THE UNIVERSITY of ADELAIDE

Adelaide Exposure Science and Health

(formerly OEH Consulting)

5 February 2018 **Ref OEH1095RRev1**

Attn: Ms Judith Hugo

Friends of Australian Rock Art
C/o Conservation Council of WA, Inc
Lotteries House
2 Delhi Street
West Perth WA 6005

Dear Ms Hugo,

Re: Burrup Peninsula Rock Art and local health concerns

Executive Summary

Data and information provided on the Yara ammonium nitrate plant emissions show a range of highly irritant gases and particulates that may move off-site due to point source and fugitive emissions. This off-site atmospheric dispersion is subject to local topography and meteorological conditions. Some air quality assessments have been undertaken for Yara using modelling and measurements methods. However, these have not captured worst case exposure conditions for people that may come into the area and in proximity to the plant. Of particular concern is photographic evidence of a nitrogen dioxide cloud emanating from the nitric acid plant. For nitrogen dioxide to be visible, the concentrations are at least four-times recommended health standards. Records from the plant show that the emission rates of nitrogen dioxide associated with the visible cloud were exceeded 76 times and by up to four-fold. These high emission rates were frequently for more than 15 minutes.

The health impacts associated with these emission substances result from very short-term exposures (e.g. ten minutes). If of sufficient intensity, as suggested from the emissions data, the pollutants would result in severe health outcomes for people exposed, particularly for people with asthmatic or other respiratory conditions. Due to the nature of these inorganic pollutants, the consequences of such high-level exposure are severe and should not be underestimated by industry or government. It is important therefore to ensure exposure assessment captures these transient exposures in areas where people are resident, in order to direct mitigation measures.

Background

Adelaide Exposure Science and Health (formerly the Occupational and Environmental Hygiene Laboratory), School of Public Health at the University of Adelaide was approached to present a brief qualitative opinion on the potential human health risks associated with ammonium nitrate plant emissions in proximity to the Burrup Peninsula Rock Art in Western Australia. This has been based on information provided by Dr John L Black of John L Black Consulting in email and telephone communications over the period 10 January 2018 to 2 February 2018.

Objective

THE UNIVERSITY of ADELAIDE

Adelaide Exposure Science and Health

(formerly OEH Consulting)

Review of available literature and site-specific data on ammonium nitrate plant emissions and potential health concerns with presentation of qualified opinion.

Scope of work

- Brief literature review to identify:
    - Similar settings elsewhere with demonstrated outcomes for public and environmental health (if reported).
    - Latest toxicological/epidemiological data regarding salient ammonia nitrate plant emissions.
- Summary consideration of the current settings and available data compared with peer-reviewed literature.
- Summary public health issues, data gaps and uncertainties.

Ammonium nitrate plant emissions and health issues

Brief literature search strategies were undertaken using Google Scholar, Scopus and Web of Science databases to identify specific epidemiological studies pertinent to population impacts associated with fertiliser plants. Specific epidemiological data associated with ammonium nitrate plants were unavailable, however, one study in Croatia (Gomzi and Saric, 1997) was located that had examined respiratory impairment among schoolchildren living near a fertiliser plant. While details of the plant were not included daily ambient air and indoor air measurement included ammonia, hydrogen fluoride, nitrogen dioxide, total suspended particulate matter (TSP) and smoke. This study over 6 months examined an exposed school 1.3-2 km downwind (N) of the plant and a control school 2-2.9km west of the plant. Adverse health effects were examined via lung function tests and tracking of acute respiratory disease. The paper concluded that levels of air pollution (both indoors and outdoors) correlated to some extent with the health parameters followed up during the period of observation. While incidence of acute respiratory diseases in children corresponded to the registered differences in the exposure to measured pollutants, a statistically non-significant outcome between the groups was reported and was considered a reflection of differences between indoor and outdoor pollution levels, as confounders were accounted for.

