10 Health Impact

10.1 Introduction

This section presents the assessment of the potential health risk / impact associated with the construction and operation phases of the I·PARK2 located in Tsang Tsui Ash Lagoon site.

With reference to the Section 3.4.10.1 and Appendix I of the EIA Study Brief No. ESB-365/2024 for this Project, a health risk assessment shall be conducted to assess the potential health impact associated with construction and operation of the Project.

Since no biogas generation, sorting and recycling plant is proposed for the Project, the Health Impact Assessment (HIA) covers the following aspects.

- Likelihood and consequences of exposure to aerial emissions from the Project during operational phase;
- Potential Health Impacts of Fugitive Emissions during Transportation, Storage, Handling and Disposal of Waste and Ash;
- Potential Health Impacts of Radon Emissions from Excavation, Filling, Handling, Storage, Transport and Disposal of Pulverised Fly Ash; and
- Potential accidental event(s).

10.2 Potential Health Impacts of Aerial Emissions from the I·PARK2 during Operational Phase

10.2.1 Project Site

The Project site is located in the northwest New Territories adjacent to the West New Territories (WENT) Landfill, the future WENT Landfill Extension, Tsang Tsui Columbarium, T-PARK, Y-PARK and the China Light and Power Company Ltd. (CLP) Black Point Power Station. The ash lagoons were constructed in the 1980s by CLP for the purpose of storing pulverized fuel ash (PFA). The site was surrendered to the Government in 2015.

10.2.2 Literature Review for Environmental Legislation, Standards and Guidelines

10.2.2.1 United Kingdom (UK) and European Union (EU) Guidance

The UK Department of Environment, Food, and Rural Affairs (DEFRA) published definitive Guidelines for Environmental Risk Assessment and Management in 2011 [1].

In Europe, this guidance also formed the foundation for the later guidance recommended by European Groundwater and Contaminated Land Remediation Information System (EUGRIS). The EUGRIS group represents 6 countries: Denmark, France, Germany, Hungary, Italy and United Kingdom, and it is coordinated by the Federal Environmental Agency of Germany. They have developed "Integrated Soil and Water Protection: Risks from Large Scale Diffuse Pollution" (EURIG-SOWA, 2005) [2], which recommends utilizing the UK DEFRA guidance for health risk assessment.

Scotland and Ireland have published "Scotland & Northern Ireland Forum for Environmental Research" (SNIFFER, 2007) guide [3]. Although it references locally specific regulations, it contains the same fundamental principles and structure.

In addition, World Health Organization (WHO) has also sponsored an effort to harmonize the various guidance documents for Human Health Risk Assessment (HHRA). In 2021 they have developed a Human Health Risk Assessment Toolkit: Chemical Hazards [4]. It offers a simplified approach, when appropriate, for the local project situation.

10.2.2.2 USEPA Guidance

The USEPA has published many specific guidance documents for various aspects of HHRA following the landmark "Risk Assessment in the Federal Government: Managing the Process" (NRC, 1983) [5] publication of the most fundamental guide to principles for practice in the US. Several US states such as California, Minnesota and Texas have also developed separate regulatory programs specific to various industrial systems and new facilities in their states, for which chemical emissions to the air, water or soil are of concern. The principal USEPA versions identified below are those that most closely resemble the UK DEFRA Guidelines (2011) detailed above.

The particular USEPA publications most relevant to HHRA for HIA use include:

- USEPA's Risk Characterization Policy; Guidance for Cumulative Assessment, Part 1: Planning and Scoping (https://www.epa.gov/sites/default/files/2015-01/documents/cumrisk2_0.pdf) [6]
- USEPA's Risk Assessment Guidance for Superfund (RAGS) (https://www.epa.gov/risk/risk-assessment-guidance-superfund-rags-part) [7];
- Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (HHRAP, 2005) [8]; and
- USEPA's Integrated Risk Information System (IRIS) (http://www.epa.gov/iris/) [9].

10.2.2.3 Approach Determination

All of these versions call for the following general steps for HHRA. Analysis were conducted in accordance with USEPA recommendations for conducting modelling in support of health risk assessment as outlined in the HHRAP guidance (USEPA, 2005) [8] and Guidelines for Environmental Risk Assessment and Management (DEFRA, 2011)[1].

A staged approach is proposed for the HIA as follows:

Stage 1: Hazard Identification

Stage 2: Exposure Assessment

Stage 3: Dose-Response Assessment

Stage 4: Risk Characterization

Stage 5: Risk Control and Management

10.2.3 Hazard Identification

10.2.3.1 General

The purpose of the hazard identification is to identify compounds of potential concern (COPC) for quantitative evaluation and to generate emissions estimates for non-carcinogenic (short-term (acute) and long-term (chronic)) and carcinogenic risks of exposure to the selected COPCs.

10.2.3.2 Compounds of Potential Concern

Sources of information for selection of COPCs include regulatory air quality requirements or stack gas permit limits such as Environmental Protection Department's prevailing guidance note on the Best Practicable Means (BPM) for incinerators (municipal waste incineration) [10] and approved EIA reports. The identified COPCs is listed below.

Trace Metals

- Antimony (Sb)
- Arsenic (As)
- Beryllium (Be)
- Cadmium (Cd)
- Chromium (Cr)
- Cobalt (Co)
- Copper (Cu)
- Lead (Pb)

- Manganese (Mn)
- Mercury (Hg)
- Nickel (Ni)
- Thallium (Tl)
- Vanadium (V)
- Zinc (Zn)
- Selenium (Se)

Organic Compounds

- Polychlorinated biphenyls (PCBs)
- Polychlorinated dibenzodioxins and furans (dioxins/furans)
- Polycyclic aromatic hydrocarbons (PAHs)

Other Compounds

- Hydrogen chloride (HCl)
- Hydrogen fluoride (HF)
- Carbon monoxide (CO)
- Nitrogen oxides, expressed as nitrogen dioxide (NO_2)
- Particulate Matters (PM_{10} and $PM_{2.5}$)
- Sulphur dioxide (SO_2)
- Ammonia (NH_3)

Carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matters (PM10 and PM2.5), lead (Pb) and sulphur dioxide (SO_2) are governed by Hong Kong's Air Quality Objectives (HKAQOs) in the Air Pollution Control Ordinance (Cap. 311). The potential impact of these HKAQO criteria pollutants generated from the Project is assessed in the Air Quality Chapter. For total organic carbon (TOC), as stated in the best available techniques (BAT) reference document for waste incineration in the European Union (EU), this parameter includes a number of gaseous organic substances, the individual detection of which is generally complex or not possible. A complete account of every substance within the TOC parameter is not available; however, incineration generally provides high destruction efficiencies for organic substances. TOC will be measured continuously as a key indicator to ensure complete combustion in the incineration process.
These COPCs are representative of MSW thermal treatment facilities in general and expected to represent those compounds or groups of compounds for which regulatory permit limits may be applicable and those that may be the most toxic, prevalent, mobile, and persistent compounds in MSW incineration emissions. The I·PARK2 shall be designed to meet the target

emission levels for the incinerator by making reference to the standards for pollution control on the MSW incineration in the Mainland China (GB 18485-2014) and Shenzhen (SZDB/Z 233-2017) [11], the prevailing guidance note on the BPM for incinerators (municipal waste incineration) in Hong Kong, as well as the best available techniques (BAT) reference document for waste incineration in the European Union (EU) [12]. For those COPCs listed in the above references, the emission rates are derived from the target emission levels and the stack gas flow rate. For those COPCs (i.e. Beryllium (Be), Zinc (Zn), Selenium (Se), PCBs & PAHs) not listed on the above references, the health risk / impact assessment is conducted with reference to the maximum emission rates in the "*Quantitative risk assessment of stack emissions from municipal waste combustors*"[13] as a conservative approach after conducting a literature review. The emission rates of the COPCs for the health risk / impact assessment are presented in **Appendix 10A**.

10.2.4 Exposure Assessment

10.2.4.1 Dispersion Model

Potential cumulative impacts due to dispersion of aerial emissions from the I·PARK2 are predicted at existing and planned/committed Health Sensitive Receivers (HSRs) with the use of AERMOD model. The methodology for the AERMOD model is presented in the Air Quality Chapter.

10.2.4.2 Identification of Sensitive Receptors

The assessment area is defined based on 500m of the Project boundary and the Areas of Influence (AoIs) in Air Quality Chapter. The representative health sensitive receivers (HSRs) within 500m from the Project boundary and AoIs have been identified in accordance with Annex 12 of EIAO-TM and are shown in **Figure 10.1-10.7** and tabulated in **Table 10-1**.

Table 10 - 1 Details of Identified Health Sensitive Receivers

HSR	Description	Nature of HSR [1]	Assessment Height above ground, m	No. of Storeys	Distance to Project Boundary, m
TPO1	Fresh Air Intake at 8/F, T-PARK Office	G/IC	39 [2]	1	226
TPO2	Fresh Air Intake at 9/F, T-PARK Office	G/IC	42 [2]	1	198
WXO1	WENTX Office	Planned G/IC	1.5	1	126
TTC1	Office, Tsang Tsui Columbarium	G/IC	4 [3]	1	88
BPS1	GBG Management Building, Black Point Power Station	I	1.5, 5, 10	3	1396
LKT1	Lau Ancestral, Lung Kwu Sheung Tan	Place of Worship	1.5	1	1945
LKT2	Hai Grove House 2, 24 Pak Long	R	1.5, 5, 10	3	3110
SPN1	295 Sheung Pak Nai	R	1.5	1	3313
HPN1	2A Ha Pak Nai	R	1.5	1	3028

HSR	Description	Nature of HSR [1]	Assessment Height above ground, m	No. of Storeys	Distance to Project Boundary, m
HPN2	Ha Pak Nai Village House	R	1.5	1	2969
HPN3	21 Ha Pak Nai	R	1.5	1	2676
NWR1	81 Nim Wan Road	R	1.5	1	1990
HPN4	West Ha Pak Nai	R	1.5	1	2181
HPN5	West Ha Pak Nai	R	1.5	1	1597
HPN6	West Ha Pak Nai	R	1.5	1	1640
HPN7	West Ha Pak Nai	R	1.5	1	1549
NWR2	Village House along Nim Wan Road	R	1.5	1	4280
NWR3	Village House along Nim Wan Road	R	1.5	1	4350
NWR4	Village House along Nim Wan Road	R	1.5	1	4600

Notes:
[1] R – Residential; C – Commercial; I – Industrial; G/IC –Government / Institution / Community;
[2] Central air conditioning is provided, and the fresh air intakes are located at 39m and 42m above ground.
[3] Central air conditioning is provided, and the fresh air intake is located at 4m above ground.
[4] The AoIs covered in this report differ from that of the approved IWMF Phase 1 EIA report due to variations in emission and stack parameters. Only the HSRs identified within the AoIs where the emission impact of representative air pollutant from the chimney of the Project exceeds the SIL as stated in **Section 3.3** of this report are included in this assessment.
[5] According to the approved WENTX VEP, Y-Park will be replaced by WENTX office during the construction and operation phases of the WENTX Project, therefore the Y-PARK office is not considered as HSR in the I·PARK2 EIA study.
[6] As presented in **Appendix 3A** of this report, the area within the tentative reclamation extent of Lung Kwu Tan Reclamation project has been identified as AoIs considering its potential future uses. Since the Lung Kwu Tan Reclamation and the Re-planning of Tuen Mun West Area project is still under study / planning, no detailed information is available for identifying representative ASRs for assessment at the time of the I·PARK2 EIA study. The potential cumulative impact would be considered by CEDD in the future EIA study for the top-side development at Lung Kwu Tan. Nevertheless, the area has been covered by the contour map in this EIA study for reference.
[7] As confirmed with the project proponent of WENTX, there is no confirmed land use for the future restored WENT Landfill and its extension at the time of the I·Park2 EIA study.

