APPENDIX D

SOLID WASTE COLLECTION VEHICLE HEALTH RISK ASSESSMENT METHODOLOGY

I. Methodology

This appendix presents the methodology used to estimate the potential cancer risk from exposure to particulate matter (PM) from solid waste collection vehicle activities**.** This methodology was developed to assist in the development of the proposed *Diesel PM Control Measure for On-Road Heavy-Duty Diesel-Fueled Residential and Commercial Solid Waste Collection Vehicles.* The assumptions used to determine these risks are not based on a specific solid waste collection vehicle daily activity pattern. Instead, source parameters that bracket a broad range of possible operating scenarios were used. These estimated risks are used to provide an approximate range of potential risk levels from solid waste collection vehicle activities. Actual risk levels will vary due to site specific parameters, including the number of solid waste collection vehicles, emission rates, operating schedules, site configuration, site meteorology, and distance to receptors.

A. Source Description

To provide an estimate of the potential cancer risks associated with exposure to diesel PM emissions associated with solid waste collection vehicle activity, ARB staff developed three hypothetical scenarios. The first scenario examined the potential cancer risk in a residential neighborhood. The second scenario examined the potential cancer risk in a mixed commercial/residential neighborhood with more frequent refuse collection than in the first scenario. The third scenario examined the potential cancer risk to residents living along a roadway leading to a solid waste disposal site.

The methodology used in this risk assessment is consistent with the Tier-1 analysis presented in the draft 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 2002a). The OEHHA draft guidelines and this assessment use 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 2002b); and the Air Toxics Hot Spot Program Risk Assessment Guidelines, Part IV, Technical Support Document for Exposure Analysis and Stochastic Analysis (OEHHA 2000).

B. Modeling Assumptions

ARB staff modeled three different hypothetical scenarios. The first scenario examined the potential cancer risk in a residential neighborhood due to diesel PM emission from solid waste collection activities. The second scenario examined the potential cancer risk in a mixed commercial/residential neighborhood with more frequent solid waste collection than in the first scenario. The third scenario examined the potential cancer risk to residents living along a roadway leading to a solid waste disposal site, or landfill. For the residential neighborhood scenario, we selected a hypothetical residential area with a dimension of 2440 ft x 2440 ft as depicted in Figure D1. The area is divided into

60 blocks and each block occupies 12 single homes (two rows each with 6 homes). Each home lot occupies about 0.14 acres with the dimension of 60 ft x 100 ft. All streets have a width of 40 ft. In this example, the area will have 18 links and 60 receptors, and the receptors are placed in the center of each block. For the mixed-use neighborhood scenario, using the same pattern of 60 receptors, one street had apartments along one side and a commercial complex on the other side as shown in Figure D2. For the solid waste disposal site scenario, one segment of 800 meters with 56 receptors spaced in a pattern on a two-lane freeway leading to a solid waste disposal site was assumed.

Three different operating activity patterns were modeled as follows:

(1) Solid waste collection vehicles in a single use neighborhood. In this case, we assumed that one or two solid waste collection vehicles collect garbage once a week in a single-use hypothetical residence neighborhood as shown in Figure D1. Pickup occurred during weekdays between 7 AM and 8 AM with each truck making 2 passes per pick-up.

(2) Solid waste collection vehicles in a mixed multi-use neighborhood. In this case, we assumed that two solid waste collection vehicles pick garbage up once a week in the residential area and twice a week in the commercial complex. In addition, one vehicle picks garbage up once a week in the apartment area. The configuration of the mixed multi-use neighborhood is presented in Figure D2. This configuration included a pattern of 18 links and 60 receptors. As with the first scenario, pick-up occurred during weekdays between 7 AM and 8 AM with each truck making 2 passes per pick-up.

