Investigation of the dust impacts from the Port Adelaide Waterfront Redevelopment Project on the Le Fevre Peninsula Primary School

Scientific Services Branch
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1. Executive Summary

1.1 *Preamble*

This document comments on the potential health implications of data from laboratory analysis of dust samples taken from the Le Fevre Peninsula Primary School. This document must be read in conjunction with the Environment Protection Authority's (EPA) report "Examination of PM_{10} measurements and wind direction at Le Fevre Peninsula Primary School. September 2008".

This document has been drafted, mindful that the reader may not have technical knowledge of health risk assessment, but in a manner that does not alter the scientific integrity of the analysis. Therefore the report still uses terms such as "risk", "unit cancer risk" and "carcinogenicity", which have specific and clearly defined meanings within the context of chemical exposure assessment. These terms are explained in the text or the glossary.

The risk assessment process outlined in this report initially considered potential exposures that could pose risks to health of students and staff attending Le Fevre Peninsula Primary School. Following this risk assessment, two main exposures of concern were identified: (1) the exposure to dust in general (particulate matter) and (2) exposure to chemical contaminants present in dust.

With respect to the assessment of the effects of exposure to chemical pollutants, it is important to understand that the scientific literature has very few data on human health outcomes for most pollutants. This is because there are no experiments that can be safely and ethically undertaken on humans to determine what dose of a particular pollutant causes an effect. For this reason the precautionary approach is commonly used for the assessment of possible risks to human health. This means that health departments will recommend <u>reducing exposure to as low as reasonably possible</u> if the pollutant is known to cause effects in animals, or exposed people (most often determined in people who work in various industries).

This approach forms the basis of this report's recommendations. It is usually never possible to reduce exposure (or risk) to zero – we are all exposed to the chemicals found in this report due to every day activities including smoking and travelling in our motor vehicles.

It was not the intent of the SA Health to identify the sources of the chemicals found in the various samples but to offer constructive advice to mitigate potential risks for adverse health effects in exposed individuals. While the data provided to SA Health is insufficient to attribute the source of the observed contamination, general intuitive observations can be made from the data.

1.2 *Risk assessment*

The data that informed this risk assessment was provided to SA Health by EPA and included: analysis of the dust impacts on EPA PM_{10} monitoring station located at the back of the school grounds, and results of the analysis of chemical composition of deposited dust samples collected from the school's classroom and gymnasium. Chemical contaminant data from the construction site was also available. The mineral composition of the dust samples was not characterised.

The EPA PM_{10} monitoring data analysis as reported in the EPA document "Examination of PM_{10} measurements and wind direction at Le Fevre Peninsula Primary School. September 2008" strongly indicates significant dust sources from the direction of the Port Adelaide Waterfront Redevelopment site adjacent to the Le Fevre Peninsula Primary School.

The samples of deposited dust were collected inside the Le Fevre Peninsula Kindergarten and the school on 1 August and 5 August 2008 respectively, while a control sample was collected from a location in Netley on 8 August 2008. These deposited dust samples were analysed for a wide range of contaminants by an appropriately certified laboratory. The dust samples from Le Fevre peninsula Kindergarten contained some of the contaminants that were found in the school samples, but at significantly lower levels. The chemical composition of the dust samples collected inside Le Fevre Peninsula Primary School was consistent with the chemical composition of the contaminated top soil layer at the Port Adelaide Waterfront Redevelopment site. The chemical composition of the dust samples collected at the control site in Netley showed distinctly different pattern of contaminants. The EPA has indicated the Netley sample represents that from an industrial area with heavy traffic.

While the identification of specific sources was neither among the aims of this risk assessment nor was it possible due to the limitations of the available data, there is sufficient evidence to suggest that activities on the Port Adelaide Waterfront Redevelopment site contribute to the dust and chemical loading in the indoor air within the school buildings. It is on this basis the recommendations in this report are made.

The EPA PM_{10} data analysis found that dust levels at the monitoring site located at the rear of Le Fevre Peninsula Primary School were in excess of the expected average for this area. Moreover, these impacts occasionally exceed the National Environment Protection Measure (NEPM) Ambient Air Quality Standard for PM_{10} (currently set at 50 $\mu g/m^3$). It is important to recognise that the NEPM standard is a regulatory standard, not a health-based threshold level and as such, does not mean that no health effects will occur when dust (PM_{10}) concentrations are below 50 $\mu g/m^3$. In susceptible or vulnerable populations, exposure to PM_{10} at concentrations below 50 $\mu g/m^3$ can result in adverse health effects in some people.

The community of Le Fevre Peninsula in general is likely to be particularly sensitive to the effects of exposure to dust due to the poorer pre-existing respiratory and circulatory health. Furthermore, the majority of the exposed population at the school is from a vulnerable group being children of a young age. Therefore, it is important that those sources of dust that can be minimised should be. This will reduce or prevent exacerbations of underlying conditions due to the added exposure to dust while attending Le Fevre Peninsula Primary School.

