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ENVIRONMENTAL PROTECTION DIVISION

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MEMORANDUM

June 7, 2019

To: James Boylan
Thru: Byeong-Uk Kim
From: Yan Huang
Subject: **Modeling Analysis for Ethylene Oxide**
Becton Dickinson (formerly, C. R. Bard), Covington, Newton County, GA

GENERAL INFORMATION

As part of a review on the EPA 2014 National Air Toxics Assessment (NATA), air dispersion modeling of ethylene oxide was conducted by the Georgia Environmental Protection Division (GA EPD) to assess the impacts of ethylene oxide emissions from Becton Dickinson (AIRS# 21700021) on ambient air surrounding the facility. Although this modeling analysis is not for issuance of a permit, GA EPD adopted procedures described in GA EPD's *Guideline for Ambient Impact Assessment of Toxic Air Pollutant Emissions*[1].

This memo discusses modeling results including the procedures used to develop the dispersion modeling. Becton Dickinson sterilizes packaged medical equipment shipped from other locations using ethylene oxide. After sterilization, the ethylene oxide is displaced with air and vented to a regenerative thermal oxidizer (RTO) and 14 exhaust fans. The air toxic impacts from ethylene oxide emissions was below its Acceptable Ambient Concentration (AAC) at the 15-min averaging period, but exceeded its annual AAC. Site-specific risk assessments were performed at five nearby residential areas and the modeled ground-level concentrations exceeded the annual AAC at all five residential areas. The results are summarized in the following sections of this memorandum.

INPUT DATA

1. **Meteorological Data** – Hourly meteorological data (2014 to 2018) used in this review were generated by GA EPD (http://epd.georgia.gov/air/georgia-aermet-meteorological-data). Surface measurement obtained from the Hartsfield-Jackson Atlanta Airport at Atlanta, GA. Upper air observations were obtained from the Atlanta Regional Airport – Falcon Field at Peachtree City, GA. These measurements were processed using the AERSURFACE (v13016), AERMINUTE (v15272), and AERMET (v18081) with the adjusted surface friction velocity option (ADJ_U*).
2. **Source Data** – Emission release parameters and emission rates were provided by the company and reviewed by the GA EPD Stationary Source Permitting Program. The point source emissions are exhausted from the facility's stack connected to an RTO, and the non-point fugitive emissions are exhausted from a total of 14 exhaust fans. Based on Becton Dickinson's submittal, the ethylene oxide

1 https://epd.georgia.gov/air/documents/toxics-impact-assessment-guideline

annual emissions in 2017 were 101.7 lbs from the RTO and 555.7 lbs from the 14 exhaust fans (see Appendix A for details).

3. **Receptor Locations** – Discrete receptors with 25-meter intervals were placed on a Cartesian grid along the fence-line. Receptors extend outwards from the fence-line at 100-meter intervals to approximately 2 kilometers, at 250-meter intervals to approximately 5 kilometers, and at 500-meter to approximately 12.5 kilometers. This domain (25 km by 25 km) is sufficient to capture the maximum impact. Additional receptors were placed at five nearby residential areas. The nearest residence is located approximately 270 meters east of the facility. All receptor locations are represented in the Universal Transverse Mercator (UTM) projections, Zone 17, North American Datum 1983.
4. **Terrain Elevation** – Topography was found to be generally flat in the site vicinity. Terrain data from USGS 1-sec National Elevation Dataset (NED) were extracted to obtain the elevations of all sources and receptors by the AERMAP terrain processor (v18081).
5. **Building Downwash** – The potential effect for building downwash was evaluated via the "Good Engineering Practice (GEP)" stack height analysis and was based on the scaled site plan submitted by the facility using the BPIPPRM program (version 04274). The BPIPPRM model was used to derive building dimensions for downwash assessment and the assessment of cavity-region concentrations appropriate for the AERMOD model.

