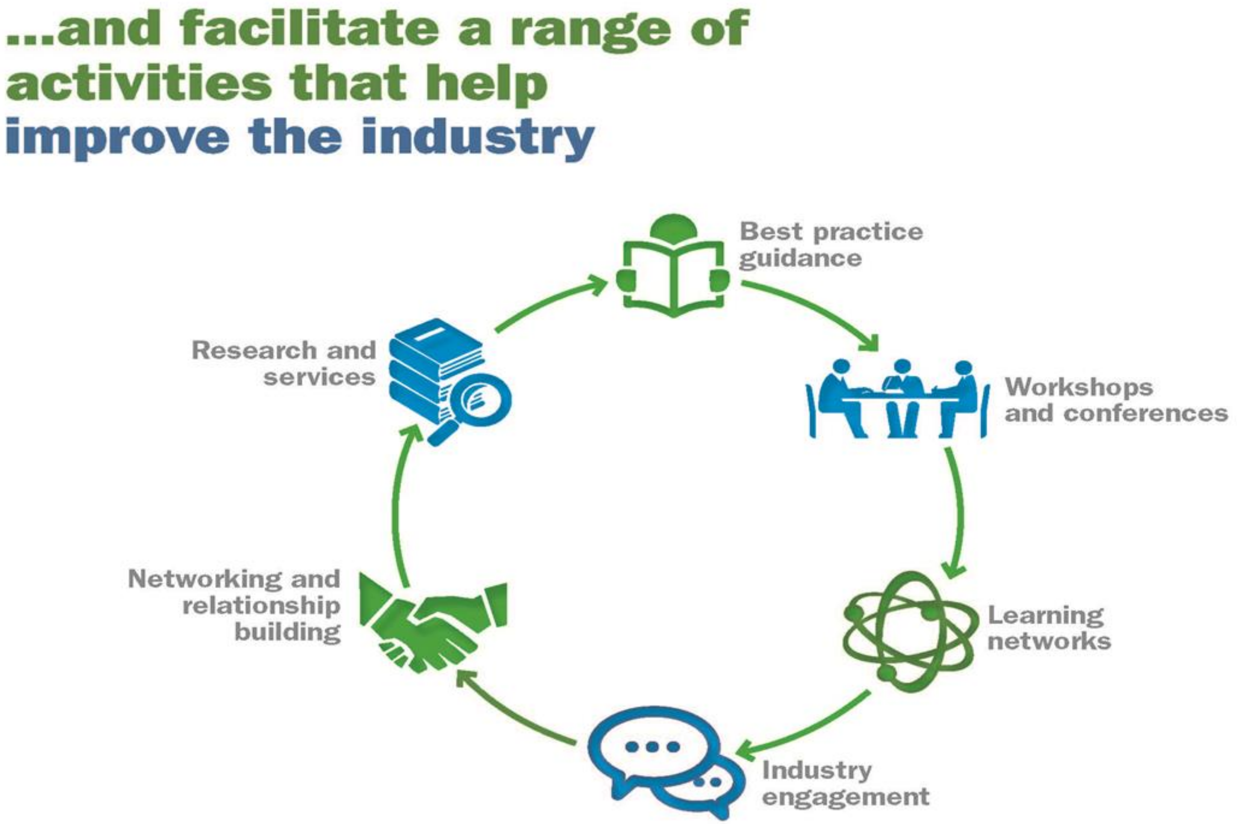
Contaminated sediments – the world's good risk assessment and management