Toxicological/epidemiological data on key ammonia nitrate plant emissions

Information on ammonium nitrate plant emission characteristics were drawn from two sources. Kirova-Yordanova (2010) examined an application of the exergy method to environmental impact estimation using ammonium nitrate production as a case study. That paper considered a range of emissions and liquid effluents with atmospheric emissions including ammonia and ammonium nitrate dust and droplets from the process stream; ammonia and ammonium nitrate dust from the prilling tower air; carbon dioxide and oxides of nitrogen from vent and flue gas streams from the ammonia plant and oxides of nitrogen and nitrous oxide from the nitric acid plant.

The summary emissions thus include ammonia, ammonium nitrate dusts and droplets, carbon dioxide, oxides of nitrogen and nitrogen dioxide. These substances are generally consistent with the information in the Commissioning report (Yara, 2017a) which specified monitoring during commissioning for particulates, ammonia, oxides of nitrogen (as nitrogen dioxide) and nitrous oxide. The Yara Baseline Air Quality Monitoring Report (Yara, 2017b) included nitrogen dioxide, ammonia, sulphur dioxide, and nitric acid as nitrate which were specified by EPBC Condition 9 excluding nitric acid which was included for comparison with historical data. The ERM (2012) draft air quality assessment update report undertook some dispersion modelling and considered TSP, PM_{10}, $PM_{2.5}$, ammonia, nitric acid in addition to examining dust and acid deposition.

For the purposes of this brief overview, the key substances include those that may be associated with short-term effects due to lower residence times for populations of interest such as visitors and tourists. It is understood that these population groups may visit the area around Hearson Cove. The substances would include particulates, ammonia, oxides of nitrogen (as nitrogen dioxide), sulphur dioxide and nitric acid (as nitrates).

Summary toxicological, relevant epidemiological information and Australian guidance are presented in

Table1.

Summary of current settings and relevant published information on health issues

Preliminary evaluation of the nature of the process emissions based on the plant characteristics from both proponent data and independent sources suggests a group of substances exhibiting both acute health effects following exposure. These substances present respiratory concerns following inhalation exposure as detailed in Table 1-1 with a range of debilitating outcomes. The nature of these inhalational toxicities is well recognised in Australia and is embedded within regulatory frameworks structured by the various State environment agencies for air quality assessment through both dispersion modelling and measurement methods. These measurement methods are focussed on short-term monitoring and long-term monitoring reflecting the inherent exposure and risk outcomes for pollutants such as fine particles, oxides of nitrogen, sulphur dioxide, ammonia and nitric acid. All of these substances exhibit short-term irritant effects as an initial exposure outcome with progressive severity with increasing intensity of exposure. As such, there exists a potential for adverse outcomes associated with relatively transient exposures as may occur with visitors or tourists in close proximity to the plant emissions.

While the toxicological information on these substances is extensive, epidemiological information specific to populations living around ammonium nitrate or fertiliser plants is limited. One study reported in the peer-reviewed literature suggested that children 1.3 to 2 km downwind of a fertiliser plant exhibited increased acute respiratory illness, however, there were some limitations to that study in relation to exposure assessment (indoor vs outdoor). Exposure assessment is the key factor in the potential health issues with the setting at the Burrup Peninsula site.

Acknowledging the complexity of air contaminant dispersion, based on a brief examination of reports, it is considered that 'worst case' scenarios have not yet been examined. For example, Figure 1 (provided by Dr John Black) suggests that monitoring locations have not been established in close proximity to the plant, e.g., in areas immediately south where registered petroglyph sites are reported nor in the prevailing wind direction in areas that may be visited by adults and children such as Hearson Cove. Note that the wind rose in Figure 1-1 is generally consistent with that presented by ERM in Figure 5.5 (p26, 2012) for Karratha Airport and that the Calmet predicted wind rose for the project site (Figure 5.6, p27, ERM 2012) further suggests a WNW prevailing direction which is more in the direction of Hearson Cove.

