Defining and Applying the Concept of Bioavailability and Bioaccessibility in Environmental Science

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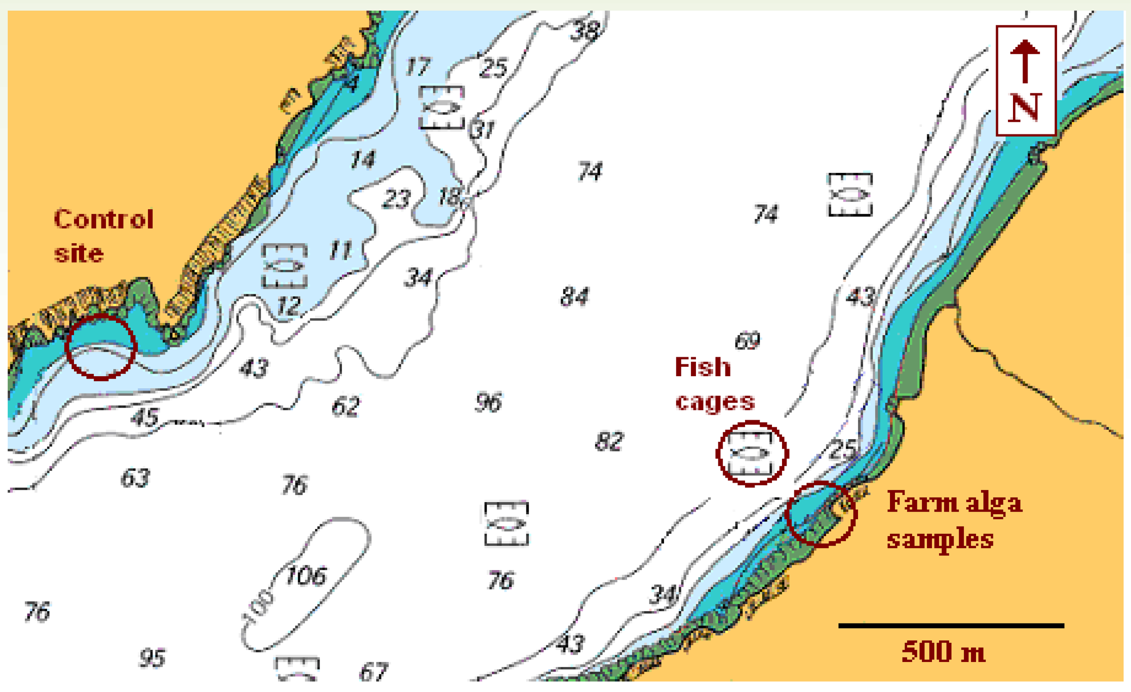
Introduction

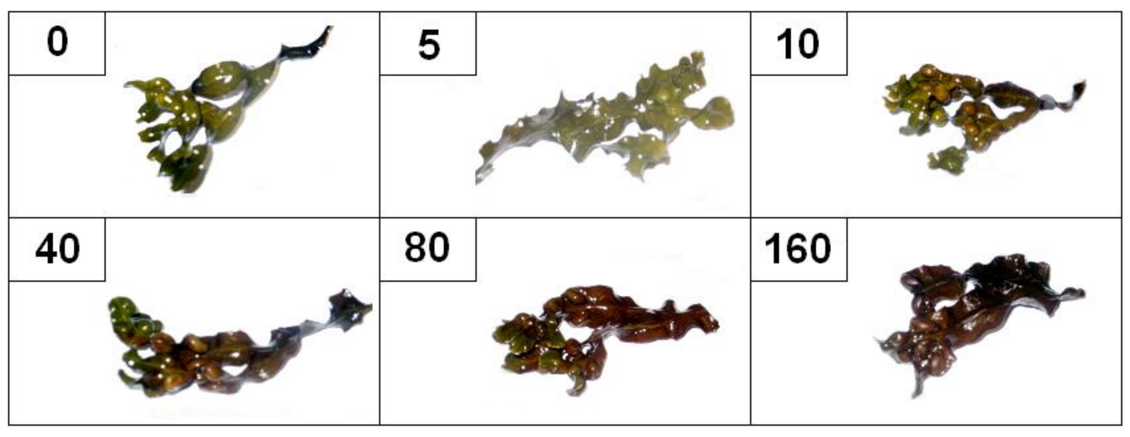
A dose-response relationship is a key assessment approach in environmental science. However, the total contaminant concentrations (doses) are not necessarily indicative of the nature and severity of the biological effects (responses). The use of bioavailable or bioaccessible concentration (fraction) offers a meaningful alternative. As such, our research targets a regulatory imperative for an empirically validated definition of bioavailability. Relating contaminant exposure measures in various environmental compartments to ecologically relevant receptors. Our understanding of the physical, chemical and biological factors controlling the noxiousness of contaminants continue to improve the management of risk, such as setting of critical limits in near-coastal marine ecosystems to protect aquatic wildlife, in soils as well as in surface and groundwater to protect ecosystems and humans.