AIR TOXICS ASSESSMENT

The impacts of facility-wide ethylene oxide emissions were evaluated according to the Georgia Air Toxics Guideline available at https://epd.georgia.gov/air/documents/toxics-impact-assessment-guideline. The annual and 15-minute AACs were reviewed based on U.S. EPA Integrated Risk Information System (IRIS) Risk Based Air Concentration (RBAC) and OSHA Permissible Exposure Limit (PEL) according to the Georgia Air Toxics Guideline (see Appendix B for details). The EPA NATA used a different annual AAC value (see Appendix C for details). For this assessment, GA EPD used the annual AAC derived according to the Georgia Air Toxics Guideline and took two approaches to evaluate the impacts. The first approach (described in the Georgia Air Toxics Guideline) selects the year with the highest annual modeled maximum ground-level concentrations (MGLC) from the 5-year modeling period and uses this year in the assessment. The second approach calculates the maximum annual modeled concentrations averaged over the 5-year modeling period. The modeled 1-hour and annual ground-level concentrations were calculated using the AERMOD dispersion model (v18081).

Analysis with the Highest 5-Year MGLCs

Table 1 summarizes the AAC levels and the MGLCs from the year with the highest value. The 15-min MGLC is based on the 1-hour MGLC multiplied by a factor of 1.32. The 15-min MGLC was below its corresponding 15-min AAC. However, the annual MGLC exceeded the annual AAC. Figure 1 shows the spatial distributions of ground level concentrations with the 2015 meteorological data (the year with the highest MGLC). Figure 2 shows a close-up look of modeled concentrations centered at the facility with the five nearby residential areas labeled. The MGLCs of the five closest residences are shown in Table 2. The areas inside the green lines indicate that the MGLC exceeds the ethylene oxide AAC annual level.

Table 1. Modeled highest 5-year MGLCs and the Respective AACs.

Averaging period	MGLC (µg/m^3)*	AAC (µg/m^3)
Annual	0.163	0.00033
15-min	3.688	900

* The highest concentration over all averaging periods was modeled in 2015.

