8. HAZARD TO HEALTH

8.1 Introduction

The sediment disposal operation at WL facility are designed to minimise the dispersion of contaminated sediments during disposal and to prevent the long-term migration of contaminants through the placement of a clean mud cap of 3 m thickness. Loss of contaminated sediment will, nevertheless, occur during placement, and as the area serves as fishing grounds, the risk of potential hazard to human health will be assessed as seafood originated within and in the vicinity of the Study Area where the CMPs are located could bioaccumulate contaminants. Pathways of contaminant release to humans include ingestion of organisms with contaminant residues (***Figure 8.1***). As stated in the EIA Study Brief (ESB-328/2019), a risk assessment on human consumption of seafood from the Project due to increase of concentration and accumulation of heavy metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and tributyltin (TBT), etc should be conducted.

8.2 Methodology

A review has been conducted with reference to the annual risk assessment reports and the EIA Report for the ESC CMPs and SB CMPs. The objective of this risk assessment is to determine whether disposal operations at WL facility are predicted to pose unacceptable risk to humans. The assessment considers the effects of the consumption of seafood by humans from the Study Area due to increase of concentration and accumulation of heavy metals, PAHs, PCBs and TBT, etc. Predicted concentrations of contaminants of concern from the bioaccumulation assessment (***Annex 8A***) and historical data from the previous monitoring programmes for the ESC CMPs and SB CMPs are used as the basis for the analysis.

The methodology utilised in this risk assessment to human health follows the guidelines of the US Environmental Protection Agency (EPA) [70][71][72] and will incorporate a four-step approach involving problem formulation, characterisation of exposure, characterisation of human health effects, and risk characterisation. This methodology has been utilised in the EM&A programmes for the ESC CMPs and SB CMPs and is based on the methodology presented in Clarke et al. 2000 [73]. The methodology for the risk assessment to human health is presented in ***Annex 8B***.

8.3 Human Health Risk Assessment Results

The intent of this evaluation is to determine the potential risks to the various populations of Hong Kong, resulting from contaminated sediment disposal at the proposed WL Facility. The exposure pathway is assumed to be consumption of food by members of the various populations included in the assessment:

- **Population 1 - Hong Kong People in general**, representing the average exposure to seafood from the Study Area by members of the Hong Kong population as a whole;
- **Population 2 - Hong Kong Fishermen**, reflecting the high end of risk and was considered to represent members of the Hong Kong fishing community ; and
- **Population 3 - WL Fishermen**, representing the absolute highest risk of exposure to the seafood at WL and was considered as representative of members of the fishing community that fish within the Study Area.

(70) US EPA (1989) Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish. A Guidance Manual. EPA-503/8-89/002.
(71) US EPA (1992) Framework for ecological risk assessment. EPA/630/R-92/001, Risk Assessment Forum, Washington, DC.
(72) US EPA (2000) Guidance for assessing chemical contaminant data for use in fish advisories. Volume 2. Risk assessment and fish consumption limits. EPA-823-B-00-008.
(73) Clarke SC, Jackson AP, Neff J (2000) Development of a risk assessment methodology for evaluating potential impacts associated with contaminated mud disposal in the marine environment. Chemosphere. 41:169-76.

