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Mike Weightman
HM Chief Inspector,
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C/o Health and Safety Executive
Redgrave Court, Merton Road
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L20 7HS

2nd September 2011

Emailed to: ***FukushimaONRReport@hse.gsi.gov.uk***

Dear Mr Weightman,

ONR NUCLEAR SAFETY REPORT ON THE IMPLICATIONS OF THE FUKUSHIMA DAIICHI INCIDENT – ANNEX TO THE SUBMISSION BY THE NUCLEAR FREE LOCAL AUTHORITIES IN ADVANCE OF THE FINAL REPORT

In addition to the main points made by the NFLA and submitted on the 1st September to the ONR, I would also like to formally submit this detailed annex, which considers marine pollution and related issues arising from the Fukushima incident. It has been prepared for the NFLA by the independent marine pollution specialist Tim Deere-Jones. It should be considered in conjunction with the main NFLA submission, which will be emailed to you with this annex report.

Yours sincerely,

Sean Morris
NFLA Secretary

Annex to NFLA submission to the final Weightman review

Recommendations arising from lessons learned from the Fukushima Daiichi event.

Tim Deere-Jones: Marine Pollution Consultant: August 2011.

Introduction:

The foci of this submission are:

1: The events preceding and giving rise to the discharge of Loss of Coolant Accident (LOCA) derived radioactive material to the marine environment adjacent to the outfalls of the Fukushima.

2: The attempts to control and manage both the coolant water which escaped from reactors and spend fuel cooling ponds (SFCPs) and the emergency cooling water (ECW) used to respond to the loss of that coolant.

3: The attempts to identify and quantify the radioactivity discharged during the event.

4: The attempts to monitor the marine environmental impacts of the radioactivity discharged during the events.

I have placed the 'Key recommendations' as the first part of the submission.

A brief review of the chronological and factual aspects of the Fukushima Daiichi disaster follows the Recommendations.

That brief review seeks to:

1. clarify a mass of poorly reported and often contradictory facts;
2. to develop a time line of events as they relate to discharges to sea;
3. to identify weaknesses/failures in procedures, management and response to the event.

Part 1 - Key recommendation of this report:

1. Generic Recommendations in light of FUKUSHIMA experience:

1.1 Despite assessments of the full range of potential threats the Fukushima event was not foreseen and safety measures designed and built in to the plant during its initial construction and during subsequent years were not adequate to the task of preventing the event**.**

1.2 Thus the event demonstrates that, no matter how much statistical analysis is applied to such issues in order to attempt to forecast potential threats, human fallibility will never be able to guarantee identification of all possibilities.

The only guarantee is that totally unexpected events will occur. This is the most important lesson to be learned from the Fukushima event.

2. Site Drainage Infrastructure and Management

Responding to the initial loss of coolants -

2.1 The Fukushima accident demonstrated that in the event of catastrophic Loss of Coolant Accidents (LOCAs) at either Reactor units and / or Spent Fuel Cooling Ponds (SFCPs), large volumes (up to the total volume contained within the units) of highly radioactive coolant can be lost from both Reactors and pond containment systems as a result of single (earthquake) and multiple events (earthquake+ tsunami), and presumably any other similar magnitude “shock” or “flood” incidents, causing disabling damage and loss of function to infrastructure and operating systems.

2.2: Having escaped from the engineered containment systems, liquid (as opposed to vaporised) coolant was then able to enter non “contained” areas of the site.

2.3: The available evidence indicates that this coolant initially entered and was retained in various “basement” and “trench” sections adjacent too and/or beneath the Reactors and turbine halls. No evidence has been offered to demonstrate that such basement areas were specifically designed and engineered to be “fit” for this purpose. The available evidence suggests that this then gave rise to uncontrolled losses of such liquid, from “trenches” and into the marine environment.

3. Recommendations for management of initial coolant losses

3.1 In the event of a Reactor or SFCP LOCA it is evidently necessary to have in place a system of Emergency Secondary Catchment systems to prevent the total escape, and loss of control, of leaking coolant.

3.2 Thus each unit or facility (Reactor, SFCP, high level liquid waste storage) should be equipped with sufficient emergency catchment space to capture and hold the entirety of coolant from the relevant source.

3.3 This emergency catchment should be sited as low as possible in order to collect escaping coolant on a gravity flow basis (with engineered flow assisting channels) and thus maximise the amount of escaping coolant which can be collected in the event of site-wide mechanical and electrical failures.

3.4 Such emergency catchment should be sealed from “outside” non-LOCA parameter sources such as heavy rainfall, flood or tsunami.

Such emergency catchment should be engineered to the highest standards of accident survivability.

3.5 Such emergency catchment should be equipped with its own integral pumping system to facilitate removal of this material to safe long term storage. Additionally it should be provided with the facility to easily and simply attach “emergency” pumping equipment if so required

3.6 Such emergency catchment should be equipped with its own integral radiation level readers and also with sampling equipment enabling thorough radiological analysis of the contents of the emergency containment to be carried out. Additionally it should be provided with the facility to easily and simply attach “emergency” sampling equipment if so required.

4. Responding to outcomes of Emergency Cooling Water Use

4.1 The Fukushima event has demonstrated that in the event of catastrophic LOCAs at Reactor and SFCP units, a primary and very long term response is the application of high volumes of Emergency Cooling Water (ECW).

4.2 It is evident that the scale of use of ECW gave rise to an additional series of problems surrounding the management and control of ECW

4.3 The available evidence suggests that, having been passed through / over fully or partially melted fuels in Reactor cores and SFCPs, the ECW initially entered the various “basement” and “trench” sections beneath the Reactors and turbine halls where it must be assumed to have mixed with the initial lost coolant.

4.4 There is a wide discrepancy between the combined volume of liquid radioactivity reported to have escaped from “trenches” and that deliberately discharged from pre-event liquid waste tanks in order to store more highly active liquid wastes generated by coolant loss and ECW use, when compared to the total volumes of ECW used as discussed in the main body of this submission.

4.5 Continuous application of ECW plainly led to the eventual spread of liquid radioactivity into other sectors of the site and hence into the marine environment.

5. Recommendations re control and management of ECW:

5.1 In the event of a catastrophic LOCA requiring the application of massive volumes of ECW, measures are required to prevent the ECW from reaching the marine environment.

5.2 Where ECW is being applied to ruptured/breached reactors and SFCPs, the Emergency Secondary Catchment systems proposed above might be used if they were of sufficient volume to hold that coolant lost during the initial LOCA + the additional ECW.

5.3 However, in the case of an incident such as the Fukushima event, it is evident that the huge volume of ECW (reportedly thousands of tonnes) would likely and quickly overwhelm any basic LOCA emergency catchment systems unless they were specifically engineered to hold such high volumes.

5.4 Controlling flow and end fate of ECW poses additional problems in the context of the "exterior use" of ECW which was applied to reactor roofs (and possibly SFCPs) by helicopter drop, riot control water cannon and fire trucks in scenarios which might exclude the collection of excess ECW etc in the proposed emergency catchment systems while generating free flowing (uncontrolled) run off of ECW.

5.5 Such difficulties could be circumvented if the initial site design and build process were to ensure that all areas in the vicinity of potential sources of radioactive material (including potential internal and external applications of ECW) were to be fully bunded and provided with gravity driven run off/drainage control systems including extensive and very high volume holding tanks such that NO site liquid run offs would be uncontrolled (i.e. ALL surface liquids generated within the site: including LOCAs, ECW, all rainfall and any other spills, would be controlled).

