Appendix E

Health Risk Assessment Methodology

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A. Introduction

This appendix presents the methodology used to estimate the potential cancer risk from exposure to diesel particulate matter (PM) emitted from diesel-fuel stationary agricultural pump engines. The methodology was developed to assist in development of the proposed amendments to the Airborne Toxic Control Measure for Stationary Compression Ignition Engines (ATCM).

The estimated potential cancer risks and assumptions used to determine these risks are not based on a specific engine location or operating parameters. Instead, general assumptions representing a fairly broad range of possible operating scenarios were used. Additionally, exposures were estimated at specific downwind distances, including the point of maximum impact (PMI), as determined using air dispersion modeling. The estimated potential risk ranges are used to provide a "qualitative" assessment of the potential risk levels near operation of diesel-fueled agricultural pump engines. Actual risk levels vary due to site-specific parameters, including horsepower rating, configuration of the engine, emission rates, operating schedules, site configuration, site meteorology, and distance to receptors.

B. Air Dispersion Modeling

The methodology used in this risk assessment is consistent with the Tier-1 analysis presented in the Office of Environmental Health Hazard Assessment (OEHHA), Air Toxics Hot Spots Program Risk Assessment Guidelines: The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments (OEHHA, 2003). The OEHHA guidelines and this assessment utilize health and exposure assessment information that is contained in the Air Toxics Hot Spot Program Risk Assessment Guidelines, Part II, Technical Support Document for Describing Available Cancer Potency Factors (OEHHA 2005); and the Air Toxics Hot Spot Program Risk Assessment Guidelines, Part IV, Technical Support Document for Exposure Analysis and Stochastic Analysis (OEHHA 2000), respectively. In conjunction with the OEHHA guidelines, staff also followed the ARB Interim Risk Management Policy (ARB, 2003d).

1. Model Used

The PM emissions are modeled in this scenario using the United States Environmental Protection Agency Industrial Source Complex Short Term Model – Version 3 (ISCST3 Date: 00101). ISCST3 is an air dispersion model that allows an estimation of the annual average above ambient diesel PM concentrations.

2. Meteorological Data

Meteorological data are site-specific parameters that are used in air dispersion modeling to calculate concentrations of emissions and subsequent risk. For this scenario, Fresno meteorological data (1985 – 1989) were selected for the dispersion modeling. Fresno data is representative of the meteorological conditions under which the majority of agricultural pump engines operate.

3. Dispersion Model Parameters and Emission Factors

For this modeling exercise ARB staff used a matrix of parameters. Staff modeled pump engines within three size categories: less than or equal to (≤) 120 brake horsepower (bhp), greater than (>) 120 bhp and ≤ 175 bhp, and > 175 bhp. For each size category, we estimated the potential health impacts at five certification standards of diesel PM emission factors: uncertified (or Tier 0), Tier 1, Tier 2, Tier 3, and Tier 4. The emission factors for each standard in the three size categories are presented in Table Sets 1, 2, and 3 in Section C of this appendix. Table Sets 1, 2, and 3 also show the cancer health risks at varying annual hours of operation between 100 and 3,000 hours per year at specific downwind distances.

For all the size categories, the dispersion modeling uses the rural dispersion coefficient because most agricultural pump engines are located in farming areas with lower rural populations. Stack parameters used for all size categories are a stack height of 84 inches and a stack diameter of four inches. The emission factors for each tiered standard are certification levels where applicable, or the emission inventory when certification values were not available. The modeling parameters are summarized in Table E-1.

Table E-1. Dispersion Modeling Parameters

Modeling Parameter	Engine Size Category		
	≤ 120 bhp	> 120 and ≤ 175 bhp	> 175 bhp
Engine Horsepower (at operational load)	86 bhp	130 bhp	225 bhp
Stack Temperature	744º K	719º K	622º K
Stack Exhaust Velocity	36.7 m/s	53.0 m/s	70.9 m/s

4. Health Risk Assessment Parameters

For the assessment of health risks, the annual average ambient concentration of diesel PM is used to estimate inhalation dose (mg/kg-day). The inhalation dose is also based on daily breathing rates and averaging time periods. The inhalation cancer potency factor is applied to the inhalation dose to estimate potential cancer health risks expressed as chances per million. The diesel particulate inhalation cancer potency factor is 1.1 $(mg/kg\text{-}day)^{-1}$. For this assessment, the OEHHA mean breathing rate of 302 liters/per kg body weight per day (L/kg-day) is used, as recommended in the ARB

interim risk management policy (ARB, 2003). This breathing rate corresponds to the 80th percentile breathing rate.

C. Risk Assessment Results

The risk assessment results are summarized in three sets of tables (starting on Page E-4), one set for each modeled horsepower (86 bhp, 130 bhp, and 225 bhp). The tables show potential cancer health risks as a function of annual hours of operation and distance from the source of the emissions. The tables also show risks at each emission rate standard beginning with Tier 0 (or uncertified) to Tier 4 standards.

