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Marine environmental factors and the impacts of a planned UAE NPS on the various water body sub-compartments of the Persian Gulf

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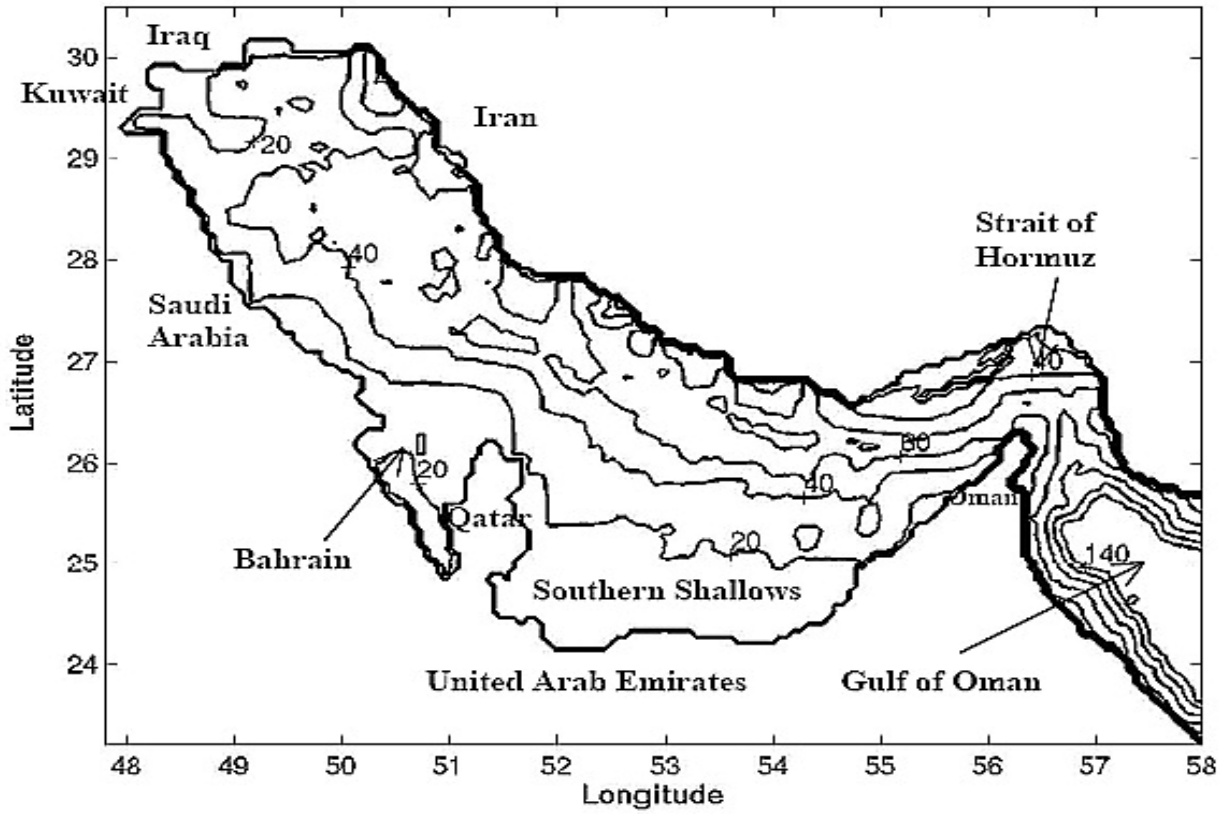
1. Marine Dynamics: Bathymetry, Flushing Times and Circulation

There is a consensus that the dominant pattern of surface water circulation in the Persian Gulf is anti-clockwise. New water enters the Gulf, via the Straits of Hormuz, and travels westwards along the Iranian coast and then trends south and east along the southern coasts of the Gulf via the Kuwait, Saudi and UAE coastal regions to exit via the southern sector of Hormuz.

The sub compartments of the Persian Gulf are widely identified as slow flushing sea areas. There is a consensus that, in general, the surface waters of the Gulf are fairly slow flushing with a time scale of more than 3 years. However, there is also a consensus that surface waters in the southern sector of the Gulf (Kuwaiti, Saudi and UAE sectors) have a longer flushing time (5 years+). It is also noted that the highly saline and dense bottom waters of the Gulf have a flushing time of approximately 6 years.