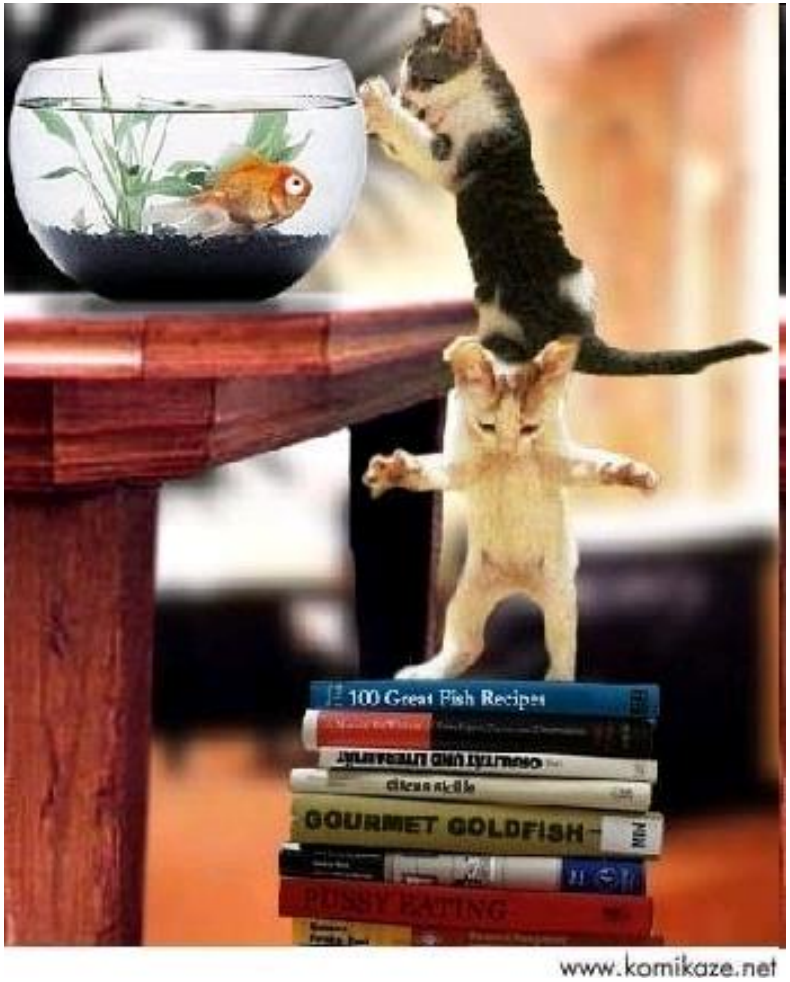
Joanne Kwan, CIRIA

Who is CIRIA?



...and facilitate a range of activities that help improve the industry
Best practice guidance
Workshops and conferences
Learning networks
Industry engagement
Networking and relationship building
Research and services

CIRIA’s believe



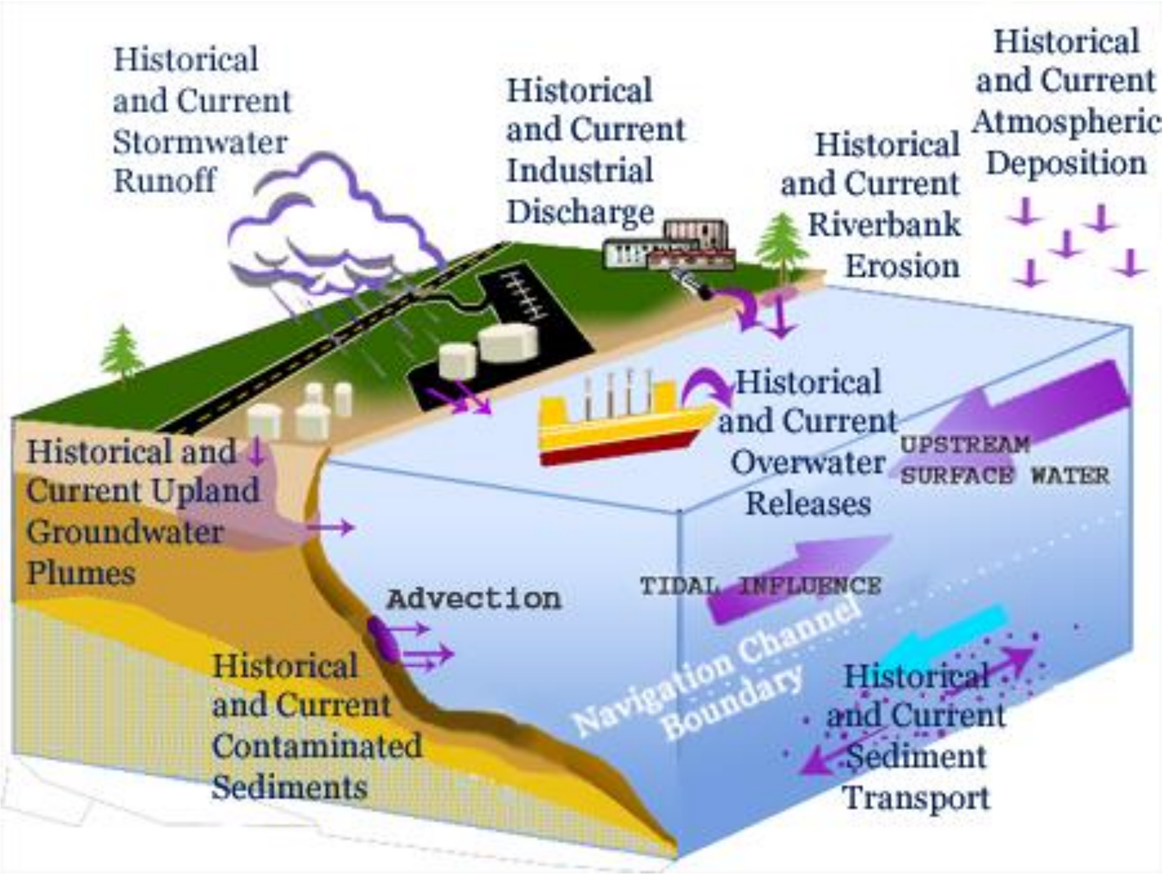
Contaminated sediments

What are sediments….

…. can be a source of diffuse pollution, a habitat and a resource or indeed all three.

Contaminated sediments have the potential to pose a risk to human health and the environment and to impact commercial, recreational, and navigational uses of waterways.

How complex is the issue?



The uniqueness of sediments

- Historically contaminated sediments can be re-suspended - caused by flooding, dredging, introduction of new structures or from other marine or river infrastructure activities.

- The movement and re deposition of these sediments further downstream .

And how contaminated is sediments in HK?