For evaluating chronic effects from long-term exposure to air pollutants, the exposure period is usually at least one year according to the definition of "chronic" in USEPA-IRIS [9], USHHS-ATSDR [14] and Cal/EPA-OEHHA [15]. For acute exposure from direct inhalation, the HHRAP (USEPA, 2005) [8] recommends evaluating acute effects only through the short-term (maximum 1-hour) inhalation exposure pathway of the acute risk scenario. All HSRs are included for chronic and acute risk assessments.

10.2.5 Exposure Response Relationship

10.2.5.1 Exposure Scenarios

An exposure scenario is a combination of "exposure pathways" to which a "receptor" may be subjected. The representative HSRS were identified in Section 10.2.4.2 above. All HSRs are included for the chronic and acute risk assessments.

10.2.5.2 Exposure Pathways

The exposure pathways include inhalation, ingestion through food and water, and direct dermal contact. Inhalation is the major route for gases and volatile chemicals. As discussed below, the indirect exposure through direct dermal contact, ingestion of soil, water or locally raised products are negligible.

Direct dermal contact and incidental ingestion of soil and water

Young children may ingest soil accidentally by transferring soil present in their hands, food or toys (that have contacted the soil) to their mouths. However, this activity is unlikely to result in ingestion of COPCs generated from the operation of the Project which are either gases or suspended particulates. These pollutants will remain airborne and dispersed by air movements. Even when these COPCs have been brought down to the land by rainfall, they will be rapidly diluted to very low concentrations and will unlikely contribute to the pollution of the soil and water. Hence, the chance of dermal exposure through contacts with contaminated water and soil would be very low. Besides, for representative HSRs in the study area, the chance of direct contact with soil resulting in accidental ingestion of soil is considered very low. On the other hand, Potable water for Hong Kong is derived mainly from the 'Dongjiang' river in China. Therefore, health risk associated with dermal contact and ingestion of soil and water due to exposure to COPCs from the Project are considered as negligible and adverse health impact due to exposure through direct dermal contact, ingestion of soil and water is not anticipated.

Ingestion of locally raised product

Most agricultural products consumed in Hong Kong is imported from neighbouring mainland China. Locally raised pigs and chickens could be exposed to emissions of COPCs through ingestion of locally raised grain and silage or through grazing on locally impacted lands. However, given the small percentage of land that is used for farming in Hong Kong, and the low probability of significant soil contamination by airborne pollutants, it is highly unlikely that home-grown vegetables and local livestock, whether fed on locally produced silage or grazed on local pastureland, would pose a risk of ingesting emissions of COPCs from the Project. Moreover, as stated above, the COPCs will be rapidly diluted to very low concentrations and will unlikely contribute to the pollution of the soil and water even when these COPCs have been brought down to the land or the sea by rainfall. Hence, emissions of COPCs from the Project should not lead to bioaccumulation inside fish or oyster for both capture fisheries and aquaculture. With consideration of the above, the risk associated with ingestion of locally raised product due to exposure to COPCs from the Project is considered as negligible and adverse health impact due to exposure through ingestion of locally raised product is not anticipated.

Inhalation Exposure

Most COPCs during the operation of the Project will be in gaseous form, vapour form or particulates suspended in the air. As they are released at high temperature, they tend to remain in gaseous phase. Even as they cool down, they would exist as vapours instead of liquids. Most COPCs will exist in gaseous or vapour state instead of solid state. In vapour state, inhalation of COPCs is the predominant route of entry into the human body because a large volume of air is breathed into the human body every minute. The inhalation exposure route is therefore the prominent pathway considered in the quantitative health impact assessment. Chronic and acute exposure were evaluated via the inhalation pathways at the selected HSRs described in **Section 10.2.4.2**.

10.2.6Toxicity Assessment

10.2.6.1 General

The purpose of the toxicity assessment is to identify the types of adverse health effects a COPC may potentially cause, and to define the relationship between the dose of a compound and the likelihood or magnitude of an adverse health effect (response). Adverse health effects are typically characterized in the health risk assessment as carcinogenic or non-carcinogenic for long-term exposure and acute hazard for short-term exposure.

10.2.6.2 Dose-Response Assessment

Human health risk assessment is a combination of procedures, models and tools by which a proposed development may be judged as to its potential effects on the health of the nearby representative human receptors. The dose-response assessment step involves an evaluation of the relationship between exposures and responses in human with respect to carcinogenic health effects as well as acute and chronic non-carcinogenic health effects. Acute effects are obvious and usually occur soon after exposure. Some may be reversible when exposure to the pollutant ends and some are often irreversible, even after exposure to the pollutant come to an end.

Consequence of Exposure

The consequences of exposure to the non-HKAQO criteria COPCs including all heavy metals identified for I·PARK2 related sources are summarised in **Table 10-2**.

Table 10 - 2 Consequences of exposure to the non-HKAQO criteria COPCs including all heavy metals identified for I·PARK2 related sources

COPCs	Characteristics	Consequence
Trace Metals		
Sb (Antimony)	Antimony is a silver-white brittle solid or a dark-gray, lustrous powder. It is used in industrially to make flame-proofing materials and in some paints, glass, and batteries. Antimony is coupled with materials like lead to improve their durability. Small amounts of	Short-term inhalation exposure of people to antimony results in effects on the skin and eyes. Long-term inhalation exposure of people to antimony results in inflammation of the lungs, chronic bronchitis, and chronic emphysema.

COPCs	Characteristics	Consequence
	antimony are released into the environment by incinerators and coal-burning power plants	
As (Arsenic)	Arsenic is a naturally occurring element. It is released into the air by volcanoes, the weathering of arsenic-containing minerals and ores, and by commercial or industrial processes.	Acute high-level inhalation exposure to arsenic dust or fumes has resulted in gastrointestinal effects (nausea, diarrhea, abdominal pain); central and peripheral nervous system disorders. Chronic inhalation exposure to inorganic arsenic of humans leads to lung cancer, irritation of the skin and mucous membranes and effects in the brain and nervous system. IARC classifies inorganic arsenic as "group 1 human carcinogen".
Be (Beryllium)	Beryllium (Be) is a dark gray metal of the alkaline earth family and is moderately rare in its natural form. Beryllium is used industrially to harden copper, for the manufacture of nonsparking alloys for tools, in the manufacture of lightweight alloys and ceramics, and in the construction of nuclear reactors. However, most beryllium in the environment is released through coal burning operations.	Data on human toxicity from beryllium are only available following inhalation exposures. The lung is the major target organ following inhalation of beryllium in a variety of forms. High levels of beryllium in air can cause an acute pneumonitis (acute beryllium disease) characterized by edema and inflammation. Extreme cases can be fatal. Chronic exposure to low levels of beryllium in air may lead to chronic beryllium disease (berylliosis). The IARC has classified beryllium as a "group 1 known carcinogen".
Cd (Cadmium)	Cadmium is an element of the transitional metal series that occurs widely in nature, usually in sulfide or zinc ores. Natural weathering of minerals releases small amounts of cadmium to the environment, but human activities are responsible for the majority of cadmium releases. Anthropogenic sources of cadmium include releases from mining and smelting, fuel combustion, manufacture and use of phosphate fertilizer, application of sewage sludges, waste incineration, and primary and secondary metal production.	Absorption of cadmium following inhalation exposure varies depending on particle size. Large particles (>10 microns in diameter) tend to be deposited in the upper airway, while smaller particles (about 0.1 microns) tend to penetrate into the alveoli. Cadmium bioaccumulates in mammals, particularly in the kidney and liver. Epidemiological studies have revealed an association between nonmalignant pulmonary diseases and inhalation of cadmium. It is also suspected that chronic exposure to cadmium produces anemia, sensory loss (particularly smell), and immunosuppression in humans. The IARC has classified cadmium as a "group 1 known carcinogen".
Cr (chromium)	Chromium is a naturally occurring metal present in low concentrations in the earth's crust. Chromium (VI) is the second most stable chromium compound, after Chromium (III). Natural occurrence of hexavalent chromium (chromium [VI]) is infrequent; it occurs in nature in the rare mineral crocoite ($PbCrO_4$). It is primarily produced from anthropogenic sources. Chromium (VI) is used extensively in industry, mainly for plating metals such as stainless and alloy steels and aluminum. It is also used as an additive in cleansing agents, paints, catalysts, fungicides, and wood preservatives.	Both acute and chronic toxicity of chromium are mainly caused by Chromium (VI) compounds. Hexavalent chromium compounds are strong oxidizing agents and are severely irritating and corrosive. Acute inhalation exposure to chromium (VI) may cause asthma attacks in sensitive individuals; concentrations at which these effects occur were not described. Acute inhalation exposure to chromium fumes may also cause fever, chills, and muscle aches. Chronic inhalation of dust containing chromium (VI) concentrations may cause respiratory irritation, emphysema, chronic bronchitis, and other respiratory conditions. USEPA has classified inhaled chromium (VI) as Group A - Human Carcinogen.

COPCs	Characteristics	Consequence
		The IARC has classified chromium (VI) as a "group 1 known carcinogen". As chromium (VI) is much more toxic than chromium (III), chromium is speciated into chromium (VI) and chromium (III) species and only chromium (VI) is selected as the key/representative compound of potential concern for the purpose of health risk assessment.
Co (Cobalt)	Cobalt is hard, gray metal that occurs naturally. It is found in rocks, soil, water, plants, and animals, including people. It is used in industrially to use in cutting and grinding tools, pigments and paints, colored glass, surgical implants, batteries, and some electroplating. Its radioactive isotope is used in imaging and food irradiation. Cobalt can be released to the environment by human activities, as well through the weathering of rocks and soil.	Short-term inhalation exposure of people to cobalt results in respiratory effects, such as a significant decrease in ventilatory function, congestion, edema, and hemorrhage of the lung. Long-term inhalation exposure of people to cobalt results respiratory irritation, wheezing, asthma, pneumonia, and fibrosis. This can be disabling or fatal.
Cu (Copper)	Copper is a reddish metal that occurs naturally in rock, soil, water, sediment, and, at low levels, air. Copper can enter the environment through releases from the mining of copper, and from factories that make or use copper metal or copper compounds. Copper can also enter the environment through waste dumps, domestic waste water, combustion of fossil fuels and wastes, wood production, phosphate fertilizer production, and natural sources.	In humans, copper is a respiratory irritant. Workers exposed to copper dust report a number of symptoms that are suggestive of respiratory irritation, including coughing, sneezing, thoracic pain, and runny nose. Copper is also considered the etiologic agent in the occupational disease referred to as "vineyard sprayer's lung". USEPA has not yet classified copper as a human carcinogen.
Pb (Lead)	Lead is a naturally occurring, soft, bluish-gray heavy metal. Due to its abundance, low cost and physical properties (low melting point, corrosion resistance, waterproof nature and malleability) lead and lead compounds have been utilized in a variety of products including cable covers, petrol (gasoline), paint, plastics, pesticides, solder, etc. This widespread use of lead has caused extensive environmental contamination and health problems in many parts of the world.	Short-term inhalation exposure of people to high levels of lead can cause gastrointestinal disturbances (anorexia, nausea, vomiting, abdominal pain), hepatic and renal damage, hypertension and neurological effects (malaise, drowsiness, encephalopathy) that may lead to convulsions and death. Long-term inhalation exposure of lead commonly causes haematological effects, such as anaemia, or neurological disturbances. There is some evidence that long-term occupational exposure to lead may contribute to the development of cancer. IARC has classified inorganic lead compounds as a "Group 2A Probably carcinogenic to humans".
Mn (Manganese)	Manganese is naturally ubiquitous in the environment. Manganese is essential for normal physiologic functioning in humans and animals, and exposure to low levels of manganese in the diet is considered to be nutritionally essential in humans. Metallic manganese is used primarily in steel production to improve hardness, stiffness, and strength. Manganese compounds have a variety of uses. Manganese dioxide is used in	Short-term inhalation exposure of people to manganese results primarily in effects on the nervous system. Long-term inhalation exposure of people to high levels may result in a syndrome called manganism and typically begins with feelings of weakness and lethargy and progresses to other symptoms such as gait disturbances, clumsiness, and psychological disturbances. USEPA has classified manganese as a Group D, not classifiable as to carcinogenicity in humans.