Taking this into account suggests that further alignment of the monitoring to predicted modelling outputs (using a non-steady state air dispersion model such as CALPUFF) is warranted. Some of this modelling has already been undertaken (ERM, 2012). The integration of such an approach is presented in regulatory documentation such as SA EPA (Figure 1, p9, 2016) which represents a risk-based approach to air quality assessment.

Table1: Summary health data and Australian criteria

Substance	Toxicology/Epidemiology[3,4,5,6,8]	Guidance[1,2,7]
Particulates		
PM_{10} and $PM_{2.5}$ Ammonium nitrate particulates	• Lung inflammatory reactions • Respiratory symptoms • Adverse effects on cardiovascular system • Increased medication use • Increased hospitalisation • Increased morbidity and mortality • Smaller particles exert greater effect. • Increased hospital admissions observed during peak exposure periods. • High exposure levels to ammonium nitrate may cause methaemoglobinaemia and body oxygen depletion.	PM_{10} 24-h average, 50 µg/m^3 Annual average, 25 µg/m^3 $PM_{2.5}$ 24-h average, 25 µg/m^3 Annual average, 8 µg/m^3 No specific level for ammonium nitrate particulates
Ammonia	• Ammonia is highly irritating to the eyes and respiratory tract. Swelling and narrowing of the throat and bronchi, coughing, and an accumulation of fluid in the lungs can occur. • Ammonia causes rapid onset of a burning sensation in the eyes, nose, and throat, accompanied by lacrimation, rhinorrhea, and coughing. Upper airway swelling and pulmonary edema may lead to airway obstruction. • Prolonged skin contact is prolonged (more than a few minutes) can cause pain and corrosive injury.	1-h average, 0.33mg/m^3
Nitrogen dioxide	• Effects on pulmonary function, especially in asthmatics • Increase in airway allergic inflammatory reactions • Increased hospitalisations • Increased mortality	1-h average, 0.24mg/m^3 Annual average, 0.06mg/m^3
Sulphur dioxide	• Effects on pulmonary function especially in asthmatics • Increased hospitalisations • Increased mortality	1-h average, 0.56mg/m^3 24-h average, 0.23mg/m^3 Annual average, 0.06mg/m^3
Nitric acid (as nitrates)	• Nitric acid is a highly corrosive, strongly oxidizing acid and may exist in the air as a gas, vapor, mist, fume, or aerosol. • Nitric acid fumes may cause immediate irritation of the respiratory tract, pain, and dyspnea, followed by a period of recovery that may last several weeks. A relapse may occur resulting in death caused by bronchopneumonia and pulmonary fibrosis. At nonlethal concentrations, allergic or asthmatic individuals appear to be sensitive to acidic atmospheres.	1-h average, 0.09mg/m^3

Table 1: Notes and references

1. DEH (2005)
2. NEPC (2015). Note this update to the Standards has introduced an annual average PM_{10} criteria and made the advisory reporting standard for $PM_{2.5}$ a standard.
3. Jalaludin B and Cowie C (2012) Health risk assessment – preliminary work to identify concentration-response functions for selected ambient air pollutants. Report prepared for EPA Victoria. Respiratory and Environmental Epidemiology, Woolcock Institute of Medical Research, Sydney.
4. ATSDR (2014) Medical management guidelines for ammonia. Agency for Toxic Substances and Disease Registry. US Department of Health and Human Services. Viewed 31 January 2018. https://www.atsdr.cdc.gov/mmg/mmg.asp?id=7&tid=2#bookmark02.
5. NIOSH (1976) Occupational Exposure to Nitric Acid. National Institute for Occupational Safety and Health, U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control.
6. ACGIH (1991) Nitric acid; Documentation of the Threshold Limit Values and Biological Exposure Indices. American Conference of Governmental Industrial Hygienists. Cincinnati, OH. pp. 1088–1089.
7. *Victorian Government Gazette*, Friday 21 December 2001, 'State Environment Protection Policy (Air Quality Management)', No. S 240, Government of Victoria, Melbourne.
8. NJ Health (2016) Hazardous Substance Fact Sheet on ammonium nitrate. New Jersey Department of Health. Viewed 01 February 2018. < http://www.nj.gov/health/eoh/rtkweb/documents/fs/0106.pdf>.