The deposited dust samples collected inside Le Fevre Peninsula Primary School were found to contain a mixture of chemicals including metals and organic chemicals. While the detected levels of most of these chemicals are possibly not sufficient to induce significant detrimental effects to health individually, the effects of exposures to mixtures of chemicals are poorly understood and not quantifiable at present.

However, the detection of chemicals from the group of polycyclic aromatic hydrocarbons (PAHs) including benzo(a)pyrene was of specific concern. Many PAHs have been assessed for their ability to induce cancer in animals and humans. Benzo(a)pyrene has been classified (by World Health Organisation) as a Class 1 agent (*"The agent is carcinogenic to humans")*; which means that it has been shown to induce cancer in humans (occupational groups) at sufficiently high levels over sufficiently long exposures. The dust in the school contains PAHs at levels above what one would ordinarily find in the general community. This may contribute to a very small increase in the risk of developing cancer (on top of the background risk) if a person was exposed to the dust continually over a long period (e.g. 20-40 yrs).

1.3 *Summary*

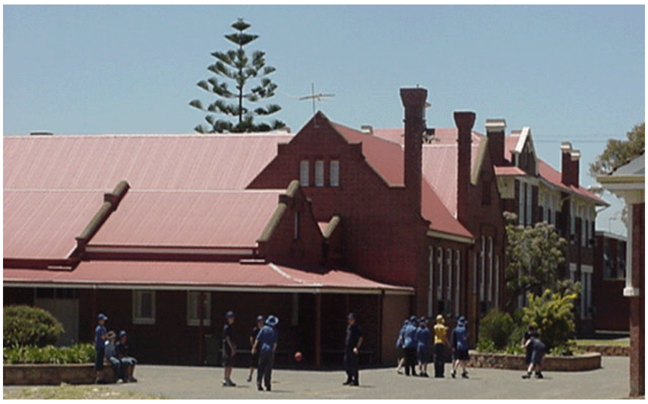
The principle of public health is to reduce risks to the health of a population as much as possible. Particular consideration ought to be given to vulnerable and sensitive sub-groups within a population. The Le Fevre Peninsula Primary School dust samples were found to contain a range of chemicals all of which have a small risk of causing adverse effects in children, along with the physical effects of the dust itself. For this reason it is recommended that the school be cleaned thoroughly, and dust levels be continuously monitored. Furthermore, it is recommended that dust emissions associated with the stockpiles, haul roads and other dust producing activities be managed to reduce overall dust emission from Port Adelaide Waterfront Redevelopment site on the Le Fevre Peninsula Primary School. Repeat cleaning of the school may be needed or other preventive measures implemented if dust control management fails.

It is not recommended that further sampling be undertaking at this stage, because the strategies for mitigating the impacts would not alter from that stated above.

2. Introduction

2.1 *Le Fevre Peninsula Primary School*

The Le Fevre Peninsula Primary School (LFPPS) is at the heart of the local community and is an important part of the history of the area as illustrated by the following: *"The Le Fevre Peninsula was named by SA's first Governor, Captain John Hindmarsh, on 3rd June 1837. In 1855 a group of residents of Sandwell (now Birkenhead) concerned about the education of the children met to discuss the problem and they decided to establish a school. The single room school house was opened on the 7th May, 1856 on the corner of Close St., and Dunneker Ave., (now Semaphore Rd.). The principal and sole teacher was John Hillard. The school opened with ten pupils aged between 8 and 12 years of age."*



Presently, the school community consists of around 350 pupils between the ages of 5 to 12 years old along with 50 teachers and staff members. The school grounds also house the Le Fevre Peninsula Kindergarten.

The school is located approximately 20 metres to the north/north east of the Port Adelaide Waterfront Redevelopment (PAWR) site across Semaphore Road. The school buildings are approximately 30 metres from some large stockpiles of possibly contaminated soil from the PAWR site. The stockpiles are located at the northern boundary of the site (Figure 1). All of the classrooms as well as the school gymnasium have windows facing south towards the PAWR site and the stockpiles. The school collects rainwater from a roof sloping towards the PAWR site, which is used for watering edible plants grown by students on the school grounds.