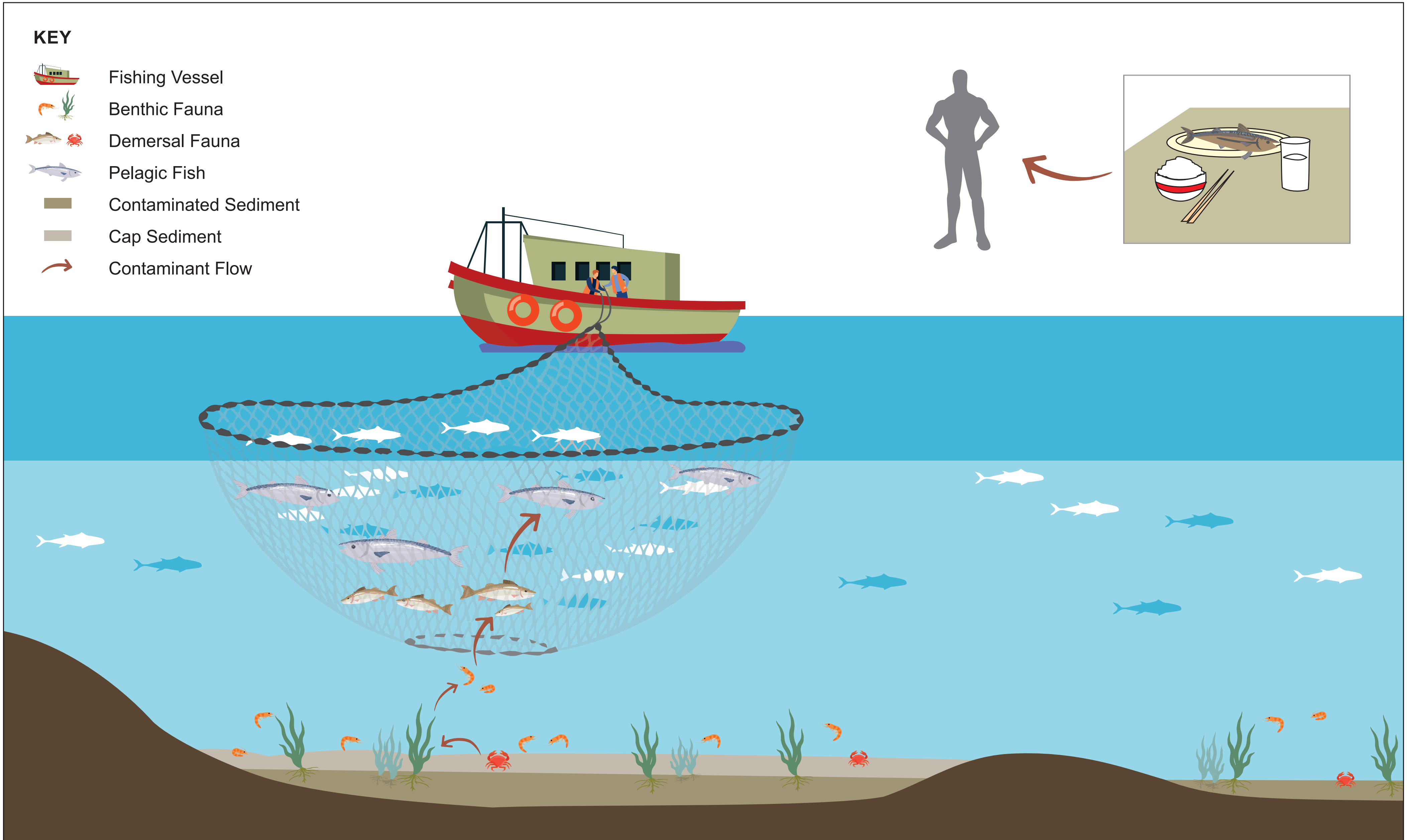

Figure 8.1

Indicative Pathways to Potential Contaminant Release

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The methodology is designed to provide a conservative estimate of the risks to these populations. As discussed in ***Annex 8B*** the evaluation has been conducted in order to provide two estimates of risk:

- Carcinogenic risk to the three populations through the consumption of contaminated seafood. The contaminants assessed in this way are those where carcinogenic effects have been demonstrated and an oral Slope Factor (SF) is known. The list of known carcinogens along with their SFs and the relevant source data are presented in ***Annex 8B***.
- An estimate of the hazard (i.e. non-carcinogenic risk) to each population through the consumption of contaminated seafood. The contaminants assessed in this way are those where hazardous effects have been demonstrated and a Reference Dose (RfD) is known. The list of known hazardous substances along with their RfDs and the relevant source data are presented in ***Annex 8B***.

Several of the organic contaminants were consistently recorded below the detection limits in the EM&A programmes for ESC CMPs and SB CMPs [(74)]. For this reason the organic contaminants included as part of this assessment were as follows:

- Total PCBs
- Low molecular weight PAHs (LMW PAHs)
- High molecular weight PAHs (HMW PAHs)

All of the inorganic contaminants listed in *ETWB TC(W) No. 34/2002* have been included in the assessment.

