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"Tritiated water and the proposed discharges of tritiated water stored at the Fukushima accident site."

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Introduction:

"ANRE to Hold Explanatory Meetings and Public Hearings on Handling of Tritium Water

On July 13 (2018), explanatory meetings were discussed by a subcommittee under Japan's Agency for Natural Resources and Energy (ANRE), addressing the handling of so-called "tritium water"—water that has been treated for radioactive contamination—at the Fukushima Daiichi Nuclear Power Plants, owned by the Tokyo Electric Power Co. (TEPCO). Public hearings are to be held at the end of August." [ANRE statement]

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The problem of accumulating tritiated water at the Fukushima site continues to grow, as cooling waters are still being continuously applied at the site. There is increased pressure from TEPCO, regional Japanese agencies and international bodies to discharge the accumulated water into the sea. This pressure is supported by various "nuclear" agencies, both Japanese and International (including the IAEA) who continue to maintain that tritiated water discharged to sea is of no, or little radiological health consequence to the environment, marine workers (fishers, aquaculturalists etc) or coastal and coastal zone populations.

This understanding of the impact of tritiated water discharges is based on an utterly discredited nuclear industry hypothesis for the behaviour and fate of radioactivity, and some very poor and now outmoded scientific research. The most recent (post 1990) UK research on the fate and behaviour of tritium (discharged as tritiated water) in marine, coastal and estuarine environments now clearly demonstrates that tritium has a significant potential for delivering high doses (both dietary and inhalation) to seafood consumers and coastal zone populations living up to 10 miles inland.

This is an issue of the highest relevance to marine stakeholders and coastal zone populations along the east coast of Japan (Honshu). Attempts to belittle the impact of the proposed release to sea of millions of gallons of highly tritiated water, either in pulses or at slow release rates, are without scientific basis, irresponsible and potentially detrimental to human health.

TEPCO and the Japanese Nuclear Regulatory Authorities are considering the release, to coastal waters, of a reported 800,000 +tonnes of radioactive water stored in over a 1,000 tanks at the Fukushima nuclear accident site.

The source of this water is the Emergency Cooling Water (ECW) applied continuously since the accident occurred, in order to cool the remaining nuclear fuel.

As much as possible of this water has been collected and subject to “scrubbing” to extract much of the radioactivity. However, since there are no technically/financially feasible processes for the removal of tritium from the water on this scale, the ECW retains very high levels of tritium.

It is important to note that the boiling water reactors at the Fukushima site would have been discharging monitored levels of tritiated water during routine operations. It is equally important to remember that un-recorded volumes of tritiated water have been leaking into the sea since the first containment breaches of multiple reactors and spent fuel containment pools. Despite attempts to prevent leakage and store as much ECW as possible, the available data confirms that radioactivity is still leaking from the Fukushima event site, it is to be presumed that this includes tritium (as tritiated water).

Currently there is no assessment of when the situation will be stabilised and the application of ECW cease. In this context the problem of storing an ongoing, ever increasing volume of used ECW is becoming extreme, hence the decision to consider release and disposal to the environment.

Tritium is a radioactive isotope of hydrogen, which allows it to readily bind to hydroxyl radicals and carbon, forming tritiated water, which behaves exactly as any other form of water behaves in both natural, and laboratory environments.

Tritium has a half-life of 12.3 years and emits low energy beta radioactivity. Because it is a low energy beta emitter the nuclear industry has always hypothesised that it is not dangerous externally because its beta particles are unable to penetrate the skin. However, it is considered a radiation hazard when ingested via food or water or inhaled as a gas.

The historical, and current, Nuclear Industry statements about the discharge of tritiated waters to sea from UK sites, insist that it has a short biological half life in the human body of 7 to 14 days, which both reduces the total effects of single-incident ingestion and precludes long-term bioaccumulation of tritium from the environment. New Build Nuclear developers in the UK have recently issued statements to this effect. Japanese Agencies and the IAEA have re-iterated such statements in the context of the proposed discharges of tritiated water

However, the emerging evidence of recent scientific studies does not support such bold announcements.

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The following paragraphs provide a summary of the emerging empirical evidence.

1: Emerging evidence on the Fate and behaviour of tritium in marine environments.