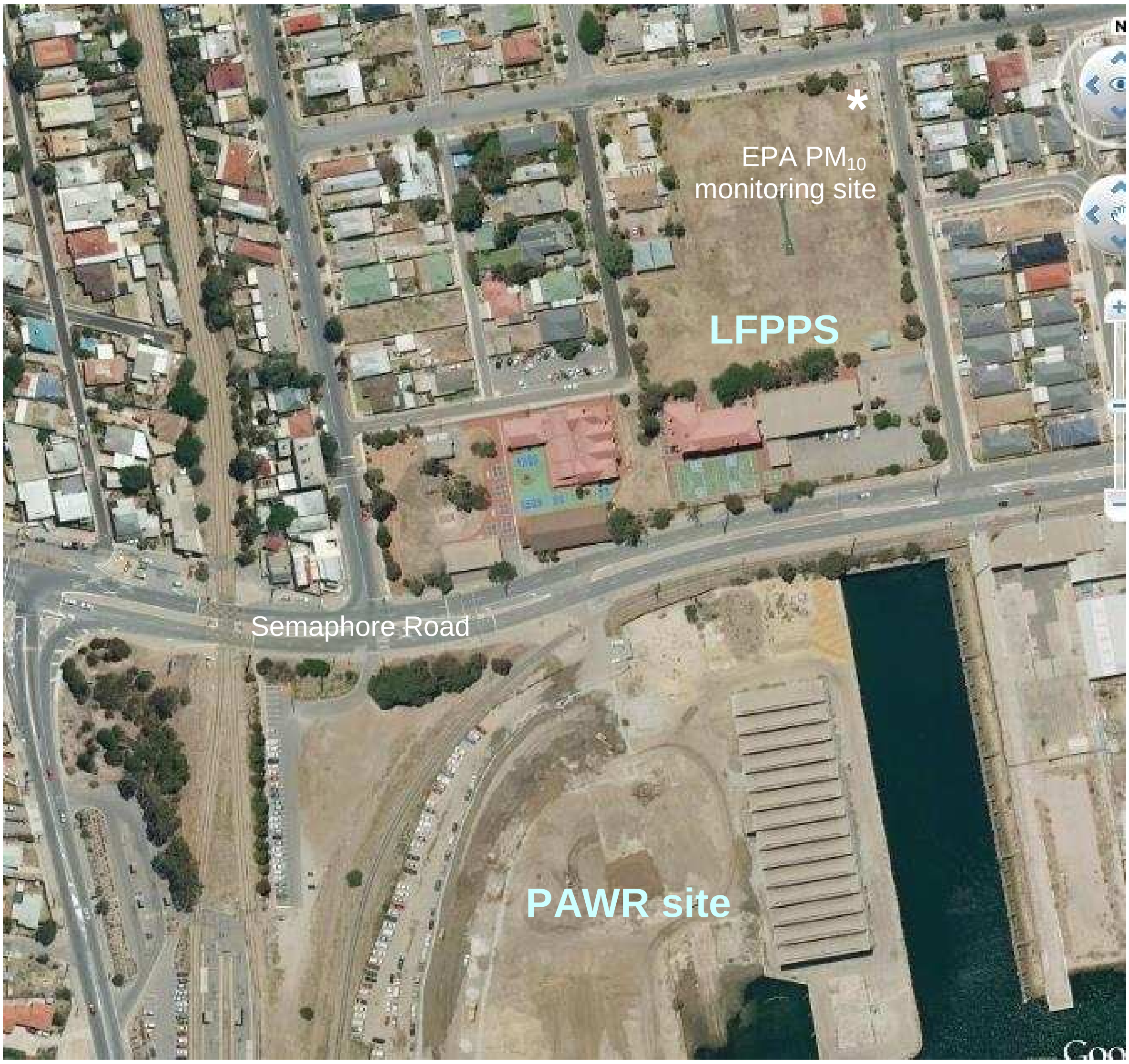
The Le Fevre Peninsula Kindergarten is located approximately 30 metres to the north of the LFPPS buildings. The kindergarten collects rainwater which is used for flushing toilets and irrigation purposes.

2.2 *Port Adelaide Waterfront Redevelopment Project*

The PAWR project is possibly the largest urban contaminated site remediation to be undertaken in South Australia. It is a complex operation that involves staged remediation of many hectares of potentially contaminated land followed by high density residential development. The project is run by Land Management Corporation (LMC) and the Newport

Quays Consortium (NPQ, a joint venture between Urban Construct and Brookfield Multiplex). The site remediation component entails excavation and *in situ* remediation of large volumes of contaminated soil. The project is expected to result in the remediation of vast areas of historically contaminated land and make this land available for urban development. It is expected that the project will continue for at least the next seven years.

Figure 1. The map of the area showing the location of the school relative to PAWR site.



Contamination associated with fill material (soil) at the PAWR site comes from a variety of sources and includes: industrial wastes (contaminants resulting from former sugar refinery, former foundry wastes, sands and slag), materials from building and demolition, and sandy soils dredged from the Port Adelaide River. SA Health has been provided with copies of Site Audit Reports issued for various sections of the PAWR site. According to these reports, elevated concentrations of, but not limited to, arsenic, barium, cadmium, copper, manganese, lead, antimony, selenium, tin, vanadium, zinc, mercury, petroleum hydrocarbons and polycyclic aromatic hydrocarbons have been detected in soils at the site. The levels of the contaminants varied between the portions of the site with the top layer of the soil most highly contaminated.

The remediation component of the PAWR Project has been inactive for the past several months (as of writing September 2008) but construction has continued on previously remediated portions of the site. It is expected that the remediation activity at the site will resume in December 2008 - January 2009, subject to appropriate development application approvals.