8.3.1 Carcinogenic Risk Assessment Results

Carcinogenic risk may be defined as the intake multiplied by the carcinogenic slope factor (SF). The resultant value reflects the additional lifetime carcinogenic risk from exposure to the particular COC. The intake is measured in terms of mg kg^{-1} (body weight) day^{-1} and has been calculated using the data presented in ***Annex 8B***.

The majority of the SF values for each of the COCs were taken from the USEPA's Integrated Risk Information System (IRIS) database, as discussed in ***Annex 8B*** of this report. As discussed in ***Annex 8B***, the assessment of risk associated with the intake of carcinogens in the edible portion of seafood is calculated over the entire lifetime of the members of the population of concern.

Values for incremental lifetime risk have been calculated for each COC and are summed to provide an estimate of the Total Incremental Lifetime Risk to which each of the populations of concern are exposed. The justification for use of an additive approach is presented in ***Annex 8B***. Once the incremental lifetime risk has been calculated the next step is to evaluate the magnitude of acceptability of the incremental risk due to the project. The USEPA has defined acceptable incremental lifetime risks for carcinogens as within the range of 10^{-4} to 10^{-6} for multiple contaminants and 10^{-4} for single contaminants. Higher risks have, however, been deemed acceptable if there were special extenuating circumstances [(75)].

The incremental lifetime risk values calculated from the predicted COC concentrations at the proposed WL facility are presented in ***Table 8.1***. The single contaminant incremental lifetime risk levels are acceptable for all of the contaminants for each of the exposure populations. The total incremental lifetime risk levels are also acceptable for all the three exposure populations.

(74) There is a lack of bioaccumulation and bioconcentration factors available in the literature for TBT and it is therefore not included in the Risk Assessment. This limitation does not limit the conservative nature of the assessment because background levels of TBT in sediment and dredged materials in Hong Kong are generally undetectable or very low. This statement is backed up by monitoring data collected at ESC CMPs since 1997 which has consistently recorded TBT in sediment and tissue samples below levels of concern.

(75) LaGrega MD, Buckingham PL, Evans JC and The ERM Group (1994) Hazardous Waste Management. McGraw-Hill Inc 1146pp

Table 8.1 Calculations of Dose and Subsequent Incremental Carcinogenic Risk Levels

COCs	Oral Slope Factor (mg kg^{-1} day^{-1})	Incremental Lifetime Risk		
		HK People	HK Fishermen	WL Fishermen
Ambient				
Low MW PAHs	3.4 x 10^{-1}	2.00 x 10^{-9}	8.09 x 10^{-8}	4.95 x 10^{-7}
High MW PAHs	3.44 x 10^{-1}	4.05 x 10^{-9}	1.64 x 10^{-7}	1.00 x 10^{-6}
Total PCBs	2	6.01 x 10^{-10}	2.43 x 10^{-8}	1.49 x 10^{-7}
Arsenic	1.5	4.51 x 10^{-10}	1.82 x 10^{-8}	1.12 x 10^{-7}
Lead	8.5 x 10^{-3}	1.49 x 10^{-10}	6.04 x 10^{-9}	3.70 x 10^{-8}
Total Lifetime Risk		**7.25 x 10^{-9}**	**2.93 x 10^{-7}**	**1.80 x 10^{-6}**
With Project				
Low MW PAHs	3.4 x 10^{-1}	2.02 x 10^{-9}	8.18 x 10^{-8}	5.01 x 10^{-7}
High MW PAHs	3.44 x 10^{-1}	4.13 x 10^{-9}	1.67 x 10^{-7}	1.02 x 10^{-6}
Total PCBs	2	1.85 x 10^{-7}	7.48 x 10^{-6}	4.58 x 10^{-5}
Arsenic	1.5	5.04 x 10^{-10}	2.04 x 10^{-8}	1.25 x 10^{-7}
Lead	8.5 x 10^{-3}	1.76 x 10^{-10}	7.12 x 10^{-9}	4.36 x 10^{-8}
Total Incremental Lifetime Risk		**1.91 x 10^{-7}**	**7.75 x 10^{-6}**	**4.75 x 10^{-5}**

8.3.2 Hazard Assessment Results for Non-carcinogens

The measure used to establish the risk of toxic effects for non-carcinogenic substances is referred to as the Hazard Quotient (HQ). The HQ is composed of two components:

- the daily intake of the particular COC from all dietary sources measured in terms of mg kg^{-1} (body weight) day^{-1} and used as the numerator, and
- the recommended Reference Dose (RfD) which is used as the denominator.