Table Set 1. Potential Cancer Health Risk (per million) for 86 bhp Engine

Tier 4 - 0.01 g/bhp-hr

Annual Hours of Operation / Distance from source (m)	20	40	60	80	100	200	500	1000	1500
100 hours of operation	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
300 hours of operation	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
500 hours of operation	< 1	1	1	< 1	< 1	< 1	< 1	< 1	< 1
1000 hours of operation	1	2	1	1	1	< 1	< 1	< 1	< 1
2000 hours of operation	2	3	2	2	1	1	< 1	< 1	< 1
2400 hours of operation	2	4	3	2	2	1	< 1	< 1	< 1
3000 hours of operation	3	5	4	3	2	1	< 1	< 1	< 1

Uncertified - 0.84 g/bhp-hr

Annual Hours of Operation / Distance from source (m)	20	40	60	80	100	200	500	1000	1500
100 hours of operation	7	13	10	8	6	2	1	< 1	< 1
300 hours of operation	22	38	30	23	17	7	2	1	1
500 hours of operation	37	64	51	38	29	11	4	2	1
1000 hours of operation	73	128	101	76	58	22	8	3	2
2000 hours of operation	147	256	202	152	115	45	15	6	4
2400 hours of operation	176	308	243	182	138	53	18	8	5
3000 hours of operation	220	385	303	227	173	67	23	10	6

Tier 1 - 0.69 g/bhp-hr

Annual Hours of Operation / Distance from source (m)	20	40	60	80	100	200	500	1000	1500
100 hours of operation	6	11	8	6	5	2	1	< 1	< 1
300 hours of operation	18	32	25	19	14	5	2	1	< 1
500 hours of operation	30	53	42	31	24	9	3	1	1
1000 hours of operation	60	105	83	62	47	18	6	3	2
2000 hours of operation	120	211	166	125	95	37	12	5	3
2400 hours of operation	144	253	199	149	114	44	15	6	4
3000 hours of operation	181	316	249	187	142	55	19	8	5

Tier 2 and Tier 3 - 0.22 g/bhp-hr

Annual Hours of Operation / Distance from source (m)	20	40	60	80	100	200	500	1000	1500
100 hours of operation	2	3	3	2	2	1	< 1	< 1	< 1
300 hours of operation	6	10	8	6	5	2	1	< 1	< 1
500 hours of operation	10	17	13	10	8	3	1	< 1	< 1
1000 hours of operation	19	34	26	20	15	6	2	1	< 1
2000 hours of operation	38	67	53	40	30	12	4	2	1
2400 hours of operation	46	81	64	48	36	14	5	2	1
3000 hours of operation	58	101	79	60	45	17	6	3	1

Risks are at mean breathing rate and 70 year exposure duration

Table Set 2. Potential Cancer Health Risk (per million) for 130 bhp Engine

Tier 4 - 0.01 g/bhp-hr

Annual Hours of Operation	Distance from source (m)	20	40	60	80	100	200	500	1000	1500
	100 hours of operation	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
	300 hours of operation	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
	500 hours of operation	< 1	1	1	1	< 1	< 1	< 1	< 1	< 1
	1000 hours of operation	< 1	1	1	1	1	< 1	< 1	< 1	< 1
	2000 hours of operation	1	3	3	2	2	1	< 1	< 1	< 1
	2400 hours of operation	1	4	3	3	2	1	< 1	< 1	< 1
	3000 hours of operation	1	4	4	3	3	1	< 1	< 1	< 1

Uncertified - 0.55 g/bhp-hr

Annual Hours of Operation	Distance from source (m)	20	40	60	80	100	200	500	1000	1500
	100 hours of operation	3	8	7	6	5	2	1	< 1	< 1
	300 hours of operation	8	24	22	18	14	6	2	1	1
	500 hours of operation	13	40	37	30	24	10	3	1	1
	1000 hours of operation	27	81	75	61	48	20	7	3	2
	2000 hours of operation	53	162	150	121	96	40	13	6	4
	2400 hours of operation	64	194	180	145	116	48	16	7	4
	3000 hours of operation	80	243	224	182	145	60	20	9	5

Tier 1 - 0.38 g/bhp-hr

Annual Hours of Operation	Distance from source (m)	20	40	60	80	100	200	500	1000	1500
	100 hours of operation	2	6	5	4	3	1	< 1	< 1	< 1
	300 hours of operation	6	17	16	13	10	4	1	1	< 1
	500 hours of operation	9	28	26	21	17	7	2	1	1
	1000 hours of operation	18	56	52	42	33	14	5	2	1
	2000 hours of operation	37	112	103	84	67	28	9	4	2
	2400 hours of operation	44	134	124	100	80	33	11	5	3
	3000 hours of operation	55	168	155	125	100	41	14	6	4

Tier 2 and Tier 3 - 0.22 g/bhp-hr

Annual Hours of Operation	Distance from source (m)	20	40	60	80	100	200	500	1000	1500
	100 hours of operation	1	3	3	2	2	1	< 1	< 1	< 1
	300 hours of operation	3	10	9	7	6	2	1	< 1	< 1
	500 hours of operation	5	16	15	12	10	4	1	1	< 1
	1000 hours of operation	11	32	30	24	19	8	3	1	1
	2000 hours of operation	21	65	60	48	39	16	5	2	1
	2400 hours of operation	26	78	72	58	46	19	6	3	2
	3000 hours of operation	32	97	90	73	58	24	8	4	2