(3) Solid waste collection vehicles near a solid waste disposal site. In this case we assumed that a fleet of solid waste collection vehicles with a traffic flow volume of 50 vehicles or 100 vehicles per day travel on a two-lane freeway toward a solid waste disposal site to dispose of the garbage. The potential diesel PM cancer risk downwind of the solid waste disposal site was examined. The following parameters were used in this scenario: 1) the diesel PM emission factor is 1.4 g/mile, which is estimated from EMFAC2000; 2) accessing the solid waste disposal site occurs Monday through Friday from 7 AM to 3 PM; 3) one segment of 800 meters in the local freeway leading to the solid waste disposal site was modeled; 4) 56 receptors are placed at the downwind locations and are perpendicular to the edge of the freeway.

In each case the estimated risk levels without the regulation (base case) were determined as well as the risk levels that would be predicted with varying levels of PM emission reductions (25 percent, 50 percent, and 85 percent) that would result from the emission controls being applied to solid waste collection vehicles.

C. Model and Meteorological Data

The PM emissions are modeled in these scenarios using the United States Environmental Protection Agency's (U.S. EPA) CAL3QHCR dispersion model to evaluate the annual average above ambient diesel PM concentrations from solid waste collection vehicles in the scenarios as described above. The potential cancer risk to receptors is obtained by multiplying annual average above-ambient concentration of diesel PM by the unit risk factor (URF) for diesel PM (300 excess cancers/ug/m^3 over a 70-year exposure period). The results are expressed as an estimate of potential cancer risk in chances per million. In these scenarios, residents were assumed to have a 70-year exposure period.

Meteorological data are site-specific parameters that are input to the air dispersion model to calculate pollutant concentrations and, subsequently, risk. For these scenarios, meteorological data input to the CAL3QHCR air dispersion model is selected from Anaheim (1981), which represents an urban setting.

D. Model Parameters and Emission Factors

The solid waste collection vehicle emission factors and key modeling parameters are presented in Tables 1 and 2, respectively. The diesel PM emission factors for solid waste collection vehicles were obtained from two sources. The emission rates for solid waste collection vehicles for the 1991 to 1993 and 1994 to 1997 model years were compiled from the New York Garbage Truck Cycle (NYGTC) testing conducted by West Virginia University and the Colorado School of Mines. The emission factors for model years not included in the NYGTC were estimated by multiplying their respective heavy heavy-duty diesel (HHD) truck emission factors in EMFAC2000 by the ratio of the NYGTC emission factor to the corresponding EMFAC2000 emission factor for known model years.[1] The weighted average diesel PM emission factor for all solid waste collection vehicles was 4.0 g/mile and is calculated using the HHD truck age distribution in EMFAC2000.

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1 *Emission factors were estimated using the following equation:*

$$\left(Calculated\ NYGTC\ EF\ for\ model\ year\ i\right)_{refuse} = \left(Known\ NYGTC\ EF\ for\ model\ year\ j\right)_{refuse}\ x\ \left(\frac{Known\ HHD\ EF\ for\ model\ year\ i}{Known\ HHD\ EF\ for\ model\ year\ j}\right)_{EMFAC2000}$$

where EF is the emission factor (g/mile).