The RfD values for each of the COCs were taken from the USEPA's IRIS database, as discussed in ***Annex 8B*** of this report. The calculation of the HQ involves dividing the daily intake value (dose) by the RfD value (discussed in ***Annex 8B***). According to the guidelines (77)(78), HQs can be interpreted in a conservative risk assessment as follows:

- **HQ < 1**: the risk of an adverse effect occurring is low (as the intake of the COC is lower than the RfD);
- **HQ 1 to 10**: there is some risk of an adverse effect occurring, however, typically within the bounds of uncertainty; and,
- **HQ > 10**: the risk of adverse effects on human health is moderate to high (depending on the HQ) as the intake of COCs is an order of magnitude, or more, higher than the RfD.

As seen from the above ranges, the greater the value of the HQ the greater the level of concern. However, it should be noted that the HQ does not define a linear dose-response relationship and therefore the numerical value should not be regarded as a direct estimate of risk (79). It is especially important to note that a Hazard Quotient exceeding 1 does not necessarily mean that adverse effects

(77) US EPA (1989). *Op cit.*
(78) EVS Environment Consultants (1999). Contaminated Mud Disposal at East Sha Chau : Comparative Integrated Risk Assessment
(79) US EPA (1989). *Op cit.*

will occur. HQs are specific to each particular COC and do not provide an indication of the total hazard to the population of concern through intake of all the COCs in their diet. The approach used to address this, as well as the assumption and uncertainties areas discussed in ***Annex 8B***, will be additive and consequently is considered a conservative method. The sum of all the HQs for each COC is referred to as the Hazard Index (HI). The HI is interpreted in the same way as described for HQs above.

Once the RfD values and intake values were obtained for each COC, the HQs were calculated for the three populations of concern (***Table 8.2***). The table indicates that all of the HQ values for all the populations were less than one.

Table 8.2 Hazard Quotients for Populations of Concern

COCs	RfD (mg kg^{-1} day^{-1})	Hazard Quotient		
		HK People	HK Fishermen	WL Fishermen
Ambient				
Low MW PAH	2×10^{-2}	3.04×10^{-6}	9.33×10^{-5}	5.66×10^{-4}
High MW PAH	5×10^{-4}	2.43×10^{-4}	7.46×10^{-3}	4.53×10^{-2}
Arsenic	3×10^{-4}	9.72×10^{-6}	2.90×10^{-4}	1.76×10^{-3}
Cadmium	1×10^{-3}	8.13×10^{-5}	2.74×10^{-3}	1.66×10^{-2}
Chromium	3×10^{-3}	2.43×10^{-4}	7.32×10^{-3}	4.44×10^{-2}
Copper	4.3×10^{-2}	5.13×10^{-5}	1.70×10^{-3}	1.03×10^{-2}
Lead	1.43×10^{-3}	1.15×10^{-4}	3.46×10^{-3}	2.10×10^{-2}
Mercury	2.2×10^{-4}	5.83×10^{-4}	1.79×10^{-2}	1.08×10^{-1}
Nickel	2×10^{-2}	9.44×10^{-5}	2.83×10^{-3}	1.72×10^{-2}
Silver	5×10^{-3}	2.07×10^{-5}	6.46×10^{-4}	3.92×10^{-3}
Zinc	3×10^{-1}	5.92×10^{-5}	1.83×10^{-3}	1.11×10^{-2}
Hazard Index		**1.50×10^{-3}**	**4.62×10^{-2}**	**2.81×10^{-1}**
With Project				
Low MW PAH	2×10^{-2}	3.07×10^{-6}	9.46×10^{-5}	5.74×10^{-4}
High MW PAH	5×10^{-4}	2.48×10^{-4}	7.63×10^{-3}	4.63×10^{-2}
Arsenic	3×10^{-4}	1.05×10^{-5}	3.33×10^{-4}	2.02×10^{-3}
Cadmium	1×10^{-3}	1.44×10^{-4}	5.57×10^{-3}	3.38×10^{-2}
Chromium	3×10^{-3}	2.75×10^{-4}	8.31×10^{-3}	5.04×10^{-2}
Copper	4.3×10^{-2}	5.76×10^{-5}	1.89×10^{-3}	1.15×10^{-2}
Lead	1.43×10^{-3}	1.37×10^{-4}	4.10×10^{-3}	2.49×10^{-2}
Mercury	2.2×10^{-4}	8.47×10^{-4}	2.71×10^{-2}	1.61×10^{-1}
Nickel	2×10^{-2}	9.53×10^{-5}	2.85×10^{-3}	1.73×10^{-2}
Silver	5×10^{-3}	2.11×10^{-5}	6.58×10^{-4}	3.99×10^{-3}
Zinc	3×10^{-1}	7.66×10^{-5}	2.59×10^{-3}	1.57×10^{-2}
Hazard Index		**1.92×10^{-3}**	**6.11×10^{-2}**	**3.71×10^{-1}**