1:1 Historically there has been a wide consensus between the nuclear industry and the regulatory agencies that Tritium was of little radio biological significance, largely based on the assumption that because discharged tritium (as tritiated water) would naturally dissolve to infinity once in the marine environment and, due to it’s inability to penetrate the skin, it thus presented no, or little radio biological hazard.

1:2 The hypothesis that “marine” tritium was of low biological significance emerged early in the history of the nuclear industry, when research into both the behaviour and fate of radioactivity in marine environments, and the understanding of how marine parameters affected the distribution and behaviour of radioactivity in general was highly limited by a lack of basic research in all fields.

1:3 Despite the evolution of research into tritium which now clearly demonstrates the weakness of the hypothesis, the hypothesis still remains the standard nuclear industry position.

1:4 the nuclear industry position was typified by the following example:
a: In 1985, liquid Tritium discharges from the Hinkley A Station were increased following work to clean the coolant circuit. The 1985 discharge was 23 TBq, compared to previous years when the annual liquid discharge of Tritium from this station was less than 1 TBq per year. (Ref 27)
b: Despite the observed 23 fold increase in tritium discharges in 1985, the regulatory authority stated that: “the increased discharges were of negligible radiological significance”.
[REF: MAFF Aquatic Environment Monitoring Report (no 14) section 6:6: page 36}

1:5 however, during the 1990’s this approach was beginning to be questioned by the ongoing independent academic research. In 1993 a paper reported that Tritium released into the environment becomes incorporated into environmental organic matter AFTER it’s release.

1:6 The 1993 paper also reported that “Organically bound tritium in that case, will show retention times in organisms that are considerably longer than those of tritiated water which has significant consequences on dose estimates.”
[REF: Diabate S. & Strack S. Health Physics: 1993 Dec;65(6):698-712]

1:7 The 1993 study further reported that
a: that metabolic reactions in plant and animal organisms, with tritiated water as a reaction partner, was of great importance in this respect
b: that the most important production process, in quantitative terms, is the photosynthesis in plant life and through translocation of OBT to the edible parts of the plant
d: that organically bound tritium enters the human body via two dietary pathways, either from primary producers (vegetation), or at a higher trophic level (animal foods)
e: early animal laboratory experiments demonstrated that the dose due to ingestion of OBT was at least twice as high as a comparable intake of tritiated water.

These findings are in clear contradiction to the nuclear industry hypothesis.

1:8 By 1999, even UK Government Agency monitoring of tritium was taking a more investigative approach, and a more precautionary note began to appear when reference was made to the “relatively high levels of organically bound tritium (OBT) in local fish and shellfish” from the Cardiff area of the Bristol Channel/Severn Estuary (max of 33,000 Bq/Kg in cod and 26,000 Bq/Kg in mussel).”
[REF: Radioactivity in Food and the Environment 1999 (RIFE-5) 2000. Section 8:2 and 112 and Tables 8:2 (a) and 8:2 (c) page 111]

1:9 RIFE 5 also reported that additional sampling of tide washed pasture and wildfowl (Curlew, Pintail), Shelduck and "duck" that feed in the Bristol Channel/Severn Estuary intertidal zone had found elevated levels of tritium (due largely to OBT) in most samples with:

a: the ambient sea water concentrations of total tritium reported to range from 9.2 Bq/Kg to 10Bq/Kg
b: intertidal sediment concentrations ranging from 18Bq/Kg to 2,500Bq/Kg : thus representing an extremely high rate/level of biological accumulation of total tritium (assumed to be OBT + tritiated water).

c: RIFE 5 also reported that tide washed pasture grass concentrations ranging from less than 3 Bq/kg to 2,000Bq/Kg
d: lowest wildfowl concentrations at 2,400 Bq/Kg
e: "the highest values found in Shelduck at about 61,000Bq/Kg total tritium": (OBT and tritiated water)

d: The RIFE 5 report conclusively revealed that although the levels of tritium (non organically bound) were relatively low in ambient coastal seawater, the concentration factors (CF) of Organically Bound Tritium bio-accumulation in fish and birds resident in the intertidal and coastal zone are remarkably high .