COPCs	Characteristics	Consequence
	the production of dry-cell batteries, matches, fireworks, etc.	
Hg (Mercury)	Mercury is a heavy, silvery-white metal that is liquid at room temperature. Compared to other metals, it is a poor conductor of heat, but a fair conductor of electricity. It occurs naturally as a mineral and is distributed throughout the environment by both natural and anthropogenic processes. Mercury is used in industrially to produce chlorine gas and caustic soda, and in thermometers, barometers, batteries, and electrical switches.	Short-term inhalation exposure of people to mercury results in lung and eye irritation, coughing, chest pain, nausea, vomiting, diarrhea, fever, high blood pressure, increased heart rate and skin rashes. Long-term inhalation exposure of people to mercury results in memory loss, headache, sleeplessness, tremors and personality changes, gum inflammation (gingivitis), high blood pressure, and in some cases kidney damage.
Ni (Nickel)	Nickel is a hard, silvery-white metal. It is a natural element of the earth's crust; therefore, small amounts are found in food, water, soil, and air. Nickel can be combined with other metals, such as iron, copper, chromium, and zinc, to form alloys. These alloys are used to make coins, jewellery, and items such as valves and heat exchangers. Most nickel is used to make stainless steel.	Short-term inhalation exposure of people to an extremely high level of nickel suffered severe damage to the lungs and kidneys. Long-term inhalation exposure of people to nickel results in respiratory effects, including a type of asthma specific to nickel, decreased lung function, and bronchitis. The IARC has classified nickel compounds as "Group 1 Carcinogenic to humans".
Tl (Thallium)	Thallium is a soft, heavy, inelastic metal. It is tasteless and odourless. It is found in trace amounts in the earth's crust. It is imported for use in the manufacture of electronics, low temperature thermometers, optical lenses, and imitation precious jewels. Thallium was used historically as a rodenticide but has since been banned in the United States due to its toxicity from accidental exposure. Small amounts of thallium are released into the air from coal-burning power plants, cement factories, and smelting operations.	Short-term inhalation exposure of people to thallium results in visual effects; rapid heart rate and high blood pressure; abnormal heart rhythms; respiratory failure; unusual, painful, or burning sensations; muscle aches and weakness; headache; seizures, delirium, and coma; loss of appetite; excessive salivation; inflammation of the mouth, lips, and gums; possible green discoloration of urine shortly after exposure; kidney damage; breakdown of red blood cells; severe acne; and dry and crusty scaling of the skin. Long-term inhalation exposure of people to thallium results in causing nervous system effects, such as numbness of fingers and toes.
V (Vanadium)	Vanadium is a hard, slivery grey, malleable transition metal. It is released to the environment by continental dust, marine aerosols, volcanic emissions, and the combustion of coal and petroleum crude oils. It is naturally released into water and soil as a result of weathering of rock and soil erosion. It is primarily used in the production of rust-resistant, spring, and high-speed tool steels; vanadium pentoxide is used in ceramics.	Short-term inhalation exposure of people to vanadium results in irritating the nose, throat and lungs causing coughing, wheezing and/or shortness of breath. Long-term inhalation exposure of people to vanadium results in causing bronchitis to develop with cough, phlegm, and/or shortness of breath.
Zn (Zinc)	Zinc is a slightly brittle metal at room temperature and has a shiny-greyish appearance when oxidation is removed. It is released into the environment as the result of mining, smelting of zinc, lead, and cadmium	Intense inhalation exposure of people to zinc results in disease called metal fume fever, which is generally reversible once exposure to zinc ceases. This is a flu-like illness with symptoms of metallic taste in the mouth, headache, fever and chills, aches, chest tightness and cough. However, very

COPCs	Characteristics	Consequence
	ores, steel production, coal burning, and burning of wastes.	little is known about the long-term effects of breathing zinc dust or fumes.
Selenium (Se)	Selenium is a naturally occurring substance that is widely distributed in the earth's crust and is commonly found in sedimentary rock. It is usually combined with other compounds in the environment, such as sulfide minerals or with silver, copper, lead, and nickel. It is used in the electronics industry; the glass industry; in pigments used in plastics, paints, enamels, inks, and rubber; as a catalyst in the preparation of pharmaceuticals; in antidandruff shampoos (selenium sulfide); and as a constituent of fungicides.	Short-term inhalation exposure of people to selenium results in irritation of the mucous membranes in the nose and throat, producing coughing, nosebleeds, dyspnea, bronchial spasms, bronchitis, and chemical pneumonia. No information is available on the long-term effects of selenium in humans from inhalation exposure.
Organic Compounds		
PCBs (Polychlorinated biphenyls)	PCBs are either oily liquids or solids and are colorless to light yellow. Some PCBs are volatile and may exist as vapor in air. They have no known smell or taste. PCBs enter the environment as mixtures containing a variety of individual chlorinated biphenyl components, known as congeners, as well as impurities. PCBs may be released into the environment by the burning of some wastes in municipal and industrial incinerators.	No reports of effects in humans following short-term exposure to PCBs are available. Long-term inhalation exposure of people to PCBs results in respiratory tract symptoms, such as cough and tightness of the chest, gastrointestinal effects including anorexia, weight loss, nausea, vomiting, and abdominal pain, mild liver effects, and effects on the skin and eyes, such as chloracne, skin rashes, and eye irritation.
Dioxins and furans	TCDD is not intentionally produced by industry. It can be inadvertently produced in very small amounts as an impurity during the incineration of municipal and industrial wastes and during the manufacture of certain chemicals. It may be formed during the chlorine bleaching process used by pulp and paper mills, and as a by-product from the manufacture of certain chlorinated organic chemicals, such as chlorinated phenols. It is primarily released to the environment during the combustion of fossil fuels (including motor vehicles) and wood, and during incineration processes. Furan appears as a clear colorless liquid with a strong odor. Flash point below 32 °F. Less dense than water and insoluble in water. Vapors heavier than air. It is a toxic, flammable, low-boiling (31℃) colourless liquid. It has a role as a carcinogenic agent, a hepatotoxic agent and a Maillard reaction product. It is a mancude organic heteromonocyclic parent, a member of furans and a monocyclic heteroarene. It is a natural product found in Perilla frutescens, Solanum lycopersicum, and Coffea arabica.	Short-term inhalation exposure of people to TCDD can cause chloracne, and a severe acne-like condition that can develop within months of first exposure. Chronic effects (non-cancer) from TCDD of inhalation in humans have not been reported in the literature. Human studies, primarily of workers occupationally exposed to 2,3,7,8-TCDD by inhalation, have found an association between 2,3,7,8-TCDD and lung cancer, soft-tissue sarcomas, lymphomas, and stomach carcinomas. IARC has classified it as "Group 1 Carcinogenic to humans". Short-term inhalation exposure of people to furans can cause severe lung damage. The substance may be irritating to the skin, eyes and respiratory tract. Long-term inhalation exposure of people to furans can cause effects on the liver and kidneys. This may result in impaired functions. This substance is possibly carcinogenic to humans. May cause genetic damage in humans.

COPCs	Characteristics	Consequence
PAHs (Polycyclic aromatic hydrocarbons)	PAHs are a group of chemicals that are formed during the incomplete burning of coal, oil, gas, wood, garbage, or other organic substances, such as tobacco and charbroiled meat. As pure chemicals, PAHs generally exist as colorless, white, or pale yellow-green solids. They can have a faint, pleasant odor. A few PAHs are used in medicines and to make dyes, plastics, and pesticides. Others are contained in asphalt used in road construction. They can also be found in substances such as crude oil, coal, coal tar pitch, creosote, and roofing tar. They are found throughout the environment in the air, water, and soil. They can occur in the air, either attached to dust particles or as solids in soil or sediment.	Short-term inhalation exposure of people to PAHs results in eye irritation, diarrhea, confusion, nausea, and vomiting. Long-term inhalation exposure of people to PAHs results in cataracts, kidney and liver damage aplastic anaemia (effect on the bone cells in bone marrow that produce red blood cells), and skin damage and photosensitization (sensitization to sun light).
<u>Other Compounds</u>		
HCl (Hydrogen Chloride)	Hydrogen chloride is a colorless to slightly yellow gas with a pungent odor. On exposure to air, hydrogen chloride forms dense white corrosive vapors. Hydrogen chloride can be released from volcanoes. It is used in industrially to use in the workplace for fumigation, electroplating, mining, chemical synthesis, and the production of synthetic fibers, plastics, dyes, and pesticides.	Short-term inhalation exposure of people to hydrochloric acid causes eye, nose, and respiratory tract irritation and inflammation and pulmonary edema in humans. Long-term inhalation exposure of people to hydrochloric acid cause chronic bronchitis, hyperplasia of the nasal mucosa, larynx, and trachea and lesions in the nasal cavity.
HF (Hydrogen fluoride)	Hydrogen fluoride is a chemical compound that contains fluorine. It can exist as a colorless gas or as a fuming liquid, or it can be dissolved in water. It can be released when other fluoride-containing compounds such as ammonium fluoride are combined with water. Hydrogen fluoride is used to make refrigerants, herbicides, pharmaceuticals, high-octane gasoline, aluminum, plastics, electrical components, and fluorescent light bulbs. 60% of the hydrogen fluoride used in manufacturing is for processes to make refrigerants.	Short-term inhalation exposure of people to hydrogen fluoride results in irritating to the respiratory tract and all mucosal tissue. Symptoms include lacrimation, cough, labored breathing, and excessive salivary and sputum formation. Excessive irritation causes chemical pneumonitis and pulmonary edema which could be fatal. Long-term inhalation exposure of people to hydrogen fluoride suffers lingering chronic lung disease.
Ammonia (NH_3)	Ammonia is a colorless gas with a very sharp odor. Ammonia is found throughout the environment in the air, soil, and water, and in plants and animals, including humans. It is also found in many household and industrial cleaners. About 80% of the ammonia produced by industry is used in agriculture as fertilizer. Ammonia is also used as a refrigerant gas, for purification of water supplies, and in the manufacture of plastics, explosives, textiles, pesticides, dyes and other chemicals. It is found in many household and industrial-strength cleaning solutions.	Short-term inhalation exposure of people to ammonia results in nasopharyngeal and tracheal burns, airway obstruction and respiratory distress, and bronchiolar and alveolar edema. Long-term inhalation exposure of people to ammonia results in bronchial reactivity/hyperresponsiveness, inflammation, cough, wheezing, or shortness of breath.

