AQMRAT Reference: C170_Rp01

Project Title: Impact investigation of accidental release of formaldehyde at Kronospan Limited site, Wales on 20th October 2015

1. Introduction

1.1 Formaldehyde vapour and process gas was accidently released from the Formalin Plant at Kronospan Limited site, Holyhead Road, Chirk, Wrexham, on 20th October 2015. The Air Quality Modelling and Risk Assessment Team (AQMRAT) was asked by NRW North PPC Compliance team to carry out an impact assessment on this accidental release.

1.2 Schedule 1 Notification of Abnormal Emissions was submitted by the operator, which includes a report "Appendix 1 - Formalin Plant Process Gas Release 20/10/2015 Investigation Report". The investigation report stated that:

"The concentration of the process gas from tower 2 would be approximately:

Nitrogen	*91.8%*
Oxygen	*5%*
Carbon Monoxide	*1%*
Methanol	*0.2%*
Formaldehyde	*2%*

Estimation of quantity emitted
Gas flow rate through the process is ~ 29000 kg / hr, of which (from vent area estimation) ~ 25% would have been vented to atmosphere.
(i.e. ~ 109 kg of Formaldehyde gas emitted, based on 45 minutes before source located & plant shut down."

"Consequences
Approximately 3625 kg of process gas, containing an estimated quantity of 109 kg of Formaldehyde was emitted to atmosphere, between ~ 07:30 & 08:15 on Tuesday 20/10/2015".

1.3 At the request of AQMRAT, the operator provided further source term information in an e-mail to NRW dated on 13 November 2015. For the emission rate, the e-mail stated "total process gas flow of 29000 kg/hr (plant data) vent area ~ 1/4 of that of process gas pipe out of absorber estimate 5437.5 kg of process gas emitted in the (maximum of) 45 minutes between odour 1st noticed & plant shut down."

2. Literature review on formaldehyde

Human Exposure and toxicity[1]

2.1 Formaldehyde is a colorless, flammable gas with a strong smell.

- Acute effects of airborne formaldehyde exposure: Odor detection, 0.05-1.0 ppm;
- Eye irritation, 0.01-2 ppm;
- Upper respiratory tract irritation (e.g., irritation of the nose or throat), 0.10-11 ppm;
- Lower airway irritation (e.g., cough, chest tightness, and wheezing), 5-30 ppm;
- Pulmonary edema, inflammation, pneumonia, 50-100 ppm;
- Death >100 ppm.
- Formaldehyde can provoke skin reactions in sensitized subjects, not only by contact but also by inhalation. According to International Agency for Research on Cancer (IARC), there is sufficient evidence in humans for the carcinogenicity of formaldehyde;
- Formaldehyde causes cancer of the nasopharynx and leukemia. Also, a positive association has been observed between exposure to formaldehyde and sinonasal cancer.

Physical properties in terms of exposure[2]

2.2 Lower Explosive Limit (LEL): 7 % (NIOSH[3], 2003)
Upper Explosive Limit (UEL): 73 % (NIOSH, 2003)

Assessment criteria

2.3 *US EPA Acute Exposure Guideline Levels for Airborne Chemicals*

Acute Exposure Level Guidelines (AEGLs) are used by emergency planners and responders worldwide as guidance in dealing with rare, usually accidental, releases of chemicals into the air. AEGLS are expressed as specific concentrations of airborne chemicals at which health effects may occur. They are designed to protect the elderly and children, and other individuals who may be susceptible.

2.4 AEGLs are calculated for five relatively short exposure periods – 10 minutes, 30 minutes, 1 hour, 4 hours, and 8 hours – as differentiated from air standards based on longer or repeated exposures. AEGL "levels" are dictated by the severity of the toxic effects caused by the exposure, with Level 1 being the least and Level 3 being the most severe.

2.5 All levels are expressed as parts per million or milligrams per cubic meter (ppm or mg/m^3) of a substance above which it is predicted that the general population could experience, including susceptible individuals:

[1] US National Library of Medicine, Toxicology Data Network, http://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~jrtihr:1.
[2] CAMEO Chemicals, http://cameochemicals.noaa.gov/.
[3] The US National Institute for Occupational Safety and Health

- **Level 1 -** 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 2 -** Irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

- **Level 3 -** Life-threatening health effects or death.

