



Human Health Criteria

The WHO (1997) report that the lowest LC₅₀ for invertebrates was measured for o-xylene at 1mg/L and 7.6mg/L for fish. For m- and p-xylenes, the LC₅₀ in fish was measured at 7.9 and 1.7mg/L, respectively.

The NHMRC (2004) guidelines advise that the no effect level for xylene, based on a 2-year gavage study using rats, is 250mg/kg body weight per day. The NHMRC (2004) drinking water guideline value is 0.6mg/L, which includes a safety factor of 1000 using the results of the animal study as a basis for human exposure. This health-based value exceeds the taste threshold of 0.02mg/L for xylenes in water.

Reference Doses and Slope Factors values provided by the US EPA (2002) PRGs for xylenes are:

- SFO = not specified
- RfDo = 7.0E-01 mg/kg body wt-day
- SFi = not specified
- RfDi = 2.9E-02 mg/kg body wt-day

12.6 Petroleum Hydrocarbons

General

Turczynowicz (1998) advises that total petroleum hydrocarbons (TPH) are a diverse range of chemicals derived from crude petroleum. Their numerous properties result in a ubiquitous distribution within our community and they are frequently encountered on contaminated sites. General classes of TPHs include liquefied gases, solvents, gasoline, kerosene, jet fuels, fuel oils, lubricating oils, asphalts and waxes. These substances are environmentally mobile and will result in contamination of soil, air and water. Their environmental fate and transport behaviour is a reflection of their molecular weight and bonding characteristics with high molecular weight substances being less mobile and more resistant to degradation.

Toxicology

The toxicology of some distillate mixtures such as diesel fuel, fuel oils and gasoline and chemicals such as benzene, 1,3-butadiene, toluene and xylenes has been extensively evaluated by regulatory agencies such as IARC, IPCS, US EPA and the US ATSDR. However, toxicological information on many constituents is limited due to commercial and historical factors. The Total Petroleum Hydrocarbon Working Group (1996), in examining toxicological information on 254 chemicals in the C3-C26 range identified approximately 65 compounds as possible surrogates for other total petroleum hydrocarbons and for which useful toxicological information was available.



In terms of acute exposure, low molecular weight petroleum distillates are poorly absorbed from the gastrointestinal tract and do not cause appreciable systemic toxicity by ingestion unless aspiration occurs, in which case primary effects include pulmonary damage and transient CNS depression or excitation.

Heavy fuel oils produce the most severe eye irritation while the middle distillates produce the most severe dermal irritation. Contact with diesel fuel can result in dermal blisters while paraffinic and naphthenic oils were the least reactive.

Inhalation exposure to volatile petroleum hydrocarbons such as low molecular weight aromatics and aliphatics, including petrol, may result in cardiac arrhythmias and CNS depression. Case reports of renal and haematological effects have also been recorded from acute high exposure.

Dermal effects from short-term exposure to solvents may include irritant and defatting effects, and exposure to lubricating oils, greases and waxes may result in skin disorders such as primary irritation, oil acne, hyperkeratosis and photosensitivity.

In terms of chronic exposures, toxicity endpoints are generally centred around concerns about the development of carcinomas and petroleum hydrocarbons are no exceptions. The IARC rankings of carcinogenic activity for some petroleum hydrocarbons, deemed as representing a significant hazard and for which data are available, include:

- Benzene - Group 1 (human carcinogen)
- Gasoline/petrol – Group 2B (possibly carcinogenic to humans)
- Jet fuel – Group 3 (not classifiable)
- Fuel oils – Group 2A (probably carcinogenic to humans)
- Residual fuel oils and marine diesel oil – Group 2B
- Light fuel oils and light diesel oils – Group 3
- Mineral-based crankcase oil – Group 3

Human Health Criteria

The WHO or Australian health authorities have not published health criteria that specify acceptable intakes for TPH mixtures. Recourse has therefore been made to the use of Reference Doses for TPH surrogate chemicals as proposed by Turczynowicz (1998). A summary of this data is provided in **Table 32**.