Table 1. Diesel PM Emission Factors for Collection Vehicles and HHD

Model Year	Truck Age	Truck Age Distribution	Refuse Truck EF (g/mile)	HHD* ZM (g/mile)	DR (g/10,000 miles)	EMFAC 2000 (miles/yr)	Accrued Miles	EF (g/mile)
2002	0	0.026	0.8531	0.26	0.003	60,701	60,701	0.2782
2001	1	0.050	0.8531	0.26	0.003	71,088	131,789	0.2995
2000	2	0.031	0.8531	0.26	0.003	75,525	207,314	0.3222
1999	3	0.024	0.8531	0.26	0.003	75,636	282,950	0.3449
1998	4	0.062	0.8531	0.26	0.007	72,756	355,706	0.5090
1997	5	0.060	1.05	0.32	0.01	67,962	423,668	0.7437
1996	6	0.050	1.05	0.32	0.01	62,102	485,770	0.8058
1995	7	0.054	1.05	0.32	0.01	55,827	541,597	0.8616
1994	8	0.030	1.05	0.32	0.01	49,615	591,212	0.9112
1993	9	0.083	3.002	0.51	0.009	43,800	635,012	1.0815
1992	10	0.058	3.002	0.51	0.009	38,591	673,603	1.1162
1991	11	0.084	3.002	0.51	0.009	34,100	707,703	1.1469
1990	12	0.043	4.945	0.84	0.008	30,355	738,058	1.4304
1989	13	0.039	4.945	0.84	0.008	27,324	765,382	1.4523
1988	14	0.039	4.945	0.84	0.008	24,929	790,311	1.4722
1987	15	0.037	4.945	0.84	0.008	23,059	813,370	1.4907
1986	16	0.044	6.947	1.18	0.012	21,587	834,957	2.1819
1985	17	0.016	6.947	1.18	0.012	20,376	855,333	2.2064
1984	18	0.029	6.947	1.18	0.012	19,292	874,625	2.2296
1983	19	0.025	10.89	1.85	0.018	18,211	892,836	3.4571
1982	20	0.025	10.89	1.85	0.018	17,021	909,857	3.4877
1981	21	0.036	10.89	1.85	0.018	16,000	925,857	3.5165
1980	22	0.018	10.89	1.85	0.018	15,404	941,261	3.5443
1979	23	0.012	10.89	1.85	0.017	14,137	955,398	3.4742
1978	24	0.007	10.89	1.85	0.017	13,289	968,687	3.4968
1977	25	0.005	10.89	1.85	0.017	12,492	981,179	3.5180
1976	26	0.004	10.89	1.85	0.016	11,742	992,921	3.4387
1975	27	0.003	10.89	1.85	0.016	11,038	1,003,959	3.4563
pre-1975	28	0.008	11.66	1.98	0.016	10,375	1,014,334	3.6029
Composite			**4.0 g/mile**					**1.4 g/mile**

***ZM = Zero mile emission rate; DR = Deterioration rate per 10,000 miles.

Table 2. Modeling and Health Risk Assessment Parameters

Modeling Parameters	
Weekly Truck Flow	2 or 4 trucks/hr
Dispersion Setting	Urban
Receptor Height	1.5 m
Source Height	2.5 m
Run Averaging Time	60 min
Receptor Height	1.5 m
Number of Links	18
Number of Receptors	60
Setting Velocity	0 cm/s
Deposition Velocity	0 cm/s
Roughness Length	175 cm
PM Emission Factor	0.85, 4.0, 11.7 g/mile
Meteorological Data	Anaheim (1981)
Health Risk Assessment Parameters	
Residents' Hypothetical Exposure Time	70 years
Adult Daily Breathing Rate Range	271 - 393 l/kg body weight -day [2]
Adult Body Weight	70 kg

[2] The low end of the breathing rate range is the mean of the OEHHA breathing rate distribution and the high end is the 95th percentile of the distribution.