Evidence of potential for serious acute health concerns

While there is residual uncertainty regarding worst case exposure settings, evidence provided by Dr John Black (Black, 2017) reports visible plumes of yellow emissions crossing a public road and moving away from the plant (Figure 2). This photograph was taken at 16.06 on 29 April 2017 (ABC North West, 2017) and was associated with the start-up period of the nitric acid plant. A report of the incident by the company to the Western Australian Government shows the nitrogen dioxide emissions were from 15.58 to 16.07, or approximately for 10 minutes. On the basis that nitrogen dioxide appears yellow at a concentration of 0.47 ppm and a distance of one mile (Leighton, (1961) as cited in Maga (1965)), it can be estimated that the minimum concentration in that cloud is 0.99mg/m^3 and may be greater. These concentrations may be compared to US National Research Council (NRC) Acute Exposure Guideline Levels (AEGLs) for airborne contaminants (NRC, 2012). These represent short-term concentrations associated with health effects as detailed in Table 2. Table 2 presents the specific AEGLs for nitrogen dioxide.

Table 2: Acute Exposure Guideline Levels (NRC, 2012)

Acute level	Descriptor	Nitrogen dioxide criteria	Duration
AEGL1	"*AEGL-1 is the airborne concentration (expressed as ppm [parts per million] or mg/m^3 [milligrams per cubic meter]) 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.*"	0.50ppm	10 min; 30 min; 60 min; 4-h; 8-h
AEGL2	"*AEGL-2 is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.*"	20ppm 15ppm 12ppm 8.2ppm 6.7ppm	10min 30min 60min 4-h 8-h
AEGL3	"*AEGL-3 is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening adverse health effects or death*".	34ppm 25ppm 20ppm 14ppm 11ppm	10min 30min 60min 4-h 8-h

Table 2 presents a range of levels and outcomes for short-term nitrogen dioxide exposure. Based on the previous calculation, the plant emissions are at level AEGL1 or even greater. Note that the concentrations differences between the levels are not great and may be within the variability of the plume concentrations. If one examines the emission values at 16.00 on 29 April 2017, around the time the plume was photographed, the value was 579 mg per Normal cubic metres, i.e. mg/m^3 at Standard Temperature and Pressure (STP). The nitrogen dioxide release rate from the emissions point at that time was 13.8 g/s. Other reported emission concentrations at various times have up to 4 times this value (refer Yara, 2017a) suggesting that plume concentrations may be significantly higher than the visibility estimate which is a lower threshold for that specific plume. Emissions exceeded 579 mg/m^3 on 237 of the 15-minute readings during the plant commissioning period and exceeded 13.8 g/s on 76 occasions. When commissioning was nearing completion and operations were close to normal, emissions of NO_x exceeded 13.8 g/s at 18.15 on most days during August and September 2017. The time of day and magnitude of emissions of NO_x as mg/m^3 or g/s are shown in Figures 3 and 4, respectively. Only one of the 76 emissions at or above 13.8 g/s occurred during full daylight hours between 06.00 and 18.15

(Figure 4). This one release during full daylight was the one photographed by a member of the public.

Taking these considerations into account, there exists a significant potential for acute health concerns should such plumes result in transient exposures to visitors or tourists, particularly those that may be asthmatic or who have other compromised respiratory conditions.

Conclusions, data gaps and uncertainties

Taken collectively this information suggests that serious consideration be given to ensure process emissions and their distribution are well understood with an emphasis on worst case conditions for short-term exposures, particularly if high-level stack and fugitive emissions arise due to various start-up, shut-down and upset conditions.