- (2002-2006) Victoria Harbour, Junk Bay and Tsuen Wan Bay - High level of heavy metals esp. copper and silver. Generally anaerobic and comprise very soft marine muds - contamination of the uppermost 1-3 m of the soil profile. DDT is above ‘Interim Sediments Quality Value’ and potentially harmful to benthic organisms
- Tsing Yi (relating to the old shipping activities), Typhoon shelters e.g. at Pak Sha Wan, Marinas e.g. Marina Cove - Tribulyltin (TBT)
- Near the incinerator facilities in Kennedy Town - Total poly aromatic hydrocarbons (PAH)
- Tolo Harbour, Jink Bay and Tsing Yi. Arsenic – north of Chek Lap Kok, west of Tuen Mun and Deep Bay - Heavy metals, Cadmium, chromium, copper, lead, mercury Nickel Silver and Zinc,

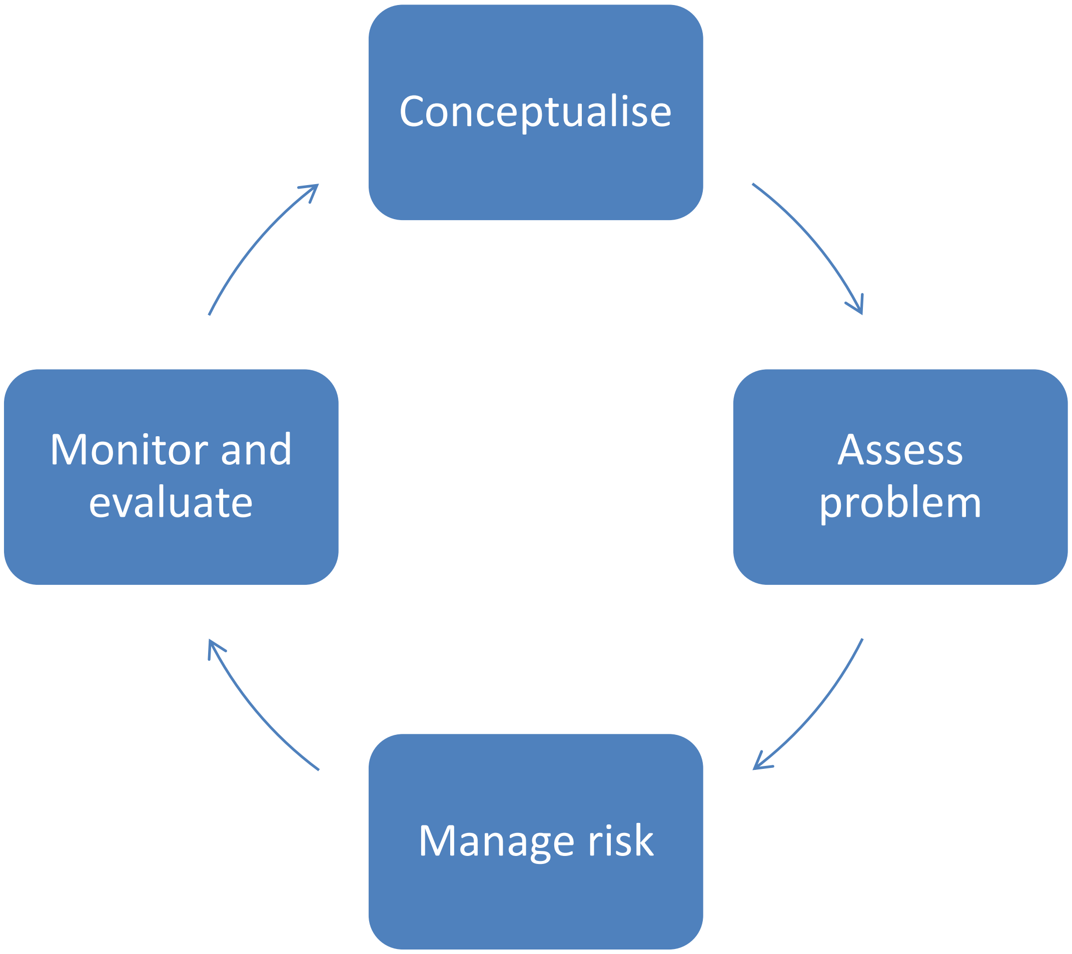
Key receptors in HK

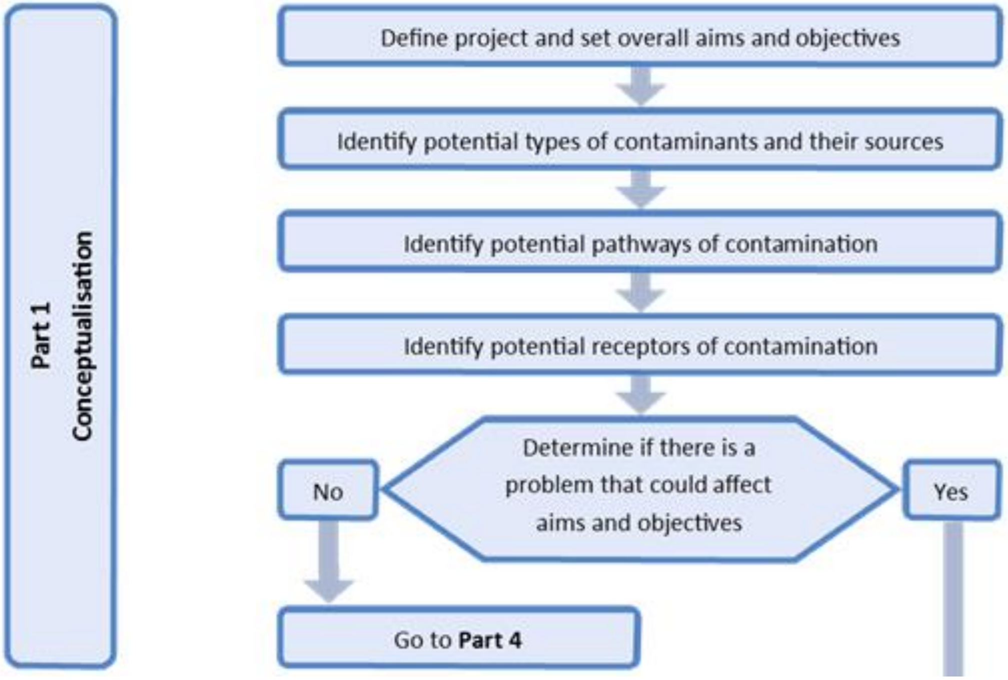
- Recognised sites of conservation importance
  - Sha Chau and Lung Kwu Chau Marine Park
  - Hoi Ha Wan Marine Park
  - Double Haven Marine Park
  - Tung Ping Chau Marine Park
  - Cape of Agular Marine Reserve