1:10 A follow on study of the behaviour of Tritium in the Severn Estuary and Bristol Channel (published in 2001) observed that highest concentrations of Tritium were found in the vicinity and at "distances down-stream", of the Hinkley C nuclear power station and the Cardiff GE Healthcare nuclear discharges. (ie: around point sources and at some distance downstream from point sources) *[REF: McCubbin D 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]*

1:11 The 2001 study also found that:
a: tritium, as tritiated water, becomes incorporated into the organic matter of cells and becomes Organically Bound Tritium (OBT)
b: Organisms which consume tritiated food accumulate OBT at a faster rate than those exposed only to tritiated water and reach higher concentrations by bio-accumulation
c: environmental monitoring through out UK waters demonstrates that concentrations of tritium in seafood in highly tritiated sea areas are significantly greater than in other UK marine areas
d: that bio-accumulation of tritium by benthic organisms and demersal fish occurs primarily via transfer up through a web of sediment dwelling microbes and meio fauna, which had been feeding on organically bound tritium (OBT). In this context it was observed that herbivorous species and pelagic fish had lower concentrations of tritium than carnivores and demersal (dwelling near the sea bed) fish. *(ie: tritium (as OBT) does bio-accumulate through marine and coastal food webs)*

2. More recent research on the fate and behaviour of tritium discharged to sea

2.1 A more recent study (published in 2009) has built upon the emerging understanding of the behaviour and fate of tritium in the marine environment reviewed above and reports that:

a: tritium's reactivity with organic materials and solids in the marine environment had previously been "assumed to be limited": and that

b: previously, 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 waste in the form of specific bio-chemicals, including carbohydrates, vitamins and amino-acids" (*i.e. that OBT was only present in the marine environment as a result of the direct discharge of OBT*)

2:2 However, **contrar**y to the claims of the nuclear industry, the 2009 research has proved that the presence of OBT in the marine environment is influenced by its affinity for organic matter in the environment and that "Significantly, a measurable fraction of sorbed tritium associates with proteinaceous material that is potentially available to sediment-feeding organisms."

(i.e. that discharged tritium, in tritiated water, became organically bound AFTER discharge to sea, as a result of its affinity for proteinaceaous material present in the marine environment)

2:3 It was also noted that the discharge of tritiated water from a nuclear establishment on the Tamar estuary resulted in the immediate dilution to activities of less than 10 Bq per Kg in ambient water, "whereas corresponding activities of about 300Bq/Kg (dry weight) in sediment" where observed.

2:4 In the context of the above effect (which has been noted in this and other, estuarine and coastal waters) it was reported that the research absorption and adsorption (sorption) experiments had demonstrated that "sediment organic matter is critical to the removal of tritium from the aqueous phase" and that the effect "was greater in seawater than in river water"

2:5 The 2009 study noted that "the most remarkable aspect of our investigation is the extent of associated tritium, with both dissolved HOM (hydrophobic organic matter) and fine estuarine particles".

2:6 "Experimental results, suggest that the presence and nature of organic matter is critical to the fate of tritium in the aquatic environment, and that there is also potential for its interaction with and uptake by inorganic phases. Association of tritium with sediment organic matter was corroborated in our studies by its near complete (greater than 95%) digestion in untreated estuarine particles"

2:7 This last observation is particularly important in the case of coastal and inshore waters where proximity to eroding coastlines, non nuclear waste disposal pipelines and river inputs via estuaries leads to increased levels of organic material entering the sea. The Fukushima coast and downstream areas (i.e. the Pacific facing coastline south of Fukushima) have numerous such sources of organic input to coastal

waters.

2:8 Noting that "these characteristics have not been reported previously" in UK studies , the 2009 study concluded that:

"Clearly the view that tritium occurs exclusively as tritiated water and therefore dissolves to infinity should be considered cautiously. Further research into the concept and nature of tritium partitioning in natural waters is required, and 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 reconsideration."
[REF: Turner.A 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]

2:9 In the context of the usually restrained language of such journals, this represents a stringent critique of the IAEA and nuclear industry stance on tritium.

2:10 It is evident from this brief summary of recent work on tritium, tritiated water and OBT that a seafood dietary dose to human consumers is strongly indicated and that some degree of biological accumulation of OBT in the human body may be expected..

3: The potential for multiple pathway doses of sea discharged tritium

3:1 UK studies, by both the nuclear industry and independent researchers, have demonstrated that water soluble Caesium 137 re-concentrates in estuarine fine sediments composed of organic and mineral fine particles and transfers from the sea to the land as a result of a variety of natural marine and meteorological processes .

