFE);

c: “Monitoring of food and the environment remote from nuclear licensed sites is also carried out, giving information on background concentrations of radio nuclides” (Preface to RIFE reports).

NB the use of the words "background concentrations" in the third clause implies an expectation of very low levels similar to those that might be experienced from "natural" radiation. This indicates that a scale of prioritisation is operated.

2.4 RIFE report prefaces also state that: "The data from the programmes will also act as a baseline against which future discharges from any new or existing nuclear power stations can be judged".

2.5 Recent desk reviews, carried out on behalf of the UK NFLA (and others) during compilation of previous Consultation Responses related to the Hinkley C proposal, have provided a detailed case study of concerns related to the proposed marine environmental monitoring programmes for the Hinkley C PWR station set out in NNB Genco's Environmental Monitoring submission (NNB-OSL-REP-000137) and those long established programmes carried out by the UK regulating agencies and reported in the annual RIFE monitoring reports. The NFLA reports are on its website http://www.nuclearpolicy.info.

2.6 Page 4 of the NNB Genco monitoring document submission (NNB-OSL-REP-000137) states that: the programme outlined for Hinkley Point C "is informed by the Environmental Monitoring Programme ongoing for Hinkley Point A and B power stations" and then (page 5) states that, with reference to the atmospheric monitoring at the A and B stations:

"A common strategy for collecting terrestrial samples is to divide areas into an inner zone, which is 1 to 6km from the station and an outer zone, which is 6 to 19km from the station" and argues that "This division helps to distinguish effects that might be due to power station operations from those attributable to external effects (non-site operations)."

2.7 Page 6 of the NNB GENCO Monitoring document, still referencing the A and B stations, but describing the proposed future marine sampling, offers no comment on the zonal division, based on distance from the site, for the collection of marine samples. Thus there appear to be no identified inner or outer zones for marine samples.

No comment is given as to why such a policy is considered useful for the terrestrial monitoring programme, but not considered useful for the marine environment.

2.8 NB. It is important to note that the proposed NNB GENCO monitoring programme is in accord with the policy and practice of the UK national monitoring programme reported in the RIFE reports.

3. Fish, Shellfish and seaweed monitoring

3.1 Para 1.2.2 (page 7) of NNB-OSL-REP-000137 says that fish are indicator species because they are foodstuffs and because "they essentially sample the local water and consume other organisms".

The Environment Agency's GDA statements and response have not taken issue, or disagreed with this statement and so it must be assumed that the EA's and indeed the FSA are in agreement with it.

However, the statement is imprecise and lacking the appropriate scientific rigour, because it should have been made clear that different fish and shellfish sample different component sections of the marine environment.

3.2 Thus, some shellfish are:

a: detritus feeders (travelling about over the seabed and feeding upon dead and decaying matter found thereon);
b: others are sessile filter feeders (remaining fixed/immobile in one spot and feeding by filtering food out of the passing water column);
c: others are vegetarian grazers which feed over a limited range and may return to one fixed spot in between grazing forays.

3:3 Fin fish are similarly varied in lifestyle and feeding strategies, thus:

a: UK Cod have identified grounds where aggregation and spawning occurs. Eggs and larvae are planktonic (i.e. they drift with the currents). As they mature, juveniles travel to the seabed where they feed on small benthic crustaceans. By the time they are fully adult, individuals may be several hundred kms for their natal site and they feed on smaller fish, shellfish and benthic worms and free range from shallow and surface waters down to depths of 600 metres.

b: There are many species of UK flatfish: unlike "round fish", flatfish have specific adaptations for living in association with the seabed where they may lie or burrow during the day and feed at night. As a general rule flatfish have identified spawning grounds and also produce planktonic eggs and larvae, older larvae and adults feed on benthic (seabed) worms, crustaceans and bivalves at depths down to 200 metres. As is the case with many other round and flatfish species adult individuals may end up hundreds of kms from their natal ground.

c: Mackerel aggregate and migrate in large shoals, often over extensive distances, to their shallow water spawning grounds. Their eggs and larvae are planktonic and feed on zooplankton. After spawning the shoals tend to break up and smaller groups migrate to post spawning feeding grounds which are often in areas of coastal upwelling. Mackerel move offshore to over winter in deeper water. Adult mackerel feed on smaller fish, copepods and shrimp and squid.

3.4 It is evident, from the brief life cycle summaries of fin fish given above, that the very generalised statement that some fish are indicator species because they are foodstuffs and because "they essentially sample the local water and consume other organisms" is imprecise and lacking in scientific rigour.

3.5 No empirical evidence is presented in support of the implication that the individual finfish or shellfish making up the observed sample types have been resident in the area for long enough to have absorbed a representative amount of radioactivity as a result of their residence or consumption of other organisms.

Similarly, no empirical evidence is presented to identify the relative concentrations of radioactivity which might be expected to be found in fin fish or shell fish feeding from the various sub-compartments of the local food webs, such as the seabed detritus, the seabed marine worms and copepods, the marine water column filtrate etc.

Thus, without such supporting empirical evidence the relevance of the specific sample types chosen for observation to potential dietary sources of marine radioactivity are not well established.

3.6 Review of the annual RIFE reports (Tables of concentrations of radio nuclides in food and the environment) shows that the "No. of sampling observations" of fin fish and shellfish made is generally less than 4, most often 1 or 2.

No further details of the sampling observations are provided, (time of year, state of tide, ambient weather or water column parameters etc). However given the low number reported it must be assumed that "sampling" is relatively infrequent and certainly in the case of 1 "sampling observation" can only be 1 per year. This may be sufficient if only 1 landing per year is made, but cannot be representative of a year round catch landing of members of the chosen sample species.

3.7 The parameters highlighted in 3.6 above are potentially highly relevant to the investigation of the radioactivity content of fish.

For example, operators of the proposed EPR reactors at Hinkley Point C and Sizewell have expressed their intention to discharge aqueous wastes in "pulses", at currently unspecified times during the operating lifespan of the proposed NPS (this is a policy adopted at some other nuclear installations for a variety of reasons)

3.8 Such a policy is specifically designed for the discharge of such materials as tritium which is now widely understood to rapidly assimilate with organic material in the environment and has been shown to be quickly absorbed and bio-accumulated by a wide range of marine and coastal species including not only fish but ducks and wading birds.