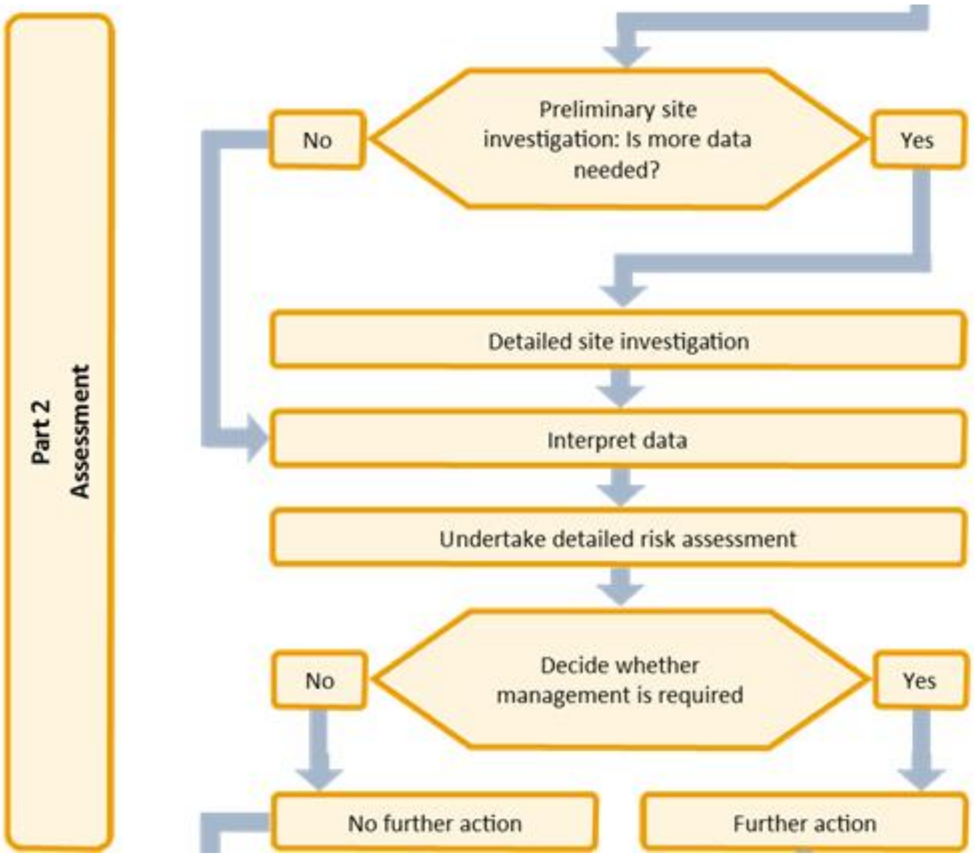
Others key receptors

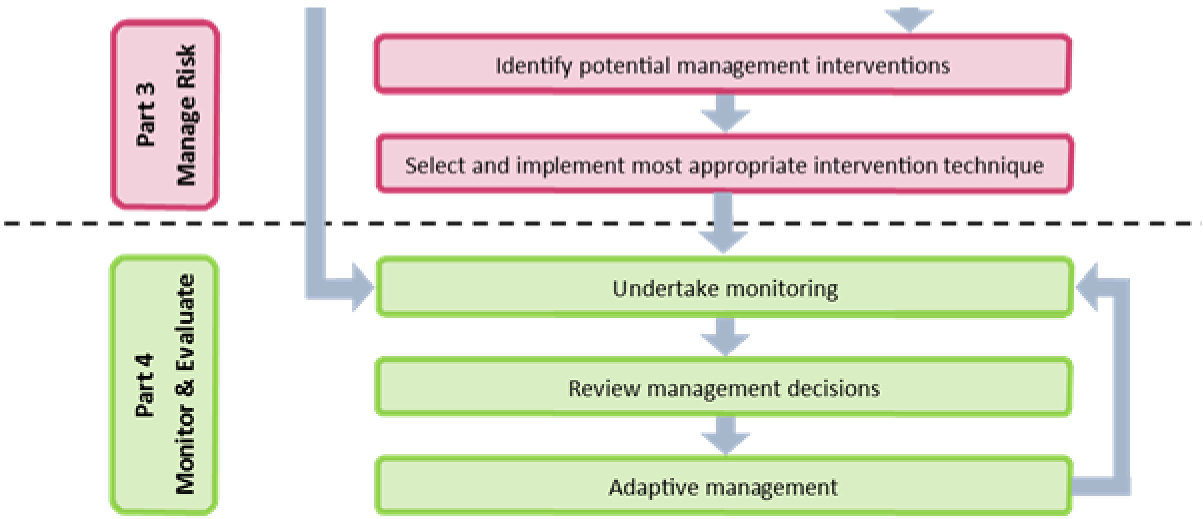
- Chinese White Dolphins - Concentrate more estuarine influenced water i.e. western waters
- Finless Porpoise
- Corals
- Marine benthic communities
- Fishing/spawning grounds
- Mariculture sites – marine fish culture e.g. green grouper, snapper etc.

Conceptual framework for managing contaminated sediments




Part 1
Conceptualisation
Define project and set overall aims and objectives
Identify potential types of contaminants and their sources
Identify potential pathways of contamination
Identify potential receptors of contamination
Determine if there is a problem that could affect aims and objectives
No
Yes
Go to Part 4


Part 2
Assessment
Preliminary site investigation: Is more data needed?
No
Yes
Detailed site investigation
Interpret data
Undertake detailed risk assessment
Decide whether management is required
No
Yes
No further action
Further action


Part 3
Manage Risk
Identify potential management interventions
Select and implement most appropriate intervention technique
Part 4
Monitor & Evaluate
Undertake monitoring
Review management decisions
Adaptive management

In HK – generation of dredged sediments

- General reclamation
- Works with creating suitable foundation for seawalls, drainage outfalls or other structures
- Works with providing protection structures for submarine pipelines and utilities
- Cases where water depth needed to be increase e.g. navigation, anchorage, typhoon shelters etc.

Sediments management in HK

Main legislation

The Environment, Transport and Works Bureau (ETWB)'s framework for the management of dredged/excavated sediment through the ETWB Technical Circular (Works) No. 34/2002 for marine disposal of dredged sediments

ETWB Technical Circular (Works) No. 34/2002

- This Circular sets out the procedure for seeking approval to dredge/excavate sediment and the management framework for marine disposal of such sediment.
