CHEMICAL AND PHYSICAL STABILITY OF SUBMARINE FIBRE-OPTIC CABLES IN THE AREA BEYOND NATIONAL JURISDICTION (ABNJ)

Lionel Carter (ICPC and Victoria University of Wellington), Ken Collins (University of Southampton), Catherine Creese (Naval Facilities Engineering Command) and Gary Waterworth (Alcatel Submarine Networks UK Ltd).
Email: lionel.carter@vuw.ac.nz

Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand.

Abstract: Submarine fibre-optic cables in the ABNJ are typically laid on the seabed without the need for burial protection. This reflects the ABNJ depth (average ~4000m), which exceeds limits of benthic fishing and ships' anchoring – the main causes of cable damage. Dominant cables are Light Weight (LW) design comprised of a marine grade, dense polyethylene sheath that encases a steel wire strength member, a copper power conductor and glass fibres. Independent laboratory studies show LW cables are chemically inert - a feature supported by the well-preserved condition of telephonic coaxial systems that have resided on the seabed for up to 44 years. For those few shallow ABNJ areas where LW cables require protective armour, the laboratory studies record release of zinc from the galvanised wire armour plus organic compounds where the armour is coated with tarred or bituminous twine. Concentrations of laboratory leachates are small and are further diluted in the open ocean.

1. INTRODUCTION

The interaction of cables with the marine environment is of interest as the world seeks to better protect the ocean while using it in a responsible and sustainable manner. That interest is exemplified by the present negotiations concerning Biodiversity Beyond National Jurisdiction (BBNJ)[1]. Under the auspices of the United Nations Convention on the Law of the Sea (UNCLOS), the BBNJ initiative seeks to formulate a legally binding instrument that fosters "conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction" (ABNJ).

A recent review[2] explored legal and environmental implications of the BBNJ negotiations for the submarine fibre-optic cable industry. Centralised controls and potential undermining of the special status of cables under UNCLOS, could have consequences for the industry as the ABNJ occupies ~65% of the ocean's surface[3]. With respect to environmental aspects of cables in the ABNJ, the review[2] concluded that cables had a nil to minor effect on the benthic environment. This paper supports that conclusion with further information on the chemical and physical stability of cables, especially unarmoured Light Weight (LW) fibre-optic systems (post-mid-1980s) and their unarmoured coaxial ancestors of the 1950s to mid-1980s[4]. That choice reflects the great depths of the ABNJ (average ~4000m)[3], which preclude the need for armoured and burial protection against benthic fishing and ships' anchoring – the main causes of cable faults[5]. However, in a few areas, the ABNJ shallows to <2000m, and if there is a threat from fishing, fish bite or abrasion, LW cable may be armoured (LWA) by applying an external layer of wire followed by tar-coated twine (Fig. 2). Alternatively, Special Application (SPA), also known as Light Weight Protected (LWP) cable is used. This is LW design with an additional outer metallic layer covered with polyethylene[6]. SPA/LWP was not analysed in this study, but given its external polyethylene sheath, its leaching response is likely to be similar to that of LW cable[7].

2. METHODOLOGY

The chemical part of this paper is based on two independent studies. One was conducted at the University of Southampton and Bangor University in the UK with the aim of assessing the potential use of recovered fibre-optic cables for artificial reefs[7]. It was commissioned by British Telecom, Global Marine Systems Ltd and the Isle of Man government. The second study was undertaken by the US Naval Facilities Engineering Service Center and the Massachusetts Institute of Technology to help decide whether out-of-service cables should be recovered or left *in situ*[8].