■ Table 32 Toxicological Data for TPH Fraction-Specific Surrogates (1)

TPH Range	TPH Surrogate	RfD Oral (mg/kg-day)	RfD Inhalation (mg/m ³)
Aromatics			
C5-C7	Benzene (2)	0.003	0.0017 (mg/kg-day)
>C7-C8	Toluene, ethylbenzene, styrene, xylenes	0.2	0.4
>C8-C16	Naphthalene, acenaphthene, biphenyl, fluorene, anthracene, fluoranthene, pyrene	0.04	0.2
>C16-C35	Pyrene	0.03	
Aliphatics			
C5-C8	n-hexane	5.0	18.4
>C8-C16	JP-8/ dearomatized petroleum stream	0.1	1.0
>C16-C35	Mineral oils	2.0	
>C35	Mineral oils	20.0	

Notes:

- (1) Reference Turczynowicz (1998)
- (2) US EPA (2002) PRGs



13 Risk Characterisation

This section of the report brings together the first three stages of the site-specific risk assessment as presented in Sections 11 and 12 and characterises the health and ecological risks and develops site-specific criteria where appropriate (Section 13). The assessment forms the fourth and final step in the site-specific risk assessment for ground contamination at the Former Gasworks site. The methodology that has been used was previously described in Section 2.4.

The analysis assesses the risks to each of the potential human and ecological receptors, these being on-site construction workers (Section 13.1), site workers (Section 13.2), nearby residents/surrounding community and off-site construction workers (Section 13.3) and the freshwater ecosystems in Alexandra Canal (Section 13.4). The analysis has also considered phytotoxicity risks to plants (Section 13.5) and aesthetic issues (Section 13.6). An assessment is then made on the need for remedial actions at the Former Gasworks site (Section 13.7).

13.1 Risks to On-site Construction Workers

The results of the data and exposure assessment presented in **Section 11.2** indicate that the main health risks to on-site construction/maintenance workers from ground contamination at the Former Gasworks site are associated with:

- Exposure to contaminated groundwater that is intercepted or extracted during the course of the redevelopment or as a result of future maintenance work. The contaminants of concern are benzene, toluene, ethylbenzene, total xylenes, TPH ($C_{10}-C_{36}$) and naphthalene; and
- Exposure to contaminated surface soils during the course of the redevelopment or as a result of future maintenance work. The contaminants of concern are total PAHs, BaP, TPH ($C_{10}-C_{36}$), benzene and total xylenes.

The human health risks associated with each of these exposure scenarios have been estimated using the estimates of intakes given in **Section 11.4.3** (intercepted/extracted groundwater) and **Section 11.4.5** (contaminated surface soils) together with the toxicological data provided in **Section 12**. The daily doses in mg/kg body weight per day have been converted into daily intake amounts in mg using a body weight of 70kg, as recommended in the NEPM (1999) Schedule B(4) guidelines.

The main exposure routes are considered to comprise:

- Ingestion of contaminants from surface soils;
- Dermal contact with contaminated soils; and
- Dermal contact with contaminated groundwater.



As previously mentioned in **Section 11.2**, the inhalation of dust and vapours have not been included in this site-specific risk assessment since such exposures will depend heavily on work practices and it has been assumed that these health risks would best be managed as part of an occupational health and safety plan covering any earthworks conducted at the Former Gasworks site. The requirement for such safety procedures will need to be incorporated into the long-term SMP to be placed on the Former Gasworks site. This recommendation is included in **Section 14.2** of this report.

A summary of the estimated contaminant intakes to an on-site construction/maintenance worker for the contaminants of concern are summarised in **Table 33**.

■ **Table 33 Daily Contaminant Intakes for On-site Construction / Maintenance Worker**

Substance	Daily Contaminant Intake (µg)			Total Daily Intake (µg)
	Ingestion of Surface Soil	Dermal Contact with Groundwater	Dermal Contact with Surface Soils	
Total PAHs	98.8	--	111	210
Benzo(a)pyrene	5.5	--	7.39	12.9
Naphthalene	--	448	--	448
TPH C ₁₀ -C ₃₆	960	2124	1168	4252
Benzene	0.175	171	0.117	171
Toluene	--	7.31	--	7.3
Ethylbenzene	--	24.4	--	24.4
Total Xylenes	5.25	51.9	3.06	60.2

The results show that dermal contact with the highly contaminated groundwater and/or soils that occur in the tar tank/gasholder area would be the main exposure pathway for on-site construction/maintenance workers at the Former Gasworks site. The risk posed by the ingestion of surface soils is secondary. These results also indicate that the ingestion of contaminated dusts would also be a secondary exposure pathway.