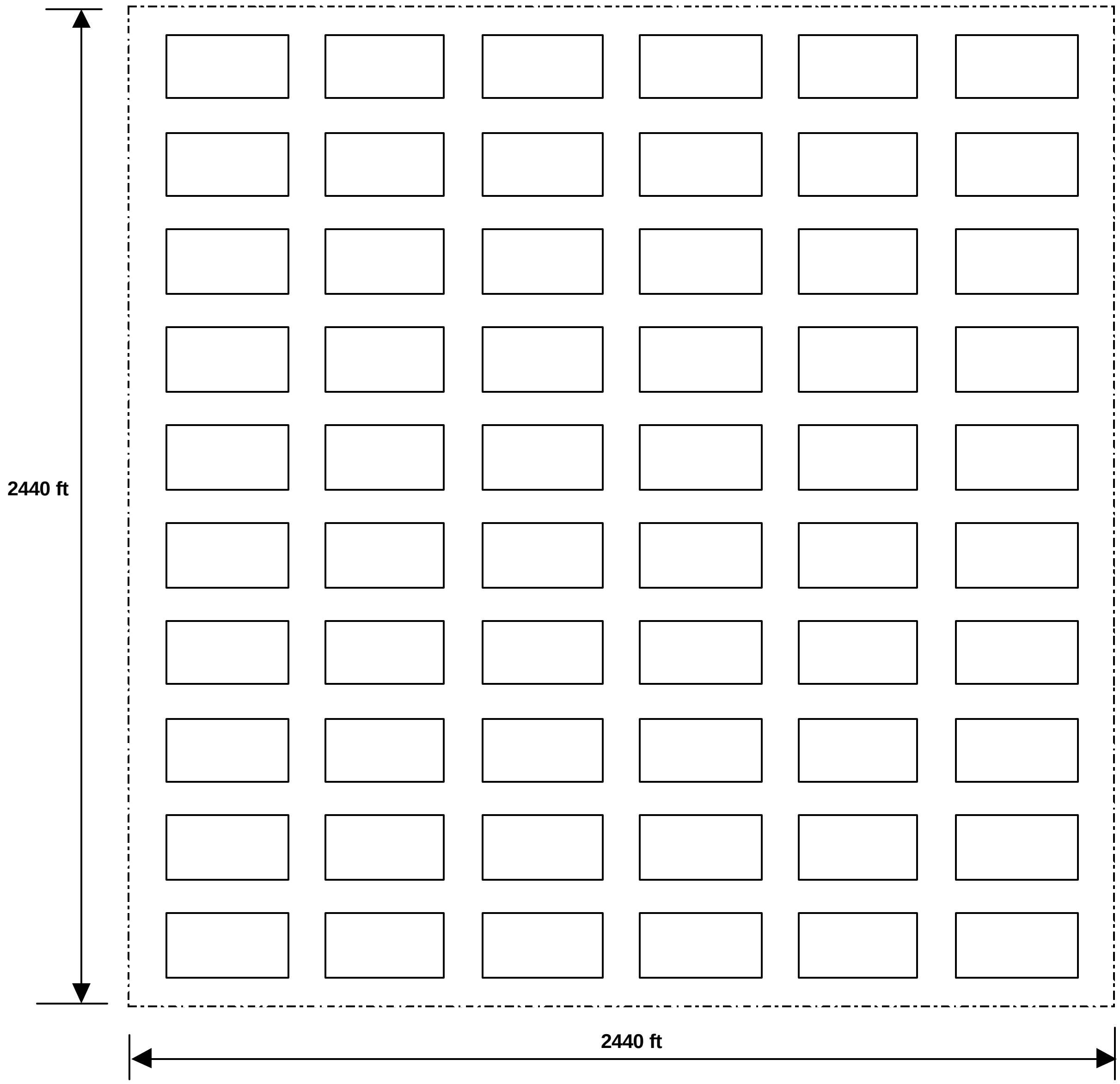

Figure 1. Layout of A Single Use Neighborhood

(A block occupies 12 home lots with two rows and each home lot occupies about 0.138 acres with a dimension of 60' x 100'. The street's width is 40'.)