The UK group analysed zinc (Zn), copper (Cu) and iron (Fe) ions released from 25cm-lengths of LW and Double Armour (DA) fibre-optic cables (Fig. 1). Only new cables, obtained from the manufacturers, were used to maximise amounts of released leachates. Cable samples, with ends sealed or open (to simulate a damaged system), were placed in closed 5L containers of fresh, natural seawater kept at 5^{o}C to limit any biological growth that may affect results. Seawater samples were extracted at predetermined intervals for up to 133 days and were analysed via Atomic Absorption Spectroscopy. Analysis of solvent (dichloromethane and methanol) extracts were performed at Bangor University and focused on DA cables whose exterior wire armour was coated with tar impregnated twine. This was considered “the most probable source of organic compounds”[7] and, as noted earlier, such compounds would be rare in the ABNJ due to the dominance of unarmoured LW systems [2][6].

Figure 1. Fibre-optic cable samples used for the UK leaching study[7] including (left to right) unarmoured Light Weight (LW) and Double Armoured (DA) cables from Alcatel (OAL-C4), and LW and DA samples from the now defunct Standard Telephone and Cables.

The US study focused on leachates from Focus LWA fibre-optic cable[8]. Sixteen aquaria, containing artificial seawater and sediment, formed closed units to assess the response of new and used LWA cables, the latter having been in service from 2003-2005 and 1994-2005 (Fig. 2).

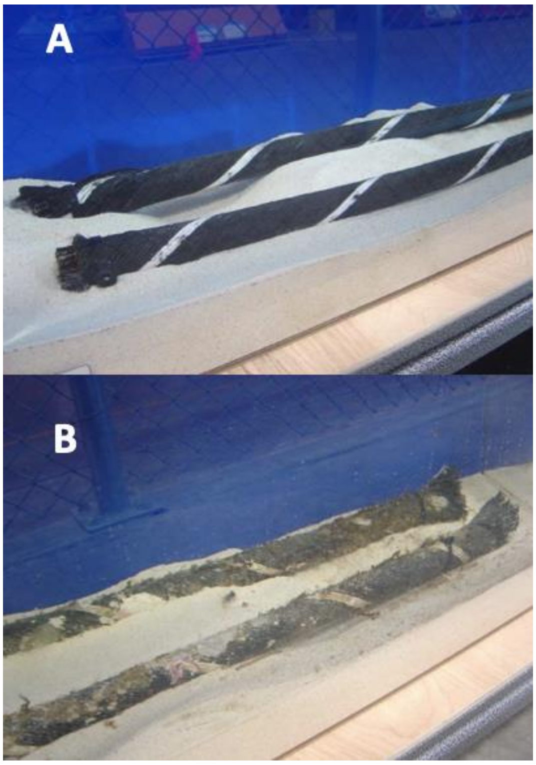

Figure 2. (A) New LWA and (B) weathered LWA. Image NESDI[8]

In addition, a shredded cable was included as a worst possible case for potential leaching. Sections were laid on and under the sediment surface with some tanks also containing bacterial-bearing rocks and living invertebrates. Aquaria waters were analysed for metal ions at 3, 4 and 12 month intervals and compared against a control aquarium without cable samples. New and used LWA were also tested for organic leachates released in seawater tanks after 60 days.

With regards to long-term physical stability, samples of unarmoured, coaxial telephone cables[4] were visually assessed. Samples came from ABNJ depths and had laid on the ocean floor for up to 44 years. Nine samples, 24-29cm long, of the HAW-3 system were recovered from water depths of 4760m to 5299m in the central Pacific Ocean (Fig. 3). HAW-3 was deployed in 1974, and recovered in 2018. Further samples came from the FRANCE-MOROCCO-1 and -2 systems in the Mediterranean Sea and the TAGIDE system along the North Atlantic Ocean floor between Portugal and France. Time on the seabed ranged over 38-44 years. All samples were examined for deterioration of the external polyethylene sheath, copper conductor and the steel strength member.

Figure 3. The general external condition of the HAW-3 cable is evident as it was stowed on the recovery vessel. Image ASN.