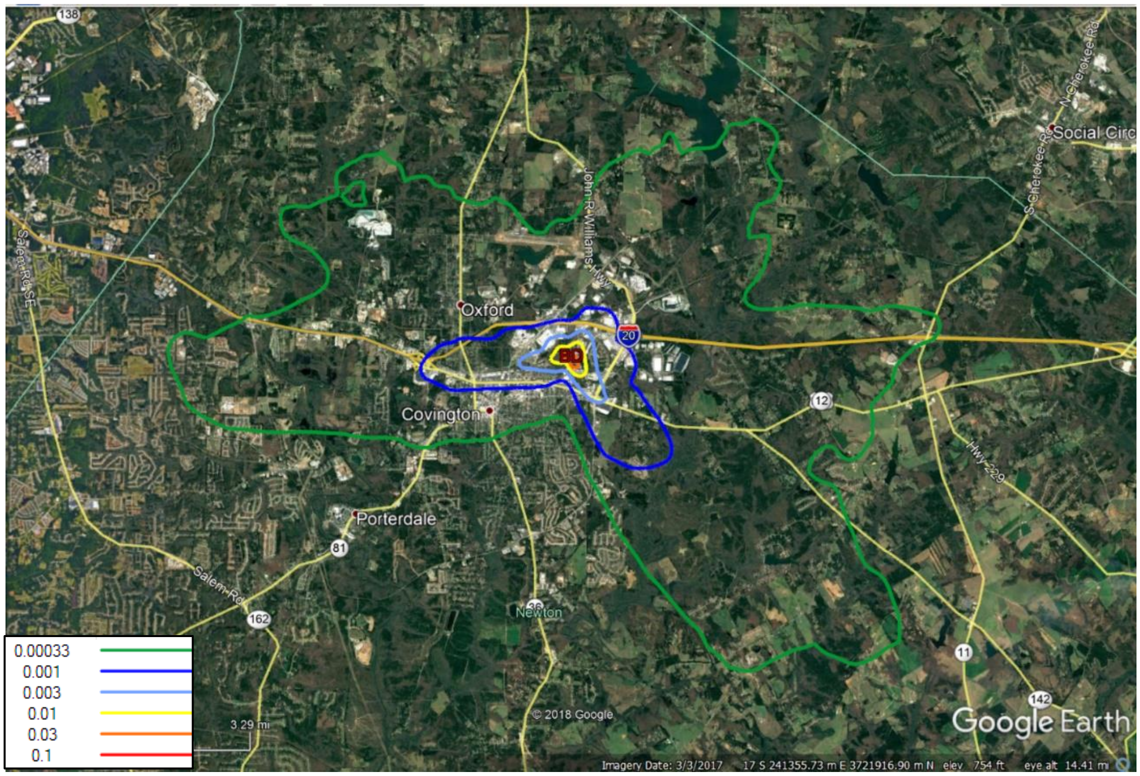

Figure 1. Contours of annual average ground-level concentrations overlaid on a Google Earth map for 2015 (the year with the highest modeled MGLC).

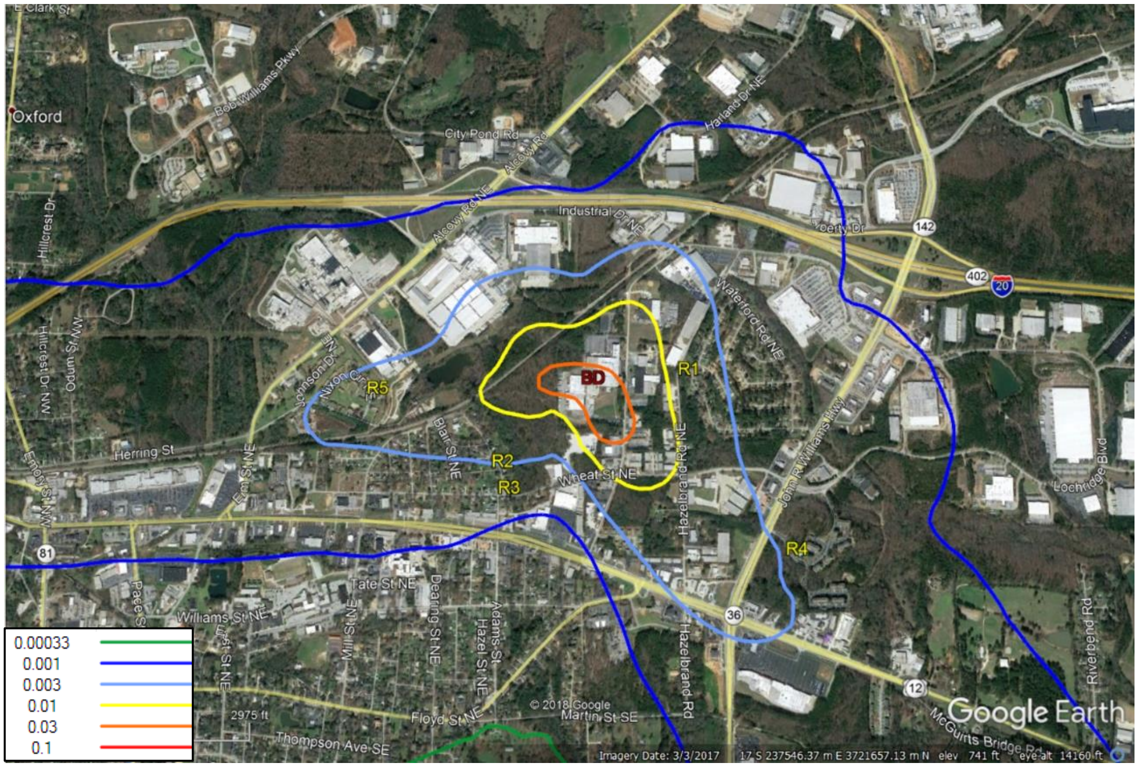

Figure 2. A close-up look of Figure 1 with the closest residential areas labeled.

Table 2. Risk Analysis for Residential Areas with Modeled highest 5-year MGLCs.

