NUCLEAR HOTSEAT #613
MARCH 21, 2023

"Tritium in Marine Environments"

Prepared by
Tim Deere-Jones: Marine Radioactivity Research &Consultancy

timdeerejones@gmail.com
info@nuclearhotseat.com

>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>><<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<

SOURCES of tritium and tritiated water.

Tritium is a radioactive isotope of hydrogen, which allows it to readily bind to oxygen based radicals and to form tritiated water (HTO). Tritium is reported to have a half-life of about 12.3 years, and is expected to have decayed so much that it is harmless after about 123 years (10 half-lives).

Tritium has both natural and man-made sources. The majority of natural Tritium is produced in the upper atmosphere as a result of nuclear reactions between atmospheric nitrogen and oxygen atoms and high-energy cosmic rays. Around 99% of the tritium produced in the upper atmosphere is oxidised to water as HTO and eventually dispersed into surface water. Annual natural production in the atmosphere is estimated at between 0.15 and 0.20 kg, i.e. 5.0 to 7.0 x 10^{16} Bq, *(16 noughts).*

A very small fraction of natural tritium is produced in the Earth's crust during neutron capture from traces of lithium-6 contained in the rock. The neutrons implicated in this reaction are produced by the spontaneous fission of uranium-238 or by reactions engendered by uranium and thorium alpha rays. Production in the Earth's crust is very small compared with production in the atmosphere.

Between 1949 and the 1980s atmospheric testing of nuclear weapons also released huge amounts of tritium to the global atmosphere, estimated to be at least 2.30 x 10^{20} Bq, *(20 noughts).* This is roughly equivalent to10,000 years of the natural production of tritium.

Accidents at nuclear sites are also major "one-off" sources of tritium input, though generally poorly quantified due to the general nuclear industry orthodoxy that tritium is not radiologically significant and therefore not requiring intensive monitoring. Analysis of the amount of tritium held in the F'shima "stored water to be discharged to sea in 2023 reported that approximately 10^{15} Bqs of tritium as tritiated water were held on site in 2020. To date, I have found no coherent data on the releases of tritium to atmosphere from F'shima, or to atmosphere and water from Chernobyl, Sellafield fire, Mayak/Chelyabinsk et al'.

In 2020, the annual production of tritium by all UK licensed nuclear sites (nuclear power sites, defence establishments, nuclear fuel factories, radio-chemical factories, research facilities and reprocessors) and it's discharge to air and water was estimated to be around 143 TBq *(143 followed by 12 noughts).* I'd make a conservative guesstimate that this figure

should be multiplied by at least 30 times to account for the sea discharges of tritium from licensed nuclear sites of other countries.

In addition, the record indicates that the amount of tritiated nuclear waste material sea dumped into both shallow and deep oceanic waters, between 1949 and 1982, probably amounts to 4.10 x 10^{16} Bq, *(16 noughts).*

The available data confirms that human activity has made a deeply significant contribution to the global inventory of tritium, and is continually "topping up" and maintaining the ambient concentrations of atmospheric and aquatic tritium from the annual routine operational discharges, the accidental discharges from multiple sites on an every-year basis and the less frequent major disaster releases such as Fukushima, Chernobyl etc. In addition, over the last few years there has been increasing pressure from nuclear site operators to be permitted to discharge large volumes of tritiated water during site decommissioning.

These ambient historical levels of man-made tritium have long been included in what is referred to as "background" concentrations of radioactivity which now consists of both "natural" and "man-made" material. Such "background" levels are often referenced in order to downplay the significance of discharges and current concentrations of tritium around nuclear sites.

In the past, discharges of tritium to the atmosphere from licensed nuclear sites was the norm, but eventually the nuclear industry and its regulators understood that population doses of atmospherically discharged tritium were receiving negative publicity related to potential health impacts of inhalation. A decision was taken to reduce atmospheric discharges (in the form of inhalable tritiated steam) and to divert more of the tritium towards the aquatic environment as tritiated water.

……..

Tritium and health:

Tritium is a low energy beta emitter which has not been considered radiologically significant or dangerous to health by nuclear industry and nuclear regulators because its beta particles are unable to penetrate the skin, and because the tritiated water form has a relatively short biological half-life in the human body (7 – 14 days), longer in the winter than in the summer.

On this basis, the nuclear industry and its regulatory agencies have historically permitted its discharge to air (as tritiated steam) and water at very high concentrations (generally at the several TBq level:*12 noughts*).

By contrast, independent experts and peer-reviewed academics take a radically different view and report that ingestion of tritiated water has been linked to increased risk of cancer and that tritiated water has been shown to cross the placenta and expose the foetus to the risk of birth defects and/or early pregnancy failures.