3. CHEMICAL LEACHATES

Leached Cu and Fe ions were undetected during the UK tests of new LW cables with capped and exposed ends over the 133-day trial (Fig. 4). In contrast, new DA cables showed a progressive release of Zn that peaked after ~75 days and declined thereafter. More Zn was released from samples with open ends to reach a maximum of 11ppm (parts per million) whereas capped samples released <6ppm (Fig. 5). Like LW cables, Cu and Fe were undetected in DA samples.

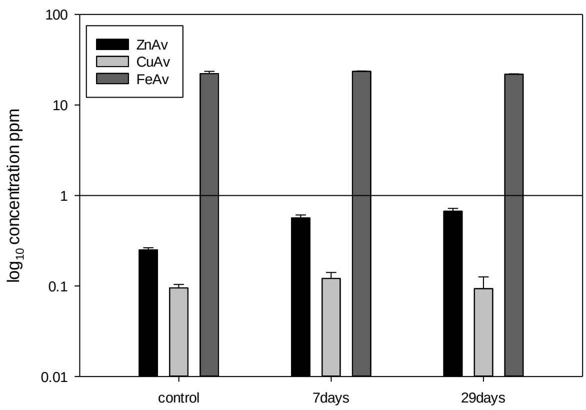

Figure 4. Zn, Cu and Fe in a seawater "control" tank without cables and tanks with LW cables that were analysed after 7 and 29 days[7]. A slight increase of 0.4ppm in Zn may reflect cross contamination from a DA cable during sample storage.

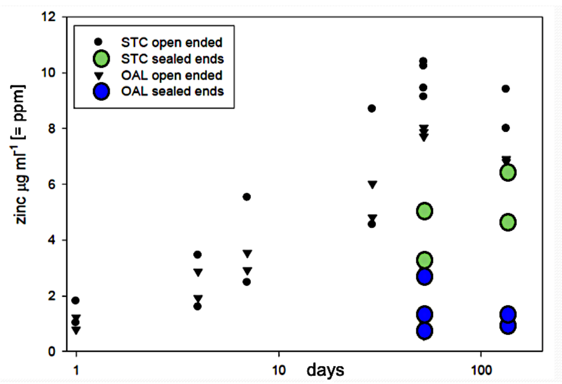

Figure 5. UK leachate results over 133 days for Zn released from DA cables by OAL and STC makers (Fig. 1). Most amounts peaked ~75 days after which

they declined[7] – a trend duplicated by the US trial[8].

US tests of various LWA cables generally confirmed UK results for armoured cables – Fe and Cu went undetected whereas Zn increased to a peak followed by a decline between 180 and 365 days (Fig. 6). New LWA cable overall released the highest amounts of Zn, which reduced from weathered samples - the 1994 cable releasing about half that from new cable but showing a similar profile with time. The new, shredded sample released an initial flush of Zn, but this declined sharply with time.

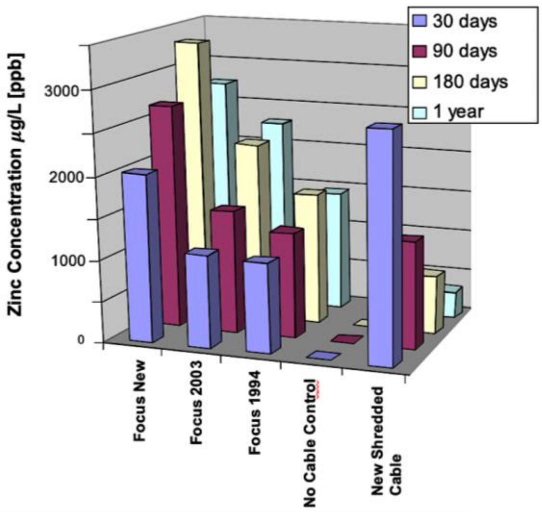

Figure 6. Dissolved Zn from various types of LWA cable over time[8]; ppb = parts per billion. Graph NESDI.