5.6 In order to combat a scenario like the Fukushima event such holding tanks would have to be numerous and large with the capacity to hold many thousands of tonnes of radioactive liquid.

5.7 Such high volume holding tanks should be engineered to withstand as best as possible, all flood and shock events, provided with inbuilt pumping systems enabling the transfer of liquids from one to the other and provided with the facility to easily and simply attach "emergency" pumping equipment if so required

5.8 In addition to providing management options for the control of ECW etc, the use of such tanks would have the additional benefit of catching and containing long term (late discovered) leaks of radioactive liquids via site drains, such as has been recorded at UK reactors under normal operational conditions.

(see Appendix 1: "Incomplete discharge Data": para 4)

5.9 All such high volume tanks should be fitted with their own integral radiation level readers and also with sampling equipment enabling thorough radiological analysis of the contents of the tanks to be carried out. Additionally they should be provided with the facility to easily and simply attach "emergency" sampling equipment if so required.

5.10 Use of such tanks to prevent direct run off of LOCA, ECW and other radioactive (or potentially radioactive) liquids in to marine and other environments would thus permit control of the initial

event and an appropriate level of management of the liquid wastes thus generated (including: thorough investigation of the radioactivity content of retained liquid, controlled discharge of low level liquids, appropriate control and manipulation of liquids in the process of decaying to acceptable levels, retention and treatment of high level liquids and settlement of particulate matter)

5.11 Additional issues thrown up by the Fukushima event include that of the application of sea water as ECW with subsequent damage and the reduction of efficiency of reactor and SFCP pipe work due to salt clogging of pipe work etc, which led to a reduced flow of water through Reactor and SFCP systems. Such impacts can be avoided by the use of freshwater instead of salt water.

5.12 The reporting of the Fukushima event makes it plain that freshwater sources were depleted very soon after the event began. Plainly, any future reactor site design must include provision for unbroken supplies of freshwater, best achieved by having both on site and regional reservoirs of freshwater dedicated to the task of coolant replenishment.

5.13 Ready access to regional supplies is necessary in order to avoid the total loss of supply in the event those on site supplies are overwhelmed.

Replacement emergency delivery systems (pumps and pipe work) must be installed or immediately available in order to avoid the catalogue of delays and interruptions to supplies reported during the Fukushima event.

6. Post event monitoring of marine environments

6.1 The purpose of post event radiological monitoring and analysis of the environment is to assess the public health impact and the behaviour and possible fate of the entire radioactivity that is discharged during the event.

6.2 Post Fukushima type event scenarios require the rapid deployment of thorough and coherent monitoring and analytical programmes, which are designed to investigate the concentrations and behaviour and fate of the full inventory of radioactive materials likely to have been discharged during the event.

6.3 The post Fukushima event monitoring and analysis of the marine environment was characterised by late inception, restricted frequency and limited investigation of limited parameters. It appears to be representative of a rushed, panicky and incoherent response to unforeseen circumstances.

6.4 The Fukushima monitoring/analytical programmes have failed to comprehensively (or even adequately) investigate the full inventory of potential radioactive pollutants in that they have focused almost exclusively on Iodine and Caesium isotopes, while ignoring many others especially the alpha emitting actinides known to be present in BWR reactor cores and SFCP (several isotopes of Plutonium, uranium, curium, americium).

7. Recommendations for post event marine monitoring programmes

7.1 Any future monitoring and analysis, following a Fukushima type event must fully take into account the full inventory of radioactivity available for release given the nature of the accident and the actions taken.

7.2 At Fukushima the monitoring authorities chose to focus on those isotopes (iodine and Caesium) which are highly soluble in water, while at the same time ignoring those which are insoluble and prefer to attach by adsorption to sedimentary particles suspended in the water column.

7.3 They also failed to investigate the presence, concentration and radiological significance of “hot” particles of reactor fuel, used fuel from cooling ponds and/or pieces of reactor of cooling pond structure released into coolant and ECW flows as a result of explosion, meltdown, containment breach, washout of coolant and through flow of ECW.

7.4 In order to adequately fulfil the purpose of future post (reactor and Cooling Pond) LOCA marine monitoring and analytical programmes those operators and agencies responsible for drawing up such programmes should prepare A CLEAR AND DETAILED POST EVENT MONITORING AND ANALYTICAL PROGRAMME, subject to wide scrutiny and peer review and available for immediate deployment in the event of such an event

7.5 Such a programme should take account of the following parameters

a: the full inventory of radioactive materials contained within both Reactor cores and spent fuel ponds

b: any monitoring and analytical work should include coverage of both beta emitters and alpha emitters, activation products and fission products

c: accident derived “hot” particles (pieces of fuel from reactors and/or cooling ponds subject to explosion or meltdown, materials likely to have escaped from reactors of SFCP as a result of coolant escape and the use of ECW)

7.6 Such a programme should take account of the known environmental behaviour of both highly soluble radioactive materials and non-soluble radioactive materials with regard to both their immediate behaviour and long term behaviour and fates.

7.7 Such a programme should investigate the behaviour of radioactivity by filtering seawater samples and identifying the concentrations of the inventory radioactivity found in filtered seawater and that found in any sedimentary particles previously suspended in the seawater.

7.8 Such a programme should identify near, mid and far field end fate deposition environments (seabed and inter tidal fine sediment deposits) where very long lived, non-soluble isotopes of Plutonium, Americium, Uranium and Curium might be expected to deposit out and re-concentrate relative to ambient water column concentrations.

7.9 Such a programme should have regard to the scientifically attested work which has demonstrated the ability of several isotopes (both highly soluble and in-soluble and in particulate form) to re-concentrate in marine micro layers, marine sea sprays and marine aerosols and hence to transfer from the sea to the land. Analytical work to assess the post event Public Health significance of these mechanisms must be undertaken, leading as they do to potential human exposure via inhalation, contact etc.

7.10 Such a programme should also have regard to the attested fact that such isotopes (including Caesiums and actinides and particulates) have been shown to transfer from the sea to the land (via sea spray, aerosols, flooding) and to contaminate terrestrial foodstuffs and thus enter

terrestrial dietary chains. Analytical work to assess the Public Health significance of these mechanisms must be undertaken in the context of potential exposure of humans via pathways of ingestion, inhalation and contact.

7.11 Such a programme should also have regard to the fact that radioactivity deposited in inter tidal sedimentary environments has been shown to be susceptible to re-suspension (in drying conditions) and blowing ashore adsorbed to fine sediment particles to contaminate house dust and perhaps terrestrial foodstuffs

Part 2 - Description/Chronology of events at Fukushima Daiichi

1. Introduction

1.1 There is now a maturing and ongoing consensus among industry commentators that the Fukushima events have been characterised by:

a: low standard of accuracy and transparency of reporting
b: confusion of chronology
c: confusion of factual detail (mistakes)
d: inadequate number of parameters reported

1.2 This has led to both an inadequate understanding of the event itself and an equally inadequate management of many issues, not least those leading to the ongoing mismanagement of issues concerning the marine environmental impacts of post-incident remedial actions.