3.9 There is a potential for pulsed discharges of soluble radio nuclides to give rise to pulsed and rapidly occurring peaks of radioactivity concentration in marine and coastal foodstuffs.

No empirical evidence has been offered to indicate that pulsed discharges will coincide with sample gathering.

No empirical evidence has been offered to demonstrate that the limited number of 1 or 2, or even 4 ”sampling observations” per year will be able to detect the radioactivity in food stuffs derived from these peaked and pulsed discharges, let alone provide data appropriate to the calculation of the potential doses of dietary radioactivity generated by those pulsed discharges

3.10 With regard to ambient environmental parameters, it is now well understood that the sediment loading of marine water columns is a major factor in the water column loadings of a range of pollutants including anthropogenic radioactivity derived from aqueous discharges.

Mechanisms of adsorbtion and flocculation have been shown to be crucial factors in the concentration, and indeed re-concentration, of radio nuclides through a variety of marine environmental media including the sea bed and inter tidal sediments, sea surface micro-layers and algal blooms, all of which may have an influence on the radioactivity bio-accumulation and concentrations of marine fin fish, shellfish and seaweeds.

3.11 Sediment loading in turn is dependant on such factors as wind and wave action at the coast and the seabed, fluvial inputs of freshwater and fluvial sediments, (such parameters having a seasonal bias), tidal cycles (springs/neaps) and residual currents.

I can find no empirical evidence to support a proposal that the limited number of 1, 2, or even 4 ”sampling observations” per year, is able to detect any potential changes in the radioactivity concentrations of foodstuffs, generated by the factors listed above.

3.12 Review of the RIFE reports confirms that similar issues and concerns are relevant to the sampling of marine algae/seaweeds and other edible coastal plants such as samphire, glasswort.

Thus at the Hinkley NPS only 1 sample of porphyra (edible), 1 sample of sea lettuce (edible) and 2 samples of undefined “seaweed” are the subject of analysis for Hinkley derived radioactivity.

4. Range and number of Isotopes monitored for

4.1 UK Nuclear sites discharge a high number of radionuclides in their aquatic waste streams. However, it appears to be difficult, if not impossible, to obtain a complete list of **all** of the isotopes/isotopes which are discharged to sea in the aqueous waste streams from such nuclear sites.

4.2 Such a list has not been made available for the proposed EPR reactors, nor to date have I been able to find such data for the Magnox and AGR reactors.

After a major search effort I was able to find such a list for the Westinghouse AP1000 PWR reactor, which listed a total of 65 nuclides described as “expected annual release of radioactive effluent discharges”

(AP1000 European Design Control Document and the Environment report" Westinghouse. Table 3.4-6. Available from www.ukap1000application.com)

On this basis it may be assumed that the proposed EPR reactor (also a PWR) may discharge a similar number of nuclides. It may be the case that the constituents of the Magnox and AGR reactor discharges are broadly similar.

4.3 Some detail of the liquid discharges to sea from the Sellafield reprocessor (under normal operation) for the years 2007-2011, are publicly available on the website: http://www.sellafieldsites.com/wp-content/uploads/2012/08/Sellafield_report_2011_800k1.pdf

It is stated that the list is not complete because of the inevitable presence of "very low levels" of other nuclides.

4.4 This website lists 21 named radio nuclides and also "plutonium alphas" and "uranium". Plutonium alphas consist of (the not listed) Plutonium 238, Plutonium 239 and Plutonium 240. Uranium discharges may often consist of more than one nuclide

Additionally the RIFE reports monitor for Curium 242 in marine foodstuffs from the Irish Sea, also not "named" or listed in the Sellafield discharge list, but possibly one of those present in very low levels.

4.5 A review of annual RIFE Reports indicates that such is also the case at the NPS's (both existing and those proposed for the future). The RIFE reports provide no list of either the partial (major nuclides only) or full (major + "lesser" radio nuclides) to be discharged.

I have been unable to find a consensual statement to the effect that scientific research has proved that these minor "very low level" and "un-named" nuclides (whether present in small physical quantities or reduced radioactivity concentrations) can not become incorporated into marine and coastal environmental samples, including the range of foodstuffs to be found in those environments.

I have not found a consensual statement from the either nuclear industry or "regulators" to the effect that scientific research has proved that there is no possible ingestion/dietary pathway health impact from the consumption of foodstuffs contaminated with these "very low level" and unnamed "minor" nuclides

4.6 In the context of the above statements it may be legitimate to assume that because the un-named nuclides are present in "very low levels" they are neither listed nor extensively researched for their potential human health impacts.

4.7 A brief review of the site specific monitoring reported in the annual RIFE reports demonstrates that there are 12 NPS sites in the UK, the majority of which are complex sites containing more than one type of reactor and reactors of a wide age range.

Sampling of radioactivity in marine samples at these sites is based on a limited number of the total number of nuclides likely to be present in the aqueous discharge streams from NPSs, as follows

a: at 4 of the twelve sites between 15 and 19 nuclides are monitored for;
b: at 3 of the 12 sites, 14 nuclides are monitored for;
c: 3 of the sites only monitor for 12 nuclides;
d: 2 of the sites (Sizewell and Bradwell) only monitor for 10 nuclides.

4.8 Given the available evidence pointing to the fact that NPS liquid discharges consist of at least 50+ nuclides, it is evident that the current monitoring programmes only investigate between 40% and 20% of the radioactivity discharged.

Additionally at the majority of UK NPSs, where the liquid radioactivity discharges may consist of over 50 nuclides, it can be calculated that 66% of sites are analysing for less than 25% of the total number of nuclides discharged.

4.9 At Naval sites, where the PWR power packs for nuclear submarines are refitted/maintained, a maximum of 18 nuclides are sampled for. Since the nuclear submarines are powered by Pressurised Water Reactors (PWRs) the discharge list given above (section 4:2 above) for the AP1000 PWR may be representative of the discharges from submarine bases.

The AP1000 PWR list consists of 65 nuclides, thus the monitoring of 18 nuclides at naval bases may represent just over 25% of the total number nuclides being discharged by those Naval Bases.