Health Risks from PAHs

The health risk posed by PAHs has been assessed by expressing all forms of PAH exposure in terms of BaP, since most health data is available for this compound, as indicated in **Section 12.1**. The first step in the process has been to convert the total PAH contaminant intake into an equivalent BaP intake. This has been done by breaking the total PAH intake into individual PAH compounds using the breakdown of PAH compounds given in the statistical analysis of fill materials at the Former Gasworks site given in **Table C**. The toxicity equivalence factors given in



Table 30 were then applied to obtain an equivalent BaP concentration. The results of this analysis are presented in Table 34.

Table 34 Conversion of Total PAH to Equivalent BaP Concentration

PAH Compound	Proportion of 95% UCL Total PAH Concentration	Toxicity Equivalence Factor	Equivalent BaP Proportion
Naphthalene	0.235	0.01	2.353E-03
Acenaphthylene	0.029	0.001	2.926E-05
Acenaphthene	0.010	0.001	1.003E-05
Fluorene	0.031	0.001	3.119E-05
Phenanthrene	0.128	0.001	1.276E-04
Anthracene	0.036	0.001	3.631E-05
Fluoranthene	0.105	0.01	1.051E-03
Pyrene	0.116	0.001	1.157E-04
Benzo(a)anthracene	0.077	0.1	7.680E-03
Chrysene	0.039	0.1	3.898E-03
Benzo(b,k)fluoranthene	0.080	0.1	8.004E-03
Benzo(a)pyrene	0.061	1	6.109E-02
Indeno(123-cd)pyrene	0.029	0.1	2.864E-03
Dibenz(ah)anthracene	0.005	4	1.921E-02
Benzo(ghi)perylene	0.019	0.1	1.924E-03
Total PAHs	1.000		1.084E-01

The results in Table 34 predict that the level of total PAH contamination in the fill at the Former Gasworks site can be converted into an equivalent BaP by multiplying the total PAH concentration by a factor of 0.108. Such a factor could also be applied to contaminant intakes. Using this approach, a total PAH intake of 210 µg is equivalent to an intake of BaP 22.7 µg, which is some 4 times higher than if only the BaP intake of 5.5 µg was used.

The dermal intake of 448µg/day of naphthalene has also been converted into an equivalent BaP intake by applying the toxicity equivalence factor of 0.001, which gives an additional BaP intake of 0.448µg/day.

Combining the ingestion and dermal intakes for total PAHs, naphthalene and BaP gives a total equivalent BaP intake of 36µg per day for an on-site construction/maintenance worker at the Former Gasworks site. This daily intake of BaP is some 4 times greater than the guidance dose of 9.5µg per day recommended by Fitzgerald (1998), as previously discussed in Section 12.1. The hazard quotient for exposure to PAHs is greater than 1, which indicates an unacceptable risk to human health if no special work procedures and personal protective equipment (PPE) were used by construction/maintenance workers at the Former Gasworks site.



Health Risks from TPHs

The data provided in **Table 33** estimates that the total amount of TPH intake for a construction/maintenance worker at the Former Gasworks site from both ingestion of contaminated soil and dermal contact with contaminated groundwater and soil is 4252 µg per day.

The health risks posed by this TPH intake has been assessed using a Reference Dose of 0.03mg/kg body weight per day, which is the recommended Reference Dose for >C₁₆-C₃₅ aromatic TPHs (**Table 32**). The aromatic value was used rather than the aliphatic one because the speciated TPH data obtained by this investigation has found that the majority of TPHs in the samples tested were aromatic, as previously discussed in **Section 9.2**. This Reference Dose for a 70kg adult gives an acceptable daily intake for TPH C₁₀-C₃₆ of 2.1 mg/day or 2,100 µg/day (**Section 12.6**).