10.2.6.3 Toxicity Criteria / Guidelines for Long-Term Exposure

COPCs are classified as to whether they exhibit cancer and non-cancer health effects and whether health effects can result from inhalation of the chemical.

The toxicity of each COPC is based on toxicity factors developed by relevant studies. The toxicity factor is referred to as dose-response values and is derived for inhalation exposure. The dose-response values derived by evaluation of potential carcinogenic health effects resulting from long-term exposure to COPCs is called unit risk factors [URFs; expressed in units of $(\mu g/m^3)^{-1}$] for direct inhalation exposure pathway. The dose-response values derived for evaluation of potential non-carcinogenic health effects resulting from long-term exposure to COPC is called reference concentrations (RfCs) or tolerable concentrations in air (TCA) expressed in mg/m3 for inhalation exposure pathways. For some COPCs, both cancer and non-cancer toxicity factors are available because the chemical has been associated with both cancer and non-cancer health effects. The health risk assessment includes an evaluation of both potentially carcinogenic and non-carcinogenic COPCs.

10.2.6.3.1 HKAQO Criteria COPCs

For the COPCs of the Hong Kong Air Quality Objectives (HKAQO), the predicted cumulative long-term (annual averaged) concentrations at the HSRs are assessed and compared against the HKAQO criteria in Air Quality Chapter. It has been analysed as part of this health risk assessment and compared against the findings of relevant toxicology studies.

10.2.6.3.2 Non-HKAQO Criteria COPCs

Based on the USEPA assessment summary, the chronic health hazard assessment for non-carcinogenic effects encompasses chronic inhalation exposure.

For carcinogenic health risk, it is measured as the incremental risks attributed to the concentrations of COPCs at representative HSRs. The inhalation risk is expressed as an "inhalation unit risk (IUR)", defined as the risk of developing cancer if a person is continuously exposed to a unit concentration (usually presented as 1 $\mu g/m^3$) for a lifetime of 70 years.

For non-carcinogenic health risk, it is measured using an "inhalation reference concentration" (RfC), which is defined as an estimate of a continuous inhalation exposure to a chemical that is likely to be without risk of deleterious noncancer effect.

For the non-HKAQO crtieria COPCs, the following sources of information have been reviewed to determine the toxicity factors for use in evaluating exposure and risk through inhalation. The following hierarchy is established to determine the acceptable values for this assessment:

- World Health Organization (WHO) [16]

- USEPA's Integrated Risk Information System (IRIS) (https://iris.epa.gov/AtoZ/?list_type=alpha) [9]
- Agency for Toxic Substances and Disease Registry (ATSDR) under United States Department of Health and Human Services (https://www.atsdr.cdc.gov/toxprofiledocs/index.html)[14]
- Reference exposure levels (RELs) established by Office of Environmental Health Hazard Assessment (OEHHA) under California Environmental Protection Agency (Cal/EPA) (https://oehha.ca.gov/chemicals) [15]
- Other relevant international publications of toxicology studies

The toxicity criteria used in the risk assessment is presented in **Table 10-3**.

Table 10 - 3 Toxicity Factors for the Risk Assessment

COPCs	Inhalation Unit Risk Factor ($\mu g/m^3$)$^{-1}$	Inhalation RfC ($\mu g/m^3$)
Trace Metals		
Sb (Antimony)	NA	0.2 (IRIS, 1995)[1]
As (Arsenic)	0.0015 (WHO, 2000)[2]	NA (WHO, 2000)[3]
Be (Beryllium)	0.0024 (IRIS, 1998)[4]	0.02 (IRIS, 1998)[5]
Cd (Cadmium)	0.0018 (WHO, 2000)[6]	0.005 (WHO, 2000)[7]
Cr (VI) (Hexavalent chromium)	0.04 (WHO, 2000)[8]	0.1 (IRIS, 1998)[9]
Co (Cobalt)	NA	0.1 (ATSDR, 2023)[10]
Cu (Copper)	NA	2 (MDEQ, 2009)[11]
Pb (Lead)	NA	0.5 (WHO, 2000)[12]
Mn (Manganese)	NA	0.15 (WHO 2000)[13]
Hg (Mercury)	NA	1 (WHO, 2000)[14]
Ni (Nickel)	0.0004 (WHO, 2000)[15]	NA
Tl (Thallium)	NA	NA
V (Vanadium)	NA	1 (WHO, 2000)[16]
Zn (Zinc)	NA	NA
Se (Selenium)	NA	20 (OEHHA, 2001)[17]
Organic Compounds		

COPCs	Inhalation Unit Risk Factor (μg/m^3)$^{-1}$	Inhalation RfC (μg/m^3)
PCBs (Polychlorinated biphenyls)	0.0001	NA
Dioxins and furans	38 [TCDD] (OEHHA, 2011)[18]	0.00004 (OEHHA, 2008)[19]
PAHs (Polycyclic aromatic hydrocarbons)	0.087 [BAP] (WHO 2000)[20]	3 [Naphthalene] (IRIS, 1998)[21]
<u>Other Compounds</u>		
HCl (Hydrochloric acid)	NA	20 (IRIS, 1995) [22]
HF (Hydrogen fluoride)	NA	14 (OEHHA, 2003)[23]
Ammonia (NH_3)	NA	8 (WHO, 2000)[24]

Source of reference:
The criteria / standard / method has been reviewed and updated using the latest reference.

Air Quality Guidelines for Europe. Second Edition. World Health Organization [16]: https://www.who.int/publications/i/item/9789289013581

1. (IRIS, 1995) Chemical Assessment Summary - Antimony trioxide; CASRN 1309-64-4 [p.2] https://cfpub.epa.gov/ncea/iris/iris_documents/documents/subst/0676_summary.pdf
2. (WHO, 2000) Arsenic, Air Quality Guidelines for Europe. Second Edition. World Health Organization. [p.37]
3. (WHO, 2000) Arsenic, Air Quality Guidelines for Europe. Second Edition. World Health Organization. [p.127] Arsenic is a human carcinogen. Present risk estimates have been derived from studies in exposed human populations in Sweden and the United States. When assuming a linear dose–response relationship, a safe level for inhalation exposure cannot be recommended.
4. (IRIS, 1998) Chemical Assessment Summary – Beryllium and compounds ; CASRN 7440-41-7 [p.34] https://iris.epa.gov/static/pdfs/0012_summary.pdf
5. (IRIS, 1998) Chemical Assessment Summary – Beryllium and compounds ; CASRN 7440-41-7 [p.9] https://iris.epa.gov/static/pdfs/0012_summary.pdf
6. (WHO, 2000) Cadmium, Air Quality Guidelines for Europe. Second Edition. World Health Organization. [p.136]
7. (WHO, 2000) Cadmium, Air Quality Guidelines for Europe. Second Edition. World Health Organization. [p.138]
8. (WHO, 2000) Chromium, Air Quality Guidelines for Europe. Second Edition. World Health Organization. [p.141] With reference to the 2020 National Emissions Inventory Data prepared by USEPA, the percentage of Cr (VI) in total Cr is 19% for emissions of large municipal waste combustors. Therefore, a 19% Cr(VI) speciation factor is applied to the total Cr emissions in this health risk assessment.
9. (IRIS, 1998) Chemical Assessment Summary - Chromium (VI) ; CASRN 18540-29-9 [p.8] https://iris.epa.gov/static/pdfs/0144_summary.pdf
10. (ATSDR, 2023) Toxicological Profiles for Cobalt – CH8. Regulations and Advisories [p.220] https://www.atsdr.cdc.gov/ToxProfiles/tp33.pdf
11. (MDEQ, 2009) Chemical update worksheet – Copper [p.5)] [17] https://www.michigan.gov/-/media/Project/Websites/egle/Documents/Programs/RRD/Remediation/Rules---Criteria/Chemical-Update-Worksheets/A---C/Copper-Datasheet.pdf?rev=c61cc9bc1389479b8e513620e9cfaee5
12. (WHO, 2000) Lead, Air Quality Guidelines for Europe. Second Edition. World Health Organization. [p.152]
13. (WHO, 2000) Manganese, Air Quality Guidelines for Europe. Second Edition. World Health Organization. [p.155]
14. (WHO, 2000) Mercury, Air Quality Guidelines for Europe. Second Edition. World Health Organization. [p.160]
15. (WHO, 2000) Nickel, Air Quality Guidelines for Europe. Second Edition. World Health Organization. [p.163]
16. (WHO, 2000) Vanadium, Air Quality Guidelines for Europe. Second Edition. World Health Organization. [p.172]
17. (OEHHA, 2001) Chronic inhalation REL, Selenium https://oehha.ca.gov/chemicals/selenium
18. (OEHHA, 2011) Cancer Potency Information, 2,3,7,8-Tetrachlorodibenzo-p-dioxin and related compounds https://oehha.ca.gov/chemicals/2378-tetrachlorodibenzo-p-dioxin-and-related-compounds

19. (OEHHA, 2008) Chronic inhalation REL, 2,3,7,8-Tetrachlorodibenzo-p-dioxin and related compounds https://oehha.ca.gov/chemicals/2378-tetrachlorodibenzo-p-dioxin-and-related-compounds
20. (WHO, 2000) Polycyclic aromatic hydrocarbons, Air Quality Guidelines for Europe. Second Edition. World Health Organization. [p.95]
21. (IRIS, 1998) Chemical Assessment Summary – Naphthalene ; CASRN 91-20-3 [p.8] https://iris.epa.gov/static/pdfs/0436_summary.pdf
22. (IRIS, 1995) Chemical Assessment Summary – Hydrogen chloride ; CASRN 7647-01-0 [p.2] https://iris.epa.gov/static/pdfs/0396_summary.pdf
23. (OEHHA, 2003) Chronic inhalation REL, Hydrogen Fluoride. https://oehha.ca.gov/chemicals/hydrogen-fluoride
24. (WHO, 2000) Effects of nitrogen-containing air pollutants: critical levels, Air Quality Guidelines for Europe. Second Edition. World Health Organization. [p.232]

10.2.6.4 Toxicity Criteria / Guidelines for Short-Term Exposure

Potential risks due to short-term inhalation exposure (such as irritant or respiratory health effects) is also recommended in the HHRAP guidance. A screening level evaluation of short-term health effects has been conducted by comparing predicted short-term (maximum 1-hour) air concentrations against the findings of relevant toxicology studies.

10.2.6.4.1 HKAQO Criteria COPCs

For the COPCs of the HKAQO, the predicted cumulative short-term (hourly averaged) concentrations at the HSRs are assessed and compared against the HKAQO criteria in Air Quality Chapter. It has been analysed as part of this health risk assessment and compared against the findings of relevant toxicology studies.

10.2.6.4.2 Non-HKAQO Criteria COPCs

For other COPCs with potential acute health effects, for the purpose of this risk assessment, the following sources of information have been reviewed to determine the inhalation reference level for use in evaluating exposure and risk through inhalation. The hierarchy is presented in order of preference from most preferred to least preferred:

- Cal/EPA Acute RELs [18] – an acute REL represents the concentration in air at or below which no adverse health effects are anticipated in the general population, including sensitive individuals, for a specified exposure period (Cal/EPA 1999)

https://oehha.ca.gov/air/general-info/oehha-acute-8-hour-and-chronic-reference-exposure-level-rel-summary

- Protective Action Criteria (PACs) [19] - are levels of chemical materials above which could threaten or endanger the health and safety of workers or the public. It is a collective term for the various chemical limits, including AEGL, ERPG, and TEEL values. https://edms3.energy.gov/pac/TeelDef
    - Acute inhalation exposure guidelines (AEGL-1) – an AEGL-1 value represents "the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However,

the effects are not disabling and are transient and reversible upon cessation of exposure."