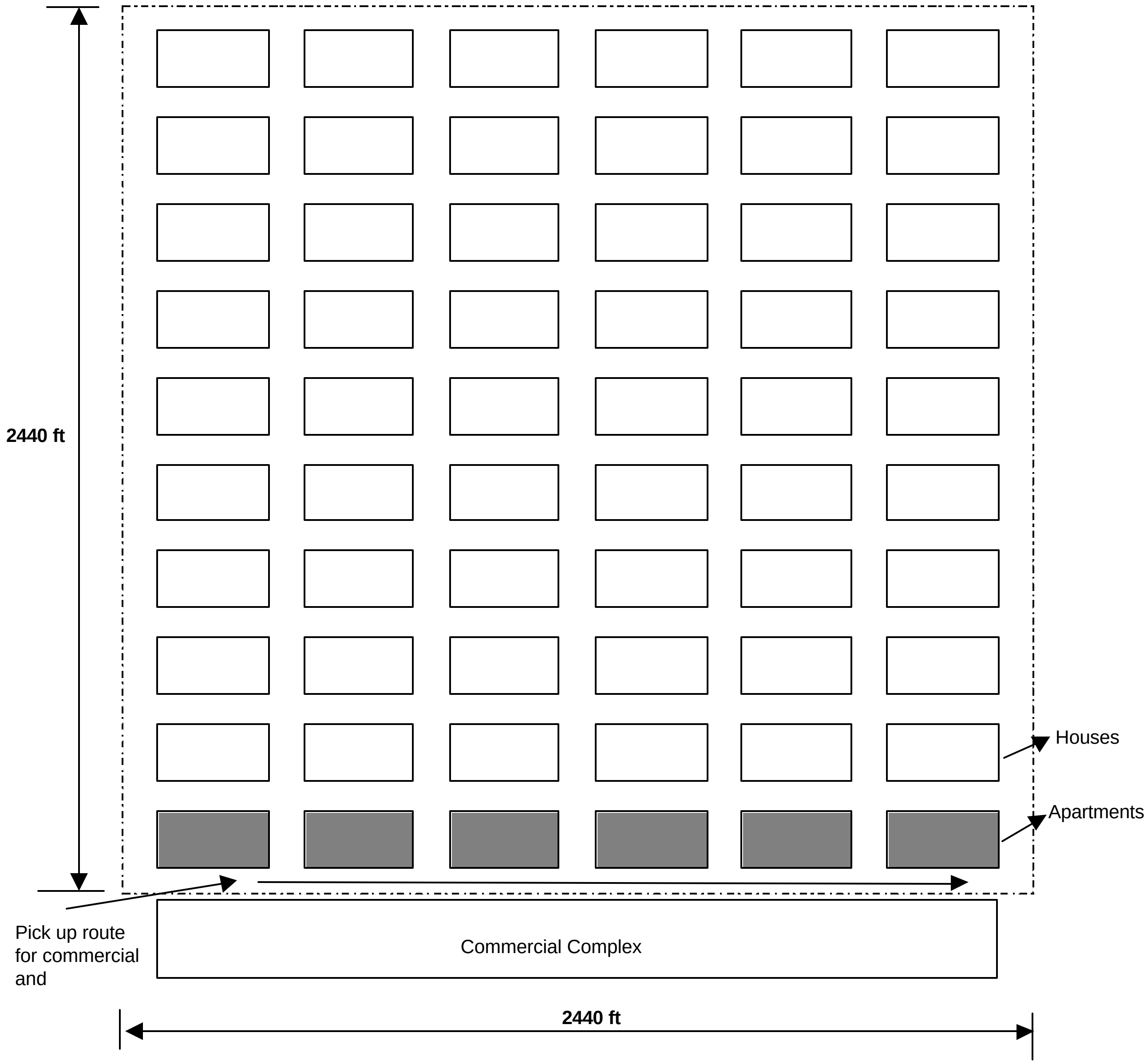

Figure 2. Layout of A Mixed Multi-Use Neighborhood

(A block occupies 12 home lots with two rows and each home lot occupies about 0.138 acres with a dimension of 60' x 100'. The street's width is 40'.)