Bioavailability of Metals in Marine Environment

As a persistent contaminant, copper and its release into the environment has to be regulated. Our study of environmental fate and impact of Cu from the Scottish aquaculture highlighted inherent variation of biological responses to Cu and signified the role of the bioavailability as a route of exposure in the marine environment.

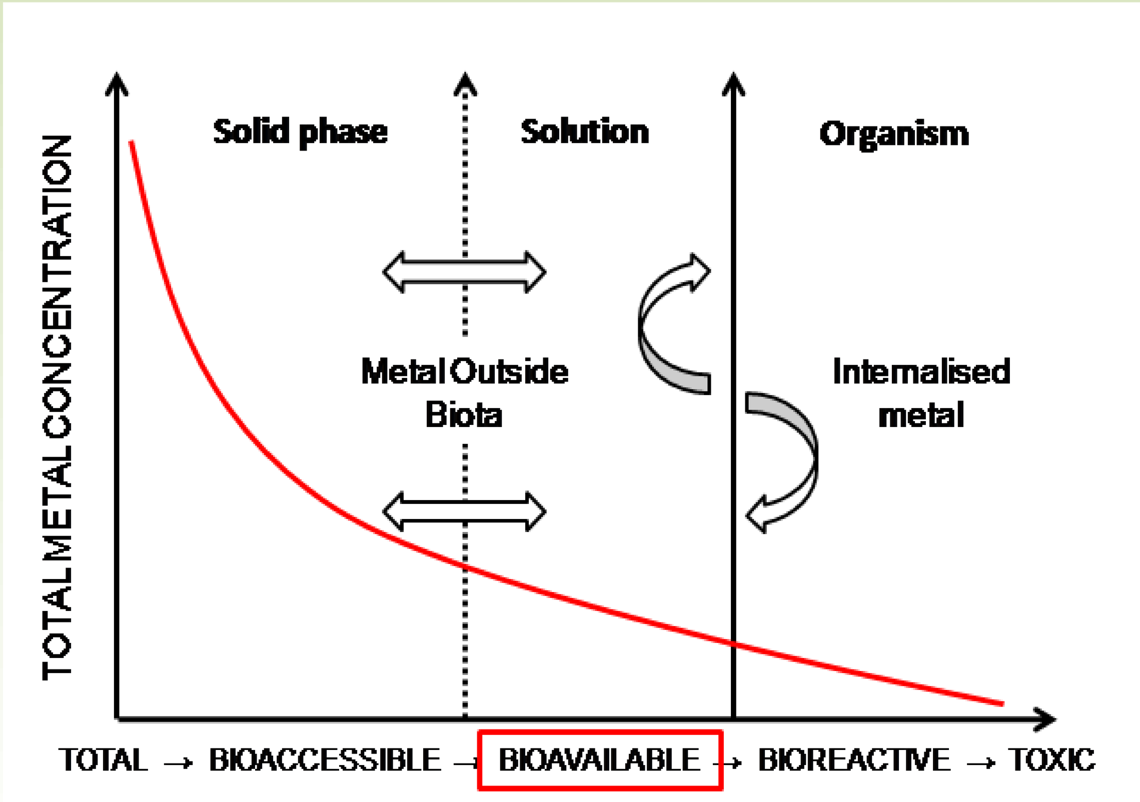


Corophium volutator, Mytilus edulis, and *Fucus vesiculosus* were challenged by fish-farm conditions and analysed for uptake of copper. There was a significant positive relationship between the sediment Cu loads and the concentration retrieved from the *Corophium* animals after 10 days as well as discolouration of *Fucus* algal fronds.