- Level 1 emergency planning guidelines (ERPG-1) – an ERPG-1 value represents "the maximum concentration in air below which nearly all individuals could be exposed for up to one hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor."
- Temporary emergency exposure limits (TEEL-1) – a TEEL-1 value represents "the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, when exposed for more than one hour, could experience notable discomfort, irritation, or certain asymptomatic, non-sensory effects. However, these effects are not disabling and are transient and reversible upon cessation of exposure."

The adopted exposure limits/reference levels for short-term exposure of COPCs are presented in **Table 10-4**.

Table 10 - 4 Exposure Limits/Reference Levels for COPCs Acute Exposure

COPCs	Exposure Limit/Reference Level ($\mu g/m^3$)	Averaging time	Source
Trace Metals			
Sb (Antimony)	1,500	1-hr averaging time	PAC: TEEL-1[1]
As (Arsenic)	0.2	1-hr averaging time	OEHHA, 2013[2]
Be (Beryllium)	0.15	1-hr averaging time	PAC: TEEL-1[1]
Cd (Cadmium)	100	1-hr averaging time	PAC: AEGL-1[1]
Cr (VI) (Hexavalent chromium)	0.5	1-hr averaging time	PAC: TEEL-1[1, 3]
Co (Cobalt)	60	1-hr averaging time	PAC: TEEL-1[1]
Cu (Copper)	100	1-hr averaging time	OEHHA, 2013[4]
Pb (Lead)	150	1-hr averaging time	PAC: TEEL-1[1]
Mn (Manganese)	3000	1-hr averaging time	PAC: TEEL-1[1]
Hg (Mercury)	0.6	1-hr averaging time	OEHHA, 2013[5]
Ni (Nickel)	0.2	1-hr averaging time	OEHHA, 2013[6]
Tl (Thallium)	60	1-hr averaging time	PAC: TEEL-1[1]
V (Vanadium)	30	1-hr averaging time	OEHHA,2013[7]

COPCs	Exposure Limit/Reference Level ($\mu g/m^3$)	Averaging time	Source
Zn (Zinc)	300	1-hr averaging time	PAC: TEEL-1[1]
Se (Selenium)	600	1-hr averaging time	PAC: TEEL-1[1]
Organic Compounds			
PCBs (Polychlorinated biphenyls)	13,000	1-hr averaging time	PAC: TEEL-1[1]
Dioxins and furans	0.13 (2,3,7,8-Tetrachlorodibenzo-p-dioxin)	1-hr averaging time	PAC: TEEL-1[1]
PAHs (Polycyclic aromatic hydrocarbons)	600	1-hr averaging time	PAC: TEEL-1[1]
Other Compounds			
HCl (Hydrochloric acid)	2,100	1-hr averaging time	OEHHA, 2013[8]
HF (Hydrogen fluoride)	240	1-hr averaging time	OEHHA, 2013[9]
NH_3 (Ammonia)	3,200	1-hr averaging time	OEHHA, 2013[10]

Sources of references:
The criteria / standard / method has been reviewed and updated using the latest reference.

1. PACs database https://edms3.energy.gov/pac
2. (OEHHA 2013) TSD for Noncancer RELs; Appendix B. Acute, 8-Hour, and Chronic Reference Exposure Levels (RELs) Summary Table – Arsenic & inorganic arsenic compounds (including arsine) [p.3] https://oehha.ca.gov/media/downloads/crnr/appendix20bfinalwithnickel.pdf
3. The exposure limit/reference level of Cr (VI) is made reference to that of Chromic trioxide (CrO_3) as a conservative assumption. (PAC-TEEL-1)
4. (OEHHA, 2013) TSD for Noncancer RELs; Appendix B. Acute, 8-Hour, and Chronic Reference Exposure Levels (RELs) Summary Table – Copper and compounds [p.5] https://oehha.ca.gov/media/downloads/crnr/appendix20bfinalwithnickel.pdf
5. (OEHHA, 2013) TSD for Noncancer RELs; Appendix B. Acute, 8-Hour, and Chronic Reference Exposure Levels (RELs) Summary Table – Mercury & inorganic mercury compounds [p.7] https://oehha.ca.gov/media/downloads/crnr/appendix20bfinalwithnickel.pdf
6. (OEHHA, 2013) TSD for Noncancer RELs; Appendix B. Acute, 8-Hour, and Chronic Reference Exposure Levels (RELs) Summary Table – Nickel & nickel compounds [p.8] https://oehha.ca.gov/media/downloads/crnr/appendix20bfinalwithnickel.pdf
7. (OEHHA, 2013) TSD for Noncancer RELs; Appendix B. Acute, 8-Hour, and Chronic Reference Exposure Levels (RELs) Summary Table – Vanadium pentoxide [p.10] https://oehha.ca.gov/media/downloads/crnr/appendix20bfinalwithnickel.pdf
8. (OEHHA, 2013) TSD for Noncancer RELs; Appendix B. Acute, 8-Hour, and Chronic Reference Exposure Levels (RELs) Summary Table – Hydrogen chloride [p.6] https://oehha.ca.gov/media/downloads/crnr/appendix20bfinalwithnickel.pdf
9. (OEHHA, 2013) TSD for Noncancer RELs; Appendix B. Acute, 8-Hour, and Chronic Reference Exposure Levels (RELs) Summary Table – Hydrogen fluoride [p.7] https://oehha.ca.gov/media/downloads/crnr/appendix20bfinalwithnickel.pdf
10. (OEHHA, 2013) TSD for Noncancer RELs; Appendix B. Acute, 8-Hour, and Chronic Reference Exposure Levels (RELs) Summary Table – Ammonia [p.3] https://oehha.ca.gov/media/downloads/crnr/appendix20bfinalwithnickel.pdf

10.2.7 Risk Characterization

10.2.7.1 General

The potential human health risks associated with COPC emissions from the MSW thermal treatment unit were estimated. The risk characterization step combines the results of the exposure assessment and exposure response relationship to estimate the potential risks to human health.

10.2.7.2 Chronic Non-carcinogenic Hazard

10.2.7.2.1 HKAQO Criteria COPCs

The cumulative annual average concentrations of HKAQO Criteria COPCs were predicted in Air Quality Chapter of the EIA Report based on the model results. The potential chronic impacts of these COPCs were assessed, based on the estimated contributions by the Project and detailed results given under **Appendix 3A** and **3M** presented in Air Quality Chapter.

The detailed results in **Appendix 3M** indicated that the Project would have small contributions on annual levels of RSP, FSP and NO_2. The health risk associated with these small additional air pollutants' concentrations would likely be negligible, taking into account the uncertainty analysis given in **Section 10.2.7.5** of this Report. Besides, the detailed results in **Appendix 3M** also indicated that the concentrations of the AQO criteria pollutants (RSP, FSP, NO_2, SO_2, CO and Pb) at representative HSRs comply with the respective prevailing AQOs.

10.2.7.2.2 Non-HKAQO Criteria COPCs

The cumulative non-carcinogenic health impact due to chronic inhalation, includes the impact arising from the I·PARK2 and contribution from the other emissions within the assessment area and AoIs and background contributions. For the cumulative assessment of Cr(VI), Pb, As, Be, Cd, Cu, Mn, Hg, Ni, V, Zn and dioxins, background concentration measured at Tuen Mun Air Quality Monitoring Station, with reference to latest annual air quality monitoring results in 2022 from Environmental Protection Department, were considered and presented in **Appendix 10B**. For the other COPCs (Sb, Co, TI, Se, PCBs, PAHs, HCL, HF, NH_3), the cumulative non-carcinogenic health impact due to chronic inhalation only includes the impact arising from the I·PARK2 and contribution from the other emission within the assessment area and AoIs based on the best available information. The cumulative annual averaged concentrations at all representative HSRs were compared with the chronic toxicity criteria to evaluate if the exposure of HSRs to the COPCs would cause an adverse chronic non-carcinogenic health effect.

The cumulative chronic non-carcinogenic health impact due to inhalation, includes the impact arising from the I·PARK2 are presented in **Appendix 10C**. Based on the assessment results, there would be no exceedance to the chronic toxicity criteria due to inhalation. It is concluded that there would be no adverse chronic non-carcinogenic health impact arising from the operation of the Project.

10.2.7.3 Carcinogenic Health Risk

For inhalation exposures, the chronic cancer risks (i.e. carcinogenic health risk) of individual COPC are estimated using the Equation below:

$$\text{Cancer Risk}_{inhalation(i)} = EC_L \times IUR \times EF$$

Where:

$\text{Cancer Risk}_{inhalation(i)}$ = Cancer risk to an individual (expressed as an upper-bound risk of contracting cancer over a lifetime);

EC_L = Estimated of long-term inhalation exposure concentration for a specific COPC; and

IUR = The corresponding inhalation unit risk estimate for that COPC.

EF = Exposure Factor ; With reference to ATSDR Guidance for Inhalation Exposure EF for cancer assessment for residential and occupational exposure is 0.42 and 0.06 respectively

$$\text{Total Cancer Risk} = \Sigma_i \text{ Cancer Risk}_{inhalation(i)}$$

The USEPA risk management guidance (USEPA, 1998) [20] suggests a target risk level of 1×10^{-5} as an acceptable total for all contributions of carcinogenic risk at a designated individual receptor from the Project. In accordance with the USEPA risk management guidance, if a calculated risk falls within the target values, the authority may, without further investigation, conclude that the proposed Project does not present an unacceptable risk. A calculated risk that exceeds these targets, however, would not, in and of itself, indicate that the proposed Project is not safe or that it presents an unacceptable risk. Rather, a risk calculation that exceeds a target value triggers further careful consideration of the underlying scientific basis for the calculation.

The incremental cancer risk of these identified COPCs at each representative HSR due to the Project were calculated. The incremental cancer risk for each individual COPC, as well as the total incremental cancer risk, were presented in **Appendix 10D**. The results indicated that the predicted total carcinogenic risk from the Project at all representative HSR are less than 1×10^{-5}. The highest total cancer risk occurs at HSR TTC1 with a value of 3.26×10^{-6}. Therefore, it is expected that the Project would not present an unacceptable risk.

10.2.7.4 Risks Due to Short-Term Exposure

In addition to the potential long-term risk to human health presented by COPCs emitted from the Project, short-term or acute risk were evaluated for direct inhalation COPCs. Acute exposure was estimated, based on maximum one-hour air concentrations predicted from the air dispersion modelling. To determine the likelihood of adverse acute effects, maximum predicted one-hour air concentrations were compared with criteria for short-term inhalation exposures.

10.2.7.4.1 HKAQO Criteria COPCs

The cumulative daily, 8-hour, 1-hour, and 10-minute averaged concentrations were predicted in Air Quality Chapter of the EIA Report based on the model results. The potential acute impacts of these COPCs were assessed, based on the estimated contributions by the Project and detailed results given under **Appendix 3A** and **3M** in Air Quality Chapter.

According to the detailed result (**Appendix 3M**), the Project would have small contributions on daily levels of RSP, FSP and NO_2. The health risk associated with these small additional air pollutants' concentrations would likely be negligible, taking into account the uncertainty analysis given in **Section 10.2.7.5** of this Report. Besides, the detailed results in **Appendix 3M** also indicated that the concentrations of the AQO criteria pollutants (RSP, FSP, NO_2, SO_2, CO and Pb) at representative HSRs comply with the respective prevailing AQOs.