It is widely agreed that the Persian Gulf is an unusually shallow sea area, as shown by the contours (in metres) shown in the following map. From the map it can be seen that the UAE coastal/territorial waters are some of the shallowest areas of the Gulf and that the (less than) 20 metre depth area extends a long way seaward.[1]

[1] *Sadrinasab. M & Kampf. J . (2004): Three Dimensional Flushing Times of the Persian Gulf. Geophysical Research Letters (Oceans): (https://doi.org/10.1029/2004GL020425*



2. Sea Water Temperatures

A 2019 modeling study investigated potential sea temperature changes in response to climate change. The study concluded that the future mean annual warming in the Persian Gulf (PG) and Gulf of Oman (GO) relative to 2015 was predicted to be highest along the north coast of the United Arab Emirates and south coastlines of the Strait of Hormuz, where Sea Surface Temperatures (SST) may reach 32 °C by 2100. Mean annual (maximum) SST across PG&GO was predicted to increase from 28.5 (29.9) in 2015 to 30.7 (31.8) °C in 2100. This 2.2 °C increase in mean annual SST would threaten natural habitats and marine ecosystems in PG&GO.

The model indicated that monthly SST in the Persian Gulf may increase by up to 4.3 °C in August by the turn of the century. Similarly, mean annual changes in SST across the PG&GO may increase by about 2.2 °C by 2100.[2]

Thus, the Persian Gulf in general and, more specifically, the coastal waters of the UAE are shown to already have relatively high sea surface and bottom water temperatures, and the trend appears ever upwards with UAE waters most susceptible (due to shallow draft and slow flushing times).

Such a temperature regime may be expected to pose a threat of reduced effective cooling of nuclear power plant.

[2] *Roohollah Noori et al. João Miguel Dias, Editor : PLoS One (2019): Recent and future trends in sea surface temperature across the Persian Gulf and Gulf of Oman; 14(2): e0212790. Published online 2019 Feb 28. doi: 10.1371/journal.pone.0212790*

3. Pre-existing Anthropogenic Environmental Impacts

Much coastal disturbance has already degraded sectors of the UAE coast and marine environment: Hydrocarbon extraction facilities, petrochemical works, road building, harbour/port facilities, urban development.

In 2017, ScanEx and the Institute of Oceanology of the Russian Academy of Sciences (IO RAS) implemented a pilot project on satellite monitoring of the Persian Gulf. The results of the research confirmed earlier information on its serious oil pollution.

The Persian Gulf is constantly exposed to oil pollution: According to news agencies, the pollution of its waters is steadily increasing as a result of oil production, which is conducted in 34 fields and more than 800 wells, tanker shipments (up to 20-30 thousand tankers per year), oil leakage in pipelines, standard ship operations and ship accidents. Experts estimate that in the Gulf waters, an average of 100-160 thousand tons of oil and oil products per year enters the Gulf marine environment - and the level of oil pollution exceeds the world average by 47 times.[3]

As a result of the rapid rate of industrial and urban pollution of the Gulf marine environment, elevated THCs, PAHs and metals from oil pollution and petrochemical industry discharges are endemic throughout the Gulf marine environment, and in some areas municipal pollution is also elevated. 'Red Tide' algal blooms have become a regional phenomenon over recent years signifying that the sea area's assimilative capacity is on the decline.

Over recent decades there has been a distinct increase in algal bloom outbreaks in the Persian Gulf. In 2008 the Gulf experienced a prolonged episode (8 months +) of Red Tide algal blooming. The causes were identified as an increase in water column nutrient loading due to sewage, agricultural and municipal discharges, climatic and oceanographic changes, and the rapid introduction to the Gulf of red tide species via the discharge of ballast waters from shipping.

The 2008 event was reported to have caused the death of 1000s of tons of fish, severely restricted regional fishery harvests, damaged coastal coral reefs and the tourist trade.