3:2 Studies have demonstrated that sea to land transferring Caesium 137 in both dissolved (liquid) form and attached to marine micro-particles undergoes enrichment in marine aerosols generated in the surf line and transfered across the coast line in onshore winds. Some studies have shown that concentrations of Caesium in marine aerosols may double, relative to concentrations in the ambient (source) marine water.
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 (page 7)

Cambray RS et al' "Pu, Am241 and Cs137 in soil in West Cumbria and a maritime effect" Letters to Nature. Nature 300. pps 46-48 (04 November 1982)

3:3 A pre Chernobyl study of the impact of sea to land transferred, soluble Caesium 137 on a Hebridean island (North West Scotland) situated 200 kms from the Sellafield point source of the Cs, clearly demonstrated that the entire island (approx 10kms wide) had been saturated with Cs 137 contained in marine aerosols and sea spray. Residents were shown to have received dietary doses of Cs derived from the consumption of island produce. Residents consuming a higher proportion of island produce were shown to have higher doses of marine sourced Cs and the islander intake of dietary marine sourced Cs (**via terrestrial produce only)** was shown to be

higher than that received by populations, living adjacent to marine discharge points and eating seafoods.
Isles. CG et al' "Body concentrations of Caesium 137 in patients from Western Isles of Scotland". British Medical Journal. Vol 302. 29th June 1991.

3:4 Since tritium is also readily soluble in both fresh and marine water and tritiated water is reported to behave like any other water, it must be assumed that the tritium (and the OBT formed in the marine environment post discharge) has a similarly strong potential to contaminate terrestrial environments and food produce during episodes of sea to land transfer generated by onshore winds.

Regretably the nuclear industry and their supporting pro-nuclear governments have not undertaken any research on the sea to land transfer (via aerosols/seaspray etc) of tritium and OBT.

3:5 The solubility of tritium in marine and coastal waters and its organic bonding as OBT also strongly imply that both forms of tritium have a strong potential to contaminate coastal environments during episodes of coastal inundation caused by unusually high tides and storm surges. (*see section 1 above*)

3:6 Studies have shown that such inundations have the potential to input high levels of marine sourced radioactivity into coastal urban and public spaces, with a subsequent risk of dose by inhalation as a result of clean up operations (dust suspension etc). Studies have also demonstrated that stock fed on sea washed coastal pasture also accumulate marine derived radioactivity from pasture grass thus subjected to marine flooding.

3:7 In addition to the proved behaviour of dietary tritium, tritiated water and organically bound tritium, the simple fact that tritiated water behaves like any form of water means that under suitable conditions tritiated water will become incorporated into marine spray, aerosols and vapours.

3:8 Wherever studied in the UK, it is universally shown that marine spray droplets, aerosols and vapour production are closely involved in the sea to land transfer of both soluble and micro particle associated radioactivity from the sea to the land. Much of this transfer involves the transport of marine sourced sedimentary and organic micro particles entrained in the spray and aerosols generated by bubble burst and micro-droplet production in breaking waves in the intertidal zone and the open sea.

3:9 UK research has shown that such sea sourced material will contaminate the coastal terrestrial zone, with a significant degree of inland penetration, and deliver dietary doses via the consumption of radiologically contaminated foodstuffs, produced in the terrestrial coastal zone, for up to at least 10 miles inland.
RADMID First Report: 1987 and 1988. Dyfed County Council. Carmarthen. Dyfed. South Wales. (page 12)

3:10 Given that such material is airborne in the terrestrial coastal zone, prior to deposition on food chain material 10 miles inland, inhalation dose pathways of exposure to coastal zone populations are strongly indicated, but remain not investigated by regulators or the nuclear industry.

3:11 Despite the available empirical evidence of sea to land transfer of radioactivity taking place across exposed coastlines, as of yet only five (Cs 137, Am 241 and 3 isotopes of Pu) of the 60+ radio isotopes routinely discharged to sea have ever been researched in sea to land studies.

3:12 Tritium and OBT are among those that have NOT been studied. However, in the context of other research it is legitimate to postulate the likelihood of sea to land transfer of both tritiated water and OBT by way of a number of discrete marine and coastal processes.