Of particular concern are visible nitrogen dioxide containing plumes (as reported on 29 April 2017) that may result in high level short-term exposures to children or adults and potential acute effects within the immediate proximity. Records from the nitric acid plant show that concentrations and emission rates of nitrogen dioxide have exceeded the values measured on 29 April 2017 on numerous occasions and by up to four-fold. Due to the nature of these inorganic pollutants the consequences of such high-level exposure are severe and pose a serious health threat to people in the vicinity. It is important therefore to ensure exposure assessment captures these transient exposures in areas where people are present.

Substances of interest should include all demonstrated process emissions as presented in Table 1 including $PM_{2.5}$ which although considered in the modelling was not considered in the monitoring to date. The monitoring of this particulate size fraction has recently been confirmed as an Ambient Air Standard (NEPC 2015). This should also include quantitative evaluation of particles for ammonium nitrate as a hazardous chemical characteristic of fine particles.

While a range of investigations have been undertaken further monitoring and evaluation is recommended to address the uncertainty of severe short-term exposures to transient populations in proximity of the emission sources. This will ensure that potential human health risks are appropriately mitigated as may be required.

Figure 1: Regional data on plant location, existing monitoring sites, proposed, petroglyph sites and wind rose

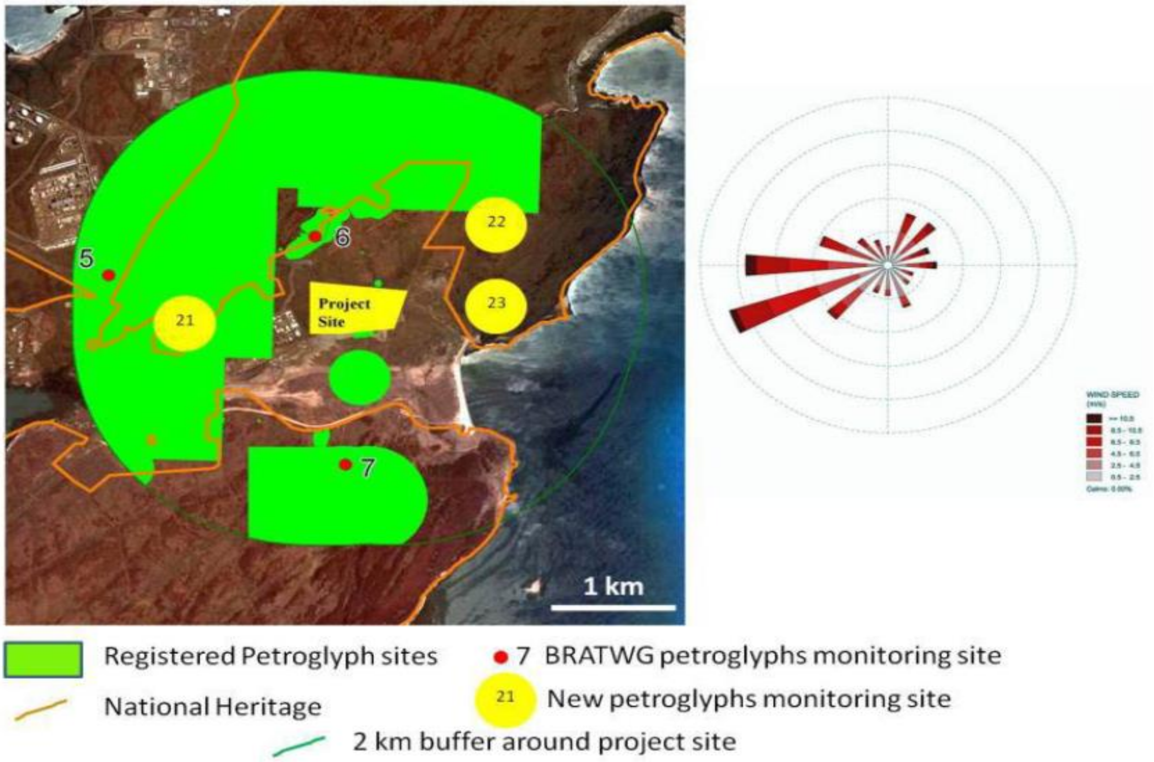


Figure 2: New sites (Yellow numbers) with dominant wind directions and speed.