In the context of nuclear new-build it is relevant to note that de-salination plants across the sea area suffered prolonged outages due to clogging of intake filtration systems by the massive Red Tide biomass accumulation.[4]

PWR marine discharges of radioactive waste, include a broad cocktail (at least 60) or radio nuclides (gamma, beta and alpha) with half-lives ranging from the short to the very long. Liquid discharges are not steady state but are proposed to be 'pulsed' with wide fluctuations in intensity and time scales. Many of the liquid rad waste discharges are expected to be soluble (Cs, H3 etc), leading to risk of both transport and incorporation into mudflats in interstitial water.

[3] Scanex (2018) : Satellite Monitoring of Oil Pollution in the Persian Gulf : http://www.scanex.ru/en/company/news/satellite-monitoring-of-oil-pollution-in-the-persian-gulf/

[4] Michlen et al (2010): The catastrophic 2008-2009 red tide in the Arabian gulf region, with observations on the identification and phylogeny of the fish-killing dinoflagellate Cochlodinium polykrikoides, Harmful Algae. 9(2): 163-172. February 2010 Harmful Algae 9(2):163-172 · February 2010 DOI: 10.1016/j.hal.2009.08.013

4. UAE Coastal and Inshore Environment

The UAE coast notable for fairly dense areas of both eel grass and mangrove : Coastal lagoon, eel grass and mangrove environments represent probably the crucial Persian Gulf environment for successful maintenance of marine life. Both ecosystems are massively important nursery & juvenile areas for a very large range of Gulf marine life, including those species that support human life. It is important to note that the UAE's extensive mangrove habitats grow on/in coastal fine sediments (mudflats: clay/organic).

Such sedimentary environments are notable for their ability to sequester a range of pollutants including metals, hydrocarbons and radioactivity. It is widely understood that fine sediment deposits act as a 'sink' for the concentrations of such pollutants which increase and concentrate over time.

It is widely reported in the scientific literature that fine clay/organic particles, when suspended in the water column, provide material onto which many radio nuclides can ADsorb (including most of the Pu and Am), leading to both long-range transport through the water column, and eventual re-concentration in deposition/accretion sites distant from the discharge point.

Sedimentary adsorbed pollutants may also (during periods of rapid deposition and incorporation) be sequestered (sub-surface) in sedimentary deposits where (isolated from UV, oxygen and biological activity) they may remain as an un-degraded 'toxic time bomb' to be released if those sediments are disturbed by storm action, tidal surge, and seismic event.

Experience on the Atlantic coasts of Europe demonstrates that the maritime transport of sea discharged radionuclides is well understood to extend to many hundreds of miles out from the point source. Discharge of radioactive materials form the 4 PWRs at Barakah will lead to inevitable dietary dose from sea foods.

For example, research by the Norwegian Radiation Protection Authority in 2011 demonstrated the presence of Sr 90, Tc 99, Cs 137, Pu 239/240, and Am 241 throughout Norwegian coastal waters, sediments and marine biota. It was concluded that a significant percentage of these radio-nuclides had been transported into Norwegian coastal waters by marine currents from distant sources including Sellafield and Cap de la Hague.[5]

In UK coastal waters sea to land transfer of marine radioactivity (Pu 239/240, Am 241 and Cs 137) - via coastal flooding during storm surges, super tides, and via marine sea spray and aerosols - has been shown to extend at least 10 miles inland of Irish Sea coast lines, and to generates human dietary doses (of marine radioactivity), via the consumption of contaminated terrestrial agricultural produce.[6,7,8,9,10]

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[5] StralevernRapport (2015): Norwegian Radiation Protection Authority, 2015.
[6] *Radmid: First Report: 1987 and 1988. Dyfed County Council. Carmarthen. Wales*
[7] Eakins et al (1982): 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.
[8] Cambray RS et al (1982): Pu, Am241 and Cs137 in soil in West Cumbria and a maritime effect, Letters to Nature. Nature 300. pps 46-48.
[9] Isles. CG et al (1991): Body concentrations of Caesium 137 in patients from Western Isles of Scotland. British Medical Journal. Vol 302.
[10] Pattenden, N.J et al: Atmospheric measurements on radionuclides previously discharged to sea, pps. 201-221. In: Proc' Int. Symp. IAEA on the Impacts of Radionuclide releases into the Marine Environment IAEA. Vienna. IAEA-SM-248/138

Any accident involving either a Fukushima type LOCA escape-to-sea of reactor coolant, cooling pond waters or emergency cooling waters, or Chernobyl type washout/fallout of aerial plume material onto sea surface, presents a risk of significant elevation of a wide range of anthropogenic radioactivity in the sea area similar to that observed in the Irish and Baltic seas following the Chernobyl incident, with consequent impact on sea area-wide fisheries, tourism, and associated public health concerns.