- **Below AEGL Level 1 -** Airborne concentrations below the AEGL-1 represent exposure levels that could produce mild and progressively increasing but transient and non-disabling odor, taste, and sensory irritation or certain asymptomatic, non-sensory effects. With increasing airborne concentrations above each AEGL, there is a progressive increase in the likelihood of occurrence and the severity of effects described for each corresponding AEGL.

Interim AEGLs for Formaldehyde (50-00-0)

Exposure Period	AEGL-1	AEGL-2	AEGL-3
10 minutes	0.9 ppm	14 ppm	100 ppm
30 minutes	0.9 ppm	14 ppm	70 ppm
60 minutes	0.9 ppm	14 ppm	56 ppm
4 hours	0.9 ppm	14 ppm	35 ppm
8 hours	0.9 ppm	14 ppm	35 ppm

US National Research Council, National Academy of Science (NAC/NRC), 2014

2.6 Environment Agency Horizontal Guidance H1
In H1 Annex F (2011) **Table B5: Environmental Assessment Levels For Air (For The Protection Of Human Health),** hourly EAL value for formaldehyde is 100 µg/m^3.

2.7 Hourly average thresholds for AEGL and EAL were used in the modelling assessment.

3. Modelling impact assessment

Model selection

3.1 ALOHA 5.4.5 and ADMS 5.1 were used in this incident impact assessment.

- US EPA ALOHA model is the hazard modeling program for the CAMEO software suite, which is used widely to plan for and respond to chemical emergencies. ALOHA allows one to enter details about a real or potential chemical release, and then it will generate threat zone estimates for various types of hazards. ALOHA can model toxic gas clouds, flammable gas clouds, BLEVEs (Boiling Liquid Expanding Vapor Explosions), jet fires, pool fires, and vapor cloud explosions. Since most first responders do not have dispersion modeling backgrounds, ALOHA has been

designed to require input data that is either easily obtained or estimated at the scene of an accident.

- UK ADMS 5.1 is an advanced dispersion model and widely used to model the air quality impact of existing and proposed industrial installations**.**

Model input parameters

3.2 Model input parameters were obtained from the operators' information.

Parameters	Values
Release point NGR	328714, 338606
Formaldehyde emission rate	109 kg/45 minutes
Height of source	14 m
Diameter of vent	0.3 m
Exit velocity	0 m/s*
Exit temperature	28 ˚C
Surface roughness	0.5 m#
Met data	Met Office UM NWP data with 1.5 km resolution, extracted at the site location

* 'china man's hat' will divert the direct flow to be diffused horizontal.

Estimated based on the Aerial map of the site.

Modelling scenarios

3.3 Three hourly modelling was carried out for 6:00 - 7:00 (BST), 7:00 - 8:00 (BST) and 8:00 - 9:00 (BST) on 20th October 2015.

Modelling results

3.4 ALOHA modelling results suggested that for the reported incident, the AEGL_1 was exceeded at a downwind zone up to a distance of 420 – 1350 m. With the meteorological condition at 8:00 – 9:00, ALOHA predicted likely exceedance of AEGL_2 at a zone close to the source.