In addition to metal ions, both studies detected dissolved and insoluble organic compounds from DA[7] and LWA[8] cables with external coats of tarred twine. Organic leachates were not measured for LW cables. Concentration of various poly-aromatic hydrocarbon (PAH) compounds, e.g. pyrene (10-100 ng/L), were reported in amounts well below drinking water standards of 200 ng/L[8].

4. PHYSICAL CONDITION OF RECOVERED DEEP-SEA CABLES

Although from different manufacturers, the samples of coaxial telephonic cables had no obvious signs of deterioration (Figs 3, 7). The outer polyethylene sheath was intact apart from patches of surficial scuffing attributed to the recovery operations. Some light coloured polyethylene sheaths were stained presumably where the cable was in contact with bottom sediment. The outer and inner conductors had not degraded. Likewise, the stranded steel strength member was corrosion free and clearly intact to allow deep ocean recovery to take place.

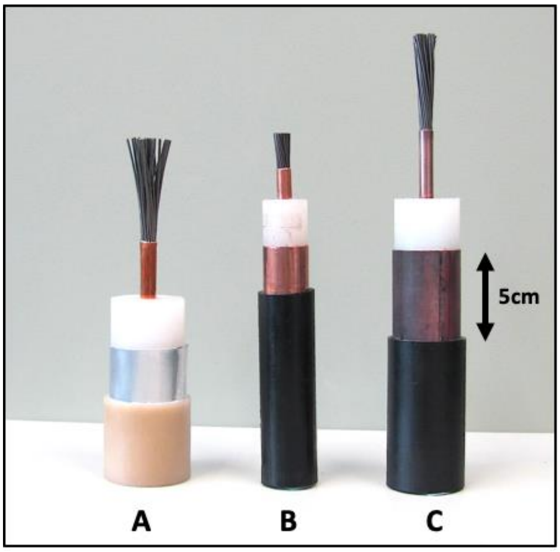

Figure 7. Recovered coaxial cables highlighting condition of components after 38-44 years on the seabed. Samples are A. TAGIDE, B. FRANCE-MOROCCO-1 and C. HAW-3. Image L. Carter.

5. DISCUSSION

In the absence of detailed information on specific cable types in the ABNJ, an approximation can be derived from their depth distributions. LW cable occurs at all ocean depths, SPA/LWP to 5000-7000m depth and LWA to <2000m depth. Given that depths <2000m occupy ~85% of the ocean, then apart from few areas of the cable-occupied ABNJ where depths are <2000m, e.g. mid Atlantic Ridge, the cable type will be overwhelmingly LW with local areas of SPA/LWP where protection is required, e.g. zones of active sediment transport. Thus cables in the ABNJ will be primarily sheathed in high density polyethylene, which does not release Cu, Fe and probably not Zn[7][8].

In those shallow reaches of the ABNJ where LWA cable is necessary for protection, the galvanised wire armour is likely to release Zn especially when the cable is both new and damaged. Such conditions increase the surface area of the armour to seawater. In the case of intact LWA cables, dissolved Zn reached a peak after 2 to 6 months; thereafter the loss declined. Thus, it is unsurprising that weathered, 10-20 year-old LWA cables produce less Zn than their new counterparts. Presumably, the galvanised wire coatings deplete with time. Tarred twine coating on armoured cables produce both solid and dissolved organic leachates including PAHs. Concentrations of specified PAH compounds were below prescribed safety limits.

It should be emphasised that the laboratory studies used closed seawater aquaria and tanks[7][8]. In the field, cable leachates released into the open ocean undergo marked dilution. For example, cables traversing the North Atlantic Ocean are exposed to abyssal currents with substantial volume transports especially along zones of bathymetric relief, e.g. 2 to 16 $x10^6$ m^3 s^{-1}[9].