1.3 As of yet there is a dearth of in-depth and peer reviewed analyses of the factual and chronological evolution of events. Additionally of course, it is undoubtedly the fact that events continue to unfold as the official Weightman Inquiry hears evidence, thus many of the outcomes of the Fukushima event are still unknown.

1.4 Evidently it is premature to conduct any reviews of the implications of the event (in respect of the UK's ongoing nuclear power developments) until such time as the Fukushima events and their aftermath are universally agreed to have concluded and a wide ranging, peer reviewed analysis of what actually happened at Fukushima, and it's full range of environmental, public health and economic impacts had been conducted and made public.

1.5 Thus, in the current context, the UK Government has acted precipitously in setting up the Inquiry and insisting on a limited time scale for conclusion and presentation of recommendations in the absence of a factually and chronologically complete, wide ranging and peer reviewed analysis of all of the available facts.

1.6 Consequently this submission relies upon the relatively "immediate" responses of various experts and commentators, which have been reported as events continue to unfold.

The following paragraphs are based on information provided by TEPCO and Japanese Government Press Releases, and a very well referenced summary of the event provided by WIKIPEDIA.

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2. Loss of Reactor 1 coolant water

For brevity's sake this submission will focus on events surrounding the 3 partial meltdown incidents at Fukushima Reactors 1, 2 and 3 all of which have required remedial injection of high volumes of emergency cooling water (ECW) supplies due to leaks following breach of containment

2.1 Reactor 1: chronology of emergency coolant water injection

A: Within 16 hours of initial major quake: containment/cooling systems completely failed and fuel rods exposed. The reactor core had melted, fallen to bottom of pressure vessel and burned through it.

B: 12 March: (20.20, Japan Time) (JT): seawater injection to reactor core initiated using fire trucks (flow rate of 2 cubic metres per hour)

C: 23rd March: Seawater injection by site feed water systems (flow rate increases to 18 cubic metres per hour)

D: 24th March: high rate of seawater injection increases pressure in reactor….steam vented and (water flow rate reduced to 11 cubic metres per hour)

E: 25th March: 1,890 cubic metres freshwater brought to site by barge and fresh water injection replaces seawater injection.

F: 12th May: TEPCO confirms that due holes in pressure vessel, coolant water continues to leak.

G: June: Japanese Government confirms that reactor containment had been breached and that pumped cooling water continued to leak

H: 23rd August: TEPCO press release confirms that water continues to be injected at flow rate of 3.7 cubic metres per hour.

No details have been provided regarding the starting date of this reduced flow rate programme, thus militating against any calculation of the volumes of water used during this period.

2.2 I have been unable to find any comprehensive assessment of volumes of emergency cooling water use re Reactor 1. Such data appears to have not been calculated.

However the following may give some impression of the volumes of ECW used at Unit 1 (cubic metre = approx 1 tonne of water)

Dates	**Given Flow rates**	**Total Volumes for period**
12 to 23 March	2 cubic metres per hour	528 tonnes per 11 days
23/24 March	18 cubic metres per hour	432 tonnes per 1 day
25 March	11 cubic metres per hour	264 tonnes per 1 day
23 August report available)	3.7 cubic metres per hour	88.8 tonnes per day (but date of flow change not

2.3 Thus, after 13 days of ECW pumping (12 to 25 March) an estimated 1,224 tonnes of water had pumped into the reactor core of Unit 1 at an average rate of 81.6 tonnes per day.

2.4 During the subsequent 151 days (March 25 to Aug 23) the ECW flow rate cannot be precisely calculated due to the very poor reporting.

However, using the data presented in 2:1 (above) the range of potential values would spread from:

Max Value a: 150 days at 264 + 1 day (Aug 23) at 88.8 = approx' 39,688 tonnes

Min Value b: 151 days at 88.8 = approx' 13,408 tonnes

2.5 Total estimated pumped ECW values for period 12 March to 23 Aug (164 days) thus range between:

Value a: 39,688 tonnes +1,224 tonnes = 40,912 tonnes

(average daily rate = 250 tonnes)

Value b: 13,408tonnes +1,224 tonnes = 14,632 tonnes

(average daily rate=90 tonnes)

2.6 As of August 23, there has been 164 days of continuous pumping of ECW through the reactor core.

In the context of the:

A: official confirmation of meltdown beginning within 5 hours of the first earthquake because of cooling failure;

And -

B: constant application of ECW to reactor core;

And -

C: `confirmation of leaks in the reactor pressure vessel and containment systems;

it cannot be denied that ECW has been continuously passing over/through the reactor core (and subsequently the molten mass of fuel arising as a result of the meltdown) for 5..5 months and flushing a range of particulate and dissolved radioactive fission and activation products from the reactor core and into non-core, non pressure vessel and non-containment system environments : i.e. transporting those various radioactive materials from within a supposedly safe and shielded environment to the outside environment.

2.7 When reactor core cooling fails in such a scenario the zirconium alloy fuel cladding fails and fission products are released. There can be no doubt that the ECW flows will have collected a highly significant quantity of the full range of fission products and transported them in the ECW flow through the reactor core, the pressure vessel and the containment buildings to whatever their end deposition site will have been.

2.8 No comprehensive calculation, assessment or estimate of the total volume/quantity of core derived fission products entrained in the ECW through flow has yet been made public.

2.9 In the absence of any other data it may be assumed that the full range of fission products derived from uranium oxide based fuels undergoing a meltdown were available for entrainment into the ECW deployed at Unit 1.

These fission products will have included approximately 17 actinides composed of:

- Several isotopes of Uranium
- Several isotopes of Plutonium
- Several isotopes of Americium
- Several isotopes of Curium

2.10 In addition the BWR cores will have contained isotopes of Caesium, Iodine, Tritium, and Rubidium and a cocktail of approximately 55 other radioactive isotopes (including corrosion products derived from the irradiation of reactor and pipe work structural materials as well as from the fuel and its cladding.)

3. Loss of Reactor 2 coolant water

3.1 Reactor 2: chronology of emergency coolant water injection

A: 14 March: fuel rods exposed and water levels falling to minimum values.

Injection of sea water into reactor vessel initiated and reactor vessel half filled

B: 14th March: pumping stopped due to four of five pumps failed and 5th ran out of fuel. Also gauge accidentally turned off and blocked flow of water into reactor vessel

C: 15 March: pumping resumed

D: 26th March: switch to freshwater injection

E: 28th March: Nuclear Safety Commission suspects radioactive materials leaked from reactor into water in trenches……volumes of pumped water reduced because of concern about leaks to sea

F: 15th May: TEPCO reports that Unit 2 leaking and that 1,000s of tonnes of pumped ECW had leaked

G: 23 May: TEPCO reports Reactor 2 achieved meltdown about 100 hours after initial quake

H: August: ECW still being pumped

3.2 As of yet I have not been able to access details of the flow rates of ECW pumping flow rates. Nor have I have been unable to find any comprehensive assessment of volumes of emergency cooling water use re Reactor 2. Such data appears to have not been calculated.

However the scant available details of the progress of events at Reactor 2 imply that pumping flow rates for ECW were probably broadly similar to those at Reactor 1.

3.3 Therefore, and subject to the release of additional information, I propose that the range of Total Pumped Volume of ECW for reactor 2, be taken as similar to that of Reactor 1.