- It does not cover the use of dredged/excavated sediment to form land but….the carrying out of such dredging and reclamation works must satisfy the requirements of the Environmental Impact Assessment Ordinance.

Sediments classification

Contaminants	Lower Chemical Exceedance Level (LCEL)	Upper Chemical Exceedance Level (UCEL)
Metals *(mg/kg dry wt.)*		
Cadmium (Cd)	1.5	4
Chromium (Cr)	80	160
Copper (Cu)	65	110
Mercury (Hg)	0.5	1
Nickel (Ni)*	40	40
Lead (Pb)	75	110
Silver (Ag)	1	2
Zinc (Zn)	200	270
Metalloid *(mg/kg dry wt.)*		
Arsenic (As)	12	42
Organic-PAHs *(μg/kg dry wt.)*		
Low Molecular Weight PAHs	550	3160
High Molecular Weight PAHs	1700	9600
Organic-non-PAHs *(μg/kg dry wt.)*		
Total PCBs	23	180
Organometallics *(μg TBT/L in Interstitial water)*		
Tributyltin*	0.15	0.15

Classification of sediments

- Category L: Sediment with all contaminant levels not exceeding the Lower Chemical Exceedance Level (LCEL). The material must be dredged, transported and disposed of in a manner which minimizes the loss of contaminants either into solution or by resuspension.

- Category M: Sediment with any one or more contaminant levels exceeding the Lower Chemical Exceedance Level (LCEL) and none exceeding the Upper Chemical Exceedance Level (UCEL). The material must be dredged and transported with care, and must be effectively isolated from the environment upon final disposal unless appropriate biological tests demonstrate that the material will not adversely affect the marine environment.

- Category H: Sediment with any one or more contaminant levels exceeding the Upper Chemical Exceedance Level (UCEL). The material must be dredged and transported with great care, and must be effectively isolated from the environment upon final disposal.

Rationale for disposal to the sea

- Disposal to the sea will not be considered unless the need of sediments 'removal' is demonstrated at the EIA stage except Cat L sediments below 50,000 m^3.