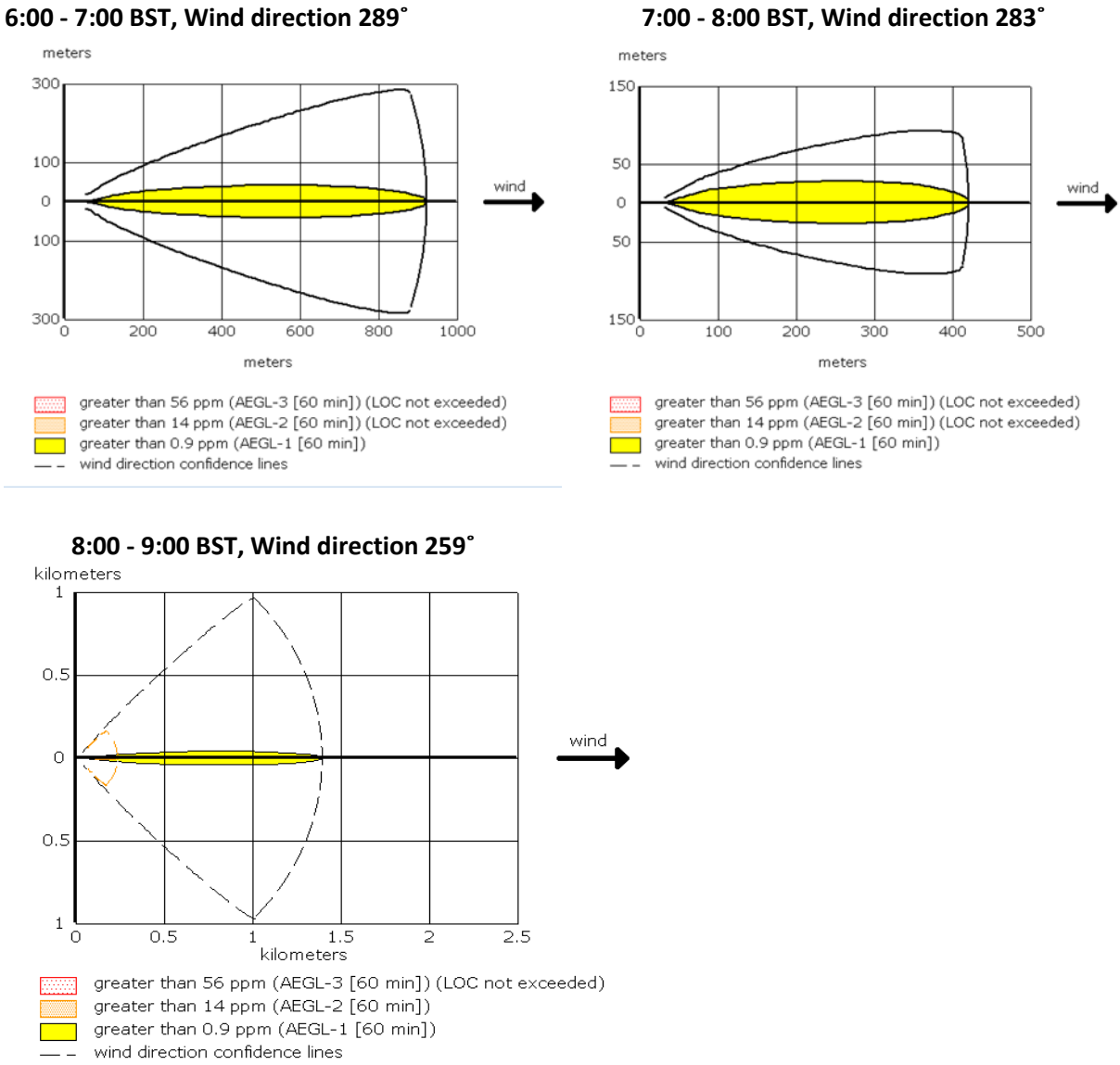

Figure 1. ALOHA predictions at three hours during incident.

3.5 For formaldehyde, 1 ppm = 1.23 mg/m^3 at 25˚C. In Figure 2, the black concentration contour represents 1107 µg/m^3 (0.9 ppm, AEGL_1) and red concentration contour is 100 µg/m^3 (EA EAL). ADMS predicted that at each of the modelled hours, the AEGL_1 would be exceeded at close by downwind resident receptors; and the EA EAL would be exceeded at a much wider scale. However, AEGL_2 exceedance was not predicted.