10.2.7.4.2 Non-HKAQO Criteria COPCs

The cumulative acute health impact due to inhalation includes the impact arising from the I·PARK2 and contribution from the other emissions within the assessment area and AoIs and background contributions. For the cumulative assessment of Cr (VI), Pb, As, Be, Cd, Cu, Mn, Hg, Ni, V, Zn and dioxins, background concentration measured at Tuen Mun Air Quality Monitoring Station, with reference to latest daily air quality monitoring results in 2022 from Environmental Protection Department, were considered and presented in **Appendix 10B**. For the other COPCs (Sb, Co, TI, Se, PCBs, PAHs, HCL, HF, NH_3), the cumulative acute health impact due to direct inhalation only includes the impact arising from the I·PARK2 and contribution from the other emission within the assessment area and AoIs based on the best available information. Cumulative acute health impact of the I·PARK2 at all representative HSRs were assessed and compared with the acute exposure limits/reference levels to evaluate any potential adverse acute effects from the Project.

The cumulative acute health impact due to inhalation, includes the impact arising from the I·PARK2 are presented in **Appendix 10E**. For illustration purpose, contour plots for Arsenic and Nickel (with closer predicted concentration to health standard) at worst-hit level (5m and 4m above ground respectively) are presented in **Appendix 10F**. Based on the assessment results, there would be no exceedance to the acute exposure limits/reference levels due to inhalation. It is concluded that there would be no adverse acute health impact arising from the operation of the Project.

10.2.7.5 Uncertainty Analysis

The health risk / impact assessment for aerial emissions arising from the operation of the Project was based on a number of assumptions and was based on 'cautious best estimates' in each stage of assessment.

Hazard Identification

COPCs were identified based on the air pollutants listed in the standards for pollution control on the MSW incineration in the Mainland China (GB 18485-2014) and Shenzhen (SZDB/Z 233-2017), the prevailing guidance note on the BPM for incinerators (municipal waste incineration) in Hong Kong, the BAT reference document for waste incineration in the EU, as well as the "*Quantitative risk assessment of stack emissions from municipal waste combustors*"[13]. Although the list of chemicals may not cover all the chemicals emitted from the stack of the I·PARK2, it has covered the key/representative air pollutant parameters and is sufficiently comprehensive for the purpose of the assessment because the above reference documents serve the purpose to prevent the air pollutant emissions from incinerator stack from harming the environment and human health or creating nuisance.

Exposure Assessment

Computational air dispersion model was used to predict the COPC dispersion in air and the COPC concentrations at potential human receptors. As computer model involves simplifications of reality and requires exclusion of some parameters that may influence the predictions, uncertainty could be introduced in the prediction of COPC concentrations at identified health impact receivers. However, the air quality modelling approach adopted for exposure assessment were based on the reasonably worst-case scenario which would likely err on the conservative side and overestimate the risk.

Dose-response Assessment

The toxicity criteria and guidelines adopted from agencies would introduce uncertainty to the assessment. These toxicity criteria and guidelines were used as single-point estimates throughout the analysis with uncertainty and variability associated with them. Moreover, the application of safety factor to exposure limit for derivation of toxicity criteria and guidelines for long term COPC exposure was another source of uncertainty. However, it should be noted that the uncertainty and variability associated with the toxicity criteria and guidelines shall be accounted for in the process that the agencies setting verified toxicity criteria and guidelines.

10.3 Potential Health Impacts of Fugitive Emissions during Transportation, Storage, Handling and Disposal of Waste and Ash

10.3.1 General

This section assessed the potential health impacts associated with fugitive emissions during transportation, storage, handling and disposal of waste and ash arising from the operation of the I·PARK2 Project. It included hazard identification and impact evaluation, and recommended mitigation measures and/or good site practices if needed to minimise the potential health impacts.

10.3.2 Description of Operation Process

The municipal solid waste (MSW) would mainly be delivered from refuse transfer stations in Hong Kong to the I·PARK2 by marine vessels and/or land transport for treatment. The MSW would be delivered to the waste reception hall of the incineration plant.

At the waste reception hall of the incineration plant, the MSW would be unloaded into the bunker. The waste would then be mixed and transferred by overhead cranes into the combustion chamber for burning. Ash would be collected at the bottom of the combustion chamber and for synergy, these ashes, commonly known as incinerator bottom ash (IBA), generated from I·PARK1 and I·PARK2 would be co-treated by the proposed on-site IBA treatment facility under the I·PARK2 Project. Metals such as ferrous metals and non-ferrous metals will be recovered from IBA through on-site treatment for recycling use. Treated IBA can be recycled for off-site beneficial uses by marine and/or land transport. Disposal of IBA at landfill would be the last resort if all possible options of beneficial uses/outlet of the treated IBA are exhausted. Storage and handling of the IBA will be carried out in an enclosed environment. Accidental events related to transportation and spillage of IBA are present in **Section 10.5** below.

The hot flue gases from the combustion chambers would flow through the boiler, releasing thermal energy which turns the water in the boiler tubes into steam. The steam produced would be used to drive the turbine to generate electricity. The cooled flue gases would be treated by flue gas treatment system including scrubbers, activated carbon powder injection and fabric filter systems. The cleaned flue gases would then be released to the atmosphere via the stack. A relatively smaller amount of fly ash and residues would be collected from the boiler and flue gas equipment. The fly ash and residues would be treated by cement solidification or chemical stabilisation to ensure compliance of the disposal criteria as stated in **Section 6.5.2** of this Report before disposal to landfill. Storage and handling of the fly ash and residues will also be carried out in an enclosed environment.

10.3.3 Hazard Identification

Transportation and Disposal of Waste and Ash

As described above, the existing transportation mode of MSW to landfills will be adopted for the future transportation of waste to I·PARK2. Bottom ash will be transported by marine and/or land transport while fly ash and residues will be transported by land transport only. The waste and ash will be fully enclosed in sealed containers or covered entirely to ensure that the waste and ash do not leak from vessels or vehicles during transportation.

Storage and Handling of Waste and Ash

When unloading waste into the storage bunker and transferring it using overhead crane grabs into the combustion chamber, there is a possibility of fugitive emissions. The storage bunker will be kept at negative pressure to ensure no leakage of fugitive emission out of the storage bunker. After combustion, bottom ash and fly ash will be produced. Bottom ash will be washed and collected at the bottom of the chamber. The wetted ash will then automatically convey to the ash storage pit via an enclosed extractor. On the other hand, fly ash and residues will be treated by cement solidification or chemical stabilisation to ensure compliance of the disposal criteria as stated in **Section 6.5.2** of this Report before disposal to landfill. The storage and treatment of bottom ash and fly ash will be conducted within an enclosed environment with air withdrawn through the bunkers into the combustion chamber of the incinerator for handing of fly ash and bottom ash. In addition, dust exhaust with fabric filter and misting system will be installed as fugitive emission control in the incinerator bottom ash facility.

Liquid wastes including bunker and ash leachate will be properly treated for reuse on-site as stated in **Section 5.6** of this Report.

10.3.4 Impact Evaluation and Recommendation

With reference to the prevailing practice of MSW transportation to landfills, the waste and ash will be fully enclosed in sealed containers or covered entirely to ensure that the waste and ash do not leak from vessels or vehicles during transportation. In addition, residues will be treated by cement solidification or chemical stabilisation to ensure compliance of the disposal criteria as stated in **Section 6.5.2** of this Report before disposal to landfill. Fugitive emissions during transportation and disposal of waste and ash are not anticipated. The potential health impacts associated with transportation and disposal of waste and ash arising from the operation of the Project is expected to be minimal.

Since the reception halls will be enclosed with negative air pressure, fugitive emissions leaking to the outdoor environment are not anticipated. For the storage and treatment of bottom ash and fly ash, they will be conducted within an enclosed environment, while with air withdrawn through the bunkers into the combustion chamber of the incinerator (for bottom ash and fly ash) or dust exhaust with fabric filter and misting system will be installed as fugitive emission control as stated in **Section 10.3.3** (for bottom ash). The potential health impacts associated with storage and handling of waste and ash arising from the operation of the Project is also expected to be minimal.

For the IBA treatment process, emissions to air are mainly dust and metals coming from IBA handling, shredding, sieving, and air separation. Major constituents of IBA (up to 90%) are silicon dioxide, calcium oxide, aluminium oxide and ferric oxide as found in roughly the same order of magnitude in the lithosphere, with some trace metal elements which may be more or less enriched in IBA as compared to the lithosphere [21]. Processing of IBA using wet treatment and separation of metals from IBA using magnetic separation (for ferrous metals) and eddy current separation (for non-ferrous metals) would reduce aerial emissions of metals and dust from the proposed IBA treatment plant. Other techniques to reduce emission to air include:

- humidify the stockpiles and the main sources of diffuse dust and heavy metal emissions;
- limit the height of discharge;
- enclose the IBA treatment plant building, stockpiles and equipment such as the shredder, sieve, conveyor belts, wind sifter, air-aeraulic separator;
- keep and operate all equipment within the enclosed IBA treatment plant building and under sub-atmospheric pressure;
- treat the extracted air with a bag filter with 99% dust removal efficiency.

With the implementation of the above techniques, it is anticipated that aerial emissions of metals from the proposed IBA treatment plant would be minimal. In addition, organic substances such as PCB, PAH, dioxins, and furans are found to have very small quantities in IBA and hence aerial emissions of organic substances from the proposed IBA treatment plant would be negligible.

The dust impact from the proposed IBA treatment plant has been assessed in **Chapter 3**. For the IBA treatment plant, the monitoring requirements shall follow the EPD's Guidance Note on the Best Practicable Means for Mineral Works (Stone Crushing Plant) BPM 11/1 (95). The monitoring frequency shall be agreed with the air pollution control authority according to the above guidance note. The monitoring locations shall include the exhaust points of the IBA treatment plant to demonstrate compliance with the requirements set out in the EIA report. Commissioning trial upon commissioning of the IBA treatment plant and further checking upon reaching the full handling capacity of the IBA treatment plant shall also be conducted to demonstrate the performance and capacity of the air pollution control measures and compliance with the emission rates assumed in the EIA report.

To minimise the potential health impacts associated with transportation, storage, handling and disposal of waste and ash during operation of the Project, the following good site practices are recommended and should be properly implemented by the I·PARK2 contractor:

- Include in the environmental management system the identification of major fugitive emission sources during transportation, storage, handling and disposal of waste and ash, and definition and implementation of appropriate actions and techniques to prevent or reduce fugitive emissions;
- Maintain good housekeeping in all plant areas with suitable equipment provided and maintained to clean up spilled materials;a
- Carry out loading, unloading, handling and storage of waste and ash in an acceptable manner (e.g. handle the waste and ash in enclosed environment and under negative air pressure, limit height of discharge, optimise moisture content, etc.) to prevent or reduce fugitive emissions;
- Provide signage for clear indication of the travelling route of waste/ash trucks;
- Monitor and control the traffic flow inside the reception hall of the plant;
- Vehicle cleaning system should be provided to clean the waste/ash trucks before they leave the plant;
- Apply good practice during unloading of MSW to waste storage pit including: provide signage to assist waste/ash truck drivers to stop at appropriate unloading position; provide sufficient training to waste/ash truck drivers;
- Detection device / alarm should be installed to prevent overfilling of waste and ash storage pit;
- In case manual handling of waste/ash is needed, the workers involved should wear personal protective equipment;
- The on-site workers responsible for maintenance and cleaning of equipment or vehicles contaminated with waste/ash should wear personal protective equipment; and
- Emergency plan should be established and implemented to handle the situation of accidental incineration units shut down.