3. Off-site dust impacts: consultations and investigation

The issue of possible off-site dust impacts from the PAWR site on LFPPS was first raised in June 2008 by the local newspaper and radio reports. Following these reports, LMC invited officers from SA Health and EPA to visit the site (24 June 2008). At the time, there were several large stockpiles of possibly contaminated soil in excess of 5-6 metres high located close to the northern boundary of the site (along Semaphore Road). At the time of inspection the stockpiles were stationary (no excavation, and/or addition of material was occurring at the time) and had been treated with crusting agent to prevent dust generation. SA Health have not been provided with documented records on the nature and concentrations of contaminants present in these stockpiles to date. At the time of inspection, there was a temporary road and a staff car park along the eastern and north-eastern boundary of the site (along the railway lines and Causeway Road). Visual inspection identified movement of cars along this road and the car park caused significant dust generation.

3.1 *Consultation*

Following the initial site visit, regular meetings were organised between the stakeholders: LFPPS, LMC/NPQ, EPA and SA Health. The meetings are being held regularly at approximately monthly intervals. The purpose of the consultation process was to address the school community's concerns and develop flexible and effective strategies to prevent any future dust impacts from the PAWR site on LFPPS.

3.2 *Investigation*

An investigation was carried out by EPA in collaboration with SA Health and other stakeholders that:

1. Examined the air quality monitoring data from a EPA air quality monitoring station located on the school grounds (north-east corner of the school oval, approximately 100 metres from the school buildings).

2. Undertook a chemical analysis of rainwater samples from the school and kindergarten's rainwater tanks.

3. Undertook an analysis of the chemical composition of deposited dust samples collected inside the school and Le Fevre Peninsula Kindergarten. Dust samples used as a control were collected from inside the EPA Air Quality Laboratory located at Netley.

3.3 *Air quality monitoring data analysis*

EPA runs a continuous PM_{10} particle monitoring station (TEOM) located at the rear of LFPPS as part of EPA's ongoing ambient monitoring network (Figure 1). PM_{10} are particles that finer than 10 micrometres (µm) effective aerodynamic diameter and are able to be breathed into the lungs. The results of the PM_{10} data analysis from this monitoring site are presented in the EPA report "Examination of PM_{10} measurements and wind direction at Le Fevre Peninsula Primary School. September 2008". The significance of the findings of this analysis for the overall risk assessment of dust impacts on LFPPS school community is addressed later in this document.

3.4 *Rainwater samples – chemical analysis*

Rainwater samples collected from LFPPS and Le Fevre kindergarten's rainwater tanks identified trace amounts of several metals which were well below the Australian Drinking Water Quality Guidelines (2004) values. Unfortunately the sampling was not ideal because one tank had been drained several weeks prior to collection, and the samples were collected after heavy rains. It is worth noting that the actual levels of contaminants are likely to he highly variable dependent upon dust fall-out, rain events and water usage.

3.5 *Chemical contaminants in the dust samples collected inside the school and the kindergarten*

Deposited dust samples were collected inside the school: one sample from Classroom 13 – aluminium window frames, and one sample from the gymnasium – painted window ledges) and the kindergarten (a composite sample from several surfaces) on 1 August and 5 August 2008.

Two samples were collected as a control in a similar manner from inside the EPA air quality laboratory located at Netley on 8 August 2008. The Netley location is approximately 600 metres from the Adelaide airport runways and is surrounded by heavy traffic on Richmond and Marion Road as well as a number of industrial sites.

The samples were analysed for a wide range of chemical contaminants by Leeder Consulting, (NATA accredited analytical laboratory). Refer to Appendix 1 for the full laboratory report. Table 1 shows the chemicals that were detected in the dust samples.

The dust samples were found to contain various levels of several organic and inorganic contaminants.

Of particular concern was the detection of members of the polycyclic aromatic hydrocarbons (PAHs) group of chemicals in dust samples taken from the LFPPS classroom and gymnasium. PAHs are a group of organic chemicals that are formed during incomplete burning of organic substances (such as wood, petroleum, coal etc) and usually occur as a mixture rather than a single chemical. There are more than 100 different PAHs but only seventeen (17) of those have been studied extensively. These are known to have various effects on human health

(ATSDR, 1995). PAHs found in dust samples from LFPPS included: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene, chrysene, fluoranthene, phenanthrene and pyrene. The World Health Organization's (WHO) International Agency for Research on Cancer (IARC) has assessed these for their carcinogenicity as follows: benzo(a)pyrene – Class 1 agent ("The agent is carcinogenic to humans"); benzo(a)anthracene, benzo(k)fluoranthene, benzo(b)fluoranthene, and crysene – Class 2B agents ("The agent is possibly carcinogenic to humans"), and benzo(ghi)perylene and pyrene are classified as Class 3 agents ("The agent is not classifiable as to its carcinogenicity to humans") (IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, http://monographs.iarc.fr/ENG/Classification/index.php).

Table 1 Chemical contaminants detected in dust samples (concentrations in mg/kg).