3.4 Total estimated pumped ECW values for period 14 March to 23 Aug (164 days) thus range between:

value a: 39,688 tonnes +1,224 tonnes = 40,912 tonnes

(average daily rate = 250 tonnes)

value b: 13,408tonnes +1,224 tonnes = 14,632 tonnes

(average daily rate=90 tonnes)

3.5 There has now been at least 162 days of continuous pumping of ECW through the reactor 2 core.

In the context of the:

A: official confirmation of meltdown beginning due to the first earthquake because of cooling failure

And -

B: confirmation of leaks in the reactor pressure vessel and containment systems

3.6 This can only mean that water has been passing over the fuel rods and subsequently the molten mass of fuel arising as a result of the meltdown.

3.7 It cannot be denied that ECW has been continuously passing over/through the reactor core (and subsequently the molten mass of fuel arising as a result of the meltdown) for 5.5 months and flushing a range of particulate and dissolved radioactive fission and activation products from the reactor core and into non-core, non pressure vessel and non-containment system environments : i.e. transporting those various radioactive materials from within a supposedly safe and shielded environment to the outside environment.

3.8 When reactor core cooling fails in such a situation the zirconium alloy fuel cladding fails and fission products are released. There can be no doubt that the ECW flows will have collected a highly significant quantity of the full range of fission products and transported them in the ECW flow through the reactor core, the pressure vessel, the containment buildings to whatever their end deposition site will have been.

3.9 No comprehensive calculation, assessment or estimate of the total volume/quantity of core derived fission products entrained in the ECW through flow at Reactor 2 has yet been made public.

3.10 In the absence of any other data it may be assumed that the full inventory of fission products derived from uranium oxide based fuels undergoing a meltdown were available for entrainment into the ECW deployed at Unit 2.

These fission products will have included approximately 17 actinides composed of:

- Several isotopes of Uranium
- Several isotopes of Plutonium
- Several isotopes of Americium
- Several isotopes of Curium

3.11 In addition the BWR cores will have contained isotopes of Caesium, Iodine, Tritium, and Rubidium and a cocktail of approximately 55 other radioactive isotopes (including corrosion products derived from the irradiation of reactor and pipe work structural materials as well as from the fuel and its cladding.)

4. Loss of Reactor 3 coolant water

4.1 TEPCO have announced that meltdown in this reactor occurred approx' 60 hours after the initial quake. In September 2010 TEPCO had announced the restart of Reactor 3 using Pu MOX fuel and Uranium Dioxide.

4.2 Reactor 2: chronology of emergency coolant water injection

A: 13 March: seawater injection of Reactor core commenced using fire truck pumps

B: 14 March: pumping stopped due to consumption of water in “reserve pool”. Pumping later resumed when alternative supplies connected

C: 17 March: 4 helicopter drops of seawater on to reactor roof (approx 13.5 tonnes each: 54 tonnes total).

D: 17 March: riot police water cannon spray water onto Reactor roof

E: 18th March: six fire engines pumping seawater (flow rate 54 tonnes per hour) but duration of this work not reported

F: 22 March: estimated that 3,742 tonnes of ECW used to date

G: 25 March: TEPCO report that reactor vessel probably breached and leaking radioactive materials

H: 15th May TEPCO report that Reactor 3 likely to be breached and leaking water

I: August: ECW pumping still continues

4.3 As of yet I have not been able to access details of the flow rates of ECW pumping flow rates for Reactor 3. Nor have I have been unable to find any comprehensive assessment of total volumes of ECW use re Reactor 3. Such data appears to have not been calculated.

4.4 However, the scant available details of the progress of events at Reactor 3 imply that pumping flow rates for ECW were, **at the very least**, broadly similar to those at Reactor 1.

But it should not be forgotten that there was an additional ECW strategy employed at Reactor 3, this being the application (by helicopter, water cannon and fire engine) of ECW to the reactor 3 roof at various rates (54 tonnes per hour) and (54 tonnes during 4 helicopter drops)

4.5 Therefore, and subject to the release of additional information, I propose that the range of Total Pumped Volume of ECW for reactor 3, be taken as similar to that of Reactor 1.

4.6 Total pumped ECW values for period 13 March to 23 Aug (163 days) thus range between:

value a: 39,688 tonnes +1,224 tonnes = 40,912 tonnes

(average daily rate = 251 tonnes)

value b: 13,408tonnes +1,224 tonnes = 14,632 tonnes

(average daily rate=90 tonnes)

BUT not forgetting the above mentioned (para 4.4) ECW applications to the Reactor 3 roof.

4.7 There has now been 164 days of continuous pumping of ECW through the reactor core. In the context of the:

A: official confirmation of meltdown beginning within 5 hours of the first earthquake because of cooling failure;

And -

B: constant application of ECW to reactor core;

And -

C: `confirmation of leaks in the reactor pressure vessel and containment systems;

it cannot be denied that ECW has been continuously passing over/through the reactor core (and subsequently the molten mass of fuel arising as a result of the meltdown) for 5..5 months and flushing a range of particulate and dissolved radioactive fission and activation products from the reactor core and into non-core, non pressure vessel and non-containment system environments: i.e. transporting those various radioactive materials from within a supposedly safe and shielded environment to the outside environment.

4.8 When reactor core cooling fails in such a situation the zirconium alloy fuel cladding fails and fission products are released. There can be no doubt that the ECW flows will have collected a highly significant quantity of the full range of fission products and transported them in the ECW flow through the reactor core, the pressure vessel, the containment buildings to whatever their end deposition site will have been.

4.9 No comprehensive calculation, assessment or estimate of the total volume/quantity of core derived fission products entrained in the ECW through flow has yet been made public.

Additionally such assessments for Reactor 3 are complicated by the fact the fuel was PU MOX.

4.10 In the absence of any other data it may be assumed that the full inventory of fission products derived from uranium oxide based fuels undergoing a meltdown were available for entrainment into the ECW deployed at Unit 3.

These fission products will have included approximately 17 actinides composed of:

- Several isotopes of Uranium
- Several isotopes of Plutonium
- Several isotopes of Americium
- Several isotopes of Curium

4.11 However, there is a wide consensus that the higher Plutonium proportion in MOX fuel increases the amount of fission product and actinide created during combustion: in particular the “activity” of fission product/actinide arisings will be greater than that of normal Uranium based fuels

4.12 In addition the BWR cores will have contained isotopes of Caesium, Iodine, Tritium, and Rubidium and a cocktail of approximately 55 other radioactive isotopes (including corrosion products derived from the irradiation of reactor and pipe work structural materials as well as from the fuel and its cladding.) Such products will also be created as a result of MOX combustion.

5. Estimating the total volume of ECW used to date during reactor cooling

5.1 As a result of chaotic, spontaneous attempts to acquire and apply ECW during the response to unforeseen major events such an estimate cannot currently (and very probably never will) be accurately calculated.

5.2 Various press statements released by TEPCO have thrown a little light on the volumes of contaminated water released from the site. On April 21st TEPCO estimated that 520 tonnes of radioactive water from Unit 2 had leaked into the sea via leaking “pits” before the leaks were plugged. Somewhat later TEPCO stated that 300,000 tonnes of “less radioactive water” leaked (or were deliberately released) in order to free up room for the storage of even more highly

contaminated waters. TEPCO have also described failed attempts to contain contaminated water in the harbour near the plant, by installing “curtains” to prevent outflow.