The results of the risk assessment show that for an on-site construction /maintenance worker at the site, the daily intake of 4252 µg of TPH C₁₀-C₃₆ is approximately twice the acceptable daily intake of 2,100 µg. The hazard quotient for exposure to TPH C₁₀-C₃₆ is greater than 1, which indicates an unacceptable risk to human health if no special work procedures and PPE were used by construction/maintenance workers at the Former Gasworks site.

Health Risks from Benzene

The data provided in **Table 33** estimates that the total amount of benzene intake for a construction/maintenance worker at the Former Gasworks site from both ingestion of contaminated soil and dermal contact with contaminated groundwater and soil is 171 µg per day.

The health risks posed by this benzene intake has been assessed using an oral (ingestion) Reference Dose of 0.003mg/kg body weight per day, as stated in **Section 12.2**. This Reference Dose for a 70kg adult gives an acceptable daily intake for benzene of 0.21mg/day or 210µg/day.

The results of the risk assessment show that for an on-site construction /maintenance worker at the site, the daily intake of 171 µg of benzene is slightly less than the acceptable daily intake of 210 µg. The hazard quotient for exposure to benzene is 0.81, which is less than 1 and indicates that potential exposure to benzene at the Former Gasworks site is within acceptable limits if benzene was the only contaminant at the site.

Health Risks from Toluene

The data provided in **Table 33** estimates that the total amount of toluene intake for a construction/maintenance worker at the Former Gasworks site from dermal contact with contaminated groundwater is 7.3 µg per day, while no significant intake would occur from the ingestion or dermal contact with contaminated soil.



The health risks posed by this toluene intake has been assessed using an oral (ingestion) Reference Dose of 0.20mg/kg body weight per day, as stated in **Section 12.3**. This Reference Dose for a 70kg adult gives an acceptable daily intake for toluene of 14.0mg/day or 14,000µg/day.

The results of the risk assessment show that for an on-site construction /maintenance worker at the site, the daily intake of 7.3 µg of toluene is much less than the acceptable daily intake of 14,000 µg. The hazard quotient for exposure to toluene is 5.2E-04.

Health Risks from Ethylbenzene

The data provided in **Table 33** estimates that the total amount of ethylbenzene intake for a construction/ maintenance worker at the Former Gasworks site from dermal contact with contaminated groundwater is 24.4 µg per day, while no significant intake would occur from the ingestion or dermal contact with contaminated soil.

The health risks posed by this ethylbenzene intake has been assessed using an oral (ingestion) Reference Dose of 0.10mg/kg body weight per day, as stated in **Section 12.4**. This Reference Dose for a 70kg adult gives an acceptable daily intake for ethylbenzene of 7.0 mg/day or 7,000 µg/day.

The results of the risk assessment show that for an on-site construction /maintenance worker at the site, the daily intake of 24.4 µg of ethylbenzene much less than the acceptable daily intake of 7,000 µg. The hazard quotient for exposure to ethylbenzene is 1.0E-03.

Health Risks from Xylenes

The data provided in **Table 33** estimates that the total amount of xylene intake for a construction/ maintenance worker at the Former Gasworks site from both ingestion of contaminated soil and dermal contact with contaminated groundwater and soil is 60.2 µg per day.

The health risks posed by this xylene intake have been assessed using an oral (ingestion) Reference Dose of 0.7mg/kg body weight per day, as stated in **Section 12.5**. This Reference Dose for a 70kg adult gives an acceptable daily intake for xylenes of 49 mg/day or 49,000µg/day.

The results of the risk assessment show that for an on-site construction /maintenance worker at the site, the daily intake of 60.2 µg of xylenes is much less than the acceptable daily intake of 49,000µg. The hazard quotient for exposure to xylenes is 1.2E-03.

Total Health Risk to Construction/Maintenance Workers

The total risk to on-site construction/maintenance workers from ground contamination at the Former Gasworks site has been estimated by the summation of the hazard quotients for the main