- Dredging/removal of sediment will be allowed without justification for:
  - emergency dredging for safety reasons or averting environmental hazards;
  - maintenance/deepening of the harbour fairways, berths, anchorages, navigation channels or approaches; and
  - maintenance (but not construction) of watercourses, rivers, stream courses, drainage channels or outfalls.

In other cases. The project should be planed with the assumption of keeping mud in place.

Application for exemption

Marine Fill Committee will scrutinise applications for exemption taking into account factors including:

- the practicality of performance specifications,
- completeness of risk management strategies,
- comprehensiveness of option assessments including consideration of new technology. Where cost is considered, the estimation must include a fair and complete estimate of all cost components, I.e. the actual cost of mud disposal and necessary dredging and transportation, disposal management, monitoring and other associated activities

Options for marine disposal

- Disposal to the sea - open sea floor disposal areas at South Cheung Chau and East Ninepin and various empty marine borrow pits for uncontaminated sediments
- Confined Disposal of Dredged Sediment at East Sha Chau for contaminated sediments

Guide Boat Leading the Barge to the Target Area
for Contaminated Mud Disposal

Determination of sediment quality

- Guidelines on the initial data assessment, the sampling and testing procedures, the biological test criteria, and the submission requirements

- Requirements may be waived in cases of: (a) emergency dredging for reasons of safety or averting environmental hazards; and (b) for small scale dredging works of maintenance nature and involving dredging volumes of less than 5,000 m^3 in situ.

Intervention types

1. Removal and transport of contaminated sediment: This intervention removes and relocates the contaminated sediment from its in situ location to an ex situ location to facilitate further intervention(s) including pre-treatment, treatment and disposal of the contaminated sediment.

2. Pre-treatment of contaminated sediment: This ex situ intervention prepares the contaminated sediment to facilitate further intervention(s), including treatment and disposal of the contaminated sediment.

3. Treatment of contaminated sediment: This in situ or ex situ intervention reduces, removes, changes or immobilises the contaminants within the contaminated sediment to facilitate further intervention including disposal of the contaminated sediment.

4. Disposal of contaminated sediment: This in situ or ex situ intervention confines, contains and controls the contaminated sediment such that contaminants cannot mobilise into the environment and pose risks to human and ecological receptors

Management measures can involve one intervention, but typically involve a series of linked interventions

In-situ vs ex-situ?

- The need to remove the contaminated sediment from its in situ location for reasons related to contamination (e.g. unacceptable environmental risk) and/or unrelated to contamination (e.g. unacceptable navigation risk).

- The need to pre-treat contaminated sediment in its in situ or ex situ location is related to removing and/or reducing contamination, such that some or all of the resulting sediment is suitable for re-use.

Pre-treatment

Dewatering

•Natural dewatering in lagoons

•Mechanically dewatering via filter or belt processes

Particle separation/soil washing

•Use of mechanical agitation to separate finer contaminated sediments

Treatment methods

- Use of physical, chemical and/or biological methods (or a combination) to remove, immobilise, degrade or destroy contaminants

- In-situ - Monitored natural recovery, electrochemcial methods
- Ex-situ - bioremediation, physico-chemical treatment, thermal treatment

Applicability of pre-treatment and treatment interventions for different sediment types, contamination levels and contaminant types

Intervention	Sediment type			Contamination level		Contaminant type	
	Silt	Sand / silt	Sand	Low	High	Organic	In-organic
De-watering	✓	✓	✓	✓	✓	✗	✓
Particle separation	✓	✓	✓	✓	✓	✓	✓
Monitored natural recovery	Not reported in cited study						
Electrochemical remediation (ECRTs)	✓	✓	✓	✗	✓	✗	✓
Bioremediation (land farming)	✗	✓	✓	✓	✓	✓	✗
Soil washing (scrubbing)	✓	✓	✓	✗	✓	✗	✓
Chemical immobilisation	✓	✓	✓	✓	✓	✓	✓
Thermal desorption	✓	✓	✓	✗	✓	✓	✗
Thermal immobilisation	✓	✓	✓	✓	✓	✓	✓

✓ = intervention complies with environmental standards, ✗ = intervention does not comply with environmental

Applicability of pre-treatment and treatment interventions for different contaminants

Intervention	Metals	PAHs	PCBs	TBT
De-watering	✓	✓	✓	✓
Particle separation	✓	✓	✓	✓
Monitored natural recovery	Not reported in cited study			
Electrochemical remediation (ECRTs)	~	~	~	✓
Bioremediation (land farming)	~	✓	✓	✓
Soil washing (scrubbing)	✓	✓	✓	✓
Chemical immobilisation	✓	✗	✗	~
Thermal desorption	~	✓	✓	✓
Thermal immobilisation	✓	✓	✓	✓

✓ = applicable, ~ = partially applicable, ✗ = not applicable

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Innovative approach 1

Reuse dredged materials as engineering fill, and other types of engineering materials (via solidification and stabilisation)

- Cement
- Carbon (8)

Carbon 8 technology

By using carbon dioxide to produce materials for re-use, or for cheaper disposal - accelerated Carbonation Technology (ACT)

It is a controlled, accelerated version of the naturally occurring carbonation process, which results in an improvement in the chemical and physical properties of the treated materials.