3:13 The emerging empirical evidence contradicts the long held industry hypothesis and strongly indicates that marine discharged tritium is of major dosimetric significance, and that doses to humans living in coastal terrestrial environments at least 10 miles inland are highly likely to be delivered by environmental processes and pathways including
a: sea to land transfer: (aerosols, sea spray/vapours etc)
b: coastal inundations: (flooding, super tides, storm surges etc)
c: dietary pathways: (dietary dose: sea foods AND terrestrial foodstuffs)
d: inhalation pathway: (inhalation dose: breathing in ambient coastal air when sea to land transfer mechanisms are operating)

3:14 A major concern is the fact that both the nuclear industry, pro nuclear governments and their agencies, and academics remain largely ignorant of the potential health impacts of marine sourced tritium and OBT because there has been no in depth research on the precise behaviour of sea to land transfering tritium or OBT undergoing any process (aerosoling, sea spray, marine inundation, and a range of other potential phenomena including fog, evaporation etc)

4: Radioactivity related Marine parameters of the Fukushima coastal waters and coastline

4:1 Coastal morphology and water body movements.
The major drivers of marine pollutant transport and mixing off the Pacific coast of eastern Japan, are the Oyashio and the Kuroshio currents.

4:2 In the Fukushima coastal region, the Oyashio appears, usually, to be the more dominant of the two. It is a strong, southward flowing current, which carries cold, nutrient rich, polar water close to the entire length of the east coast of Honshu from the north to the vicinity of Tokyo in the south, where it meets the Kuroshio. The Oyashio is ranked as having high biological importance (*rich in organic material*).

4:3 The Kuroshio is a western boundary current of the Pacific Ocean, which carries tropical warm water east and north along the south coast of Honshu, until it collides and combines with the Oyashio, to trend east and north-eastward away from the Japanese coast and out into the ocean as the North Pacific Drift Current. This current has received much attention since the Fukushima event, due to its potential to carry radioactive material from Japan towards North America.

4:4 Both the Oyashio and the Kurashio are characterised by meanders and by the formation of large eddies, or gyres, which spin away from the main path. These

eddies may have life spans of several months and transport both biological and pollutant material away from the main track of the current.

4:5 Interactions between the Oyashio and the Kuroshio are variable on seasonal, annual and longer term time scales. Thus, southerly or northerly penetration of either current is not fixed and eddy formation varies from year to year. There is a consensus that climate change parameters are having an influence on both currents and their interactions but long term trends remain very uncertain.

4:6 Although the southward trend of Oyashio current surface water along the east coast of Japan is not in doubt, the understanding of seabed/bottom currents in the region is less certain.

4:7 The Fukushima event site is situated almost centrally on the east coast of Japan. South of Fukushima the coast extends for approx 200 kms. This stretch of coast consists of coastal plain backed by higher ground from which a significant number of rivers flow towards the sea. Sections of the coastline, especially the river deltas, are in general highly urbanised/industrialised and have armoured flood defences. Elsewhere the coastal plain is agricultural. The shoreline, where un-armoured, is typically a narrow, sandy intertidal and beach zone backed by sand dune systems.

4:8 Urbanisation of almost all of the river deltas (land reclamation and port developments) mean that many of the rivers no longer have recognisable delta systems and that shoreline fine sediment deposits (mudflats, salt marshes etc) are unusual. The unbroken nature of this stretch of coast (no sheltered/low-energy environments) also strongly militates against deposition of fine sediments.

The consequence of this must be that the southward moving water body of the Oyashio current has elevated levels of sedimentary material which cannot settle out in non-existent, natural river deltas.

4:9 North of Fukushima the coastline eventually becomes more rocky and broken, There are a number of inlets and embayments where extensive subtidal and intertidal fine sediment deposits occur.

4:10 Although the general surface water movement (southward trend) of the Oyashio current along the east coast of Japan is not in doubt, the definition of possible seabed/bottom currents in the region is also uncertain.

5: Sedimentary environments

5:1 Satellite imagery of the Pacific coast of Japan shows a band of relatively shallow and turbid (high suspended sediment load) water extending off shore for between 1 to 5 kms/ along the coastal regions upstream and downstream of the Fukushima event site.

5:2 Satellite imagery also shows the presence of a number of rivers running down off the high ground inland, across the relatively narrow coastal plain and into the sea. In the wet season, these rivers will make a significant fine sediment (both clay mineral and organic material) contribution to the coastal water sediment budget. Such

sediments are particularly prone to the Ad-sorbtion of actinides and other radio nuclides subject to concentration in fine sediment environments (ie: Tritium/ OBT).