Residential Areas	Receptor UTM Zone: 17		MGLC (µg/m³)*	Averaging Period	AAC (µg/m³)	Ratio of MGLC (µg/m³) to AAC (µg/m³)
	Easting (meter)	Northing (meter)				
R1	236,932.5	3,722,361.2	0.032	Annual	0.00033	97
R2	236,137.9	3,721,995.0	0.011	Annual	0.00033	34
R3	236,163.0	3,721,885.6	0.008	Annual	0.00033	23
R4	237,343.8	3,721,603.8	0.012	Annual	0.00033	38
R5	235,611.0	3,722,319.2	0.014	Annual	0.00033	42

* The highest concentration over all averaging periods was modeled in 2015.

Analysis with 5-Year Average Ground-level Concentrations

To further assess the impact over longer period, maximum values from the 5-year averaged ground-level concentrations are summarized in Table 3. Contours of modeled annual ground-level concentrations averaged over the 5-year period are shown in Figure 3. Figure 4 shows a close-up look centered at the facility with the five nearby residential areas labeled. The 5-year averaged modeled ground-level concentrations of the five nearby residential areas are shown in Table 4.

Table 3. Modeled Maximum 5-year Annual Average Ground-level Concentrations and the Respective AAC.

Averaging period	MGLC (μg/m³)*	AAC (μg/m³)
Annual	0.144	0.00033

* The maximum of ground-level concentration averaged over 5 years.

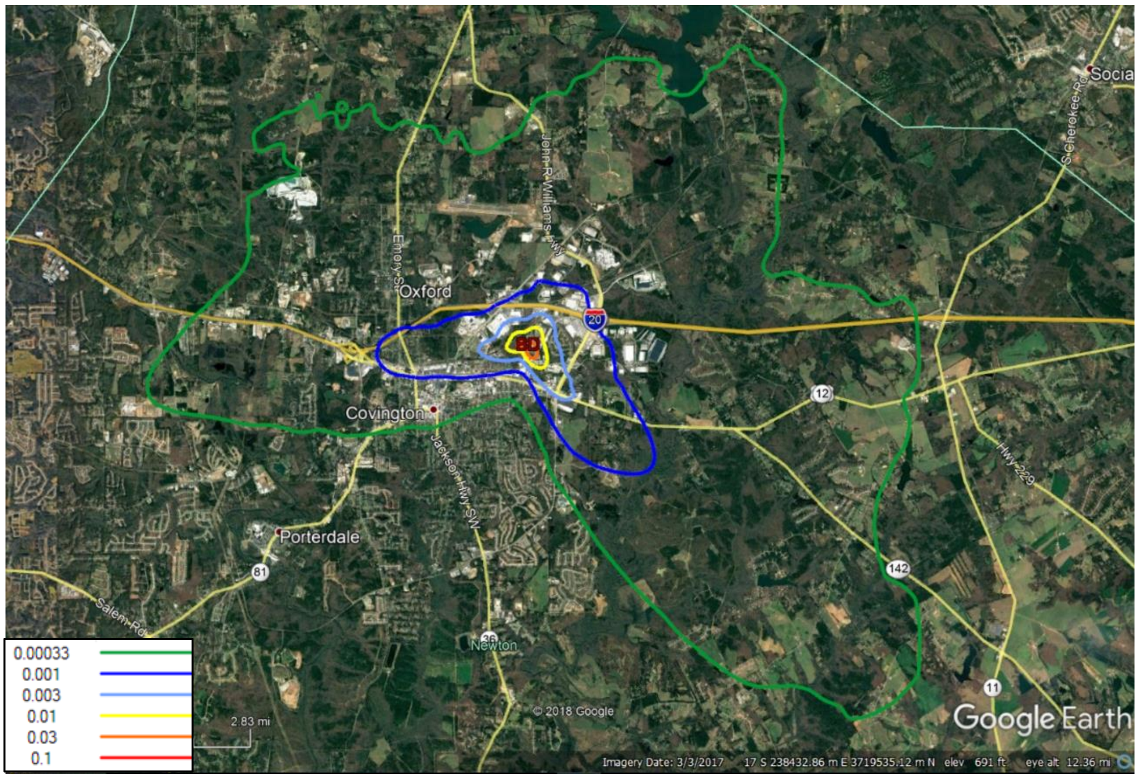

Figure 3. Contours of 5-year annual average ground-level concentrations modeled overlaid on a Google Earth map.