Advantages

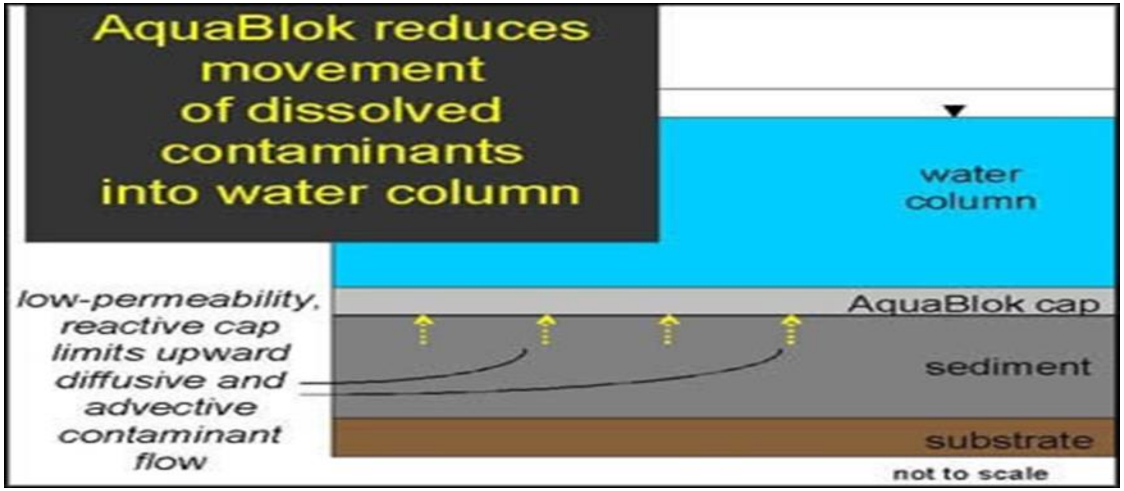
- Rapid treatment – only a few minutes (as opposed to days or months with other technologies)
- Waste CO_2 is sequestered and converted into carbonate salts, providing carbon credits
- The immobilisation of a wide variety of materials, including heavy metals, in carbonated products (at near neutral pH) renders them permanently non-hazardous or inert
- The process results in increased product density, controlled particle size and improved geotechnical properties
- The product can be used as a secondary aggregate, engineering fill or specialist construction materials

Innovative approach 2 (for in-situ capping)

- Use clean mineral based materials, reactive or adsorptive materials in small amounts on the sediment surface for the reduction in contaminant concentrations in the biologically active zone
- Can be disturbed by seasonal mobilisation or water course users
- May impact on benthic flora and fauna for thick layers

AquaBlock

- Composite particle technology that consists of a coated core (typically stone aggregate).
- The particles act as a delivery system by placement of fine-grained active ingredients through a water column to appropriate target locations.



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AquaBlok Sealing & Non-Contamination Solutions | Contamination Remediation Solutions

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THIN-LAYER CAPPING

AQUABLOK® WILL FORM A LOW-PERMEABILITY ISOLATION CAP OVER CONTAMINATED SEDIMENTS IN A LAYER THICKNESS OF 6-INCHES OR LESS.

Despite sand's attributes as a sediment capping material, results of this comparative study also indicate that AquaBlok could offer several advantages over sand in capping contaminated deep water or wetland sediments in select circumstances. As opposed to more permeable sand material, AquaBlok application does not appear to result in significant compaction-related movement of sediment pore waters into capping material, thus maximizing the effective, contaminant-free thickness of an AquaBlok cap. AquaBlok displays significantly higher resistance to unidirectional current flow than sand, which could give more flexibility in cap design (perhaps no armor needed) as well as the range of hydrologic environments into which AquaBlok caps could be applied.

By virtue of its lower permeability and amenability to organic additions, AquaBlok should act as a more effective barrier to long-term contaminant transport of dissolved, sediment-borne contaminants into the bioturbation zone. AquaBlok is physically similar to fine-grained contaminated sediments and could therefore be a more effective substrate than sands for colonization by local invertebrate communities. By virtue of its higher resistance to erosive forces and effectiveness as a chemical barrier, a relatively thin AquaBlok cap (one foot or less) could be deployed to collectively meet all functional objectives at a given site. Such a relatively thin, yet effective cap could minimize restrictions on waterway uses and navigation – as opposed to sand caps, which may need to be applied at thicknesses significantly greater than one foot in order to meet functional objectives.

In summary, a one-foot AquaBlok cap would appear to be at least as effective as a one-foot sand cap in biologically, physically, and chemically isolating sediment-borne contaminants in deep water and wetland ecosystems. Both capping materials can be viable substrate for macro invertebrate colonization. Both capping materials can physically stabilize contaminated sediments, either with or without additional capping components (e.g. stone armor). Finally, transport simulations indicate that both sand and AquaBlok caps can effectively limit upward migration of hydrophobic contaminants into bioturbation zones for a period of many decades. Both cap types should also be relatively easy to deploy, monitor, and maintain over time. Cost comparisons for sand versus AquaBlok sediment capping can be readily determined on a sitespecific basis. Costs for implementing an in situ capping approach can be significantly less than costs associated with sediment removal,treatment,and disposal in many applications.