Chemical	LFPPS Classroom 13	LFPPS Gymnasium	Kindergarten	Control (Netley)
Metals				
Antimony	5	12	5	21
Arsenic	15	28	4	14
Barium	180	300	59	220
Cadmium	2	3	nd	36
Chromium	38	110	14	140
Cobalt	7	9	3	110
Copper	200	190	64	19000
Lead	400	520	87	720
Manganese	360	280	50	430
Mercury	nd	nd	nd	5
Molybdenum	6	6	nd	21
Nickel	46	27	8	110
Selenium	nd	nd	nd	5
Silver	nd	4	2	41
Tin	87	21	17	120
Zinc	990	9800	460	3600
Organic compounds				
Benzo(a)anthracene	0.8	0.5	nd	nd
Benzo(a)pyrene	1.0	0.7	nd	nd
Benzo(b)fluoranthene	1.1	1.0	nd	nd
Benzo (ghi) perylene	0.6	nd	nd	nd
Benzo(k)fluoranthene	nd	0.6	nd	nd
Chrysene	1.1	0.9	nd	nd
Fluoranthene	2.4	1.8	nd	1.2
Phenanthrene	1.4	1.7	nd	2.5
Phenol	nd	nd	1.3	1.1
Pyrene	2.2	1.7	nd	0.6
Dieldrin	nd	nd	nd	1.8
Arochlor 1254	nd	nd	nd	5.5

“nd” = Not detected

4. Characterisation of possible health risks associated with inhalation of the dust at Le Fevre Peninsula Primary School

4.1 *Introduction*

The approach to air quality needs to be risk-based taking into account all exposures along with the health status of the population especially sensitive (vulnerable) sub-populations in order to develop effective management measures.

The National Environment Protection Measure (NEPM) for Ambient Air Quality Standard for PM_{10} is currently set at 50 µg/m^3 (NEPC, 1998). It is important to recognise that this is a regulatory standard which should *not to be mistaken for a health based threshold level* (indicating that no health effects are likely to occur below the given concentration). This means that in susceptible or vulnerable populations, exposure to PM_{10} at concentrations below 50 µg/m^3 can result in adverse health effects in some people (WHO, 2006). This is particularly important in the light of the current review of NEPM guidelines for air pollution which aims to take into account new research data that demonstrate that adverse health effects occur at PM_{10} concentrations below 50 µg/m^3.

4.2 *Air quality and human health – Le Fevre Peninsula*

The SA Social Health Atlas indicates that the Le Fevre Peninsula has an excess burden of respiratory diseases, asthma and circulatory diseases when compared to the SA population as a whole (Glover et al., 2006). On this basis, the general community in the Le Fevre Peninsula is likely to be sensitive to the effects of exposure to airborne particulate matter due to overall poorer pre-existing respiratory and circulatory health.

4.3 *Dust impacts on Le Fevre Peninsula Primary School*

The EPA PM_{10} data analysis found that dust particles are impacting on the monitoring site located at the rear of Le Fevre Peninsula Primary School in excess of the expected average for this area. Moreover, these impacts occasionally exceed the National Environment Protection Measure (NEPM) for Ambient Air Quality Standard for PM_{10}. There are several directions from which a higher than average amount of particles impact on the monitoring site. The data strongly indicate significant dust sources from the direction of the PAWR site adjacent to the LFPPS. Please, refer to the EPA report “Examination of PM_{10} measurements and wind direction at Le Fevre Peninsula Primary School. September 2008”.

4.4 *Toxicological hazard identification and selected risk assessment methodology*

The spectrum of inorganic contaminants found in the deposited dust samples in LFPPS is of concern. At sufficiently high concentrations some of these chemicals (e.g. lead, barium, magnesium) are known to have adverse effects on human health in general, and respiratory health in particular (WHO, 1999; WHO, 2001).

The dust samples contained a range of organic chemicals all of which have a potential for adverse health effects. Most notably this included the detection of benzo(a)pyrene (BaP), a known human carcinogen, at the level of 1 mg/kg. This level is the same as the National Environment Protection Measure's Health Investigation Level A (NEPM HIL A) for BaP in soil (NEPC, 1999). An estimate of whether there was a possible ***excess lifetime risk of cancer*** **due to the exposure to BaP via inhalation of the contaminated dust** was attempted.

The risk assessment was limited by the available data. It is only possible to estimate the approximate contaminant concentrations in the classroom air through extrapolation from ambient air PM_{10} concentrations. The only available data on PM_{10} concentrations is the estimated average daily ambient air concentration at the location of the EPA air monitoring station. The station is located 200 metres from the classroom fronting the development site. As such, the risk characterisation could not model the risk in the school classroom, but in a theoretical classroom situated next to the EPA air quality monitoring site.

It is therefore important to recognise that any risk characterisation based on the available data should be considered an underestimate (refer to Appendix I for detailed discussion on the uncertainties of the risk assessment analysis).