5.3 However, for one reactor specific response action (Reactor 1) there appears to have been at least an attempt to maintain an estimate of the flow rate of ECW being applied to the reactor core. This has allowed an estimated “range” of total volumes of ECW applied to Reactor 1 to be drawn up.

5.4 As demonstrated above this allows a range of daily ECW application to be estimated (for the period early March to late August) at between 90 tonnes per day and 250 tonnes per day per reactor.

5.5 Allowing for ECW application to 3 Reactors over a 164 day period (13 March to 23 August) we can calculate that the range of total ECW application for the period was between 44,190 tonnes and 122,750 tonnes.

5.6 However this is strictly dependent on the:

a: reliability of the flow rate figures given by TEPCO for the Reactor 1 ECW

b: the reliability of assumptions that the ECW flow rate for the other 2 reactors is broadly similar to that of Reactor 1

c the reliability of chronological details of ECW application provided by TEPCO.

5.7 However, as discussed earlier at 1.1 above, there is now a maturing and ongoing consensus among industry commentators that the Fukushima events have been characterised by:

a: low standard of accuracy and transparency of reporting
b: confusion of chronology
c: confusion of factual detail (mistakes)

6. Spent Fuel Cooling Ponds: damage and remedial actions

6.1 Reporting of Spent Fuel Cooling Pond (SFCP) response is at least as confused and lacking in detail as is that for Reactor actions, possibly more so.

There does seem to be a consensus that

A: the SFCPs, which sit above the reactors within the Unit buildings, are now without any form of containment since explosions have torn away their roofs and exposed the fuels to open air.

B: the SFCP at Units 1, 2 and 3 at least, had lost their cooling systems.

6.2 Unit 1 SFCP

31st March onwards: additional sea water added to spent fuel pond using concrete pump

14th May: freshwater replaces sea water use

29th May: freshwater injection via temporary pump and SFCP line

10 Aug: freshwater via circulatory SFCP line with heat exchangers

No flow rate data is provided for the volume of ECW used at Unit 1 SFCP.

6.3 No information is offered to clarify if the additional sea water added from 31st March was to:

a: replace water which had evaporated due to residual heat of spent fuels

b: replace water which was leaking due to damage of pond structure

c: replace water lost during an explosion scenario

6.4 The available scant information implies that injection pumping was continuous until August 10 when the circulatory SFCP lines with heat exchanger were finally deployed.

It may therefore be assumed (in the absence of any information to the contrary) that there were either leaks in the ponds or relatively rapid evaporation of pond water, requiring constant application of ECW until Aug 10 because prior to that date there is no mention of any circulatory cooling mechanism such as the heat exchangers.

6.5 Lack of detailed flow rate information means that at this stage absolutely no assessment can be made of the volume of Unit 1 SFCP water lost to the environment as steam or leaked water

6.6 **Unit 2 SFCP**

20th March onwards: seawater added to spent fuel pond cooling line

29th March: seawater substituted for seawater

31st May: freshwater via circulatory SFCP line with heat exchanger

6.7 Once again no flow rate data was provided for the volume of ECW used in the Unit 2 SFCP

No information is offered to clarify if the additional sea water added from 31st March was to:

a: replace water which had evaporated due to residual heat of spent fuels

b: replace water which was leaking due to damage of pond structure

c: replace water lost during an explosion scenario

Thus the comments made in paragraphs 6:4 and 6:5 above apply in the case of Unit 2

6.8 **Unit 3 SFCP**

14th March: Water believed boiling away from SFCP (note this pond holding PU MOX assemblies which are thermally hotter than uranium fuel assemblies)

24th March: 35 tonnes of seawater added to pond via cooling system

25th June: 90 tonnes of “borated water” pumped into SFCP

2nd July: water now injected into SFCP via circulatory cooling system with heat exchangers.

6.9 No information is offered to clarify if the additional sea water added from 24 March was to:

a: replace water, which had evaporated due to residual heat of spent fuels

b: replace water, which was leaking due to damage of pond structure

c: replace water lost during an explosion scenario

As was the case with the other units, no flow rate data was provided for the volume of ECW used in the Unit 3 SFCP.

Thus the comments made in paragraphs 6:4 and 6:5 above also apply in the case of Unit 3.

6.10 However, in the context of the need to respond to the elevated thermal heat of PU MOX fuel in the Unit 3 SFCP, it can be seen that the addition of 90 tonnes of borated water was required. This was not reported for Units 1 and 2.

6.11 In the context of that elevated thermal output, it appears probable that the basic cooling requirements of Unit 3 SFCP were greater than those of the other 2 SFCPs and thus a greater volume of ECW was required.

6.12 In summary it can be seen that

a: there was a consensus that the SFCPs for Units 1, 2 and 3 had all lost their cooling water systems

b: the SFCPs at Units 1, 2 and 3 were all in receipt of ECW,

c: no data has been provided for the loss rate of cooling water in the ponds due leaks or evaporation

d: no data has been provided for the flow rates of ECW application at any of the three SFCPs

7. Explosion at SFCP Unit 3?

7.1 Various sources continue to argue that the SFCP for Unit 3 (where the reactor was burning PU MOX fuels) had suffered some sort of explosion, which had ejected highly radioactive material to the outside environment.

7.2 In early April, the New York Times published details of a Nuclear Regulatory Commission assessment of the status of the Fukushima Daiichi plant. (“US Sees Array of New Threats at Japan’s Nuclear Plant”: by James Glanz and William J Broad).

7.3 It is this NRC assessment which suggests that fragments or particles of nuclear fuel from spent fuel pools above the reactors were blown “up to one mile from the units” and that pieces of highly radioactive material fell between 2 units and had to be bulldozed over to protect workers. The NYT article also reported that the ejection of this material may indicate more extensive damage to the highly radioactive SFCP than previously disclosed.

7.4 “American nuclear engineer Arnold Gundersen, noting the much greater power and vertical debris ejection compared to the Unit 1 hydrogen blast, has theorized that the Unit 3 explosion involved a prompt criticality in the spent fuel pool material, triggered by the mechanical disruption of an initial, smaller hydrogen gas explosion in the building. Low-dose radiation researcher and anti-nuclear activist Christopher Busby speculated on Russia Today that the explosion that destroyed the Reactor 3 building was a "nuclear explosion" of some kind in the spent fuel pool.” (from Wikipedia: The Fukushima Nuclear Disaster)

7.5 Fairwinds Associates reported August 26th that the very high Caesium 137 and 134 levels reported by TEPCO (19 and 20 August) following the analysis of SFCPs (Units 1, 2 and 3) water is evidence of spent fuel damage and confirms that the source of the spent fuel fragments found a mile from the Units was indeed spent fuel. from one or other of the SFCPs.

7.6 Whatever the cause of the explosion and subsequent ejection of highly radioactive material, there is no doubt that there is agreement that the event was of sufficient force to carry the highly radioactive material for "up to a mile" before deposition.

7.:7 Evidently this scenario would have permitted the deposition of such material directly into the marine environment.

8. Marine Environmental outcomes of Fukushima events.

8.1 The major monitoring/analytical effort has focused on the detection of radioactive Iodine and Caesium. Radiological analysis of sea water by TEPCO, Greenpeace International and Japanese Government Agencies has proved the presence of very highly elevated concentrations of radioactive Iodine, 2 isotopes of Caesium, in seawater, seaweed and marine fish within a 30 to 50 mile radius of the Fukushima site.