10.4 Potential Health Impacts of Radon Emissions from Excavation, Filling, Handling, Storage, Transport and Disposal of Pulverised Fly Ash

10.4.1 General

Since the I·PARK2 will be situated on the Tsang Tsui ash lagoon, it is necessary to evaluate the potential health risk caused by radon emissions related to pulverised fuel ash (PFA) during the construction and operation of the I·PARK2.

According to the EIA Study Brief, a literature search shall be carried out to determine the best approach for the risk assessment. The findings of the literature search indicated the following:

- Health risks for radon emission due to construction and operation activities of the I·PARK2 would be insignificant;
- Radiation exposure to the staff in the I·PARK2 from the radon flux out of the ground filled by PFA may be increased but would not be of great significance with implementation of proper mitigation measures; and
- A review of radon risk should be undertaken, based on the confirmed construction method.

This section presents the literature review and assessment for the health risk associated with radon emissions from PFA during the construction and operation phases of the I·PARK2.

10.4.2 Health Hazard of Radon

Radon-222 is a radioactive gas found in nature, originating from radium-226, which can be found in geological materials like rocks, soil, and concrete. Radon has a half-life of 3.82 days. It undergoes a natural decay process, transitioning into a series of radioisotopes known as "radon progeny." Each element in this series emits alpha or beta radiation, and sometimes gamma radiation, transforming into the subsequent element in the sequence.

Radon is a concern for indoor air quality due to the presence of radium-related elements in common building materials. These radioisotopes can expose individuals occupying the building to external radiation. Additionally, inhalation of radon gas and its short-lived by-products can internally expose the respiratory tract to alpha particles.

When radioactive particles are inhaled, they can damage the DNA of lung cells. If the damaged cell later becomes cancerous, it can potentially spread throughout the lungs and lead to the individual's death. The Relative Risk Model (Yu et al.) [22] considers factors like age and sex to estimate the additional deaths caused by lung cancer due to radon exposure. Research indicates that around 1988, approximately 300 annual lung cancer deaths in Hong Kong, accounting for about 13% of total cases, were attributed to radon. Furthermore, prolonged exposure to low levels of ionizing radiation can have long-term health effects that may manifest anywhere from 5 to 30 years after the exposure. The most significant consequence of such exposure is an elevated risk of developing malignant diseases in the affected individuals.

The risk model suggest that the risk of health issues related to radon exposure is proportional to the dose received, with a higher likelihood of damage occurring when exposure begins at a younger age.

10.4.3 Radon Associated with PFA

The literature research indicates that the health risk associated with radon emissions from the construction and operation of the I·PARK2 is considered to be negligible. This section discusses the findings of previous studies to support the conclusion of an insignificant health risk. The evaluation of the annual effective dose takes into consideration both alpha particles and gamma ray doses.

Green [23] carried out study in 1986 regarding the radiological impact of using and disposing of coal ash from power plants. The study aimed to evaluate the radiological relevance of using PFA as building material and the actions of both the general public and workers at disposal sites in both indoor and outdoor environments. This was computed using mathematical models, field research, and lab investigations.

Field measurements were taken at three coal ash disposal sites in the United Kingdom (UK). Radionuclide content, porosity, radon emanating fraction and exhalation rates of building blocks containing PFA were analyzed. Mathematical models were used to estimate the exposure to gamma-ray dose rates and radon concentrations under the tested conditions:

- Exposures from building materials; and
- Exposures from disposal sites under indoor and outdoor conditions

It was determined from the field research that there is a surge in radioactive content from coal to PFA. This was in line with the findings of the 1989 evaluation of the particular activity of coal, fuel bottom ash (FBA), and PFA samples from the Castle Peak Power Stations carried out by the EPD and Hong Kong Observatory in collaboration with CLP. **Table 10-5** displays the retrieved results that have been converted to radium equivalent activities. It suggests that PFA and FBA are seeing an upsurge in activity from the unburned coal. **Table 10-6** presents an overview of the more recent observations carried out by Lu et al (2006) [24].

When estimating flux for different soil cover thicknesses in the field studies, it was shown that if 30 cm of soil cover were placed on top of the PFA, the flux would be decreased by a factor of two.

Table 10 - 5 Radium Equivalent Activities of PFA, FBA and Coal from the Castle Peak Power Station

Coal Source	Date of Sample Collection	Radium equivalent activity (Bq/kg)		
		Coal	PFA	FBA
Columbia	22/02/1989		233	255
Australia	22/02/1989		373	347
Australia	02/03/1989		532	163
South Africa	07/03/1989		407	343
South Africa	08/03/1989			
South Africa	10/03/1989	72	423	382
South Africa	15/03/1989	66	443	335
Australia	19/03/1989	27	211	197
Sampled by HKO	1987		377 [(a)]	
Source not specified	1987		378 [(a)]	

Remark: (a) Data from Hong Kong Observatory

Table 10 - 6 Radium Equivalent Activities of PFA, FBA and Coal from Power Plant in other Countries

Power Plant	Radium equivalent activity (Bq/kg)		
	Coal	PFA	FBA
Baoji, China	86	350	298
Lodz, Poland	26-71	157-309	97-248
India	-	283	-
Hong Kong, China	47	375	260
Shanghai, China	94	408	307
Beijing, China	86	285	-

Reference: Natural radioactivity of coal and its by-products in the Baoji coal-fired power plant, China, Xinwei Lu, Xiaodan Jia and Fengling Wang, July 2006

10.4.4 Health Impact Associated with PFA due to Radon Emissions

10.4.4.1 Construction Phase

Prior to the commencement of construction of the I·PARK2 Project, the existing ash lagoon for PFA within the Project site would be decommissioned by another project with the levelled PFA surface covered by at least 1m thick general fill. The USGS (1997) [25] concluded that the radioactivity in coal / fly ash is not significantly different from that of more conventional concrete additives or other building materials such as granite. In this regard, the exposure to radiation from excavation of PFA should be similar to the exposure to radiation from excavation of granite. The construction works of the I·PARK2 will mainly include excavation, foundation and superstructure work. Localised excavation of PFA will be required for construction of the waste bunker. The excavated PFA will be reused for backfilling on-site so that no off-site disposal of PFA will be required in this Project. Hence, the potential health risk from radon emissions due to transport and off-site disposal/ storage of PFA are not anticipated. To the on-site worker, exposure pathways via dermal contact and incidental ingestion of PFA are considered as low risk, since eating will be prohibited on-site. Therefore, major risks during excavation of PFA would be coming from external irradiation by γ-radiation and internal irradiation from inhaled 222Rn daughters. Because natural ventilation dilutes radon gas levels, construction employees working at open air excavation work sites are not likely to be exposed to hazardous concentrations of radon except in rare circumstances [26]. The health risk from radon emissions due to excavation, filling, and handling of PFA on-site is considered to be insignificant, which is explained by the paragraphs below.

The National Radiological Protection Board (NRPB) conducted a study (Green, 1986) [23] on the radiological impact of using and disposing of coal ash from power stations. It evaluated exposure levels from building materials and exposure near ash disposal sites during leisure activities or construction. **Table 10-7** presents the estimated annual effective dose for both the standard scenario and scenarios involving power station ashes.

In Green (1986) [23], the dose assessments of radon were conducted on the basis of a radon concentration above active or restored sites of 4 Bqm^{-3}. More recent research (L. Mljač 2004) [27] shows only 2-3 Bqm^{-3} increase in radon concentration in fly-ash disposal site as compared to its surroundings. According to Green (1986) [23] as a more conservative approach, it was estimated that the annual effective dose equivalent to a worker spending 2000 hours each year on an ash disposal site would be 60 µSv, a conversion factor of 10 mSv WLM^{-1} being used because of the breathing rate of workers.

A mass-loading approach was used to predict the airborne activity levels due to dust particle suspension. It was assumed that particulates in air had the same activity per unit mass as the surface material. Besides, a dust loading of 100μgm^{-3} over a PFA disposal site and an annual intake of dust of about 0.84g was assumed. The committed effective dose from the annual intake of thorium, uranium and their long-lived decay products was calculated to be 35µSv as presented in **Table 10-7**.

Table 10 - 7 Summary of Estimates of Annual Effective Dose

Situation	Normal Ground			PFA disposal site 50cm soil cover			PFA disposal site no soil cover		
	From gamma	From radon	Total	From gamma	From radon	Total	From gamma	From radon	Total
Indoors									
All-brick dwelling	0.740	0.260	1.000	0.750	0.360	1.110	0.760	0.780	1.540

Heavy block dwelling	0.700	0.290	0.990	0.710	0.400	1.110	0.720	0.820	1.540
Light block dwelling	0.530	0.340	0.870	0.540	0.440	0.980	0.560	0.860	1.420
Outdoors									
Workers such as farm or disposal site labour (2000 hrs in a year)	0.056	0.057	0.113	0.070	0.060	0.130	0.130	0.060	0.190
Members of the public (500 hrs in a year)	0.014	0.007	0.021	0.018	0.008	0.026	N/A	N/A	N/A
Inhalation of Re-suspended Dust									
(8,760 hrs in a year)			0.011			-			0.035
(2,000 hrs in a year)[4]									0.016

Notes:

1. Values are rounded to three decimal places.
2. N/A: Not applicable
3. All units in mSv
4. By Man-yin W. Tso& John K. C. Leung [28]

According to EPRI (2009) [29], in a worst-case evaluation, exposure to an outdoor worker at an ash storage facility (8 hours per day for 225 days per year) was estimated as 8 mrem/yr (0.08 mSv), or only about 2.3% of background exposure. Research by US EPA, US Geological Survey, EPRI, and others has shown that exposure to radiation from coal ash does not represent a significant health risk.

EPRI (2014) [30] further conducted an assessment of occupational exposure to a model fly ash pile using the “outdoor worker scenario” in which a worker was assumed to be exposed for 1,800 hours per year. It was envisioned that the employee was a heavy machine operator who worked in an ash storage area and was exposed to the radiation from ash stored at a coal-fired power plant. An ash-particle emission rate of 1.36 x 10^9/kg was used. An air inhalation rate of 60 m^3/day and an ash inhalation rate of 100 mg/day were assumed. The total effective dose from this model fly ash was about 3.3 mrem/year (0.03 mSv).

According to EPRI (2022) [31], the respirable dust measured for activities that involved movement of coal combustion product (CCP) material (e.g., grader operator, dozer operator, trackhoe operator, excavator, dump truck operator) was 0.095 mgm^{-3} (95 μgm^{-3}). The mass loading factor based on the worst-case respirable dust value of 0.095 mgm^{-3} and the air inhalation rate of 1.8 m^3/hr were assumed in the calculation of effective dose from inhalation of CCP particulates under an implausible scenario in which the worker was assumed to be continuously exposed to placement activities within 3 feet of the operations during the 1,680-hour work year. The additional annual effective dose was 43.1 mrem/year (0.43 mSv).

All the above studies concluded that the estimated effective doses for outdoor on-site workers in coal ash disposal sites were well below the recommended annual dose limit of 100 mrem/year (1 mSv). The effective dose equivalent to the workers during the construction phase of the I·PARK2 would be more or less similar to the estimation in the above studies. The differences between the situations in Hong Kong and the UK mainly concern higher background radon level and longer working hours in Hong Kong.