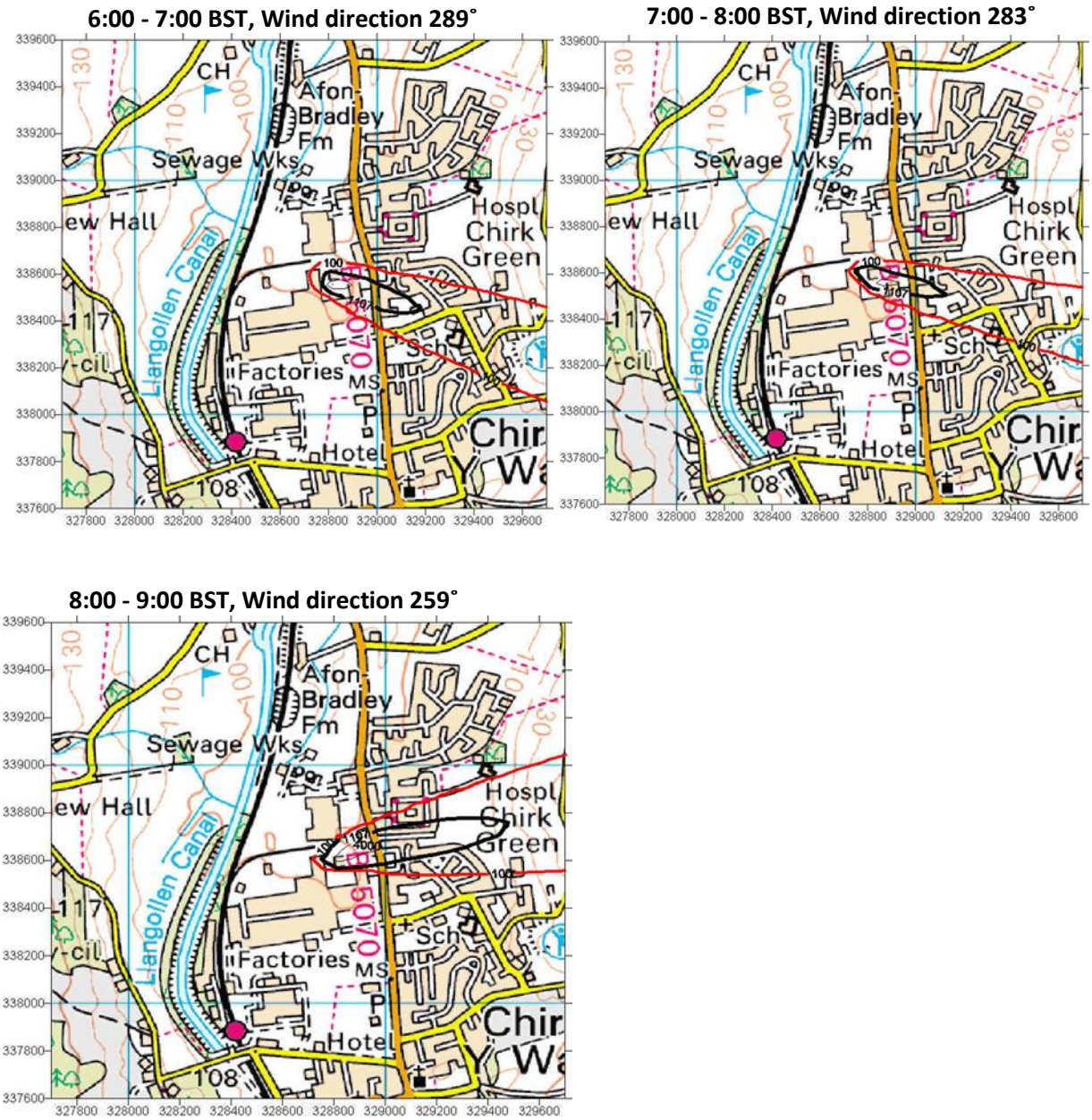

Figure 2. ADMS predictions at three hours during incident.

Discussion and uncertainty

3.6 The operator reported that the formaldehyde concentration in the released gas was 2%, which was smaller than the Lower Explosive Limit (LEL) of 7 %, therefore, ALOHA did not predict explosion.

3.7 CAMEO Chemicals database (and references therein) suggests that the odour

of formaldehyde would be detectable at a concentration of up to 1 ppm (1.23 mg/m^3). Both models predicted that it was likely for odour exposure at the resident area close to and downwind the source.

3.8 ADMS can only deal with neutrally buoyant air dispersion but not heavy gas. Based on the provided component and concentration of the progress gas, we conclude that it was not a heavy gas release, therefore ADMS model can be used. ADMS is expected to provide a more robust air dispersion prediction than ALOHA.

3.9 Looking at the aerial map, we believe that the surface roughness of 0.5 m would reflect the area of interest. We have also carried out sensitivity analysis with a surface roughness of 0.2 m. The previously predicted exceedance of AEGL_2 by ALOHA was not seen. However, this will not change the conclusions.

3.10 The exact release time and duration was not known. We have carried out assessment for each hour covering the whole period of possible release. The emission rate was based on the provided information of 109 kg/45 minutes.

4. **Conclusions**

4.1 Based on the provided information about the Process gas component and concentration, potential impact due to explosion was unlikely.

4.2 Both ALOHA and ADMS predicted that the AEGL_1 would be exceeded at the resident area close to and downwind the accidental release point. EA EAL would be exceeded at a wider scale. However, the exceedance of AEGL_2 was unlikely.

4.3 Both models predicted that it was likely for odour exposure at the resident area close to and downwind the source.

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