4.10 Additionally, is evident from the relevant Tables in the annual RIFE reports, that not all of the nuclides tabulated for monitoring/sampling are actually measured in ALL samples at the majority of sites (Civil and military). Thus, at some sites, some of listed nuclides are only analysed for in 1 sample, others are only analysed for in 2 or 3 samples.

4.11 Given the complexity of the waste streams from UK nuclear establishments a brief search for literature on the interactions between various discrete radio nuclides, and between various radio nuclides and other non-radioactive toxins, has not found an extensive data base on such interactions.

Thus, on the combined effects of the above parameters, there is a major shortfall of data covering such issues as

a: synergy (one toxin increasing the effect of another)

b: antagonism (one toxin reducing the effect of another)

c: additive effects (the addition of one effect to another)

5. Monitoring of terrestrial foodstuffs impacted by the sea to land transfer of marine radioactivity

5.1 To date, wherever the phenomenon of sea to land transfer has been studied, there is strong evidence to demonstrate that terrestrial foodstuffs, from the coastal zone of the UK, are being contaminated by radioactive wastes previously been discharged to sea from nuclear sites. Such transfer occurs by way of a number of pathways. The principle mechanisms for such phenomena are dictated by the solubility or in-solubility of the various nuclides present in the liquid radioactive waste discharge streams.

5.2 There is now a strong and long established consensus that some radio nuclides (insoluble) adsorb to the outer surface fine sediment particles suspended in the marine water column and/or deposited in marine/coastal/estuarine fine sediment deposits such as mud flats and salt marshes. This is particularly noteworthy in the case of actinide/alpha emitters such as Plutonium, Americium, Curium etc.

Because a given volume of fine particles will have a greater surface area than the same volume of large particles the relative concentrations of radioactivity in fine sediment samples are generally higher than those in coarse sediments.

5.3 There is an equally strong consensus that some radio nuclides, such as Caesium and Tritium, are soluble and thus “dissolve” uniformly in the ambient water. Behaviour and fate of such nuclides is then closely bound to the behaviour and fate of the water molecules in the ambient water body. Thus tritium is widely reported too become evenly distributed through the water body and to then behave exactly like the water in terms of its

environmental distribution and end fate. There is evidence that Caesium may be closely similar in its behaviour.

5.4 Since the 1980s, a small number of studies, initiated by the UK Government and/or nuclear industry, have investigated the phenomenon and provided evidence that such transfer can occur by way of multiple pathways including:

a: inundation of coastal land by marine sea water: demonstrated in the case of storm surge (but also possible in tsunami type scenarios)

b: use of marine organic wastes as fertilisers: demonstrated in the case of seaweed (but presumably also possible with the use of other marine organic wastes: fish meal, commerciu0ally available sea weed preparations)

c: transfer across the surf line of marine aerosols and sea spray containing man made radioactive wastes.

Assigning relative "significance" to such phenomenon is not easy.

5.5 Coastal flooding (inundation from the sea) is relatively common on all UK coasts and is widely reported. However, both the "post incident" remedial action and the reporting of such events is principally focussed on the immediate and more "human" impacts (loss of life, damage to property etc) than with radioactivity issues, as was the case with the following examples:

a: Extensive areas of the east coast of England (from the Tees estuary down to Dover) were inundated by the storm surge event of 1953.

b: Morecambe (Lancashire) has suffered such inundation many times, most recently in 1977, 1983 and 1990.

c: Towyn (North Wales) was similarly inundated in 1990

5.6 Uniquely, in the Towyn case, marine sedimentary material deposited by the flood, in the urban environment was analysed for radioactivity.

Analysis of the flood born sediment demonstrated that, across the relevant coastal zone (about 6 to 10 miles in extent) from Kinmel Bay through Towyn to Pensarn, Americium 241 was present at levels 10 times higher than the NRPBs Generalised Derived Limits for exposure to that nuclide. Additionally it was postulated that, given the presence of the Americium (Am), it was possible that Plutonium was also present. If that was the case then there can be little doubt that a number of other sediment bound nuclides would also have been present.

5.7 In the time scale of production of this submission, no thorough review of the total acreage of foodstuffs or food growing land exposed to coastal inundation (from the sea) has been identified.

However, it seems from the above-mentioned urban based reportage, that inundated coastal urban acreages are relatively high. Accordingly it is possible that inundated agricultural acreages may be equally high, and from the Towyn evidence, that there may be a relatively high potential for sea borne, "inundation" transported, radioactivity to contaminate a wide range of foodstuffs including arable/vegetable crops and dairy/livestock produce.

This Submission notes that research into the possible radiological impact of coastal inundation events, and its associated import of marine sediments contaminated by radio active wastes, does not routinely investigate the potential dietary impact of such events by monitoring coastal soils and the crops grown upon them in the wake of such major "one-off" events.

5.8 On a more "local" level, review of reportage such as that presented in the Annual RIFE reports indicates that the ongoing, long term, dietary potential of more minor and regular "inundation" phenomena are given some attention in the immediate vicinity of nuclear sites.

Thus (RIFE 17: page 119) explains that wild growing leaf beat and marsh samphire were collected and analysed near the Bradwell NPS, because they were eaten locally and grow in areas that are tidally inundated. These subjects were monitored under “marine samples”.

However, for each plant species only 1 “sampling observation” was made and only 2 radio nuclides (Cs 137 and Am 241), out of the total of ten, were analysed for at the Bradwell station.

Additionally, sea kale is monitored at the Dungeness NPS and samphire at the Heysham NPS.

5.9 Further monitoring is sometimes carried out to assess the radiological impacts of the use of marine organic material as a fertiliser/soil conditioner.

Thus, at the Hinkley Point NPS, RIFE 16 (page 121) reported that vegetable and soil samples were monitored in plots near Hinkley in order to assess the potential radiological impact of such a practice.

During the course of the assessment, 1 sampling observation was made on each of: carrots, potatoes and soil.

5.10 The sea to land transfer of radioactivity across the UK surf line via marine aerosol and sea spray pathways has also been confirmed by a small number of studies.
Much of this work has been carried out by the research division of the UK AERE who chose the Irish Sea as their field of work (because of the presence of Sellafield and its large volume discharge of radioactive wastes to sea), and various nuclides of Plutonium and Americium, which became the radio nuclides of interest.