8.2 A range of less well know and lower profile radioactive materials have also been analysed for (and found) in seawater: they are isotopes of tellurium, technetium, chlorine, barium and lanthanum (March 29th). Analysis for these items is at a much lower level than that for Iodine and Caesium.

Other nuclides have been identified in contaminated water (derived from reactor/SFCP leaks and ECW) found in basements and trenches attached to various reactor units; Thus in the basement of Unit 1 (March 25th) TEPCO recorded the presence of isotopes of chlorine, arsenic, yttrium, iodine, lanthanum and three isotopes of caesium.

8.3 Direct deposition of "explosion ejected" radioactive debris into adjacent marine environment appears to be highly likely in the context of issues discussed in paras 7:1 to 7:7 above.

TEPCO have stated that small traces of Plutonium have been identified in 5 soil samples near Reactors 1, 2 and 3. TEPCO have agreed that the Plutonium in 2 of the samples is confirmed as "direct result of the recent incident".

TEPCO have also reported that some of those soil samples also contain Curium 242, which supports the proposal that the Fukushima accident has indeed ejected alpha emitting actinides (from at least one of the reactors or SFCPs) into the site environment.

8.4 I have not found any statement giving details of the pathway of transport by which Plutonium and Curium was ejected from within contained structures.

Thus it remains an open question as to whether the Plutonium and Cm found and analysed by TEPCO was carried out of containment as a result of explosion followed by atmospheric discharge or whether it was carried out of containment in cooling water or ECW flows.

As of yet there is no evidence to support or reject either theoretical pathway and so the aquatic pathway remains a viable potential transport pathway for the Plutonium and Curium.

8.5 It is highly noteworthy that none of the actinides or recognised major alpha emitters, expected to be found inside the reactors and SFCPs, have been reported as analysed for in any marine samples (seawater, marine algae of marine fish) by any industrial or governmental agency. No explanation has been given for this omission.

8.6 Entry of radioactive water (from within the Fukushima site) into the marine environment has been confirmed by TEPCO and other observers/commentators. Given the admitted earthquake damage to reactor containment and SFCP containment there can be no doubt that a percentage of that radioactivity is derived directly from the cooling waters from both sources PRIOR to the post-accident response injection of ECW to reactors and ponds.

8.7 Further radioactive contamination of the marine environment will inevitably have been caused by the remedial (post accident) inputs of ECW injected into leaking reactors and ponds

8.8 I have found no statement to the effect that radioactive waters from within the site have ceased to enter the marine environment. It must therefore be assumed that, at the time of writing this submission, the site radioactive run off continues to enter the marine environment

8.9 Official monitoring of radioactivity in terrestrial and atmospheric environments confirms that a reportedly large, but unquantified total amount, of radioactivity has been injected into the atmosphere and subsequently deposited via fallout and washout, onto terrestrial surfaces over a wide swathe of Japan.

There has been no indication that atmospheric leaks from within the Fukushima site have ceased, so it remains the case that radioactive fallout from the accident site continues to fallout and wash out onto land surfaces from which they can wash or leach into watercourses and hence to the marine environment.

8.10 The meteorological data demonstrates that winds have blown from many opposing compass directions since the initialisation of the accident. Thus, it is reported that during the first week of the accident winds blew from the west, thus taking (and depositing) most of the atmospheric releases seaward. At other times since the earthquake/tsunami winds have blown radioactive atmospheric releases inland or seaward.

Plainly there has been ample opportunity for significant percentages of the atmospheric releases to be deposited onto the sea at varying distances from shore.

8.11 A number of media reports confirm that the Japanese authorities are aware that many standing (non-marine) waters have been contaminated by radioactive fallout and washout (e.g.: public and school swimming pools) and that these cannot be emptied and their contents disposed of as radioactive wastes because of lack of appropriate disposal sites and infrastructure.

8.12 The deposition of Fukushima accident derived radioactivity onto terrestrial surfaces means that under a variety of meteorological conditions (rainfall, snow melt, re-suspension of radioactive

small particles in dry weather etc) such material will be remobilised to enter the marine environment by means of a range of mechanisms including:

A: leaching/remobilisation into rivers and streams running down to sea

B: aerial mobilisation leading to “secondary” deposition to sea

8.13 In the context of the atmospheric discharges and subsequent fallout of radioactive contamination onto land surfaces, it should be noted that, due to the meteorological fluxes described in the preceding paragraph, Fukushima derived radioactivity has now crossed the coastal watershed and fallen onto land and water surfaces from which watercourses are running westward, rather than eastward into the Pacific.

Thus, in the longer time scale, Fukushima derived radioactivity will be transported into the relatively enclosed Sea of Japan and impact upon coastal and estuarine environments there.

9. Immediate behaviour of ex-containment cooling waters and ECW

9.1 As described earlier, throughput of ECW through damaged reactor cores and damaged SFCPs must have transported a (so far un-quantified) percentage of that standard Uranium fuelled BWR isotopic inventory + the additional elevated concentrations of fission and actinide arisings from the MOX fuel:

a: out of the reactor core or cooling pond containment systems

b: into the immediate *exterior* environment of the Unit sites, (i.e. outside the containment buildings)

c: and then, as a result of continuing and expanding volumetric flow, further away from the Unit sites and out into the wider environment, where as liquid always does it will have gravitated towards the lowest possible physical level such as drainage systems, trenches, pits, canals, streams/rivers and the sea.

9.2 A study of the available, very poor description of the physical events and their chronology strongly implies that the process outlined above must have occurred in two stages.

9.3 Stage 1 must have consisted of the initial surge of very highly contaminated reactor and SFCP coolant, which would have leaked as soon as physical breaches (holes/leaks etc) of reactor containment vessels and SFCPs were created.

The volumes of such coolant remain unknown due to the lack of data about the volumes of steam and explosive hydrogen generated following the failure of reactor and SFCP cooling systems. This phase was relatively short lived by comparison to the second phase

9.4 Phase 2 consisted of the chronologically much longer term flow of ECW applied to reactor cores and SFCPs (still continuing through August as this submission is written) following the leaks/water loss associated with the initial incidents.

Within phase 2 there were evidently a series of “pulses” due to various technical failures and management decisions regarding the use of different pumping/ECW application techniques and equipment as set out in earlier paras above.

9.5 It is inevitable that these various surges and pulses will have exercised some significant modifying influences on the speed/direction, behaviour and end fate/destination of the highly

contaminated radioactive waters under discussion. However, these cannot be quantified as the events in question are over and done and no observations were made.

9.6 What percentage of this “escaped” liquid radioactivity may have reached the marine environment is un-quantified at this time and is almost certainly going to remain precisely un-calculable due to the lack of useful basic data already alluded to in many places above.

9.7 The relative radiological significance (concentration of radioactivity) of the Phase 1 leaked material compared to that of the Phase 2 leaked material can not be assessed in the current absence of relevant data. However, the fact that Phase 2 leakage from the reactor cores includes ECW which has been poured over and run through the molten mass of the melted fuel in Reactors 1, 2 and 3 and the SFCP at Unit 3 offers the possibility that the cumulative radiological impact of the Phase 2 ECW may be higher than that of the Phase 1 initial loss of coolant from reactors and SFCPs.

