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Original Contribution

Adverse Birth Outcomes Associated with Open Dumpsites in Alaska Native Villages

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This retrospective cohort study evaluated adverse birth outcomes in infants whose birth records indicated maternal residence in villages containing dumpsites potentially hazardous to health and environment. Birth records from 1997 to 2001 identified 10,073 eligible infants born to mothers in 197 Alaska Native villages. Outcomes included low or very low birth weight, preterm birth, and intrauterine growth retardation. Infants from mothers in villages with intermediate (odds ratio (OR) = 1.73, 95% confidence interval (CI): 1.06, 2.84) and high (OR = 2.06, 95% CI: 1.28, 3.32) hazard dumpsites had a higher proportion of low birth weight infants than did infants from mothers in the referent category. More infants born to mothers from intermediate (OR = 4.38, 95% CI: 2.20, 8.77) and high (OR = 3.98, 95% CI: 1.93, 8.21) hazard villages suffered from intrauterine growth retardation. On average, infants weighed 36 g less (95% CI: −71.2, −0.8) and 55.4 g less (95% CI: −95.3, −15.6) when born to highly exposed mothers than did infants in the intermediate and low exposure groups, respectively, an effect even larger in births to Alaska Native mothers only. No differences in incidence were detected across exposure levels for other outcomes. This is the first study to evaluate adverse pregnancy outcomes associated with open dumpsites in Alaska Native villages.

Alaska; environmental exposure; ethnic groups; fetal growth retardation; hazardous waste; infant, low birth weight; pregnancy outcome; premature birth

Abbreviations: CI, confidence interval; IUGR, intrauterine growth retardation; OR, odds ratio.

Increased risks of adverse birth outcomes have been reported near individual landfill sites and in some multisite studies (1–7). Outcomes such as low birth weight, preterm birth, intrauterine growth retardation (IUGR), and other reproductive outcomes are considered to be sensitive indicators of potential health threats from environmental hazards (7–14). These studies have never been performed in rural Alaska. Historically, Alaska has had one of the lowest low birth weight rates in the United States, but low birth weight rates have increased from 1990 to 1998 (15). Low birth weight rates are still lower than the national average with 3.8 percent of singleton births to Alaska women classified as low and 0.9 percent classified as very low in 2000 (16). A recent study found no differences between Alaska Native and non-Native birth weights (15). Alaska Native women had a slightly higher proportion of preterm births (11.8 percent) than did the overall state proportion of 10.1 percent in 2000 (16).

In 2000, Alaska had 626,932 residents, 119,241 of whom were Alaska Native (17). In this work, Alaska Native includes any people indigenous to the Western Hemisphere: Alaska Native, Native mixed, Aleut, Eskimo, Canadian Eskimo and Indian, and American Indian (18). Many of these Alaska Natives are dispersed throughout federally recognized tribal villages.

Solid waste management is severely deficient in many of these remote villages, comparable to what is found in developing countries (19, 20). Over 95 percent of Alaska

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Native villages use open dumpsites for solid waste disposal rather than landfills. An open dumpsite is a solid waste site that is not maintained, contains uncovered wastes, and has no boundaries (19). Open dumping can enable water and soil contamination, disease transmission, fire danger, and injury to site salvagers (21). In an attempt to reduce waste volume, dump fires are set, or nonseparated wastes are burned in metal containers in approximately 75 percent of villages, releasing potentially toxic fumes (22). Many Alaska Natives have subsistence diets, and there are concerns about contaminants getting into food and water supplies (23, 24). Many villages lack waste management services and are responsible for disposing their own wastes, resulting in potential exposures to hazardous wastes and disposal methods. Approximately 45 percent of villages do not have running water to homes, and villagers must haul their own wastewater (25), often discarded at or near open dumps, increasing risks of exposure to pathogens when disposing of trash (25–27).

Negative birth outcomes were selected to evaluate potential environmental hazards posed by these dumpsites. The purpose of the study was to determine if women living in villages with open dumpsites ranked high hazard have a higher incidence of negative birth outcomes than do women living in villages with sites that have lower hazard rankings.