5:3 This stretch of coast also shows the presence of some significant, fine sediment embayments 50 kms + to the north of the Daichii plant outfalls, these include Matsushima Bay and Ishinomiki Bay

6: Potential Japanese terrestrial (Coastal Zone) Critical Groups exposed to marine radioactivity from the Fukushima event

6:1 The lessons learned from studying the behaviour and fate of "normal" operational discharges of liquid radioactivity to UK coastal waters provide some baseline evidence for identifying the potential pathways by which terrestrial coastal human populations will be exposed to doses of marine radioactivity from the Fukushima event.

6:2 During the course of the Fukushima event, aerial plumes of radioactive debris were transported to the sector north of the site and deposition of plume material took place over fluvial watersheds that drain into coastal waters north (upstream) of the Fukushima outfalls. Following rainfall and incorporation into fluvial flow, such material is then eventually available for longer term/distance transport in the Oyashio current, in a southerly direction and back past the Fukushima sea discharge point, to join the existing southward flowing marine plume of radioactivity from the site.

6:3 Situated in this northern area, both Matsushima Bay and Ishinomaki Bay are receiving waters for the run-off from those fluvial watersheds. Both bays are extensive and characterised by high sediment loadings and sediment deposits (inter tidal & sub tidal mudflats, salt marsh).

Such environments have the potential to be long term deposition and re-concentration sites for any actinide/alpha emitter present in environments. Radioactive material from similar environments is shown to cross the tide line during inundation events driven by storm surge, peak high tides, severe storms etc. Seaweed culture, fish farming etc represent important potential exposure pathways (external, dietary, inhalation) for populations around these bays.

6:4 Open coasts, such as those to the immediate north of Fukushima and extending southward (downstream) of the Fukushima outfalls, will also be subject to the sea to land transfer of "soluble" nuclides during periods of strong onshore wind and enhanced wave activity. Prolonged periods of onshore winds are a strong feature of the annual meteorological cycle and the east coast of Japan is a frequent victim of tropical cyclonic storms. In this context, sea to land transferred doses of tritium as both tritiated water and OBT are strongly indicated

6:5 Open coasts are also subject to the sea to land transfer of particle associated in-soluble nuclides, particularly during those seasons when the sediment loading of coastal water bodies are elevated (autumn/winter, tsunami/tropical storm activity).

This is shown to be particularly significant when the water column has a high loading of those fine suspended sediment and organic micro-particles susceptible to both the ad-sorbtion of radioactivity, and to sea to land transfer, in aerosols and sea sprays.

These mechanisms of transport generate massive enrichments (EFs of 400+) of some forms of radioactivity relative to concentrations in the ambient (source) seawater.

6:6 Thus, populations living in the terrestrial coastal zone may be exposed to sea to land transferred radioactivity via a number of pathways.

Flooding of a Welsh coastal town was shown to have transported hundreds of tons of marine sediment contaminated with elevated concentrations of Am 241 into private, commercial and public spaces and to have provided the potential for inhalation and contact doses during clean up and possibly for some time after.

6:7 In Wales, airborne radioactivity transferred from the marine environment in spray and aerosols has been observed in coastal produce grown at least 10 miles inland. At a number of other UK sites, distant from source points of marine radioactivity, contamination derived from sea to land transfer, and consumed in terrestrial foods, has been shown to generate higher doses than those received by seafood eaters close to point sources.

6:8 As described above, exposure of populations living in areas (up to at least 10 miles inland: possibly more) to inhalation doses is also strongly indicated along the Fukushima event downstream coasts. Thus the Fukushima event (downstream) coastal populations are those most likely to emerge as the marine/coastal Critical Population Group due to their exposure to dietary doses of tritium (mostly as OBT) from both sea foods and terrestrial produce. This Coastal Critical Population Group is also strongly indicated as the potential receiver of inhalation doses of airborne tritium (due to sea to land transfer processes).

7: Principal Conclusions:

7:1 At the commencement of liquid radioactive waste discharges to sea there was no knowledge of the way such radioactivity would behave in marine and coastal environments and a very poor understanding of those marine parameters that govern the behaviour and fate of radioactivity in such environments.

7:2 In the absence of any relevant empirical data, the IAEA and the nuclear industry, hypothesised that liquid tritium (as tritiated water) was of low biological significance because it was a low activity beta emitter, which would dissolve into infinity once in the marine environment.