A proportion of the tritium absorbed by inhalation or ingestion is fixed to organic materials such as lipids, carbohydrates, proteins and DNA and RNA. This is known as organically bound tritium (OBT). These unusual properties strongly indicate that tritium should be regarded as hazardous by radiation protection authorities. Sadly, this has not been the case and the nuclear industry and its regulators refuse to act on this information . Tritium's unusual properties are not at all recognised by the ICRP and national authorities which take

their lead from the ICRP and the IAEA and no international hazard index for radionuclides exists at present although one has been proposed

Main Conclusions

1: At the commencement of liquid radioactive waste discharges to sea, in the 1950's, there was no knowledge of the way radio nuclides would behave in marine and coastal environments and a very poor understanding of those marine parameters that govern the behaviour and fate of any radio nuclides in such environments.

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 they proposed would dissolve into infinity once in the marine environment. ***Following the official adoption of this position, there never has been a rigorous scientific justification, based on detailed empirical evidence, for the discharge to sea of tritiated water.***

3: However the IAEA/nuclear industry claim that tritium is of low radiological significance, is now shown to be comprehensively inaccurate and neither body has adopted the empirical outcomes of recent (post 1990's) scientific studies which contradict almost every facet of the official position.

4: The post 1990s research has clearly proved that
a: tritium in discharged tritiated water becomes bound to organic material in organically rich receiving marine environments
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

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 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 the context of the enrichment factors described above (para 4:), 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 "downstream" coasts because of the direction of water body movements, the generally relatively high sediment loadings of inshore and 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.

6: In the context of the annual multiple TBq level discharges of tritium from nuclear sites coupled with the apparent absence of any detailed and widespread monitoring of:
a: marine and coastal tritium in inshore and coastal waters, wildlife and sea foods,
b: coast shoreline and intertidal environments, wildlife and wild foods
c: coastal zone terrestrial environments, wildlife and agricultural/horticultural product monitoring for post event tritium
d: doses to coastal populations, especially those adjacent to, and downstream of tritiated water discharge point sources
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 practice of disposing of the very high volumes of tritiated water with its equally high calculated aggregated radioactivity is strongly contra-indicated

7: This review concludes that coastal populations downstream of tritiated water releasing nuclear sites 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.
Such Coastal Critical Population Groups are also strongly indicated as the potential receiver of inhalation doses of airborne tritium (due to sea to land transfer processes).

8: Soluble, sea discharged Caesium 137 has been found on agricultural produce at least 10 miles inland from the coast. This material was consensually agreed by nuclear industry sources to have originated from the Sellafield liquid discharges to sea, via the discharge pipeline.
Given the even greater solubility of tritium to form tritiated water and the fact that tritiated water behaves in the same way as any other water, it is proposed that Tritium (as tritiated water) is also highly likely to transfer from the sea to the land in sea-spray and marine aerosol micro-droplets. It is noted that the nuclear industry and nuclear regulators have ignored requests to undertake research on these issues.

…….

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

However, it has been admitted by some proponents of the nuclear industry, that discharges of radioactive wastes to sea were essentially experimental. This is no surprise since such discharges began shortly after the commencement of nuclear weapons testing which were also conducted as "experiments" to investigate not only the military effectiveness of various types of nuclear weapon but also the impacts of radioactivity on humanity and the environment.

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.

Despite the post 1980s evolution of research into tritium which clearly demonstrates the weakness of the hypothesis, the hypothesis still remains the standard nuclear industry position.

This 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.
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}

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.

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]

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 had 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 contradiction to the nuclear industry hypothesis

By 1999 UK Government Agency monitoring of tritium was taking a more investigative approach, and a more precautionary position 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]

It was 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: 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).A bio-concentration/magnification factor of 6,100 times

Such studies reveal that although the levels of tritium (as tritiated water) 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 .

Other peer reviewed studies have demonstrated that tritium, becomes organically bound to, and has an extended life span in fish egg RNA and DNA. Similarly, tritium in juvenile mice born to pregnant mothers fed on tritiated water is also shown to have an extended life span, as OBT, in DNA and RNA, body lipids and proteins with peak concentrations found in mouse heart and brain tissue. Similar work on rats and monkeys confirms these parameters in a range of mammalian species with powerful implications for human subjects. Presumably the implications for foetus, post-natal juveniles, women the aged and the infirm may be greater than for "reference man".

There has been some investigation of the impact of industrial/nuclear worker exposure to high doses of tritium. By contrast however, there is a major lack of study into the post discharge impact of environmental tritiated water and Organically Bound Tritium (OBT) on marine and coastal communities, stakeholders and ecologies.

A follow on study of the behaviour of Tritium in the Severn Estuary and Bristol Channel (published in 2001) found that the highest concentrations of Tritium were found in the vicinity of , 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]

The 2001 study also found that:
a: tritium 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. *(tritium does bio-accumulate through marine and coastal food chains)*

2. More recent research on the fate and behaviour of tritium discharged to sea
A more recent study (published in 2009) has built upon the emerging understanding of the behaviour and fate of tritium in the marine environment illustrated 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: and that 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*)

However, contrary 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 material

in the environment and that "Significantly, a measurable fraction of sorbed tritium associates with proteinaceous material that is potentially available to sediment feeding organisms", ie that tritium as tritiated water becomes organically bound AFTER discharge to sea, as a result of its affinity for organic material in the marine environment.