MATERIALS AND METHODS

This was a population-based study that utilized a retrospective cohort design for the years 1997–2001. Birth records were obtained from the Alaska Bureau of Vital Statistics for all births to women living in federally recognized Alaska Native villages during 1997–2001. It is estimated that over 97 percent of births are electronically entered (18). Eligible pregnancies were those coded as live singleton births without congenital anomalies, whose mothers' residences were listed as a Native village. Additionally, the women had to reside in villages for which there existed an evaluation of the hazard potential of the community dumpsite(s).

Negative birth outcomes included low birth weight (from 1,500 to <2,500 g), very low birth weight (<1,500 g), preterm birth (<37 weeks' gestation), and IUGR (at least 37 weeks' gestation and <2,500 g (28)). Outcomes were not mutually exclusive, although low birth weight births were excluded from the analyses involving very low birth weight births, and preterm births were excluded from analyses involving IUGR.

Exposure information was the hazard ranking of the dumpsite of the village that was indicated on the birth certificate as the mother's residence. The Alaska Native Tribal Health Consortium ranks dumpsites on the basis of waste contents, average rainfall, distance to drinking waster and domestic water source, site drainage, potential to create leachate at site, accessibility and exposure to the public and vectors, frequency of burning, and degree of public concern over the site (Appendix table 1) (20). Dump scores were categorized into high, intermediate, and low hazard potential to health and environment. During the time period of the study, 159 of the villages' dumpsites had been scored, with 17 other sites being ranked as either high, intermediate, or low hazard. An additional 21 sites were ranked on the same hazard point factors as above, by use of data from the solid waste management database of the Central Council of Tlingit and Haida Indian Tribes of Alaska.

Covariate information was obtained from birth records and included gender, interpregnancy interval, parity, adequacy of prenatal care, smoking status, alcohol intake, race, mother's age, and education. More information on the mothers' villages was obtained from the state of Alaska Community Database (29). This included average family household size and income, percentage of population Alaska Native, percentage of population in poverty, and the land area of the village in square miles (1 square mile = 2.6 km^2). Additionally, information was gathered on whether the whole village had piped water, part of the village had piped water, or none of the homes in the village were plumbed. Villages were also categorized into those that were isolated with restricted health-care options, villages with qualified emergency care centers, and regional centers with a qualified acute care facility.

For data analysis, chi-square tests were used to determine if the distribution of covariates was homogenous across exposure groups. Crude odds ratios and 95 percent confidence intervals were calculated for the effect of hazard ranking on each negative birth outcome. Crude odds ratios and 95 percent confidence intervals were calculated for each covariate on each negative birth outcome.

Logistic regression was used to determine adjusted odds ratios and 95 percent confidence intervals to quantify the relations between hazard potential and occurrences of low birth weight, very low birth weight, preterm birth, and IUGR. Because the outcomes of interest were rare, the odds ratios approximate the relative risks (30–32). Information on gender (female vs. male), interpregnancy interval, parity (no previous pregnancies, one or two previous pregnancies, and three or more previous pregnancies), adequacy of prenatal care, smoking status (did not smoke, smoked during pregnancy), alcohol intake (did not drink, drank during pregnancy), race (Caucasian, unknown and other, and Alaska Native), mother's age (under 20 and over 39 vs. 20–39 years), mother's education (less than 11 years, 12 years, and more than 12 years), year of birth, village health-care options (restricted, qualified emergency care center, and qualified acute care facility), and village water hookup (all households plumbed, some households plumbed, and no households plumbed) was used in models. Interpregnancy interval was categorized into two pregnancy endpoints in less than 2 years, two endpoints in 2 years or more, and no previous pregnancies. The Kessner Index (33) is a classification scheme of adequacy of prenatal care that accounts for the gestational month when prenatal care began and the number of prenatal visits with respect to length of gestation. The Kessner Index was used to define adequacy of prenatal care into categories of adequate, intermediate, inadequate, and unknown. The race of the baby was designated as the reported race of the mother in accordance with standards from the National Center for Health Statistics. For the analysis on low birth weight, two different models were constructed. The first model included all records with birth weight information, while the second model adjusted for weeks of gestation.