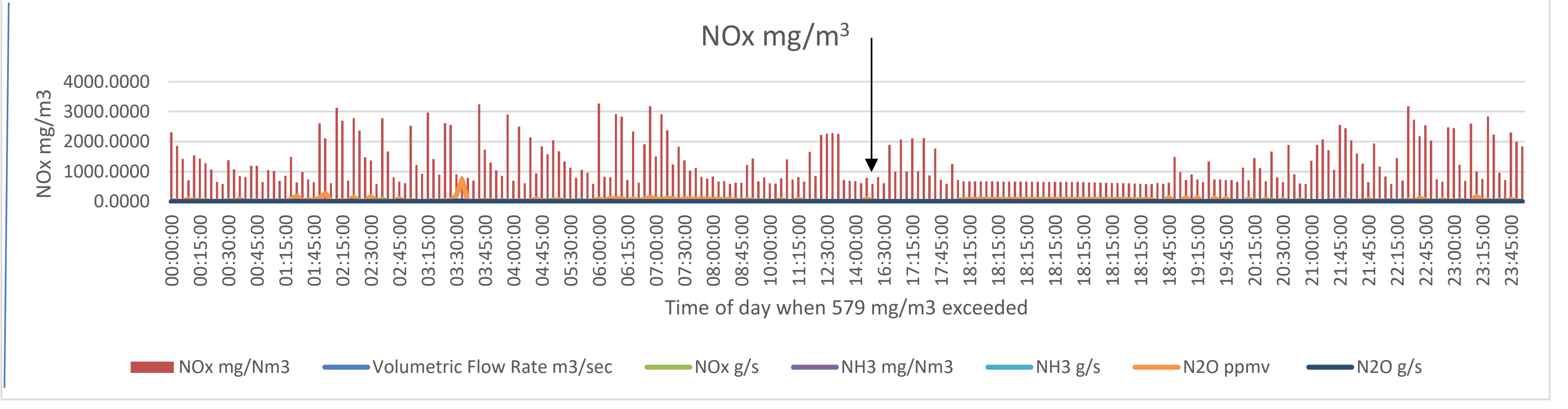
Figure 2: Yellow nitrogen dioxide cloud visible at centre of picture (from ABC Karratha, photo by Erin Kelly Hardy)

THE UNIVERSITY of ADELAIDE

Adelaide Exposure Science and Health

(formerly OEH Consulting)

Figure 3: Time of day when Nitric Acid stack emissions exceeded 579 mg/m³, the concentration when the nitrogen dioxide cloud was visible (arrow).