E. Results

The estimated cancer risk from solid waste collection vehicles operating in a residential area varies depending on the age and quantity of collection vehicles operating in the neighborhood on a weekly basis (Table 3). The estimated cancer risk is calculated assuming different emission rates for the truck(s) servicing the neighborhood depending on if they are new, old, or a mix of new and old (fleet average). As expected, the maximum risk and the highest average risk would occur in neighborhoods serviced by older trucks and multiple trucks servicing the area (for example separate collection for trash and recyclable). The estimated maximum cancer risk ranges from a low of 0.2 (single newer truck per week) to a high of 6.0 (two older trucks per week) potential excess cancer cases in a million. The neighborhood average cancer risk ranges from a low of 0.2 (single newer truck per week) to 4.1 (two older trucks per week) potential excess cancer cases in a million.

The estimated cancer risk from solid waste collection vehicles operating in a mixed commercial/residential area also varies depending on the age and quantity of collection vehicles operating in the neighborhood on a weekly basis. Staff assumed twice a week pickup in the commercial area, and once a week collection using two trucks at the residences and apartments. The maximum cancer risk ranges from a low of 0.3 (newer trucks) to a high of 6.0 (older trucks) potential excess cancer cases in a million (Table 4). The neighborhood average cancer risk ranges from a low of 0.2 (newer trucks) to 3.9 (older trucks) potential excess cancer cases in a million.

The estimated cancer risk level near a roadway handling 50 or 100 refuse trucks per day is greater than in residential and mixed commercial/residential neighborhoods by an order or one to two magnitudes. The diesel PM emission rate was lower (1.4 grams per mile) compared to the first two scenarios because of the steady state operating condition associated with transporting material to a solid waste disposal site. The higher the traffic volume and the closer the receptors are to the roadway, the greater the potential cancer risk (Table 5).

Table 3. Potential Cancer Risks (Per Million) from Collection Vehicles in a Neighborhood Before Retrofit

	Maximum Risk at Residence		Average Risk in Neighborhood	
Fleet Condition	Single Truck (2 Pass)	Two Trucks (4 Pass)	Single Truck (2 Pass)	Two Trucks (4 Pass)
New Trucks (0.85 g/mile)	0.2 – 0.3	0.4 – 0.6	0.2 – 0.3	0.4 – 0.6
Old Trucks (11.7 g/mile)	2.0 – 3.0	4.0 – 6.0	1.4 – 2.1	2.9 – 4.1
Fleet Average (4.0 g/mile)	0.7 – 1.0	1.3 – 2.0	0.5 – 0.7	1.0 – 1.4

Notes: The low-end risk is based on the mean breathing rate and high-end risk is based on the 95th percentile breathing rate. These risk values assume an exposure duration of 70 years for nearby residents.

Table 4. Potential Cancer Risks (Per Million) from Collection Vehicles in a Mixed Multi-Use Neighborhood Before Retrofit

Fleet Condition	Maximum Risk at Residence	Average Risk in Neighborhood
New Trucks (0.85 g/mile)	0.3 – 0.4	0.2 – 0.3
Old Trucks (11.7 g/mile)	4.0 – 6.0	2.7 – 3.9
Fleet Average (4.0 g/mile)	1.4 – 2.0	1.0 – 1.4

Notes: The low-end risk is based on the mean breathing rate and high-end risk is based on the 95th percentile breathing rate. These risk values assume an exposure duration of 70 years for nearby residents.

Table 5. Potential Cancer Risks (Per Million) from Solid Waste Collection Vehicles Near a Solid Waste Disposal Site before Retrofit

Receptor Distance (m)	Risk Traffic Volume = 50 veh/d	Risk Traffic Volume = 100 veh/d
20	10.7 – 15.6	21.5 – 31.2
50	6.3 – 9.1	12.5 – 18.2
75	4.2 – 6.1	8.4 – 12.1
100	3.1 – 4.6	6.3 – 9.1
200 (1/8 mile)	1.5 – 2.2	3.0 – 4.4
400 (1/4 mile)	0.7 – 1.0	1.3 – 1.9
800 (1/2 mile)	0.2 – 0.3	0.4 – 0.6

Notes: The low-end risk is based on the mean breathing rate and high-end risk is based on the 95th percentile breathing rate. These risk values assume an exposure duration of 70 years for nearby residents.