It is unclear what the UAE nuclear development will generate in terms of nuclear waste handling: but a significant increase in the maritime transport of radioactive materialsinto and through the Persian Gulf would be expected (i.e. U hex through to finished fuel rods manufactured outside the region). HLW and INF 3 standard cargo would be expected to travel out of the region, ILW and LLW would require storage – presenting a major risk terrestrial and maritime target potential, whether directly intended or un-intentional.

Assessments of climate change sea level rise, sea water temperature rise, thermal expansion, and increasing salinity in the Gulf are, as yet, unrehearsed and incomplete. However, review papers of the available literature conclude that the Gulf marine system exhibits severe oceanographic conditions; notably, the world's highest sea temperature with seasonal maxima between 34 and 36 °C, along with abnormal seasonal fluctuations (of about 20 °C) and hypersaline seawater.

In addition to extreme evaporation, parts of the Gulf are experiencing a steady rise in salinity levels, owing to the significant water diversions and dam construction along the Tigris-Euphrates river basins, which are drastically reducing the discharge of freshwater into the Gulf. The likely repercussion of such elevated salinity levels is declining trends in the phytoplankton community and fish recruitment.

Other significant anthropogenic stressors include substantial coastal developments, sewage discharge and the disposal of brine from desalination plants. Given these extreme physical water properties coupled with various sources of marine pollution, the biota inhabiting the Gulf is already under tremendous pressure—and the conditions are expected to be amplified by climate change.[11]

There is understood to be a lack of specific work on sea level rise (SLR) specifically related to the UAE coast. However, a 2008 study on the potential impacts of SLR on the coasts of nearby Bahrain presents some evidence relevant to the potential impacts on the UAE coast.

The low-lying nature of the coastal zone of the UAE, coupled with significant land reclamation investments and extensive industrial, commercial, and residential activity, emphasizes the country's critical vulnerability to Climate Change induced sea level rise.

To date there is little evidence of a UAE national plan to assess vulnerability to the impacts of SLR. In fact, the hazard is frequently considered minimal. This is mainly due to the lack of relevant studies and to a very limited public awareness on SLR impact potential. Ecological and socio-economic systems are currently facing tremendous pressures due to the rapid urbanization, industrialization, and economic development.

[11] Ben-Hasan. A and Christensen. V (2019: Vulnerability of the marine Ecosystem to Climate Change impacts in the Arabian Gulf:. Global Ecology and Conservation: Vol 17. January 2019.

The SLR phenomenon is likely to accelerate the degradation of the coastal and marine resources of the south shores of the Gulf. These resources have been over-exploited in the last 30 years due to economic forces, as well as weaknesses in policies, regulations, research and information communication. The multiplicity of institutions and ambiguities in their jurisdictions; and the lack of integrated approaches have multiple potential impacts on the management and planning problems of the coastal and marine resources in the country.[12] As the levels of planet-warming greenhouse gas emissions continue to rise year on year, and satellites show accelerated rates of melt-off from massive ice sheets atop Antarctica and Greenland, it remains plausible that under the business-as-usual emissions scenario, sea-level rises could exceed two metres by 2100.[13]

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[12] S. Al-Jeneid Æ M. Bahnassy Æ S. Nasr Æ M. El Raey (2008): Vulnerability assessment and adaptation to the impacts of sea level rise on the Kingdom of Bahrain . Mitig Adapt Strat Glob Change (2008) 13:87–104 DOI 10.1007/s11027-007-9083-

[13] PysicsOrg (2019): 2-metre sea level rise 'plausible' by 2100: study : https://phys.org/news/2019-05-metre-sea-plausible.html