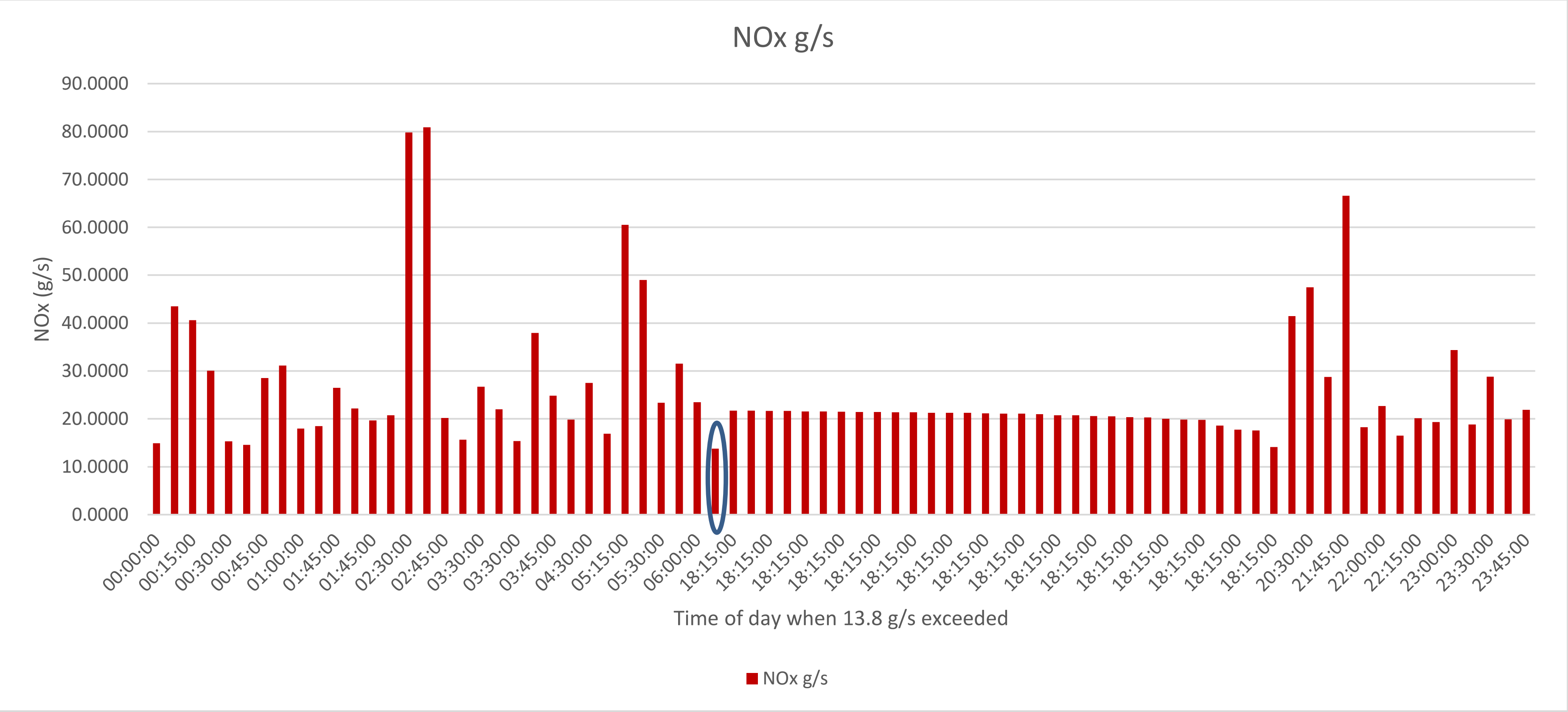


THE UNIVERSITY of ADELAIDE

Adelaide Exposure Science and Health

(formerly OEH Consulting)

Figure 4: Time of day when Nitric Acid stack emissions exceeded 13.8 g/s, the concentration when the nitrogen dioxide cloud was visible. Only one emission occurred in full daylight between 06.00 and 18.15 and this was the one photographed (circled).



THE UNIVERSITY of ADELAIDE

Adelaide Exposure Science and Health

(formerly OEH Consulting)

In Closing
If you have any further queries, please do not hesitate to contact me on 08 8313 3571 or by email on dino.pisaniello@adelaide.edu.au.

Yours sincerely

Dino Pisaniello

Professor in Occupational and Environmental Hygiene
School of Public Health
The University of Adelaide, AUSTRALIA 5005
Ph.: +61 8 8313 3571
Fax: +61 8 8313 4955
E-mail: dino.pisaniello@adelaide.edu.au
CRICOS Provider Number 00123M

--

Len Turczynowicz

BAppSc MPH PhD (Med) MRACI CChem
Senior Public Health Scientist & Risk Assessor
Adelaide Exposure Science and Health, ABN 612 498 78937
School of Public Health, University of Adelaide
AUSTRALIA 5005
Ph: +61 8 8313 4956
Fax: +61 8 8313 4955
e-mail: leonid.turczynowicz@adelaide.edu.au
CRICOS Provider Number 00123M

--

References

ABC North West (2017). Social media post, "Yara NO2 leak, May 2017". Kendall O'Connor, ABC North West.