5.11 The various AERE studies reported that:

a: several nuclides of Plutonium (Pu) and one of Americium (Am) were found to be airborne in any shore line area where air sampling fieldwork was carried out in onshore wind conditions and that this was closely linked to the presence of salt and moisture (thus confirming the marine source of the radioactivity);

b: the magnitude of the effect was also closely linked to both the volume of fine sediment particles ejected into the air in spray or aerosol droplets and increasing wind speeds and fine sediment loadings of the ambient near surface water body;

c: however, it is also reported that the work was unable to provide accurate data on the true extent of the sea to land transfer of these nuclides, because the attempts to quantify the phenomenon were based on the use of flawed technology and methodology, which was itself derived fro the absolute non-availability of appropriate equipment;

d: it was specifically noted that the research data should be used “only as a qualitative tool to compare relative concentrations of actinides in sea spray” (i.e. not as a record of the true QUANTITIES of radio nuclides in sea spray).

e: it was also noted that Caesium 137 was also transported across the surf line and into the terrestrial coastal zone.

(Eakins et al’: “Studies of Environmental Radioactivity in Cumbria: Part 5: The Magnitude and Mechanism of Enrichment of Sea Spray with Actinides in West Cumbria.” Report no R10127. AERE: Harwell. 1982)

5.12 One of the most significant observations of the AERE studies was that plutonium and americium became highly enriched in the marine aerosols and sea spray relative to the concentrations found in the ambient sea water.

Enrichment factors (EFs) in offshore generated marine aerosols were reported as follows:

Plutonium 238 = EFs of 291

Plutonium239 = EFs of 347

Plutonium 240 =EFs of 347

Americium 241=EFs of 583

(Walker et Al' "Actinide Enrichment in Marine AEROSOLS". Nature 323, 6084, 11th Sp' 1986 (pages 141-143).)

5.13 Other studies report EFs (relative to ambient seawater) of 812 fro Am 241 in aerosols generated in the inshore surf zone of the Cumbrian coast. It was reported that this evidence implied that coastally generated aerosols may produce higher EFs than those produced in more open sea environments (because of the higher ambient fine sediment loadings of inshore waters) and it was estimated that about 2 curies of Pu 239 and 240 had been transferred from the sea to the land over a 14 year period.

(Eakins et Al'. "Studies of Environmental Radioactivity in Cumbria: Part 5. The magnitude and enrichment of sea spray with actinides in West Cumbria" report no R10127. AERE Harwell. 1982)

5.14 The transfer of marine fine particles, re-suspended from the drying surfaces of exposed inter tidal sediment deposits during periods of onshore wind has also been alluded to in some studies, but is very poorly researched.

There may also be a possibility that other pathways such as fog formation, and evaporation from enriched sea surfaces and the drying out of inter tidal sediments may also make a contribution to sea to land transfer. Such processes may be particularly relevant in the case of soluble nuclides such as Caesium and Tritium, but such pathways remain hypothetical at the present as no studies appear to have investigated such a possibility.

6. Independent studies of sea to land transfer.

6.1 As mentioned above, the study of the sea to land transfer of anthropogenic marine radioactivity, and parallel work to assess the radiological significance of the phenomenon, commissioned by the nuclear industry and/or government agencies has been focussed:

a: on the coastal areas of the northern basin of the Irish Sea in the vicinity of the Sellafield sea discharge point sources;

b: on the insoluble alpha actinides/transuranics.

However there is a body of independently commissioned and conducted work, which has reported on the phenomenon in other coastal areas, some examples follow.

6.2 *Western Isles of Scotland -*
In 1991 an independent research team, composed of Scottish physicians and staff of the Scottish Universities Research and Reactor Centre staff, published a study of patients from North Uist (Western Isles of Scotland) which

a: reported a 5 times excess Caesium (Cs) 137 body burdens compared to those in patients from the Scottish mainland and

b: investigated the source of the Cs body burdens found in the N. Uist patients.

The study was based on data gathered between 1979 and 1986 and all measurements were taken and recorded before the Chernobyl nuclear accident.

6.3 The North Uist study reported that earlier research (1981) had also reported high concentrations of body Cs137 in some patients from the Western Isles and had suggested that fish contaminated with Sellafield derived Cs was the main source. The N. Uist study noted that this conclusion had been contested.

6.4 The island of North Uist is generally less than 15kms wide and the study noted that "The prevailing winds blow sea spray several kilometres inland. Thus most of the island's inhabitants, livestock and grasslands are exposed to the sea".

The immediate dose source for the North Uist Cs 137 was shown to be dietary intake of Cs, which was identified in all types of island grown food produce and environmental samples. Island dairy produce, meat and fish all had higher Cs concentrations than their mainland counterparts. High concentrations of Cs were also reported for North Uist seaweed, beach sand, inland peat and both coastal and inland pasture grass.

6.5 Islanders often ate locally produced foods: particularly milk, mutton/lamb and potatoes. Higher body burdens of Cs (and highest concentrations in urine samples) were found in those patients shown to be consuming the greatest dietary percentage of island produce. Lower body burdens were observed in those consuming "shop food" from mainland sources.

The single highest body burden of Cs 137 was observed in a subject who owned sheep and cattle with access to both the shore/machair and inland grasses, ate home grown sheep meat and drank home produced milk, but "never ate fish".

The **average** islander dietary dose, from Cs 137 alone, was calculated at 13.7 micro Sv. The Cs137 body burden of the above mentioned "single highest" was not published. It was concluded that the finding of Cs134 in association with the Cs 137 confirms reprocessing (at Sellafield) as the ultimate source.