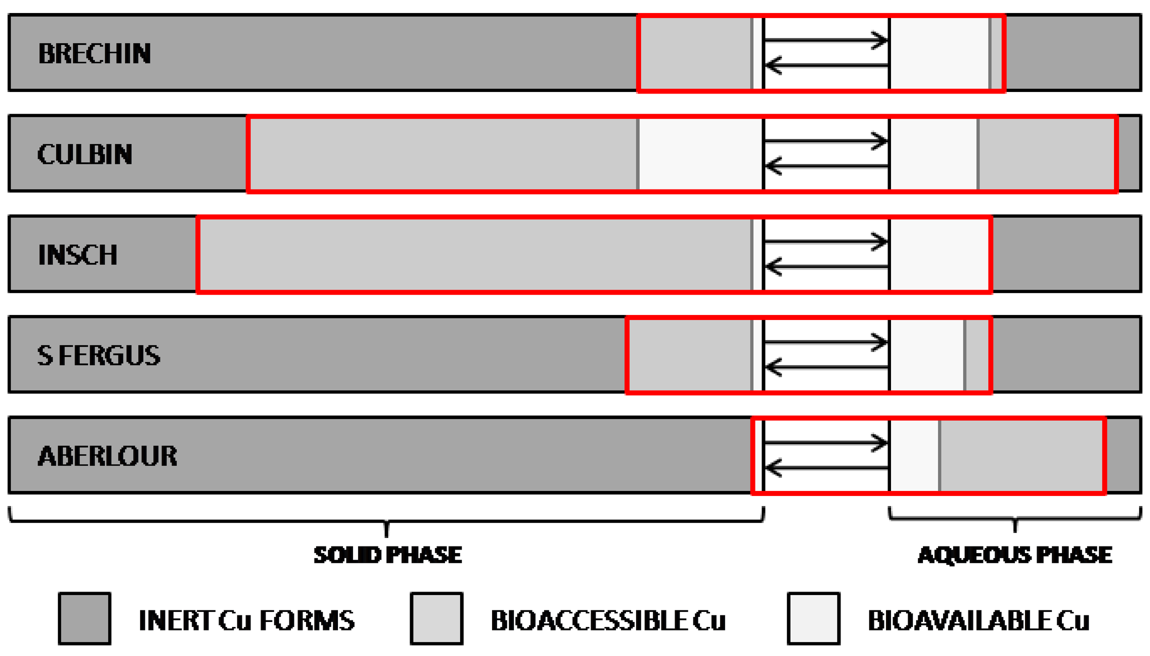


However, the Cu complexation with dissolved organic matter and presence of competing ions mitigated Cu impact on the marine bacterium *Vibrio fisherii*. Our observations are readily explained by the concept of free meal ion activity in solution and its binding with biological membranes (biotic ligands). Numerous studies with aquatic species show such effects.

Bioavailability as a Form of Exposure in Soil

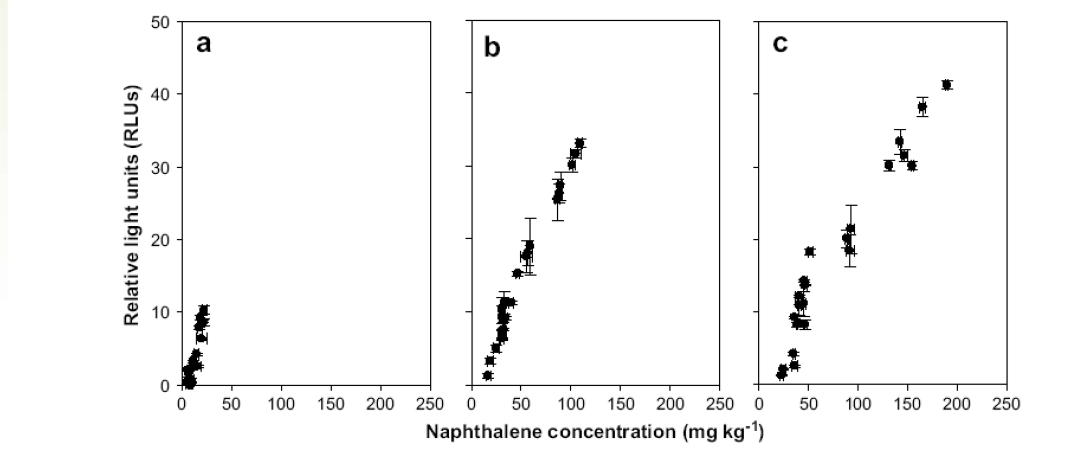


Our study of Cu (and other metals) in soils suggests that the biotic ligand approach is equally valid for terrestrial organisms. The relative affinity sequences for *Escherichia coli* HB101 pUCD607 obtained in interstitial pore waters of Cu and Ni amended soils were: Cu^{2+} > H^{+} >> Ca^{2+} and Mg^{2+}, and H^{+} > Ni^{2+} > Mg^{2+} > Ca^{2+}. The response of two standardised plant bioassays *Hordeum vulgare and Lycopersicon esculentum* suggested similarities between plant and microbial exposure to these metals in soils. Further, prediction of metal bioavailability in soils requires a knowledge of their partitioning in solid phase. Only part of solid-phase metal is bioavailable. Bioaccessibility refers to a greater portion than the bioavailable fraction but enables an insight into human exposure pathways.