ACGIH (1991) Nitric acid; Documentation of the Threshold Limit Values and Biological Exposure Indices. American Conference of Governmental Industrial Hygienists. Cincinnati, OH. pp. 1088–1089.

ATSDR (2014) Medical management guidelines for ammonia. Agency for Toxic Substances and Disease Registry. US Department of Health and Human Services. Viewed 31 January 2018. https://www.atsdr.cdc.gov/mmg/mmg.asp?id=7&tid=2#bookmark02

Black JL (2017) Detailed information on effects of industry on rock art Burrup Peninsula. Report to Friends of Australian Rock Art, 31 October 2017.

DEH (2005) National standards for criteria air pollutants in Australia. Viewed 31 January 2018. < http://www.environment.gov.au/protection/publications/factsheet-national-standards-criteria-air-pollutants-australia>.

ERM (2012) Draft Burrup Peninsula Technical Ammonium Nitrate Production Facility Air Quality Assessment Update. Environmental Resources Management Australia, Docklands, Victoria.

Gomzi M and Saric M (1997) Respiratory impairment among children living in the vicinity of a fertiliser plant. *Int Arch Occup Environ Health*, 70: 314-320.

Jalaludin B and Cowie C (2012) Health risk assessment – preliminary work to identify concentration-response functions for selected ambient air pollutants. Report prepared for EPA Victoria. Respiratory and Environmental Epidemiology, Woolcock Institute of Medical Research, Sydney.

Kirova-Yordanova, Z (2010) Application of the exergy method to environmental impact estimation: The ammonium nitrate production as a case study. *Energy*, 35: 3221-3229.

Leighton PA (1961) Photochemistry of air pollution. Academic Press, New York.

Maga JA ((1965) Considerations in Setting Standards for Oxides of Nitrogen. Journal of the Air Pollution Control Association, 15:12, 561-564, DOI:10.1080/00022470.1965.10468423.

NEPC (2015) Variation to the Ambient Air Quality NEPM – particles standards. Viewed 31 January 2018. http://www.nepc.gov.au/resource/variation-ambinet-air-quality-nepm-particle-standards.

NIOSH (1976a) NIOSH Criteria for a Recommended Standard. (HEW(NIOSH) 76-141). [Jan. 29, 2013]. National Institute for Occupational Safety and Health, Washington, DC. [online]. Available: <http://www.cdc.gov/niosh/docs/1970/76-141.html>.

NJ Health (2016) Hazardous Substance Fact Sheet on ammonium nitrate. New Jersey Department of Health. Viewed 01 February 2018. <http://www.nj.gov/health/eoh/rtkweb/documents/fs/0106.pdf>.

NRC (2012) Acute Exposure Guideline Levels for Selected Airborne Chemicals. Volume 11. Committee on Acute Exposure Guideline Levels/Committee on Toxicity. National Research Council, Washington, D.C.

SA EPA (2016) Ambient air quality assessment. South Australian Environment Protection Authority, Adelaide, South Australia.

Victorian Government Gazette, Friday 21 December 2001, ‘State Environment Protection Policy (Air Quality Management)’, No. S 240, Government of Victoria, Melbourne.

Yara (2017a) Works Approval W4701/2010/1. Commissioning Report. Technical Ammonium Nitrate Plant. Yara Pilbara Nitrates Pty Ltd. Perth, Western Australia.

Yara (2017b) Yara Pilbara Nitrates. EPBC Approval 2008/4546. Baseline Air Quality Monitoring Report. Yara Pilbara Nitrates Pty Ltd. Perth, Western Australia.