The inert nature of LW cables is consistent with the acknowledged long-term resistance of high density, polyethylene to biochemical degradation in the marine environment[10]. That resistance is confirmed here by observation of recovered coaxial systems whose components show no obvious deterioration – a feature that underpins the cable recycling industry. However, we are mindful that this preliminary study is based on a small number of samples. Thus, it is unlikely to have captured variations associated with different cable manufacturers and different seabed conditions. Nevertheless, the consistency of observations for the 7 samples collected randomly along ~1000km of the HAW-3 cable, the wide geographic/environmental spread of recycling operations and the results from two independent laboratory studies provide some confidence in the results.

6. CONCLUSIONS

- Laboratory studies of submarine fibre-optic cables show that LW types - the main design in the ABNJ - are chemically inert.
- In those parts of the ABNJ, where depths shallow to <2000m, LWA or SPA/LWP cable may be used for additional protection. The LWA galvanised wire armour can release Zn that peaked and then declined after 2.5 - 6 months. Where armour has an exterior coat of tarred twine, insoluble and soluble organic compounds may be released; the latter in concentrations within safety limits for PAHs.
- While SPA/LWP cables were not tested, the presence of an exterior polyethylene sheath suggests their leaching characteristic will resemble that of LW cable.
- Laboratory studies used closed systems with small volumes of seawater. In nature leachate concentrations will be markedly diluted by the open ocean.
- Coaxial cables residing on the seabed for up to 44 years, show no visual decline of their components.
- The study confirms that the cables in the ABNJ are mainly long-lived, inert structures with nil to minor environmental effects.

7. ACKNOWLEDGEMENTS

We express our thanks to the BT Group, Global Marine Group and the US Naval Facilities Engineering and Expeditionary Warfare Center for access to results of their cable-leaching studies. Samples of submarine telephonic coaxial cables were generously supplied by Alcatel Submarine Networks (Simon Cluer) and CRS Holland (Kasper Moormann). Further information came from Mertech Marine. Samples of coaxial cables (Fig. 7) were prepared by D'Arcy Mandeno, and the paper was reviewed by Ron Rapp (SubCom LLC) and Bob Wargo (ATT).

8. REFERENCES

[1]. United Nations, Intergovernmental Conference on Marine Biodiversity of Areas Beyond National Jurisdiction, 2019. https://www.un.org/bbnj/

[2] Burnett DR and Carter L, 'International Submarine Cables and Biodiversity of Areas Beyond National Jurisdiction - The Cloud Beneath the Sea'. Brill Research Perspectives in the Law of the Sea. Brill/Nijhoff vol. 1. ISBN 9789004351592, 2017

[3] United Nations, 'The conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction' 31pp, 2017. http://www.un.org/depts/los/global_reporting/8th_adhoc_2017/Technical_Abstract_on_the_Conservation_and_Sustainable_Use_of_marine_Biological_Diversity_of_Areas_Beyond_National_Jurisdiction.pdf

[4] Hagadorn L, 2009. 'Inside submarine cables' *in* Carter L, Burnett D, Drew S, Hagadorn L, Marle G, Bartlett-McNeil D, Irvine N, 'Submarine Cables and the Oceans - connecting the world'. UNEP-WCMC Biodiversity Series 31, 64pp, 2009.

[5] Kordahi ME, Stix RK, Rapp R, Sheriden S, Lucas G, Wilson S, Perratt B, 2016. 'Global trends in submarine cable system faults'. SubOptic 2016, April 2016, Dubai.

[6] Rapp R, Personal communication SubCom LLC, 2019.

[7] Collins K and Mudge S, 'IOM Cable study – preliminary material environmental impact studies'. Unpublished report to British Telecom, Global Marine Systems and Isle of Man government, 23pp, 2008.

[8] Navy Environmental Sustainability Development to Integration, 'Studying the impact of seafloor cables on the marine environment'. Currents (Spring), 7-21, 2014.

[9] Schmitz J Jr and McCartney MS, 'On the North Atlantic Circulation'. Earth Science Reviews 31, 29-49, 1993.

[10] Moore CJ, "Synthetic polymers in the marine environment: a rapidly increasing, long-term threat." Environmental Research 108, 131-139, 2008.