UK Government reporting has confirmed 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.

In the context of the above effect (which has been noted in this and other, estuarine and coastal waters) it is reported that the research absorption and adsorption (sorption) experiments have 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"

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".

"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"

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.

N.B. 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. Likewise, the Oyoshio current, which runs north to south along the Honshu coast is reported to be rich in organic nutrients.)

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]

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.

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 other pathway doses of sea discharged tritium

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

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 during episodes of coastal inundation caused by unusually high tides and storm surges.

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 subjected to marine flooding.
The readiness of tritium, discharged as tritiated water, to become bound as OBT to organic material in marine environments has clear implications for fish, shellfish, shrimp and seaweed farming. The potential financial implications of this in the case of large scale, high concentration and extended time scale releases of tritiated water are enormous. These implications apply to both the potential health and viability of the farmed species and to the health of apex (human) consumers. Elevated radioactivity concentrations in food stuffs has always had a negative impact on sales.

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.

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.

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.

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 in the case of tritium these issues have not been investigated by regulators or the nuclear industry. 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. Caesium 137 dissolves into the ambient water and is shown to transfer from the sea to the land in sea-spray and marine micro-drop aerosols. During this process the CS in the spray and microdroplets is re-concentrated to double the concentration in the ambient source water.

In the context of the similar behaviour exhibited by both the soluble Caesium 137 and the soluble Tritium and in the absence of any data about the sea to land transfer potential of Tritium it is postulated that tritium is a strong candidate for sea to land transfer in sea spray and marine aerosol microdroplets. It is telling that, to date, the nuclear industry and nuclear regulators world-wide have refused to investigate these issues further.

4: Additional potential dose pathways:
Evaporative processes at the intertidal zone
Evaporation taking place at intertidal environments exposed during low tide cycles, in periods of onshore air movement, is also shown to transport marine originating material across the coastline and into the coastal zone terrestrial environment. There is a wide consensus that tritiated water behaves just like any other water, this is supported by the official confirmation that nuclear industry discharges of tritium consist of tritiated water to sea, and tritiated steam to atmosphere.

UK studies of the rate of evaporation from a temperate climate sandy beach found that, at Port Erin (Isle of Man), the reported daily rate of evaporation was between 2 to 2.5 litre per sq per metre. ***Ref: "Physical Factors on the Sandy Beach: Part 1. Tidal, Climatic and Edaphic." (page 547). JR Bruce. Msc. Aic. Marine Biological Station. Port Erin.***

Studies from a tropical, mangrove fringed shoreline confirm that the evaporation rate on such shorelines may exceed that of the temperate zones. It is clear that, in conditions with onshore winds, this evaporated marine originating water will transfer across the shoreline, penetrate inland and deliver inhalation doses of dissolved/soluble radio-nuclides to regional coastal zone populations. Tritium as tritiated water, behaving like any other water, is clearly a major candidate for transfer to coastal air mass by such mechanisms.

Consideration of such issues is not assisted by the relatively inefficient analytical methods generally deployed by the nuclear industry and nuclear regulators, whose beta analysis for tritium as tritiated water and OBT generally reports that the technologies deployed for the purpose cannot detect tritium at all at concentrations below around 20Bq per kg (or litre).

However, even in the absence of generally accurate analytical technologies, it is evident from the few intensive studies that have been reported that evaporative processes from exposed intertidal environment can generate very large aggregated tritium releases to coastal air mass. At the UK multiple reactor nuclear site Hinkley Point on the coastline of the Bristol Channel an area with characterised by hundreds of sq kms of intertidal mudflats, the UK Government's radiological analysis of seawater in 2019 reported that the Tritium content of seawater has risen to a detectable 24 Bq per Kg (or litre).

If such concentrations are also present in the interstitial water of regional intertidal zones, it can be calculated (on the basis of the Port Erin results) that evaporation may be responsible for the release to the coastal atmosphere of an aggregated daily average of between 48 and 60 million Bqs of tritium per square km of exposed intertidal zone.

Sadly, under the current regimes of tritium analysis employed by regulatory authorities, with the support (tacit or otherwise) of bodies such as the ICRP and the IAEA, regular, wide geographical scale and precise analyses of tritiated water and OBT are not carried out. There is no indication that the regulatory authorities have any intention of initiating such post discharge analysis if they are permitted to carry our such major discharges as those proposed for Fukushima, Cape Cod Bay (Holtec/Pilgrim) etc.

5: The emerging empirical evidence now clearly 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)