6.6 **Table 1: Comparative dietary doses of marine radioactivity (1985)**

N.Uist (1979-85) terrestrial food	Cs137 only	13.7 micro Sv
Hunterston NPS (1985) seafood	17 nuclides	30 micro Sv
Chapelcross " (1985) seafood	15 nuclides	20 micro Sv
Hinkley Point " (1985) seafood	10 nuclides	less 10 micro Sv
Bradwell " (1985) seafood	14 nuclides	less 10 micro Sv

NPS data for 1985 is reproduced from *MAFF "Aquatic Environment Monitoring Report. No 14. Radioactivity in Surface and Coastal Waters of the British Isles, 1985" Lowestoft 1986.*

N.B. No data is available for the marine radioactivity content of terrestrial diet for the identified Coastal Critical Groups at NPS in 1985, so seafood dietary contents are quoted for comparative significance purposes.

6.7 The "fingerprint" of the analysed Cs indicated a clear Sellafield sea discharge component in the majority of samples, and the "excess" over background (weapons test fall out etc) was therefore attributed to the Sellafield discharges The study concluded that it was "important to note that an isotope discharged into the sea as waste may return to land at considerable distance from the site of discharge and enter the human food chain".
(CG. Isles et Al' "Body Concentrations of Caesium 137 in patients from the Western Isles of Scotland". BMJ> Volume 302. 29th June 1991)

6.8 Since North Uist (approx 200kms north [by sea] of the Sellafield discharge outfall) is shown to be saturated with significant concentrations of Sellafield sea discharged Cs, it is not unreasonable to assume that other nuclides discharged from the site (Plutonium. Americium etc) and known to transfer from the sea to the land are also present in the islanders diet. Islander doses for total nuclides will plainly be significantly greater than the calculated dose for CS only.

6.9 Evidently there is a flaw in the then current, and unfortunately ongoing, assumption that maximum doses will only occur in populations close to nuclear establishments.

7. MAFF: Hinkley Duplicate Diet Study

7.1 In 1987, the UK MAFF carried out a Duplicate Diet Study as part of their evidence to the Hinkley C. PWR Inquiry on Critical Groups adjacent to the Hinkley Reactors in Somerset. The MAFF study examined the dietary doses of 7 nuclides discharged from the Hinkley site, which would be delivered to local residents via the consumption of fresh, locally produced, terrestrial foodstuffs.

7.2 The study reported that the Hinkley participants were selected on the basis of "proximity to Hinkley Point combined with a preference for locally produced foodstuffs". There is no suggestion that the Hinkley study was seeking to identify, or calculate the dietary dose from, marine radioactivity, so it is assumed that this study was INTENDED to refer only to deposited radioactivity derived from atmospheric discharges.

7.3 A control group of fresh, locally produced, terrestrial foodstuff consumers was selected from Kingsbridge, South Devon, situated on the upper reaches of an extensive estuary system. This group was selected because it was considered by MAFF to be distant from any point sources of radioactive waste discharges.

7.4 The study delighted supporters of nuclear power at the Hinkley Inquiry because at first it appeared to demonstrate that the dietary dose received by the Hinkley Group (14.2 micro Sv) was actually lower than that received by the Kingsbridge control group (16.0 micro Sv).

However, an independent forensic analysis of the MAFF data revealed that the whole study was deeply flawed and some surprising facts emerged.

7.5 Of particular significance was the fact that although most of the 7 nuclides were present in both diet sets in broadly similar concentrations, the Cobalt 60 (Co60) concentrations in the Kingsbridge dietary samples greatly exceeded those in the Hinkley samples. Given that Kingsbridge was supposed to be distant from point sources radioactive discharges, this elevated C0 60 appeared to be an anomaly.

7.6 However, the independent review revealed that the Kingsbridge estuary is approximately 30 Kms east, by sea, of the point sources of radioactive waste discharges from the Devonport nuclear submarine base which discharges liquid radioactive wastes into the Plymouth Estuary.

The general near surface water column movement off the S. Devon coast trends from west to east and Kingsbridge is therefore the first major estuary "down stream" of the discharge source.

Devonport discharges consist of fission and activation products (including Caesium and Co 60) and actinides such as Pu and Am, arising principally from the repair and maintenance of nuclear submarine PWRs.

7.7 MAFF's annual Aquatic Environment Monitoring Reports (AEMR) monitored marine materials and analysed for 10 nuclides in the immediate vicinity of Devonport, where maximum radioactivity concentrations are found in association with fine sedimentary particles and the most significant nuclide is found to be Co60.

MAFF have identified a coastal population Critical Group at Devonport and calculate that the dietary dose received by this group, from all 10 nuclides, via consumption of seafood alone was 12.0 micro Sv

7.8 In the absence of any evidence to the contrary, there is a compelling case that the source of the Kingsbridge excess Co60 was the Devonport nuclear base, 30 kms distant by sea.

7.9 Since their dietary dose of man made radioactivity is higher than both the Hinkley Critical Group and the Devonport Critical group, the Kingsbridge group should also be defined as a coastal Critical Group on the basis of the fact that they are receiving higher doses of man made radioactivity than either of the identified groups close to nuclear sites and sources of radioactive waste discharges.

Evidently there is a flaw in the then current, and unfortunately ongoing, assumption that maximum doses will only occur in populations close to nuclear establishments.

7.10 Since only 7 nuclides were monitored for in the MAFF study, it is not unreasonable to assume that other nuclides from the Devonport site (where annual analysis of 10 nuclides was reported in contemporary AEMRs) known to be susceptible to transfer from the sea to the land (i.e. Americium 241) may also have been present in the Kingsbridge diet, and that total dietary doses would actually have been markedly higher than those recorded by the study.
(Hinkley Inquiry papers: Topic 2. MAFF 5: Addendum 1 "Duplicate Diet Studies" 1989)

8. The RADMID study (South West Wales)

8.1 Following an independent study which had identified the presence of Sellafield (sea discharged) radioactivity in south west Wales estuaries, and had postulated that such material might transfer from the sea to the land, Dyfed County Council commissioned RADMID, a study of radioactivity in the county, in the late 1980s. One of the tasks of the RADMID work was to confirm or deny the presence of indications of sea to land transfer of Sellafield derived sea discharged material in inland environments.

8.2 This study confirmed the presence of Caesium 137 in pasture grass up to 10 km inland of the Cardigan Bay coast of south west Wales, and reported that:

a. "The grass samples show positive results for both Cs 134 and Cs 137 from locations in excess of 10 miles from the sea coast";
b. "Surprisingly, the ratio *(of the two Caesiums)* suggests that there may be some additional Cs137, perhaps from Irish Sea spume blown inshore during gale force conditions";
c. the presence of certain nuclides "indicates the presence of radioactive isotopes….possibly associated with nuclear installations of the western seaboard."