Figure 4. A close-up look of Figure 3 with the closest residential areas labeled.

Table 4. Risk Analysis for Residential Areas with 5-year Average Ground-level Concentrations.

Residential Areas	Receptor UTM Zone: 17		MGLC (µg/m³)*	Averaging Period	AAC (µg/m³)	Ratio of Ground-level Concentration (µg/m³) to AAC (µg/m³)
	Easting (meter)	Northing (meter)				
R1	236,932.5	3,722,361.2	0.028	Annual	0.00033	84
R2	236,137.9	3,721,995.0	0.009	Annual	0.00033	27
R3	236,163.0	3,721,885.6	0.006	Annual	0.00033	17
R4	237,343.8	3,721,603.8	0.010	Annual	0.00033	32
R5	235,611.0	3,722,319.2	0.012	Annual	0.00033	35

CONCLUSIONS

The dispersion modeling analysis for ethylene oxide shows exceedances at the annual AAC level with the revised 2017 emissions submitted by the facility. The risk assessment indicates that the ethylene oxide concentrations at the nearby residential areas are well above the AAC level (17-97 times).

Appendix A

Revised Emissions for Year 2017 and Model Input Parameters

Ethylene Oxide (EtO) Emissions

Emission Source	2017 EtO Emissions (lb/yr)
RTO	101.7
Fugitives	555.7

Model Input Parameters for EtO Emissions Sources

Model ID	Stack Description	Source Type	UTM E[1] (m)	UTM N[1] (m)	Emis %	Modeled EtO Emissions[3] (g/s)	Stack Height		Stack Temperature		Exhaust Gas Flow Rate (cfm)	Exit Velocity		Stack Diameter	
							(ft)	(m)	(°F)	(K)		(ft/s)	(m/s)	(inch)	(m)
EF17	Exhaust Fan	POINT	236,448.9	3,722,282.1	4%	3.197E-04	30.0	9.144	70	294.26	10,000	34.0	10.363	30.0	0.762
EF18	Exhaust Fan	POINT	236,450.5	3,722,304.2	4%	3.197E-04	30.0	9.144	70	294.26	10,000	34.0	10.363	30.0	0.762
EF20	Exhaust Fan	POINT	236,452.0	3,722,280.9	4%	3.197E-04	30.0	9.144	70	294.26	10,000	34.0	10.363	30.0	0.762
EF21	Exhaust Fan	POINT	236,473.6	3,722,300.3	4%	3.197E-04	30.0	9.144	70	294.26	10,000	34.0	10.363	30.0	0.762
EF22	Exhaust Fan	POINT	236,485.7	3,722,302.2	10%	7.993E-04	36.0	10.973	70	294.26	24,000	37.9	11.552	44.0	1.118
EF23	Exhaust Fan	POINT	236,489.1	3,722,324.3	10%	7.993E-04	25.0	7.620	70	294.26	24,000	36.2	11.034	45.0	1.143
EF24	Exhaust Fan	POINT	236,487.8	3,722,345.4	10%	7.993E-04	25.0	7.620	70	294.26	24,000	36.2	11.034	45.0	1.143
EF25	Exhaust Fan	POINT	236,470.2	3,722,347.0	10%	7.993E-04	25.0	7.620	70	294.26	24,000	36.2	11.034	45.0	1.143
EF26	Exhaust Fan	POINT	236,449.8	3,722,348.7	10%	7.993E-04	25.0	7.620	70	294.26	24,000	36.2	11.034	45.0	1.143
EF44*	Exhaust Fan	POINT	236,432.1	3,722,277.0	5%	3.996E-04	28.0	8.534	70	294.26	13,200	40.0	12.192	31.8	0.808
EF45*	Exhaust Fan	POINT	236,433.7	3,722,301.4	5%	3.996E-04	28.0	8.534	70	294.26	13,200	40.0	12.192	31.8	0.808
EF47	Exhaust Fan	POINT	236,429.5	3,722,320.3	8%	6.394E-04	25.0	7.620	70	294.26	21,200	33.5	10.211	44.0	1.118
EF48	Exhaust Fan	POINT	236,431.1	3,722,342.5	8%	6.394E-04	25.0	7.620	70	294.26	21,200	33.5	10.211	44.0	1.118
EF49	Exhaust Fan	POINT	236,445.2	3,722,348.8	8%	6.394E-04	25.0	7.620	70	294.26	21,200	33.5	10.211	44.0	1.118
RTO	regenerative thermal oxidizer	POINT	236,424.2	3,722,295.0	N/A	1.463E-03	50.0	15.240	250	394.26	23,000	30.5	9.296	48.0	1.219