The summation of the HQ values to produce the HI also indicates that for both areas the HI was less than one. The exposure pathway examined in this risk assessment is focussed on exposure to COCs via ingestion of seafood from within a specific area only. It is acknowledged that other pathways, such as other seafood sources and foods other than seafood will also expose the study populations to the COCs and thereby could affect the HI value. Hence chemicals with a HQ (as well as the HI) of less than one does not necessarily imply that there is no risk. Concerning the WL fishermen sub-populations the HI value is 0.371 of which 44% is related to Mercury. It should be noted that Mercury in this risk assessment refers to total Mercury which includes metallic (elemental), inorganic and organic Mercury. Dietary inorganic mercury is of little toxicological concern and the toxicity of Mercury generally refers to its more toxic organic forms (e.g. methylmercury). It is also noted that exposure to Mercury from other pathways, such as via air (inhalation), water (drinking) and dermal contact are minor when compared to the diet and of the diet seafood contains the largest source of these COCs [80][81]. Therefore, the hazard quotient for Mercury is considered conservative assuming it is totally bioavailable and in the more toxic organic forms. Overall, the results of this assessment indicated that the incremental risk of an adverse effect occurring from consuming seafood collected at the Study Area is low.

8.4 Conclusion

The risk assessment work has employed two approaches to predict the effects on human health of consuming seafood due to sediment disposal at the proposed WL Facility. The first approach examined the risks associated with exposure to carcinogens and the second examined the hazards to human health associated with exposure to non-carcinogens. Three populations with differing potential to be exposed to seafood from the Study Area were examined. The first population represented the average exposure to seafood from the Study Area by members of the Hong Kong population as a whole and was referred to as Hong Kong People. The second population of concern reflected the high end of risk and was considered to represent members of the Hong Kong fishing community and was referred to as Hong Kong Fishermen. The third population represented the absolute highest risk of exposure to the seafood at WL and was considered as representative of members of the fishing community that fish within the Study Area and was referred to as WL Fishermen.

The carcinogenic risk assessment has indicated that the lifetime risks associated with consumption of seafood are below the acceptability criterion for both the WL Facility and the reference areas. Results of the hazard (i.e. non-carcinogenic risk) assessment indicated that risks associated with consumption of seafood were low for both the WL and reference areas. A biomonitoring programme is recommended to address stakeholders' concerns on the contamination of seafood in the vicinity of the Project during backfilling works. The details of the biomonitoring programme will be presented in the EM&A Manual attached to this EIA Report.

(80) Food and Environmental Hygiene Department (2002). Risk Assessment Studies Report: Dietary Exposure to Heavy Metals of Secondary School Students.

(81) Food and Environmental Hygiene Department (2008). Risk Assessment Studies Report: Mercury in Fish and Food Safety