Based on the concentration of BaP detected in the dust samples, the estimated daily average concentration of PM_{10} as derived from the EPA PM_{10} monitoring data analysis, and assuming continuing long term exposure at the current levels of BaP, the inhalation of the dust in the air surrounding LFPPS is expected to lead to *a small but finite increase in the lifetime risk of cancer*.

5. General discussion

Cumulative exposure to particulate matter and air pollution throughout childhood can compromise respiratory health of children. The effects may be immediate, such as exacerbation of existing ailments or may have long-term implications if the normal development and maturation of the respiratory system is affected (WHO, 2006). It is also important to recognise that children have a lifetime of environmental exposures ahead of them and a lifetime to develop environmental exposure-related illnesses which have long latent period, such as cancer (Wigle et al., 2007). Therefore it is an imperative to aim to reduce exposures as much as possible.

The chemical composition of the dust samples collected inside LFPPS is consistent with the chemical composition of the contaminated top soil layer at the PAWR site. This conclusion is based on the information about contaminants found in the top soil layer of the PAWR site provided in Site Audit Reports. It is noteworthy, that according to Site Audit Reports, BaP has been found in the top soil in most sections of the PAWR site at various concentrations (up to around 4,000 mg/kg in some hotspots).

The control site in Netley is located about 600 metres from the Adelaide airport runways and is surrounded by heavy traffic on Richmond and Marion Road. The chemical signature of the dust samples taken from the Netley site is different (especially with respect to the PAH group of chemicals) from the school dust samples.

While the identification of specific sources was neither among the aims of this risk assessment nor was it possible due to the limitations of the available data, there is sufficient evidence to suggest that activities on the Port Adelaide Waterfront Redevelopment site contribute to the dust and chemical loading in the indoor air within the school buildings. It is on this basis the recommendations in this report are made. Therefore, the exposure to dust and chemical contaminants in LFPPS children can be reduced if dust emissions from PAWR site are minimised as much as possible. It is on this basis the recommendations in this report are made.

6. Recommendations

The following recommendations are based on the premise that exposing school children to dust, in particular dust that may contain a range of toxic contaminants, may lead to exacerbation of existing health effects or increase the risk of adverse health effects.

6.1 *Initial School clean-up*

To prevent further exposure to contaminated dusts present inside the school, a thorough clean-up of the school buildings is recommended. The clean-up should be conducted by a contractor with experience in dedusting and decontamination of buildings. This initial clean-up should include floors and all accessible surfaces in addition to ceiling spaces. The contractor should use appropriate HEPA-filtered equipment. When choosing the contractor, advice should be sought from DECS.

During dry weather and/or at times of high dust generating activity at the PAWR site, ongoing weekly cleaning of all accessible surfaces inside the school buildings should be conducted using HEPA-filtered equipment.

6.2 *Reduction in dust emissions from the PAWR site*

It is recommended that the dust emissions arising from the PAWR site is reduced to as low as possible, in particular when the wind is in the direction of the LFPPS. Many of these recommendations have been discussed with the various parties. Important measures include:

- Ensuring zero or at least as low as reasonably practical dust emissions occur (which needs to be defined in consultation with the school community).
- Use of crusting agent on the stockpiles at all times when the stockpiles are not moved (monitor and reapply as required).
- Watering and vacuuming of the car park and access roads should be more frequent during dry weather and times of increased vehicular movement at the site.
- Continuous watering during dust generating activities in accordance with the EPA Guidelines for environmental management of on-site remediation.

To aid with identification of significant dust sources it is recommended that records of weather conditions, remediation/construction activities, actions taken to control and prevent dust generation are kept along with the records of public complaints. These should be reviewed periodically to monitor the effectiveness of the adopted preventive measures. The results of this review process should be provided to all stakeholders.

6.3 *Monitoring*

To aid dust suppression a monitoring program is recommended with an aim to proactively reduce dust to a level that can be achieved using best work practices. Consideration should be given to the following:

- Monitoring at point locations to enable the assessment of dust impacts on LFPPS and other sensitive receptors including residential areas surrounding PAWR site.

- The monitoring program should be flexible enough to allow responses to operational changes on the site.

- Routine analysis and reporting to all parties of monitoring data including the PM_{10} data from the EPA air monitoring station located at the rear of the school.

- In the event there is difficulty in controlling dust at the construction site, consideration should be given to monitoring of dust within the school complex, including active air sampling inside classrooms.

6.4 *School*

- It is recommended that vegetable beds constructed close to the southern boundary of the school grounds in close proximity to the PAWR site should not be used to grow edible plants for consumption by the students until the potential health risks are addressed.

- Rainwater from the LFPPS rainwater tank could be used for irrigation, although given the possibility of significant fluctuations in the contaminant concentrations; it should not be used for irrigation of edible plants.

- If dusty conditions continue and are uncontrollable it may be worth considering applying Grade F5 or greater filters to the school’s air conditioning system.