When comparing the differences of radiation dose between the UK situation and the current situation for the I·PARK2, the incremental risk due to the PFA on site shall be considered. The estimation indicates that there is no significant radiological hazard to workers working out of doors or near either restored or working ash disposal sites. The annual effective dose to a worker spending 2000 hours outdoors on an ash filled lagoon is about 0.19mSv and is not of great radiological significance level when compared with an annual limit of 1 mSv for general public suggested by the International Commission on Radiological Protection (ICRP). Since there will be no off-site disposal of PFA in this Project, the health risk on off-site health receptors will also be insignificant as well.

A study was conducted by Tso and Leung (1996) [28] to evaluate the radiological impact of coal ash from power plants in Hong Kong. It involved collection of PFA samples from the two local electric companies and measurement of radon produced from the samples. It indicated for situation that the PFA is not covered with soil (e.g., construction phase for the I·PARK2 Project), the radon concentration at locations above the uncovered PFA is only slightly higher than the ambient background radon concentration. Also, precaution could be undertaken to suppress re-suspension of ash particles for protection to people on-site.

Based on the literature review, it is anticipated that the health risk from radon emissions due to excavation, filling, and handling of PFA on-site during construction of the I·PARK2 Project would be insignificant. Nevertheless, the I·PARK2 contractor shall be required to implement the dust suppression measures stipulated in the Air Pollution Control (Construction Dust) Regulation, including regular watering of the excavation area to maintain the entire surface wet and reduce dust emissions. The I·PARK2 contractor shall also be required to provide personal protective equipment including suitable dust masks to the workers, consult the Labour Department on the need to conduct occupational dust monitoring at the location where the workers conducting the excavation of PFA, observe relevant requirements promulgated by the Labour Department in respect of occupational safety and health and comply with relevant statutory requirements.

10.4.4.2 Operation Phase

The health risk due to radon emission from PFA in the operation phase would primarily involve the staff in the I·PARK2. As building structures would be constructed on the ash lagoon, it is expected that the ingress of radon into and subsequent accumulation inside the building structures may increase the radiation exposure when people stay within the buildings.

Referring to **Table 10-5** and **Table 10-6**, PFA Tables a higher radium equivalent activity compared to coal. Nevertheless, Stranden (1988) [32] suggested that a higher specific activity does not always mean higher radiation release. This is especially relevant for radon, given its gaseous nature at room temperature and pressure, tending to emanate from materials containing radium. Radon emanation occurs within the interstitial pores of a material, making subsequent releases or exhalation complex.

Sutton (2001) [33] researched radon emissions from a high-volume coal fly ash structural fill site in Tennessee, USA, using radon as an indicator to measure potential emissions of naturally occurring radioactive materials at the site. Radon levels were measured under normal conditions and within various structures with different treatments simulating diverse slab-on-grade conditions. The study spanned seven years. The findings of this extensive research revealed that a large-scale fly ash structural fill did not lead to increased presence of Radon-222 or other alpha emitters in structures situated above the fill. This study provided evidence indicating that radon need not be a significant concern when siting a structure on a properly designed and constructed pulverized fly ash fill site. It was discovered that fly ash contains higher radium levels but emits less radon compared to the nearby soils around Bull Run in Tennessee. The reduced radon release from fly ash, along with compacting the fly ash fill, covering the surface with compacted soil, and isolating it from the underlying soils and bedrock, all help in reducing environmental radon levels in the region of the fly ash structural fill site.

Green's study (1986) [23] investigated indoor radon levels within a structure positioned on an ash disposal site. Three scenarios were analyzed, as displayed in **Table 10-7**: normal ground, PFA disposal site with a 50cm soil cover, and without a soil cover. It was estimated that the annual effective dose from radon at the PFA disposal site without soil cover ranged from 2 to 3 times higher than the other two scenarios. It was concluded that there might be a potential rise in radiation exposure for occupants in the building over ash disposal sites due to increased radon emissions from the ground. However, he noted that these increases were not significantly radiologically impactful. He recommended including basic preventive measures during the planning stages of projects involving PFA to ensure radiation doses remain as low as reasonably achievable.

Additionally, Tso and Leung (1996) [28] suggested that based on sample measurements, covering the PFA in the ash lagoon with soil would render the radiological risk from the PFA beneath the soil negligible, making the land safe for use.

To further minimize radiation effects, restrictions on radium-226, thorium-232, and potassium-40 levels (**Table 10-8**) in construction materials will be implemented. These limits are intended to decrease external gamma radiation in both indoor and outdoor environments. Additionally, the restriction on radium-226 concentration aims to reduce the source of radon emissions.

Table 10 - 8 Maximum Activity Concentration Limit

Standard	Maximum activity concentration (Bq/kg)		
	Radium-226	**Thorium-232**	**Potassium-40**
EU (Radiation Protection 112)	300	200	3000
China (GB 6566-2010)	370	260	4200

WHO (2009) [34] and WHO (2023) [35] advised countries to establish national programs to lower the population's risk from exposure to the average radon concentration and to reduce risks for individuals exposed to high radon levels. It recommends implementing building codes to decrease radon levels in newly constructed homes, with a suggested reference level of 100 Bq/m^3. However, if this level cannot be achieved under specific country conditions, the reference level should not exceed 300 Bq/m^3. In Hong Kong, as per "Protocol of Radon Measurement for Non-residential Building" of EPD ProPECC Note PN 1/99, the average radon concentration within a building's confined areas (excluding spaces not meant for full-time occupancy) should ideally be lower than the territory-wide mean concentration of 100 Bq/m^3. Additionally, no individual measurement should exceed 200 Bq/m^3. A number of measures to minimize potential impacts from accumulation of Rn in new buildings are outlined in the PN. These measures should be followed as far as relevant and applicable during operation by the I·PARK2 contractor.

10.4.5 Impact Evaluation and Recommendation

Based on the reviewed studies in this literature review, the health risks associated with radon emissions from PFA during the construction and operation of the I·PARK2 are considered to be insignificant.

During the operational phase, the potential health risk arises primarily for the staff within the I·PARK2. Since the Project is situated on the area that was an ash lagoon before, there is a possibility of radon ingress and subsequent accumulation inside the facility. This could lead to increased radiation exposure for the staff. However, it is important to note that the resulting increase is expected to be minimal in terms of radiological significance. The I·PARK2 contractor will also be required to observe relevant requirements promulgated by the Labour Department in respect of occupational safety and health and comply with relevant statutory requirements during construction and operation of the I·PARK2 Project. To minimise the potential health risks from radon emissions associated with PFA, the following good site practices are recommended and should be properly implemented by the I·PARK2 contractor:

- Prevention of radon influx from the PFA to the I·PARK2 buildings is preferred. Apply at least 1m thick general fill soil cover on the PFA surface can significantly reduce the influx of radon. Utilize a slab-on-grade foundation design or employ soil suction techniques to draw radon from below the building and vent it through pipes above. These measures ensure a radon-free environment in the I·PARK2 buildings.

- Ensure adequate ventilation within the I·PARK2 buildings by implementing both natural and forced ventilation systems to enhance air exchange rates. For basement areas, consider pressurization techniques using external fans to prevent radon infiltration. It should be noted that most of the underground plant areas will be under negative air pressure.

- Regular maintenance should be conducted on floor slabs and walls, with proper sealing of cracks and openings in the foundation to minimize radon entry. This sealing process reduces radon flow, enhances the effectiveness of other radon reduction methods, and minimizes conditioned air loss.

- Conduct regular measurement of radon concentrations during the work period. Observe the guidance on reduction of radon exposure outlined in EPD's ProPECC Note PN 1/99 "Control of Radon Concentration in New Buildings".

10.5 Health Impacts Associated with other Potential Accidental Events

10.5.1 General

The I·PARK2 contractor will be required to design, construct and operate I. PARK2 according to the state-of-the-art technology and standards, emphasizing the necessity for well-trained operators to prevent potential accidental events. A list of potential accidental events that may give rise to potential health impacts and their respective preventive measures are presented in **Table 10-9**.

Table 10 - 9 Potential Accidental Events and Preventive Measures

Risks	Preventive Measures
• Aerial emissions (emission discharges exceed the discharge limit)	• Use the best practicable means requirements for the prevention of emission of air pollutants including proper operation and maintenance of equipment, supervision when in use and training and supervision of properly qualified staff and conduct regular monitoring and checking to ensure optimal performance.
• Transportation, storage and handling	• Implement good waste/ash transportation, storage and handling practices (see Section 10.3) • Arrange transportation routes to avoid of densely populated or sensitive regions.

	• Establish protocols for and deploy emergency response measures, including spill response, in the event of accidents involving transportation vehicles. • Enforce rigorous driver skill standards and provide training on safe driving practices for both drivers and navigators, emphasizing road and marine safety behaviours.
• Chemical spillage and leakage	• Ensure the implementation of appropriate procedures for handling and storing chemicals and chemical wastes. • Establish a spill prevention and response plan, which includes the provision of necessary equipment and trained personnel to effectively respond to spills.
• Employee health and safety	• Follow industry best practices based on international standards and guidelines. • Observe relevant requirements promulgated by the Labour Department in respect of occupational safety and health and consult Labour Department if needed.

The I·PARK2 contractor will be required to develop and implement a Project-specific emergency response/ contingency plan to handle potential accidental events during construction and operation of the I·PARK2 Project with a view to minimise the health impacts associated with the potential accidental events. By implementing the recommended preventive measures and a well-executed emergency response / contingency plan for the I·PARK2 Project, the likelihood of health impacts resulting from accidental events can be minimized, if not entirely avoided.

10.6 Conclusion

This chapter assessed the health impacts arising from the construction and operation of the Project. Based on the assessment results, the predicted total carcinogenic risk from the Project at all representative HSRs due to inhalation are less than $1x10^{-5}$. It is concluded that the Project would not result in a significant carcinogenic health risk. The cumulative chronic and acute non-carcinogenic health impacts were evaluated and compared to local and international criteria. The assessment revealed that there would be no exceedance to the chronic toxicity criteria and acute exposure limits/reference levels due to inhalation. It is concluded that there would be no adverse chronic and acute non-carcinogenic health impact arising from the operation of the Project. For the COPCs of the HKAQO, the health risk associated with small additional air pollutants' concentrations would likely be negligible, taking into account the uncertainty analysis given in **Section 10.2.7.5** of this Report.

The existing practices of waste transportation will be followed. To ensure proper storage and handling of waste, the reception halls and ash storage pits will be enclosed with negative air pressure. Ash will be handled in enclosed environment, minimizing the possibility of any emissions escaping to the outside. By implementing the recommended good site practices, the potential health impacts associated with transportation, storage, handling and disposal of waste and ash during operation of the Project will be minimal.

The potential health risks from radon emissions associated with PFA arising from the construction and operation of the Project were also evaluated. The excavated PFA will be reused for backfilling on-site so that no off-site disposal of PFA will be required in this Project. By implementing the recommended good site practices, the potential health risks from radon emissions associated with PFA arising from the construction and operation of the Project will be minimal.

Potential accidental events that may give rise to potential health impacts and their corresponding preventive measures were identified. The I·PARK2 contractor will be required to develop and implement a Project-specific emergency response / contingency plan to handle potential accidental events during construction and operation of the I·PARK2 Project with a view to minimise the health impacts associated with the potential accidental events. By implementing the recommended preventive measures and a well-executed emergency response / contingency plan for the I·PARK2 Project, the likelihood of health impacts resulting from accidental events can be minimized, if not entirely avoided.

10.7 Reference

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