8.3 The Dyfed study confirmed:

a: an unexpectedly deep inland penetration of this isotope;
b: the fact that, as a contaminant of pasture grass, it must therefore be entering into the regional terrestrial dairy and meat food chain;
c: and strongly implying its possible entry into other local produce food chains (potatoes, vegetables and fruit etc).

Regrettably, no dose calculations were attempted with regard to the radioactivity noted during the RADMID study.

(RADMID: Radiation Monitoring in Dyfed. 1987-1988. First Report. Dyfed County Council. Carmarthen, Wales)

9. Tritium

9.1 Historically there has been a wide consensus between the nuclear industry and the regulatory agencies that Tritium was of little radio biological significance. This hypothesis was based largely on the assumption that discharged tritium (as tritiated water) would naturally dissolve to infinity once in the marine environment and thus present no radio biological hazard.

9.2 However, in 1999, this hypothesis appears to have been under review, when a more precautionary position began to be manifest and reference was made to the fact that "relatively high levels of organically bound tritium (OBT) in local fish and shellfish" from the inner Bristol Channel (max of 33,000Bq/Kg in cod and 26,000Bq/Kg in mussel).

9.3 At this time it was also reported that sampling of tide washed pasture and wildfowl had also found highly elevated levels of tritium in most samples and that

a: "the highest values found were in Shelduck at about 61,000 Bq/Kg total tritium"
b: concentrations in the tide washed pasture grass peaked at 2,000 Bq/Kg
c: inter tidal sediment concentrations peaked at 2,500 Bq/Kg

(RIFE 5: Section 8:2 and 11.2 and tables 8:2(a) and 8.2(c))

Given that the ambient sea water, maximum Tritium concentration, was only 10 Bq/Kg the figures for wildfowl, tidal pasture grass and inter tidal sediments represented an extremely high rate/level of biological accumulation of total tritium (described as OBT and tritiated water).

9.4 In 2001, a study reported that marine organisms incorporate Tritium, via exposure to tritiated water, very rapidly and, within a range of a few minutes to a few hours and reach concentrations close to that of the tritiated sea water in which they are immersed or from which they are acquiring their food.
(McCubbin et Al' "Incorporation of Organic tritium (3H) by marine organisms and sediment in the Severn Estuary/Bristol Channel (UK)". Marine Pollution Bulletin. Vol. 42.Issue 10 October 2001. pps 852-863)

9.5 More recent findings (published in 2009) noted that the accumulation of tritium in organic rich sediment and the food chain of the Severn Estuary "including concentration factors in excess of 100,000 for demersal fish and shellfish, were ascribed to the existence of organically bound tritium (OBT) in local nuclear wastes in the form of specific bio-chemicals, including carbohydrates, vitamins and amino acids".

9.6 However, the 2009 study reported that the distribution of tritium "appears to be influenced by it's affinity for organic matter" in the marine environment, and that "Significantly, a measurable fraction of sorbed tritium associates with proteinaceous material that is potentially available to sediment feeding organisms".

9.7 The study reported that "these characteristics have not been reported previously" and concluded that:

a: "Clearly the view that tritium occurs exclusively as tritiated water and therefore dissolves to infinity should be considered cautiously";
b: "Further research into the concept and nature of tritium partitioning in natural waters is required."
c: "the adoption of unit value (or sub-unit value) distribution coefficients and concentration factors that are currently recommended by the IAEA, but not supported by clearly defined measurements, may require re-consideration."

NB: Clause c (above) plainly implies that modelled/hypothetical calculations may be flawed.

(Turner et Al'. "Distribution of tritium in estuarine waters: the role of organic matter." Journal of Environmental Radioactivity. Vol 100. Issue 10. October 2009. pps 890-895)

9.8 The 2001 study also reported that measured Tritium concentrations in Bristol Channel seawater were at their highest (between 2 and 10Bq/Kg in the vicinity of the Hinkley NPS outfalls.

However, when reporting environmental monitoring at Hinkley Point NPS in 2002, RIFE 8 (page 104), notes that the " relatively high level of tritium levels in seawater was probably

due to the sampling taking place in coincidence with a specific discharge from the “B” station” (i.e. monitoring coincided with a pulsed discharge).

9.9 NB: In contrast to the 10Bq/Kg in seawater reported by the 2001 study, the concentrations recorded by the RIFE 8 sampling effort were as follows:

Seawater (2 samples): (Hinkley outfall): 8,300Bq/Kg of Tritium as 3H: thus represents an 830 times increase in ambient tritium levels and will plainly exercise a major influence on the concentrations of tritium in various marine biota including sea food species..

9.10 The chosen management strategy for the UKs proposed new NPS is to be based on that employed at EDF reactors in France, where tritium discharges are pulsed rather than continuous.

If such a strategy is adopted, as much as 21% of annual discharge of tritium may be released over a 1 month period, leading to major peaks and troughs of discharge across a 12 month period.

9.11 New PWR NPS will raise current discharges of tritium to marine environments. Thus, if the proposed Oldbury and Hinkley PWRs come on line:

a: tritium discharge limits (for combined existing and proposed new Bristol Channel NPS) will rise by 50% from 653 TBq to 983 TBq per annum and

b: the actual annual discharge of tritium (for combined existing and proposed new Bristol Channel NPS) will rise from 105:4 TBq to 314.6 TBq per annum (3 fold rise)

9.12 Current monitoring and sampling policies dictate that tritium monitoring strategies for sea foods at many NPS sites are based on only minimal sampling (1 or 2 sampling observations only). Such a strategy will be totally unable to capture details relating to the maximum inputs of tritium in the context of the proposed “pulsed” intermittent discharges of tritium.

9.13 Furthermore, the RIFE (RIFE 6 and 8) reports demonstrate that, in the specific case of tritium, the monitoring programme is not consistent. Thus:

a: during the Hinkley NPS 2002 programme, tritium analysis was carried out on all marine foodstuffs sampled (4 species: 5 sampling observations);

b: during the Hinkley NPS 2000 programme, tritium analysis was carried out on 1 of all marine foodstuffs sampled (2 species: 4 sampling observations).