Implementation of the proposed *Diesel PM Control Measure for On-Road Heavy-Duty Diesel-Fueled Residential and Commercial Solid Waste Collection Vehicles* will result in reduced PM emissions from solid waste collection activities. Estimates of the predicted risk levels that would result from a 25, 50, or an 85 percent reduction in PM emissions are presented in Tables 6 through 10. Not surprisingly, risk levels with implementation of this diesel PM reduction measure are lower than uncontrolled risk levels with greater reductions in potential risk resulting from the higher reductions in diesel PM emissions.

Table 6. Potential Cancer Risks (Per Million) from Collection Vehicles in a Neighborhood with 25 Percent Reduction in Diesel PM Emissions

	Maximum Risk at Residence		Average Risk in Neighborhood	
Fleet Condition	**Single Truck (2 Pass)**	**Two Trucks (4 Pass)**	**Single Truck (2 Pass)**	**Two Trucks (4 Pass)**
New Trucks (0.85 g/mile)	0.2 – 0.2	0.3 – 0.5	0.2 – 0.2	0.3 – 0.5
Old Trucks (11.7 g/mile)	1.5 – 2.3	3.0 – 4.5	1.1 – 1.6	2.2 – 3.1
Fleet Average (4.0 g/mile)	0.5 – 0.8	1.0 – 1.5	0.4 – 0.5	0.8 – 1.1

Notes: The low-end risk is based on the mean breathing rate and high-end risk is based on the 95th percentile breathing rate. These risk values assume an exposure duration of 70 years for nearby residents.

Table 7. Potential Cancer Risks (Per Million) from Collection Vehicles in a Neighborhood with 50 Percent Reduction in Diesel PM Emissions

Fleet Condition	Maximum Risk at Residence		Average Risk in Neighborhood	
	Single Truck (2 Pass)	Two Trucks (4 Pass)	Single Truck (2 Pass)	Two Trucks (4 Pass)
New Trucks (0.85 g/mile)	0.1– 0.2	0.2 – 0.3	0.1 – 0.2	0.2 – 0.3
Old Trucks (11.7 g/mile)	1.0 – 1.5	2.0 – 3.0	0.7 – 1.0	1.5 – 2.1
Fleet Average (4.0 g/mile)	0.4 – 0.5	0.7 – 1.0	0.3 – 0.4	0.5 – 0.7

Notes: The low-end risk is based on the mean breathing rate and high-end risk is based on the 95th percentile breathing rate. These risk values assume an exposure duration of 70 years for nearby residents.

Table 8. Potential Cancer Risks (Per Million) from Collection Vehicles in a Neighborhood with 85 Percent Reduction in Diesel PM Emissions

Fleet Condition	Maximum Risk at Residence		Average Risk in Neighborhood	
	Single Truck (2 Pass)	Two Trucks (4 Pass)	Single Truck (2 Pass)	Two Trucks (4 Pass)
New Trucks (0.85 g/mile)	0.03 – 0.05	0.06 – 0.09	0.03 – 0.05	0.06 – 0.09
Old Trucks (11.7 g/mile)	0.3 – 0.5	0.6 – 0.9	0.2 – 0.3	0.4 – 0.6
Fleet Average (4.0 g/mile)	0.1 – 0.2	0.2 – 0.3	0.08 – 0.1	0.1 – 0.2

Notes: The low-end risk is based on the mean breathing rate and high-end risk is based on the 95th percentile breathing rate. These risk values assume an exposure duration of 70 years for nearby residents.