6.5 *Progress review*

It is recommended that the outcomes of the implementation of a robust dust management plan should be undertaken by an appropriate authority or third party within the next twelve months. The review could include analysis of: (1) dust monitoring data which may include further collection of deposited dust samples, (2) records of public complaints and an audit of implemented dust control measures against agreed measures. Such a review should include active participation of all stakeholders through such activities as focus groups.

7. Glossary

Agent

A chemical, biological, or physical entity that contacts a target.

Ambient air

Means the external air environment, it does not include the air environment inside buildings or structures.

Cancer

A malignant and invasive growth or tumour, especially one originating in the epithelium, tending to recur after excision and to metastasise to other sites.

Carcinogen

Any substance which tends to produce a cancer in a body.

Contaminant

A contaminant is any physical, chemical, biological or radiologic substance or matter that has an adverse effect on air, water, land/soil or biota. The term is frequently used synonymously with pollutant.

Dust

Earth or other matter in fine, dry particles.

Exposure

Concentration or amount of a particular agent that reaches a target organism, system, or (sub)population in a specific frequency for a defined duration.

Exposure assessment

Evaluation of the exposure of an organism, system, or (sub)population to an agent (and its derivatives). Exposure assessment is the third step in the process of risk assessment.

Exposure route

The way in which an agent enters a target after contact (e.g., by ingestion, inhalation, or dermal absorption).

Inhalation exposure refers to contact between an air pollutant and the respiratory tract

Ingestion exposure refers to contact between an agent and the gastrointestinal tract (stomach, large and small intestine etc)

Dermal exposure is the contact between an agent and the external skin.

Hazard

Inherent property of an agent or situation having the potential to cause adverse effects when an organism, system, or (sub)population is exposed to that agent.

Hazard characterization

The qualitative and, wherever possible, quantitative description of the inherent property of an agent or situation having the potential to cause adverse effects. This should, where possible, include a dose–response assessment and its attendant uncertainties. Hazard characterization is the second stage in the process of hazard assessment and the second of four steps in risk assessment.

Hazard identification

The identification of the type and nature of adverse effects that an agent has an inherent capacity to cause in an organism, system, or (sub)population. Hazard identification is the first stage in hazard assessment and the first of four steps in risk assessment.

Inorganic chemicals/compounds

Chemical substances of mineral origin, not of basically carbon structure.

Metric units

Kilogram	kg	1000g
Gram	g	1g
Milligram	mg	0.001g – (1x10^{-6} kg)
Microgram	µg	0.000001g – (1x10^{-9} kg)
Nanogram	ng	0.000000001g – (1x10^{-12} kg)
Liter	L	1000mL (1000 cm^3)
Milliliter	mL	1mL (1 cm^3)
Cubic meter	m^3	1000L

Examples of units used in this technical document

ng/m^3 – 0.000000001g agent in 1000L air

µg/m^3 – 0.000001g agent in 1000L air

mg/kg – 1 in a 1,000,000 or part per million

Organic chemicals/compounds

Substances containing mainly carbon, hydrogen, nitrogen, and oxygen.

Particulate matter

Solid particles or liquid droplets suspended or carried in the air.

PM_{10}

PM-10 or PM10 - refers to particles in the atmosphere with an effective aerodynamic diameter of equal or less than ten to 10 micrometres.

Precautionary principle

(1) Principle adopted by the UN Conference on the Environment and Development (1992) that in order to protect the environment, a precautionary approach should be widely applied, meaning that where there are threats of serious or irreversible damage to the environment, lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation. (2) The precautionary principle permits a lower level of proof of harm to be used in policy-making whenever the consequences of waiting for higher levels of proof may be very costly and/or irreversible.

Public health

Is the organised response by society to protect and promote health, and to prevent illness, injury and disability. The starting point for identifying public health issues, problems and priorities, and for designing and implementing interventions, is the population as a whole, or population sub-groups.

Risk

The probability of an adverse effect in an organism, system, or (sub)population caused under specified circumstances by exposure to an agent.

Risk assessment

A process intended to calculate or estimate the risk to a given target organism, system, or (sub)population, including the identification of attendant uncertainties, following exposure to a particular agent, taking into account the inherent characteristics of the agent of concern as well as the characteristics of the specific target system. The risk assessment process includes four steps: hazard identification, hazard characterization (related term: *Dose–response assessment*), exposure assessment, and risk characterization. It is the first component in a risk analysis process.

Risk characterization

The qualitative and, wherever possible, quantitative determination, including attendant uncertainties, of the probability of occurrence of known and potential adverse effects of an agent in a given organism, system, or (sub)population, under defined exposure conditions. Risk characterization is the fourth step in the risk assessment process.

Toxicological endpoint

Toxicological endpoint refers to a specific effect associated with exposure to an agent within a specific tissue/organ under specified conditions.