10. Am 241/transuranics

10.1 Plutonium 241 was originally thought to be unimportant in terms of human radiobiology and was consequently discharged to sea in unlimited and un-quantified amounts. It is “guestimated" that, up to the end of 1982, some 20,350 TBq of Pu 241 had been discharged through the Sellafield pipelines alone.
(First Report of the House of Commons Environment Committee, HMSO, London.1986)

10.2 It is now accepted that Pu 241 presents a risk to human health in its own right. Moreover, Pu 241 decays to produce the daughter product Americium 241 which is both a beta and an alpha emitter. Am 241 is considered to be 2.5 times more hazardous to human health than the most dangerous of the Plutonium’s.

Americium accumulates in marine sediments and silts, bio-accumulates through marine food chains and transfers readily to land across the surf line in marine aerosols and sea sprays. Americium 241has been shown to be prone to very high enrichment factors of up to 812 (see sections 5:12 and 5:13 above) during processes of sea to land transfer.

The available evidence on Pu 241 decay demonstrates that, during the decay process, the "daughter" or "decay product" Americium (Am) 241 is generated at a ratio of about 32 to 1.

10.3 As a result of this late realisation of the potential effects of Pu 241 discharges, restrictions/limits were placed on the Am 241 discharged in its pure form from all nuclear sites, but in rather small quantities. For instance, "back of the envelope" calculations suggest that in 1988, the total annual discharge of Am 241 from UK nuclear sites was approximately 16.8 TBq.

10.4 By contrast, although the restrictions were put on the discharge of Pu 241 in the early 1980s, the House of Commons Environment Committee was told that the **rate** of Americium 241 production in the Irish Sea alone, by decay of the Pu 241 discharged up to that time, would peak at towards the end of the 21st century at an annual rate of around 48 TBq per year.
(First Report of the House of Commons Environment Committee, HMSO, London.1986)

10.5 No estimate has been offered for Am 241 production (by decay of Pu 241) in other sea areas. However RIFE and other reports frequently point out that Delafield's sea derived actinides are to be found in other UK sea areas as far away as the southern North Sea.

By contrast, RIFE 17 (Appendix 1: Table A2.2, 20111 results) states that the Sellafield site discharged 0.0318 TBq of Americium to sea through its sea pipelines in 2011.

Thus, the hypothesised Irish Sea production of Am 241(from decay of historically discharged Pu 241) at the close of the 21st Century may be expected to roughly equal the Am 241 discharges of 1,500 Sellafield sites.

As mentioned above, the Am 241 production (by Pu 241 decay) in other sea areas (Bristol Channel, Scottish waters and the various compartments of the North Sea) remains un-quantified.

10.6 Despite the limits put on the discharge of Pu 241 in the early 1980s, it is important to note that discharges of both the Pu 241 and pure Am 241 continue to be made from existing nuclear sites, and that the proposed new build NPS are also expected to discharge both substances to marine environments in their liquid radio active waste streams.

Thus the hypothesised figures for Am production via Pu241 decay (see above) presented to House of Commons Committees will be augmented and increased by the Nuclear New Build programme.

10.7 In the context of the demonstrable readiness of Am 241 to transfer from the sea to the land by a variety of routes (via inundation at Town, via aerosols and sea spray in the AERE Cumbrian studies) and the very high enrichment factors achieved during some of these processes (EF of 812 in aerosols crossing the surf line) there is potential for such Am 241 to make a significant impact on both marine and (via sea to land transfer) terrestrial foodstuffs.

10.8 Monitoring and sampling of Pu 241 and Am 241 suffers from a number of weaknesses as set out in Section 3 (above) e.g. low number of sampling observations and the fact that a "once a year" sampling strategy will not record those peaks and troughs of Pu241 and

Am241 which are driven by the seasonal (meteorological and water column) parameter fluxes.

10.9 RIFE 17 reports that 1 sapphire sampling observation for Am 241 analysis was undertaken during the 2011 sampling programme at the Heysham NPS

Table 2.14 ("Monitoring of Am in terrestrial foods and the environment near Ravenglass") of RIFE 17, lists 22 foodstuffs, of which, 1, had 4 sampling observations, 3, had 2 observations, and 18 had 1 sampling observation.

Neither case offers a description of the adjacent coastline environment, strength or duration of pre-sampling onshore winds, strength or duration of any pre sampling rainfall, sea states, sediment loadings of the ambient water column or season at the time of sampling.

Neither case offers a scientific justification for the low number of sampling observations.

10.11 Section 6:8 above discussed the North Uist case study and noted that since North Uist (approx 200kms north [by sea]] of the Sellafield discharge outfall) is shown to be saturated with Sellafield sea discharged Cs 137, it is not unreasonable to assume that other nuclides discharged from the site (e.g. Plutonium and Americium) and known to transfer from the sea to the land are also present in the islanders diet.

This Submission concludes that there is every reason to suspect that N. Uist is not an isolated case and that other island and coastal environments and their populations also experience the effects of such widespread sea to land transfer of sea borne a range of sea borne radio nuclides.

10.12 In the context of the consensually agreed rapid growth of Am241 production due to decay of Pu 241 in UK waters, this Submission concludes that the current level of research into the dietary implications of the Am production on both sea foods and (via sea to land transfer pathways) coastal zone terrestrial foods is insufficient and does not take account of the expected rate and degree of the delivery of Am 241 to environmental media and biota.

N.B. This Submission notes that research demonstrates that the environmental behaviour of other transuranic nuclides such as Plutonium replicates that of Americium, though enrichment factors may not be so quite so high.

11. Flawed modelling

11.1 It is a well understood principle that the accuracy and reliability of hypotheses and hypothetical models is strictly dependant upon both the amount and the accuracy of input data.

11.2 Earlier sections of this Submission have drawn attention to the failure/inability of monitoring programmes (based on a failed hypothesis) to generate appropriate accurate data on both the behaviour and fate of radioactive wastes discharged to sea and the concentrations of radioactivity in food stuffs contaminated with sea discharged radioactive wastes in both the marine and the coastal zone terrestrial environment.