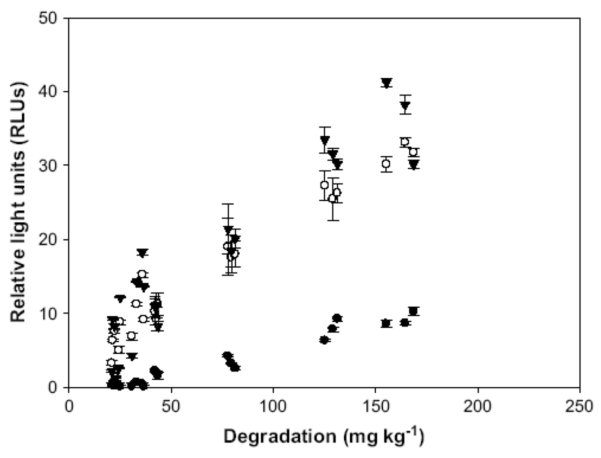


Bioavailability as a Remediative Potential

Bioavailability of hydrocarbons determines the suitability of bioremediation. This means that there is a need to develop and apply extraction systems that are ecologically relevant and offer strategic data. We have uniquely combined the role of microbial biosensors with a suite of extraction systems to elucidate the factors that drive biodegradation.

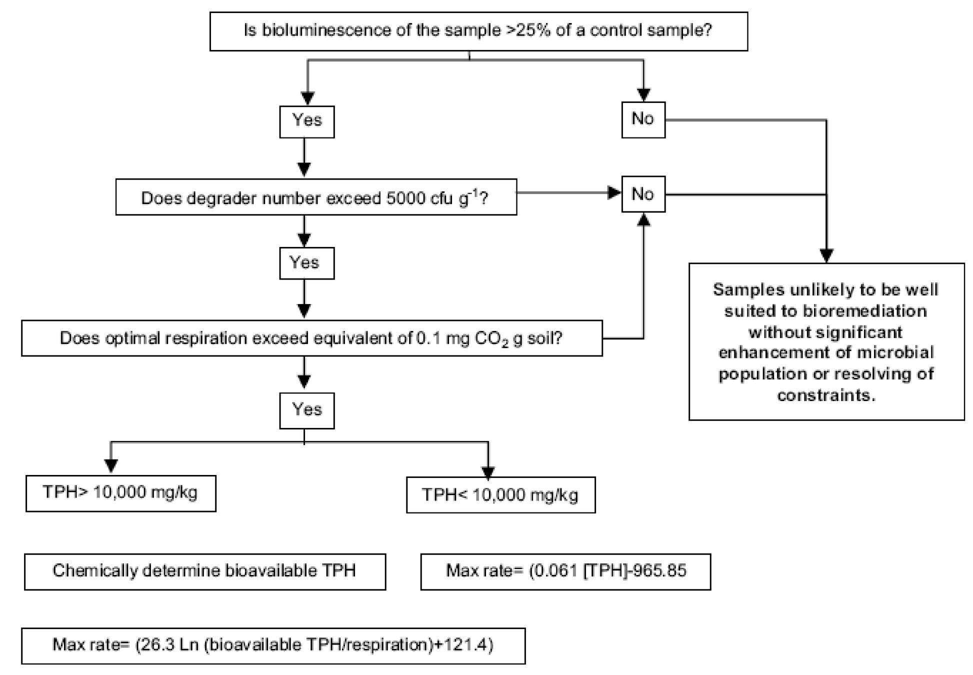


The bioluminescence response (as relative light units) of Pseudomonas fluorescens HK44 pUTK21 to (a) water, (b) HPCD and (c) methanol extracts from a range of soils historically contaminated with naphthalene. Naphthalene concentrations have been calculated as mg kg1 to enable a direct comparison between the techniques used (n = 3, error bars represent the standard error of the mean).



The bioluminescence response (as relative light units) of Pseudomonas fluorescens HK44 pUTK21 in extracts of water, HPCD and methanol from historically contaminated soils prior to degradation plotted against the net degradation of naphthalene (mg kg1) in those soils after one month (n ¼ 3, error bars represent the standard error of the mean).

Having established the importance of a suitable measure of bioavailability we have integrated it into a predictive equation that has been field validated.



Conclusions

Bioavailability and bioaccessibility mean different things to different audiences. For considering ecological impacts and remediation strategies **bioavailability** is the key parameter to define. **Bioaccessibility** measurements are essential in the protection of humans and mammals from contaminated soils where the assimilated dose is in part defined by the process of ingestion. Rapid advances in regulatory and stakeholder understanding of these terms has two consequence- 1. the needs for accurate data and 2. the development of legislative strategies that embrace the concepts.

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