Analyses of variance were used to compare mean birth weight (grams) and mean gestational length (days) in the three exposure areas by use of the least significant difference for multiple pairwise comparisons. Multivariate analysis of covariance was used to compare means for birth weight and gestation, while simultaneously adjusting for covariates. Birth weight and gestation were the outcome variables, with hazard ranking of the predictor variable and gender, interpregnancy interval, parity, adequacy of prenatal care, smoking status, alcohol intake, race, mother's age (the mean of each 5-year age class), years of education (used continuously), village health-care options, and village water hookup used as covariates. The mean of years of mother's education was used to replace missing values, and an additional categorical dummy variable was added to adjust for the missing data on education (34). The same analysis was performed again, restricted to Alaska Native births and substituting the race covariate with the percentage of the village population that was Native, used continuously.

RESULTS

Of the 199 Alaska Native villages that reported births during the study period, there were hazard rankings available for 197. There were 10,073 births to mothers from these villages determined to be eligible.

Chi-square tests revealed that the distributions of gender, alcohol use, and year of birth were roughly equal throughout exposure levels (table 1). The quality of prenatal care ($p = 0.04$) and cigarette use ($p = 0.03$) were less evenly distributed (table 1). There were disparities ($p < 0.001$) in the distributions of interpregnancy interval, parity, race, maternal age, maternal education level, type of health care, and water hookup to households (table 1). Mothers in villages with low hazard-ranked dumpsites tended to have had fewer short interpregnancy intervals and previous pregnancies, were more frequently Caucasian and between 20 and 39 years of age, completed more years of education, more often had access to acute care medical facilities, and were more likely to have households in their villages completely plumbed compared with mothers from villages with intermediate and higher hazard-ranked dumpsites. Other village-level covariates (villages' size, percentage of population in poverty, and so on) are not displayed because these factors did not add any additional information to the models.

Low birth weight

Among the 10,073 infants born between 1997 and 2001 and included in the analyses, 10,056 had complete birth weight information in their records. A total of 353 (3.5 percent) of these infants were low birth weight (table 2). All factors except gender, year of birth, and type of health care available were associated with a change in risk for low birth weight.

Crude estimates revealed that mothers residing in villages with intermediate hazard rankings were at a mildly increased risk for low birth weight births (odds ratio (OR) = 1.73, 95 percent confidence interval (CI): 0.90, 1.84) compared with mothers residing in villages with low hazard rankings (table 3). Mothers residing in villages with high hazard rankings were 43 percent (95 percent CI: 1.12, 1.81) more likely to have low birth weight babies than were mothers who had low hazard-ranking villages listed on birth records (table 3). Adjusted estimates detected an increased risk for mothers residing in villages with both intermediate hazard rankings (OR = 1.73, 95 percent CI: 1.06, 2.84) and high hazard rankings (OR = 2.06, 95 percent CI: 1.28, 3.32) compared with the referent category. When weeks of gestation were added to the model, risks for intermediate hazard and low hazard villages rose to 2.69 (95 percent CI: 1.50, 4.84) and 2.20 (95 percent CI: 1.26, 3.85), respectively.

Very low birth weight

Of the 10,056 records that had complete birth weight information, 9,766 records were used for the very low birth weight analyses. Sixty-three (0.7 percent) of these infants were very low birth weight. Gender, parity, year of birth, and health-care options were not associated with a change in risk for very low birth weight infants (table 2). Interpregnancy interval, quality of prenatal care, cigarette use and alcohol intake, race, maternal education, and water hookup were associated with very low birth weight births.

Crude odds ratios revealed that mothers residing in villages with intermediate (OR = 1.28, 95 percent CI: 0.57, 2.89) and high (OR = 1.49, 95 percent CI: 0.87, 2.56) hazard rankings had slight increases in risk for very low birth weight births compared with mothers residing in villages with low hazard rankings (table 3). Adjusted estimates detected no risks for mothers residing in villages with intermediate hazard rankings (OR = 0.82, 95 percent CI: 0.25, 2.75) and high hazard rankings with a risk estimate of unity (OR = 1.02, 95 percent CI: 0.33, 3.12) compared with the referent category.

Preterm birth

Of the qualified births, 10,054 records had complete gestational information. A total of 734 (7.0 percent) of these infants were born preterm. All factors except gender and year of birth were associated with a change in risk for preterm birth (table 2).