11.3 In the context of these failures and weaknesses this Submission concludes that any hypothetical modelling programmes which repeat and encapsulate those flaws, failure and

omissions must be of questionable value and can not represent an appropriate degree of scientific rigour.

11.4 The NNB Genco Submission for the Hinkley C proposed discharges (NNB-OSL-REP-000147 Sub Chapter 12:2) explains that the general methodology used to calculate environmental concentrations of radioactivity and the doses derived from those concentrations is described in the EC guidance document Radiation Protection: 72 RP72.

It is explained that RP72 describes what is defined as a "comprehensive model" called the Consequences of Releases to the Environment Assessment Methodology otherwise know as CREAM. This model was developed as a tool for carrying out radiological impact assessments.

11.5 This Submission draws attention to the fact that RP 72 was first published in 1995 and that the edition of the CREAM model, used by the Environment Agency and the HPA's Radiation Protection Division and referenced by NNB Genco for use during the assessments of outcomes for the proposed Hinkley C UK EPR station liquid discharges, is PC CREAM 98

11.6 However, the website address:
www.hpa-radiationservices.org.uk/pccream/featureoverview
introduces PC-CREAM 08 which is stated to be "a significant improvement to the PC-CREAM 98 version of the software because it takes into account feedback from users and recent model developments".

NNB-OSL-REP-000147 (page 8: sub chapter 12.2) specifically states "The PC CREAM 08 model was not available when the assessment process was undertaken"

Furthermore the HPA's Radiation Protection division is on record as stating that, as of February 28th 2010 it will no longer be committed to providing support for PC CREAM 98

11.7 This Report therefore concludes that, in the context of the evidence above, it is evident that the PC CREAM 98 modelling software should be considered redundant This Report also concludes that since the assessment process was evidently undertaken some time ago it may therefore not be fully informed about the latest consensually agreed advances in radiological science regarding a range of issues discussed by this Submission (Tritium for instance).

11.8 NNB-OSL-REP-000147 (page 8: sub chapter 12.2: fifth paragraph) states "All discharges are assumed to be continuous, uniform, routine releases". This, as is explained above, applies to the modelling conducted under PC CREAM 98.

However, as shown in earlier sections of this Report, discharges of some nuclides from the proposed Hinkley C rectors are expected to be pulsed or intermittent and thus the work carried out under PC CREAM 98 will not be relevant to any such pulsed or intermittent discharges.

11.9 The Environment Agency's GDA Assessment report UK EPR-05 (page 25: para 119) states that : "For GDA, EDF and AREVA selected Irish Sea/Cumbrian Waters for predicting dispersion of liquid radioactive discharges using the model PC CREAM. They said this would give pessimistic results for the dose impact calculations". The Environment Agency GDA Report does not question the assumption.

11.10 This Submission draws attention to the fact that neither NNB Genco, EDF/AREVA, nor the Environment Agency offered any review, discussion or examination of the statement.

This Submission has already introduced evidence to demonstrate that there are major differences between Irish Sea and Bristol Channel fine particle sediment loadings of the

water column (with Bristol Channel fine sediment loadings vastly exceeding those reported for the Irish Sea and Bristol Channel fine sediments reported as being more likely to be organic in origin)

N.B. mechanisms of re-concentration of radio nuclides (alpha/actinides) by adsorption to fine sediment particles and attachment of some radio nuclides (e.g. tritium) to organic particles are shown (see earlier sections) to be a major factor in the behaviour and fate of sea discharged radioactive wastes.

11.11 In the context of the above, this Submission thus concludes that there is no scientific evidence to support the assumption that the choice of Irish Sea/Cumbrian Waters is appropriate to assessments for the Bristol Channel or for claims that model outcomes will be pessimistic; in fact the available evidence tends to suggest that they may well be optimistic.

This Submission thus concludes that the use of Irish Sea data in a Bristol Channel context lacks both evidential justification and scientific rigour on the part of both NPS developers and the Regulating bodies.

This Submission is concerned that the application of Irish Sea/Cumbrian coast data may be being used in modelled assessments for other, additional sea areas and warns that such a policy may be miss-placed.

11.12 This Submission draws attention to the fact that the DORIS marine dispersion component of the CREAM model has been revised since the 2003 publication of the EC MARINA all study into the behaviour of radioactivity in the marine environment, and thus assumes that these revisions are not encapsulated in PC CREAM 98.

11.13 This Submission also notes that a research study with the working title “Identifying Key Parameters which Control Coastal Dispersion Modelling” has been under way for some time, was originally supposed to be published in 2010 but had not yet been published.

Although this study has been variously attributed to the Environment Agency, the HPA and the National Dose Assessment Working group and is referenced as ongoing in several websites, inquiries to each body, while confirming that such a research project is underway, have been unable to clarify either the authors, the proposed date of completion of the study or a confirmed future date of publication.

11.14 This Submission therefore concludes that the outcomes of what must be highly important research input to the modelling processes and software discussed above are still not available and thus that the modelling processes and software in question are therefore not informed by the latest subject specific research.

11.15 This Submission re-iterates that, in order to generate the most reliable and accurate hypothetical models of the behaviour and fate of radioactive wastes discharged to sea, models of potential pathways of dose delivery to the public and models of potential actual doses received by the public, it is imperative to input the most recently identified, accurate, reliable and up-to-date data and understanding of all relevant parameters.

11.16 This Submission draws attention to the fact that, in the context of the issues set out in preceding paragraphs of this section, the various modelling programmes concerning the environmental behaviour and fate of marine discharges radioactive wastes, pathways of exposure and the subsequent doses of radioactivity to the public are **not** informed by the most recently identified, accurate, reliable and up-to-date data and understanding of all relevant parameters.

11.17 This Submission draws attention to the fact that although hypothetical models are generally calibrated against observed data, in this case much of the existing observed data is deeply

flawed because it is based on the flaws and weaknesses set out in preceding sections of this Submission.

11.18 This Submission therefore concludes that the entire suite of hypothetical models, upon which the assessment of doses of dietary radioactivity derived from marine discharges is based, are significantly flawed and that their use by the Regulating agencies has very limited evidential justification.