Risks are at mean breathing rate and 70 year exposure duration

Table Set 3. Potential Cancer Health Risk (per million) for 225 bhp Engine

Tier 4 - 0.01 g/bhp-hr

Annual Hours of Operation	Distance from source (m) 20	40	60	80	100	200	500	1000	1500
100 hours of operation	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
300 hours of operation	< 1	< 1	1	< 1	< 1	< 1	< 1	< 1	< 1
500 hours of operation	< 1	1	1	1	1	< 1	< 1	< 1	< 1
1000 hours of operation	< 1	1	2	1	1	1	< 1	< 1	< 1
2000 hours of operation	1	3	3	3	2	1	< 1	< 1	< 1
2400 hours of operation	1	3	4	4	3	1	< 1	< 1	< 1
3000 hours of operation	1	4	5	4	4	2	1	< 1	< 1

Uncertified - 0.55 g/bhp-hr

Annual Hours of Operation	Distance from source (m) 20	40	60	80	100	200	500	1000	1500
100 hours of operation	2	8	9	8	7	3	1	< 1	< 1
300 hours of operation	5	24	28	24	20	9	3	1	1
500 hours of operation	8	39	46	40	34	15	5	2	1
1000 hours of operation	16	78	92	81	68	31	10	5	3
2000 hours of operation	32	157	183	162	136	62	21	10	6
2400 hours of operation	39	188	220	194	163	74	25	12	7
3000 hours of operation	49	235	275	243	204	93	31	14	9

Tier 1 - 0.40 g/bhp-hr

Annual Hours of Operation	Distance from source (m) 20	40	60	80	100	200	500	1000	1500
100 hours of operation	1	6	7	6	5	2	1	< 1	< 1
300 hours of operation	4	17	20	18	15	7	2	1	< 1
500 hours of operation	6	29	33	29	25	11	4	2	< 1
1000 hours of operation	12	57	67	59	49	22	8	3	< 1
2000 hours of operation	24	114	133	118	99	45	15	7	< 1
2400 hours of operation	28	137	160	141	119	54	18	8	< 1
3000 hours of operation	35	171	200	176	148	67	23	10	< 1

Tier 2 and Tier 3 - 0.15 g/bhp-hr

Annual Hours of Operation	Distance from source (m) 20	40	60	80	100	200	500	1000	1500
100 hours of operation	< 1	2	3	2	2	1	< 1	< 1	< 1
300 hours of operation	1	6	8	7	6	3	1	< 1	< 1
500 hours of operation	2	11	13	11	9	4	1	1	< 1
1000 hours of operation	4	21	25	22	19	8	3	1	1
2000 hours of operation	9	43	50	44	37	17	6	3	2
2400 hours of operation	11	51	60	53	45	20	7	3	2
3000 hours of operation	13	64	75	66	56	25	9	4	2

Risks are at mean breathing rate and 70 year exposure duration

1. Estimated Cancer Health Risk As A Function Of Emission Factor

For the range of engine sizes modeled, engines emitting 0.01 g/bhp-hr (Tier 4) or less could run up to 1,000 hours per year without exceeding the lowest range of estimated risks (10 or less chances per million). For the engines with emission rates of 0.15 g/bhp-hr and 0.22 g/bhp-hr (Tier 2 and Tier 3), hours of operation and downwind

distance did not exceed the lowest range of risks, with the higher risk ranges occurring at greater than 300 annual operating hours and low to moderate downwind distances. For engines with emissions rates of 0.4 g/bhp-hr and higher (Tier 1 and uncertified), the assessment found higher risks at low to moderate downwind distances and longer annual operating hours, with the proportion of moderate to high risk level results increasing as emission factors increase.

2. Estimated Cancer Health Risk as a Function of Hours of Operation

Generally, as the hours of operation increased, the number of engines that exceeded the lowest risk range increased. However, most engines could operate for 10 to 20 hours per year without exceeding the lowest range of risk.

3. Estimated Cancer Health Risk as a Function of Horsepower

For the engine configurations evaluated in these scenarios, the smaller horsepower engines (86 and 130 bhp), typically demonstrated higher near source risk for a given number of hours of operation than the larger engine (at 40 meters). The larger engine (225 bhp) had the point of maximum impact further from the engine (60 meters) due to the greater plume dispersion that occurs with the larger horsepower engines.

REFERENCES FOR APPENDIX E

ARB, 2003d. Air Resources Board Recommended Interim Risk Management Policy for Inhalation-Based Residential Cancer Risk. October 9, 2003.

OEHHA, 2000. Office of Environmental Health Hazard Assessment. Air Toxics Hot Spots Program Risk Assessment Guidelines, Part IV, Technical Support Document for Exposure Analysis and Stochastic Analysis; 2000.

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