302 Proceedings of the 1999 Conference on Hazardous Waste Research

Case study 1 - Dredge and cap

Historic refinery site (Sinclair Refinery) along the Genesee River.

- Removal of 3 feet of sediments
- Isolation by Aquablock
- Minimize removal volumes (with all associated costs).
- Provides 100% clean surface for restoration – Eliminates risks associated with residual.
- Reduces risk of recontamination from other sources.

Case study 2 - Passaic River / Newark Bay Restoration USA

- Sediments found to be contaminated with dioxins, PCBs, and metals. After multiple sampling events, it was decided to remove and stabilize 500 cubic yards of sediment and place them on-site under an asphalt cap.
- During construction it became evident that the dredged material would not readily dewater sufficiently allow for compaction and to be used as fill under the asphalt cap. Several small batches of sediment were mixed with cement and allowed to stabilized for a couple of days until it was sufficiently stable to allow proper compaction.

Mixing and capping techniques for activated carbon based sediment remediation

Activated carbon (AC) has been proven to be highly effective for the in-situ remediation of sediments contaminated with a wide range of hydrophobic organic contaminants

Field pilot study in Trondheim harbour, Norway, in which powdered AC alone or in combination with sand or clay was tested as a thin-layer capping material for polycyclic aromatic hydrocarbon (PAH)-contaminated sediment.

Remediation of Contaminated Marine Sediment Using Thin-Layer Capping with Activated Carbon—A Field Experiment in Trondheim Harbor, Norway

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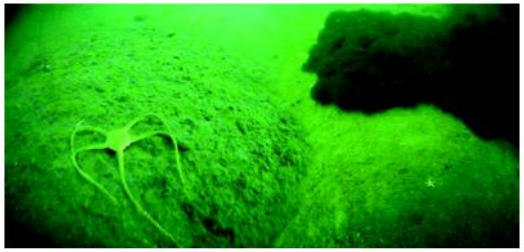
Abstract



In situ amendment of contaminated sediments using activated carbon (AC) is a recent remediation technique, where the strong sorption of contaminants to added AC reduces their release from sediments and uptake into organisms. The current study describes a marine underwater field pilot

The results from the study

- The capping efficiency was in general AC + clay > AC-only > AC + sand.
- AC + clay reduced bioaccumulation of PAH and PCB congeners between 40% and 87% in the worms and between 67% and 97% in the clams.

Thus the best thin-layer capping method in this study was AC mixed with clay

Use of geotextile

The details….

- created a patch -- black geotextile mats designed to cap and stabilize pollution in place.
- The mats are six feet square and one inch thick. They consist of a mixture of reactive materials sandwiched between two layers of geotextile fabric, creating a sort of quilt that traps pollutants but allows water to flow through.
- The reactive "filling" of this quilt contains three different substances that bind and stabilize different pollutants. One such substance -- a UNH-patented technology based on a natural form of phosphorus -- treats toxic heavy metals e.g. lead, copper, zinc and cadmium.
- add organoclay and activated charcoal, which adhere to and treat toxic chemicals such as polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons, (PAHs), and petroleum products that routinely enter waterways through storm water runoff.

Some EU and US guidance

- CEFAS publications
- Energy Institute's report Guidance on characterising, assessing and managing risk(s) associated with potentially contaminated sediments
- CONCAWE Report 11/13: Supplementary guidance for the investigation and risk assessment of potentially contaminated sediments
- RHDHV's project
- AINA report Sustainable management of dredged materials from inland waterways
- Sednet, Dredging in Europe and Central Dredging Association
- Civil Engineering Application for Marine Sediments (CEAMaS) project led by University College Cork.
- ITRC New Guidance Document on Contaminated Sediments Remediation

CIRIA's project – Risk assessment and remediation of contaminated sediments

- How does the risk assessment affect the management of the sediments if they are 'contaminated'?
- What are the cost and benefits for the various options?
- Dredging is common practice in the UK but it does have its limitations. Will other methods such as capping which has been applied in other countries may be a better options for some sites? Can we learn from experience from other countries?
- What are the potential contaminated sediment management issues associated with extreme weather events

Target audience

- An owner is simply aware that there are historic contaminated sediments in land owned by them e.g. harbour limit, a stretch of canal, a stretch of river

- An owner is planning navigation / maintenance dredging and wishes to understand where the dredgings can be used treated or dumped

- An owner is identified as owning land from which sediments are contaminating a commercial or natural habitat nearby

- A developer is proposing undertaking work in or near water that stands a risk of re-suspending and/or distributing sediment that will:
  - Move the sediment to land in others' jurisdiction
  - Threaten nearby natural habitats or commercial installations

- A consultant and other advisors

- Regulators

What is next?

- Open publication in Spring 2018
- Looking for case studies and experience
- First good practice guidance for UK (and may be applicable to HK?)

Thank you for listening

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