10. Fukushima Site Drainage System

10:1 Although a few, very basic, diagrams of parts of the site drainage system have been made public, these are:

a: universally highly simplistic and lacking in detail

b: focused on reactor units and turbine halls and associated basements and trenches

c: fail to describe standard infrastructure across the rest of the Fukushima sites such as those designed to respond to normal site drainage issues such as rainwater

d: fail to describe any additional emergency drainage infrastructure across the Fukushima sites such as those designed to deal with “planned for” emergency flooding scenarios such as excess rainfall

e: fail to describe emergency drainage infrastructure across the rest of the Fukushima sites, specifically designed to deal with leaked reactor and SFCP coolant and/or other radioactive contaminated liquids

f: fail to provide any detail of the volume of liquid which may be held within such basements or trenches, nor of the potential flow rate of liquid entering, running through or exiting such basements or trenches

g: do not discuss emergency systems that may have been fitted to the drainage systems either to restrict excess flow or to hold/store excess flow. (All the available evidence strongly implies that no such emergency storage facilities existed.)

10.2 Statements issued by TEPCO and Japanese Government agencies have only referenced two routes by which contaminated water from within the site has reached the sea, they are:

a: as a result of deliberate discharge of pre-incident contaminated waters in order to make space in holding tanks etc for more highly radioactive waters arising as a result of the accident

b: the overflow/escape of some radioactive water from the “trenches” and “pits” associated with Unit buildings.

It is hard to reconcile these confirmed leaks with the enormous quantities of ex-containment radioactive water reported to have been generated as a result of ex-containment cooling waters and the subsequent use of ECW.

10.3 I have been unable to access charts/maps/ground plans of the Fukushima site drainage system, in particular for those areas outside the reactor containment and SFCP buildings. I have also been unable to access any information on the drainage flow rate of such site infrastructure. I have been unable to access any data about whether any radiological analytical or monitoring equipment was installed / attached to any of the Fukushima site drainage infrastructure.

10.4 I have not found any reportage or discussion of the effect of either the earthquake, or the tsunami, on the integrity of any such site drainage infrastructure as may have been in existence prior to the events.

10.5 Despite the lack of such detail noted in 10:4 above, it may be concluded that (as is the case with other severe flooding events) the site drainage system was probably overwhelmed by the tsunami.

Thus, blocking of drainage channels and pipelines and their entrances and exits with debris, lifting/removal of man hole covers etc as a result of pressures forces, physical destruction of various infrastructure installation (reservoir walls, bunding, pumping equipment etc) has certainly occurred given the scale of both earthquakes and tsunami.

10.6 I therefore conclude that gravitational flow across the least impeded surface routes will have been the route by which the majority of the radioactive coolant and ECW will have entered the marine environment. No evidence is offered to prove that this was not the case. Reportage of the issue of pits and trenches should not be allowed to obscure this fact.

11. Attempts to assess the radiological significance of marine radioactivity

11.1 Quantitative clarification of the amount and significance of radioactivity likely to have entered the sea and its environmental impact has not been completed and cannot be so done until such time as thorough monitoring and analysis of ALL potential isotopes discharged is undertaken. This work requires both a thorough examination of the melted fuels in Reactors 1, 2 and 3 and the damaged fuels in the SFCPs and also a comprehensive analytical monitoring programme of a wide range of environmental media (terrestrial, atmospheric and marine) for a wide range of representative radioactive substances. At the time of writing this submission no proposal for the above work has been identified

11.2 Focus on Iodine and Caesium isotopes is not sufficient, nor representative of the range of radioactivity discharged into the environment, and will not provide a full suite of data useful for the calculation/assessment of public health, environmental and commercial impacts because it fails to address the impacts of the other radioactive material released during the incident, especially that of the actinides/alpha emitters.

11.3 Various marine environmental sampling programmes have been undertaken by TEPCO, Japanese government agencies and environmental groups but these have all been characterised by:

a: a very narrow range of nuclides/isotopes analysed for

b: an apparent poor understanding of short, mid and long term behaviour of radioactivity in the marine environment

c: a very restricted geographical range of sample sites

d: a very restricted range of environmental parameters subjected to analysis

11.4 *Narrow range of nuclides/isotopes:*

As explained in section 8 above, the main focus of the analytical work has concentrated on Iodine and Caesium isotopes.

As also indicated above (paras 2:7 to 2:10) a large number of fission products, actinides and other isotopes will have been present in side the BWR cores of Units 1 to 3 and the used BWR fuel assemblies stored in SFCPs. Additionally high levels of actinides will have been present in the MOX fuel in Reactor 3 and SFCP 3.

11.5 The fuel assemblies of the MOX fuels from reactor 3 and SFCP 3 will contain elevated concentrations of fission product and actinide created during combustion: in particular the "activity" of fission product/actinide arisings will be greater than that of normal Uranium based fuels (see para 4:10 above).

11.6 Despite the "in-site" discovery of both Plutonium and Curium, confirmed as having originated from within the site, and being a "direct result of the recent incident" and well understood to be present in reactor cores and SFCPs, (especially those containing MOX fuels) none of the range of alpha emitters/actinides known to be present in both reactor cores and SFCPs are reported as having been analysed for in any marine samples.

12. Poor understanding of the behaviour of radioactivity in marine environments

12.1 Some nuclides such as the isotopes of Caesium and Iodine are highly soluble and dissolve relatively easily in NPP cooling water and in seawater

Highly soluble nuclides become well distributed through the water body and concentrations generally appear to dilute with distance from source**.** However, a few minor pathways of re-concentration do exist: thus Cs concentrations can be shown to be enhanced through marine food chains relative to sea water concentrations and indeed through coastal zone foodstuffs (impacted by sea spray and marine aerosols) relative to adjacent ambient sea water concentrations.

(See Appendix 1: relevant headings)

12.2 Irish Sea Caesium isotopes, derived from Sellafield liquid discharges to sea, have been found up to 10 kms inland in (south Wales) in pasture grass (having transferred from the sea to the land) and hence available for entry in to the dairy and meat food chains

Irish Sea caesiums from Sellafield liquid discharges have been found in the entirety of Hebridean island local food production (with highest CS doses received by terrestrial produce eater who did not eat fish). See Appendix 1.

12.3 These two examples provide evidence of both sea to land transfer and dietary doses at DISTANCE from discharge point.

(See Appendix 1)

N.B. In the context of these terrestrial doses it is evident that there's a potential for inhalation doses of Cs and Iodine, both from sea spray, marine aerosols and evaporation from coastal mud flats.

12.4 I have no doubt that populations resident along the Pacific coast of Japan are currently, and will be for some time in the future, exposed to doses of highly soluble isotopes (derived from the Fukushima accident) transferring from the marine to the terrestrial environment by way of the mechanisms described above. Such exposure will give rise to doses of radioactivity via a number of pathways including ingestion of contaminated locally grown/gathered terrestrial foodstuffs, ingestion of locally grown/gathered marine foodstuffs and inhalation.

12.5 In the context of both the very high levels of soluble radioactivity expected to be discharged throughout the incident and the demonstrated ability of soluble radioactivity to travel for long distances from input source, the failure to conduct radiological mid field and far field monitoring and analytical work has been a major failure in both public protection and the gathering of scientific data.