7:3 The IAEA and the Japanese Nuclear Regulators commentary on tritium has not significantly changed since the 1950s.

However the IAEA/nuclear industry claim, that tritium is of low radiological significance, is now shown to be comprehensively inaccurate as neither body has adopted the outcomes of recent (post 1990's) scientific studies which contradict almost every facet of the official position.
Thus there never has been a rigorous scientific justification, based on detailed empirical evidence, for the discharge to sea of tritiated water.

7:4 The post 1990s research demonstrated that

a: tritium in discharged tritiated water becomes bound to organic material in the organically rich receiving marine environment
c: organically bound tritium (OBT) is biologically available and highly mobile through the marine food webs
d: OBT is found to be highly bio-accumulated in species towards the top of the marine/coastal trophic level (cod fish, shelduck). Such species typically held concentrations between 2,000 to 6,000 times more enriched than the concentrations in the receiving waters
e: OBT is of far greater radiological significance than tritiated water
f: from this work it may be deduced that relatively elevated dietary doses of marine sourced tritium to humans (via sea foods) are strongly indicated

7:5 Other mechanisms of delivery of doses of marine discharged tritium (as tritiated water and OBT) which include non sea foods: are also strongly indicated in the context of reported UK studies of the sea to land transfer of marine soluble and particle associated radioactivity, these include
a: the consumption of terrestrial meat products such as beef and mutton, produced on coastal pasture washed by high tide, storm surge/coastal inundation events (s seen with other nuclides associated with marine mineral and organic particles) such as Caesium, Plutonium and Americium
b: the consumption of terrestrial agricultural and arable products grown up to at least 10 miles inland, but contaminated by marine sourced tritium transported in land by sea to land transfer mechanisms and deposited onto crops and land surfaces as seen with other soluble nuclides (Cs 137)
c: From such data it may be proposed that human dietary doses of tritium, with evidence of significant bio-accumulation, are also to be expected from the coastal zone terrestrial produce dietary pathway in areas where the conditions for sea to land transfer of radioactivity are favourable.
d: In the absence of any detailed studies on the sea to land transfer of tritium, there is no evidence to disprove such a proposition.
e: In light of the enrichment factors described above, OBT evidently has the potential to make a significant dietary dose contribution to human consumers.
f: conditions for exposure of coastal populations to doses of additional tritium and OBT (by inundation and sea to land transfer) are favourable along the Fukushima (downstream) coast because of the direction of water body movements, the apparently relatively high sediment loadings of Fukushima coastal waters and ambient annual weather conditions of onshore winds, and seasonal storms including coastal inundations and high seas with a heavy surf line wave action and associated marine sea spray and aerosol production.

7:6 In the context of the post-event, ongoing, but un-quantified discharges of tritium from the Fukushima event site coupled with the apparent absence of any detailed and widespread monitoring of
a: marine and coastal post-event tritium in pacific coast inshore waters, wildlife and sea foods,
b: pacific coast shoreline and intertidal environments, wildlife and wild foods post-event tritium monitoring
c: coastal zone terrestrial environments, wildlife and agricultural/horticultural product monitoring for post event tritium

there is a major absence of data to support any claim that the tritium released to date has NOT given rise to doses to coastal populations. In such a context, the proposal to dispose of the very high volumes of stored tritiated water with its very high calculated aggregated radioactivity is strongly contra-indicated

7:7 This review concludes that the Fukushima event (downstream) coastal populations are those most likely to emerge as the marine/coastal Critical Population Group due to their exposure to dietary doses of tritium (mostly as OBT) from both sea foods and terrestrial produce. The Fukushima event Coastal Critical Population Group is also strongly indicated as the potential receiver of inhalation doses of airborne tritium (due to sea to land transfer processes).

7:8 In the context of the emerging empirical evidence, the significant data gaps described above and the release of over 800,000 tonnes of highly tritiated water (with an aggregated radioactivity calculated at nearly 3 times the average annual discharge of tritiated water from the UK Sellafield reprocesor sea pipelines) it is concluded that:

the proposals lack both scientific rigour and justification

the proposals are grossly irresponsible in regard to the health of the coastal zone inhabitants of the Fukushima coast (downstream) and coastal zone and consumers of food stuffs produced in inshore waters, the intertidal zone and the terrestrial coastal zone for at least 10 miles inland.

…….