Threshold level

Time-weighted average pollutant concentration values, exposure beyond which is likely to adversely affect human health. http://www.epa.gov/OCEPAterms/tterms.html

Toxic equivalency factor

For comparative purposes, the PAH concentrations can be expressed as benzo[a]pyrene equivalents, their relative concentrations being weighted in relation to the carcinogenic potential of each individual PAH compounds using toxic equivalency factors (TEF). The assumptions implicit in utilization of the TEF approach include: the individual compounds all act through the same biologic or toxic pathway; the effects of individual chemicals in a mixture are essentially additive at relevant levels of exposure; the dose-response curves for different congeners should be parallel; and the organotropic manifestations of all chemicals within the group must be identical over the relevant range of doses.

Uncertainty (analytical, in the context of risk assessment)

Imperfect knowledge concerning the present or future state of an organism, system, or (sub)population under consideration.

Unit cancer risk – 2 definitions

The result of applying linear models to carcinogenicity data to estimate the upper limit on lifetime risk per unit of dose. Specific properties of substances are generally not taken into account.

The unit cancer risk is defined as the slope of a straight line drawn from the lowest apparent effect dose to zero.

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9. Appendix I: Risk characterisation – exposure to BaP in dust

9.1 *Estimation of the concentration of BaP in the air*

- According to the EPA PM_{10} monitoring data analysis estimated maximum daily average concentration of PM_{10} for the area between Feb 2007-Jan 2008 was approximately 20 $\mu g/m^3$ (20,000 ng/m^3);

- Dust samples taken from classrooms in LFPPS were found to contain 1 mg/kg ($1x10^{-6}$ kg/kg – unitless) of BaP;

- Total concentration of BaP associated with PM_{10} in the air at LFPPS air monitoring site can be estimated as: 20 000 ng/m^3 x $1x10^{-6}$ = **0.020 ng/m^3**

9.2 *Risk characterisation*

Based upon epidemiological data from studies of coke-oven workers, a unit cancer risk for BaP exposure via inhalation is estimated to be 8.7×10^{-5} $(ng/m^3)^{-1}$ (WHO, 2000). Please note that the unit cancer risk *is not* an estimate of cancer risk. Unit cancer risk is a compound-specific coefficient that is used for calculating or deriving cancer risk estimates. It is derived from the scientific data on the carcinogenic potential of a compound, which are available from different types of studies. The best characterised carcinogens (most Class 1 agents) have their unit cancer risks derived from epidemiological studies in human populations whose exposure can be defined and measured. Most often, such populations are exposed to the compound in question in an occupational setting (work environment).

Due to the limitations of the available data, no numeric measure could be assigned to describe the excess lifetime risk of cancer for children attending LFPPS. However, the data does allow for qualitative description of the risk.

Based on the above, exposure associated with the inhalation of dust in the air surrounding LFPPS is expected to lead to *a small but finite increase in the lifetime risk of cancer,* assuming long term exposure at current levels.

It is worth noting that the indoor concentration of PM_{10} in schools has been reported to be 1.5 times higher than outdoor concentration of PM_{10} (Diapouli et al., 2007). As a result, if children spend most of their time in the classroom, excess lifetime cancer risk would be greater.

9.3 *Discussion*

The risk characterisation for BaP exposure via inhalation of contaminated dust presented in this document is considered to be an underestimate for a number of reasons:

1. The data used are measurements of PM_{10} particles in the ambient air at the location of the EPA monitoring site at LFPPS. This analysis does not include particles of greater diameter, which tend to fall out from the air sooner than finer PM_{10} particles and therefore do not travel as far from the source. The deposition of larger particles could contribute to the overall exposure through pathways other than inhalation (such as ingestion and dermal uptake);

2. The EPA air quality monitoring station is located approximately 200 metres north from the front of the school buildings (away from the PAWR site), as a result, the concentrations of PM_{10} at the LFPPS classrooms is likely to be higher than that used in this risk characterisation;

3. It is likely that the PM_{10} levels near the LMC site and at the school classrooms are higher during working hours/school hours. It is worth noting that the daily average PM_{10} concentration has exceeded the NEPM standard of 50 $\mu g/m^3$ on several occasions (reaching up to 76 $\mu g/m^3$);

4. The hazard characterisation was based on dose-response relationships developed in epidemiological studies for adults in an occupational setting, whereas children may be more vulnerable/susceptible to BaP toxicity.

5. The risk characterisation was based on exposure to BaP via inhalation of the contaminated dust only, while alternative pathways of exposure i.e. oral and dermal were not considered. The risk characterisation presented in this report addresses the presence of only one of the PAH contaminants detected in the dust samples. Other PAHs could be included in the analysis using a compound's toxic equivalence factor (TEF) (Safe, 1998). Including TEF-adjusted values for other PAHs detected in the dust samples in the calculation would increase the characterised risk by approximately 40%.

6. There are several other contaminants present at elevated concentrations in the dust samples collected in the school classrooms. While the individual levels of these chemicals found in the dust samples are not high enough to induce detectable effects to health, the effects of exposure to mixtures of chemicals are poorly understood. There is no standard methodology for risk assessment to chemical mixtures in general population that could be applied to the available data and exposure scenario.

10. Appendix II: Laboratory report of the results of rainwater and dust sample analysis.