12.6 Other nuclides have a low solubility and tend to be adsorbed onto the surface of particulate matter suspended in the water column. These sediments will in time settle and accumulate in sedimentary deposits such as inter tidal and estuarine mud flats: fine sediment, with their larger surface area, will accumulate more than coarse sediments: thus the mud will have far higher concentrations than in the sand.

12.7 Many actinides and alpha emitters are preferential absorbers. Thus, Irish Sea Plutonium and Americium isotopes discharged from Sellafield are shown to become **Ad**sorbed to fine sediment particles suspended in coastal water columns, and (in this form) enriched in marine micro layers relative to bulk seawater by factors of about 4. (Appendix 1)

12.8 Plutonium and Am are shown to become enriched (still in the adsorbed to particulate form) in marine aerosols (generated by bursting bubbles) by factors ranging up to 600 relative to bulk seawater. These aerosols are airborne and readily cross the surf zone and penetrate inland having. Such enrichment mechanisms are found in the context of relatively high sedimentary (fine) particle loadings of the ambient water column. (Appendix 1)

12.9 Such “adsorbing” actinides are also highly susceptible to re concentration in fine sediment deposits, thus, even at distance from input source, they may be found (in mud flats, river estuaries etc) at concentrations several hundred times higher than those observed in ambient sea water samples. (see Appendix 1: relevant headings)

12.10 Such mud flats may provide a source of readily air mobile fine sediments (in drying conditions with high winds) contaminated with adsorbed, and elevated concentrations, of actinides. Such conditions offer the potential for additional sea to land transfer of actinides.

13. Restricted range of marine sample sites

13.1 The various descriptions of marine monitoring efforts make it plain that they are focused on the fate and behaviour of radioactivity within a relatively “near field” range of the Fukushima site liquid discharge point source: i.e. no further than up to some 30/40 miles radius distant from the discharge point source.

13.2 Results from this work have been fairly widely publicised and some commentators have noted the declining levels of concentrations of (mainly Iodine and Caesium isotopes) within the specific area and claimed that they demonstrate a positive environmental development.

13.3 I can report that satellite imagery of the Pacific coast of Japan (Fukushima Prefecture) shows an area of relatively shallow and turbid (high suspended sediment load) water extending off shore for about 1 to 2 kms/ along the relevant stretch of coast

13.4 I note the presence of a number of rivers running down off the high ground inland, across the relatively narrow coastal plain and into the sea. I postulate that (in the wet season) these rivers will make a fairly high fine sediment (clay and organic mineral) contribution to the coastal water sediment budget. Such sediments are particularly prone to the Adsorbtion of actinides

13.5 I have not yet accessed data about the local/regional inshore currents along that stretch of coast. However I can confirm that the general annual near-surface water body movement along the Pacific coast of Japan (Kuro Shio current) trends northwards

13.6 Satellite imagery of the relevant coast also shows the presence of some significant embayments 50 kms + to the north of the Daiichi plant outfalls. Both Matsushima Bay and Ishinomaki Bay are extensive and appear (from visual my inspection of satellite imagery) to be characterised by high sediment loadings and extensive inter tidal sediment deposits.

13.7 Such environments have the potential to be long term deposition sites for any long lived actinide/alpha emitter present in the northerly moving water column environment, and hence to act as potential sources of (Fukushima accident derived) alpha emitting isotopes transferring from the sea to the land. Should this be the case then those coastal zone populations that are resident and adjacent to such environments may be exposed to such material by a number of pathways including ingestion of contaminated locally grown/gathered terrestrial foodstuffs, ingestion of locally grown/gathered marine foodstuffs and inhalation.

13.8 It is my conclusion that the official monitoring regime being carried out by TEPCO and others is inadequate to the task of identifying the potential radiobiological threats to the public because:

a: they are under-measuring both in terms of nuclides and isotopes because they have chosen to focus on relatively short lived Caesium and Iodine and ignored the issue of the alpha emitting actinides (some of which: including plutonium, americium and curium isotopes have half lives extending into the 1,000s of years) which must also be present in the environment.

b: they over represent the issue of dilution and dispersion in that they fail to take account of widely attested mechanisms of re-concentration in specific marine environments

c: they under represent the issues of long distance transport, transfer from one environmental media to another and pathways of delivery to human populations

13.9 It's also relevant to note that a severe storm surge event in Liverpool Bay (UK) caused heavy flooding of coastal town during the course of which large quantities of offshore and near-coastal marine sediments (historically contaminated with Sellafield derived alpha radioactivity) were carried into the town and deposited in the streets, gardens and houses. This material was heavily contaminated with actionable concentrations of man made radioactivity (significant quantities of Americium were recorded). (See Appendix 1: relevant section) In the current context, it seems not impossible that such a scenario may unfold in the future along this seismic and tsunami susceptible coast, and return a percentage of Fukushima event discharged radioactivity back to the land.

13.10 Any attempts to truly quantify the radiological impact of the Fukushima events will of course be restricted by the accuracy and scale of any historical (pre-event) baseline data which may have been gathered on the volume, quantity and isotopic make up of historical discharges from the site: i.e.:

a: the quantities of man made radioactivity that may have been present in the coastal muds as a result of pre-event discharges from Fukushima NPs?

And -

b: just how much of that radioactivity came ashore with the Tsunami inundations?

14. Restricted range of environmental parameters subjected to analysis

14.1 As may be deduced from the discussion in the immediately preceding paragraphs, monitoring of radioactivity in non-living environmental parameters should certainly not be restricted to sea water alone. Fine sedimentary (and indeed organic) particles suspended in the ambient near coastal water column should also be analysed for both soluble and soluble isotopes. Water samples should be filtered in order to better, or more completely, isolate the sedimentary matter. Both filtrate and solids should then be analysed for soluble and less soluble isotopes.

14.2 Such work would greatly assist the plotting of the movement of both soluble and non soluble isotopes and hence diagnosis of the movement and potential deposition sites of alpha/actinides.

14.3 Similarly, those fine sediment inter tidal, near shore and offshore deposition environments regarded as being downstream of the Fukushima marine radioactivity inputs require both identification and subsequent monitoring/analytical work to identify current and ongoing rates of deposition of potentially harmful concentrations of alpha/actinides and enable contingency planning and early warning systems to be put in place should any potential or actual mechanism for the transfer of such material from the marine to the terrestrial environment be identified or occur.

14.4 In the context of those well attested mechanisms of sea to land transfer shown to be contributing to the delivery of doses of marine radioactivity (via ingestion of terrestrial foodstuffs and no doubt inhalation) following sea to land transfer of man made radioactivity, there is a strong case for the monitoring and analysis of:

a: sea surface micro layers where preliminary concentrations of radioactivity build up prior to the production of marine aerosols

b: marine aerosols , especially those produced in the surf zone of sediment enriched coastal waters, where very high re-concentration factors have been observed

c: sea spray droplets especially those coming ashore in onshore winds

14.5 In the context of the list of occurrences at the Fukushima site (explosions, meltdowns, breaching of reactor containment, possible breaching of SFCP containment, massive loss of coolant, massive throughput of ECW) there are no scientific grounds for denying that actual “hot” particles of radioactive fuel, radioactive fuel cladding and possibly) SFCP structure have also entered the non-containment environments both within the site and outside the site.

14.6 There is absolutely no evidence that any of the marine monitoring programmes so far initiated are making any attempt to identify and quantify “hot” particles of radioactive fuel, reactor or SFCP structures.