Notes:

1. Coordinates reflect UTM NAD83, Zone 17. EF20 coordinates were revised based on site plan
2. EF44 and EF45 - Roof mounted uplast type fan, modeled diameters were derived from flow rate and exit velocity
3. EF23~26 - Rectangular Duct shows as the round equivalent

Appendix B

GA EPD Calculation of the Annual and 15-min AAC
for Ethylene Oxide

GA EPD Calculation of the Annual and 15-min AAC for Ethylene Oxide

According to the GA EPD's *Guideline for Ambient Impact Assessment of Toxic Air Pollutant Emissions*, the annual and 15-min AAC for ethylene oxide are calculated as following:

Annual AAC

In the EPA Integrated Risk Information System (IRIS), the Inhalation Unit Risk (IUR) for ethylene oxide is 3×10^{-3} $\mu g/m^3$. Since ethylene oxide is carcinogenic to humans, it belongs to Group A[2] with a cancer risk of 1/1,000,000. Therefore, the annual AAC is calculated as:

$$\text{Annual AAC} = \text{cancer risk} / \text{IUR} = (1/1{,}000{,}000)/(0.003\ \mu g/m^3) = \mathbf{0.00033\ \mu g/m^3}$$

15-min AAC

The OSHA permissible exposure limit (PEL) for ethylene oxide is 5 ppm. To convert the PEL from ppm to mg/m^3, use the following conversion formula from the guidance:

$$(5\ \text{ppm} \times 44.05\ g/mol) / (24.45\ L/mol) = 9\ mg/m^3$$

where, 44.05 is the molecular weight for ethylene oxide and 24.45 is the molar volume at 25^oC and 760 mmHg. After applying a safety factor of 10 for acute sensory irritants, the 15-min AAC is calculated as:

$$\text{15-min AAC} = 9\ mg/m^3 \times 1000\ (\text{convert mg to } \mu g) / 10\ (\text{safety factor}) = \mathbf{900\ \mu g/m^3}$$

[2] https://www.epa.gov/fera/risk-assessment-carcinogenic-effects

Appendix C

EPA Calculation of the Annual AAC
for Ethylene Oxide

EPA Calculation of the Annual AAC for Ethylene Oxide

According to EPA's IRIS, inhalation unit risk (IUR) for ethylene oxide (EtO) is 3×10^{-3} per µg/m^3 (as discussed in Appendix C). However, because of the elevated risk due to the mutagenic mode of action through early-life exposures, EPA multiplied the IUR by 1.6:

Modified IUR for EtO = 3×10^{-3} per µg/m^3 x 1.6 = 0.005/µg/m^3

EPA's NATA used (100/1,000,000) individual risk for the purpose of determining "acceptable risk" (AR) in their national assessment.

AR Exposure Concentration = Cancer Risk / IUR = (100/1,000,000)/(0.005/µg/m^3) **= 0.02 µg/m^3**

However, EPA uses (1/1,000,000) individual risk to incorporate an "ample margin of safety" (AMS) for setting emission standards[3] (e.g., benzene NESHAP).

AMS Exposure Concentration = Cancer Risk / IUR = (1/1,000,000)/(0.005/µg/m^3) **= 0.0002 µg/m^3**

[3] https://www3.epa.gov/ttn/atw/rrisk/risk_rep.pdf