Table 9. Potential Cancer Risk (Per Million) from Collection Vehicles in a Mixed Multi-Used Neighborhood with Varying Levels of Diesel PM Emission Reductions

Vehicle Category	25% PM Emission Reduction		50% PM Emission Reduction		85% PM Emission Reduction	
	Max. Risk at Residence	Ave. Risk in Neighborhood	Max. Risk at Residence	Ave. Risk in Neighborhood	Max. Risk at Residence	Ave. Risk in Neighborhood
New Trucks (0.85 g/mile)	0.2 - 0.3	0.2 - 0.2	0.2 - 0.2	0.1 – 0.2	0.05 - 0.06	0.03 - 0.04
Old Trucks (11.7 g/mile)	3.0 - 4.5	2.0 - 2.9	2.0 - 3.0	1.4 - 1.9	0.6 - 0.9	0.4 - 0.6
Fleet Average (4.0 g/mile)	1.1 - 1.5	0.8 - 1.1	0.7 - 1.0	0.5 - 0.7	0.2 - 0.3	0.2 - 0.2

Note: The low-end risk is based on the mean breathing rate and high-end risk is based on the 95th percentile breathing rate. These risk values assume an exposure duration of 70 years for nearby residents.

Table 10. Potential Cancer Risk (Per Million) from Collection Vehicles Near a Solid Waste Disposal Site with Varying Levels of Diesel PM Emission Reductions

Receptor Distance (M)	25% PM Emission Reduction		50% PM Emission Reduction		85% PM Emission Reduction	
	Traffic Volume 50 veh/d	Traffic Volume 100 veh/d	Traffic Volume 50 veh/d	Traffic Volume= 100 veh/d	Traffic Volume 50 veh/d	Traffic Volume 100 veh/d
20	8.0 – 11.7	16.1 – 23.4	5.4 – 7.8	10.7 – 15.6	1.6 – 2.3	3.2 – 4.7
50	4.7 – 6.8	9.4 – 13.7	3.2 – 4.6	6.2 – 9.1	0.9 – 1.4	1.9 – 2.7
75	3.2 – 4.6	6.3 – 9.1	2.1 – 3.2	4.2 – 6.0	0.6 – 0.9	1.3 – 1.8
100	2.3 – 3.5	4.7 – 6.8	1.6 – 2.3	3.2 – 4.6	0.5 – 0.7	0.9 – 1.4
200	1.1 – 1.7	2.3 – 3.3	0.8 – 1.1	1.5 – 2.2	0.2 – 0.3	0.5 – 0.7
400	0.5 – 0.8	1.0 – 1.4	0.4 – 0.5	0.7 – 1.0	0.1 – 0.2	0.2 – 0.3
800	0.2 – 0.2	0.3 – 0.5	0.1 – 0.2	0.2 – 0.3	0.03 – 0.05	0.06 – 0.09

Note: The low-end risk is based on the mean breathing rate and high-end risk is based on the 95th percentile breathing rate. These risk values assume an exposure duration of 70 years for nearby residents

These estimated risk levels provide a quantitative assessment of the potential risk levels in hypothetical neighborhoods. Actual risk levels from solid waste collection vehicles at any individual site will vary due to site specific parameters, including engine technologies, emission rates, fuel properties, operating schedules, meteorology, and the actual location of off-site receptors. Nevertheless, based on the risk scenarios above, it can be concluded that the reductions in diesel PM emissions that will result from implementation of the solid waste collection vehicle control measure will result a reduction in the associated potential cancer risk. As shown above, based on the hypothetical risk scenarios above, an 85 percent reduction in diesel PM emissions will reduce the potential health risk levels in most cases to less than one in a million.

In addition, although the overall magnitude of the diesel PM emissions and risk reductions from the collection vehicle control measure may appear modest, reducing these emissions are necessary if we are to achieve the goals outlined in the Diesel Risk Reduction Plan and to fulfill the requirements of H&SC section 39666. As described in the Diesel Risk Reduction Plan, it is necessary to reduce diesel PM emissions from essentially all diesel-fueled engines if we are to be successful in reducing the significant public health risk associated with diesel PM. Also, because diesel PM is a non-threshold carcinogen we are required under H&SC section 39666 to reduce emissions to the lowest level achievable through the application of best available control technology.

II. References

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