Crude odds ratios revealed that mothers residing in villages with intermediate hazard rankings were at no appreciably different risk for preterm births (OR = 0.89, 95 percent CI: 0.68, 1.17) compared with mothers residing in villages with low hazard rankings. Mothers residing in villages with high hazard rankings were 45 percent (95 percent CI: 1.24, 1.70) more likely to give birth prematurely than were mothers from low hazard-ranking villages (table 3). Adjusted estimates indicated slighty reduced risks for preterm birth in mothers from intermediate hazard villages (OR = 0.70, 95 percent CI: 0.48, 1.01), while mothers from high hazard villages were at no increased risk (OR = 1.09,

TABLE 1. The distribution and chi-square *p* values of individual-level and village-level characteristics across villages with low, intermediate, and high hazard potential dumpsites, Alaska, 1997–2001

Covariates	Low hazard dumpsite (n = 4,369)		Intermediate hazard dumpsite (n = 1,247)		High hazard dumpsite (n = 4,457)		*p* value
	No.	%	No.	%	No.	%	
Individual-level characteristics							
Gender of infant							0.63
Male	2,299	52.6	644	51.6	2,302	51.6	
Female	2,070	47.4	603	48.4	2,155	48.4	
Interpregnancy interval							<0.001
>2 years	2,714	63.9	781	63.9	2,707	61.8	
≤2 years	413	9.7	170	13.9	648	14.8	
No previous pregnancy	1,118	26.3	272	22.2	1,025	23.4	
Parity							<0.001
1 or 2 previous pregnancies	1,793	41.2	478	38.4	1,544	34.8	
0 previous pregnancies	1,117	25.6	272	21.8	1,025	23.1	
≥3 previous pregnancies	1,445	33.2	496	39.8	1,872	42.2	
Quality of prenatal care							0.04
Adequate	2,166	49.6	612	49.1	2,094	47	
Intermediate	1,438	32.9	417	33.4	1,531	34.4	
Inadequate	619	14.2	175	14	710	15.9	
Unknown	146	3.3	43	3.4	122	2.7	
Cigarette use during pregnancy							0.03
Did not report smoking	3,143	72.3	877	70.7	3,101	69.8	
Reported smoking	1,203	27.7	363	29.3	1,341	30.2	
Alcohol use during pregnancy							0.27
Did not report drinking	4,082	94.1	1,170	94.3	4,138	93.4	
Reported drinking	256	5.9	71	5.7	294	6.6	
Race							<0.001
Caucasian	2,002	45.8	265	21.3	375	8.4	
Not reported or other	216	4.9	15	1.2	53	1.2	
Alaska Native	2,151	49.2	967	77.5	4,029	90.4	
Maternal age							<0.001
20–39 years	3,687	84.4	1,016	81.5	3,595	80.7	
<20 years or ≥40 years	682	15.6	231	18.5	862	19.3	
Maternal education							<0.001
>12 years	1,554	36.4	210	17.5	618	14.3	
12 years	1,933	45.3	693	57.6	2,774	64	
<12 years	778	18.2	300	24.9	940	21.7	
Year of birth							0.33
1997	866	19.8	251	20.1	946	21.2	
1998	874	20	266	21.3	897	20.1	
1999	902	20.6	226	18.1	902	20.2	
2000	876	20.1	240	19.2	864	19.4	
2001	851	19.5	264	21.2	848	19	
Village-level characteristics							
Available health care in village							<0.001
Qualified acute care facility	3,957	90.6	239	19.2	155	3.5	
Qualified emergency care center	210	4.8	188	15.1	960	21.5	
Restricted health care options	202	4.6	820	65.8	3,342	75	
Piped water to households in village							<0.001
All households plumbed	3,586	82.1	160	12.8	1,097	24.6	
Some households plumbed	748	17.1	726	58.2	1,695	38.0	
No households plumbed	35	0.8	361	28.9	1,665	37.4	

TABLE 2. The distribution and risks associated with individual-level and village-level characteristics and outcomes of low and very low birth weight, preterm birth, and intrauterine growth retardation, Alaska, 1997–2001†

Covariates	Low birth weight (cases = 353)		Very low birth weight (cases = 63)		Preterm birth (cases = 734)		Intrauterine growth retardation (cases = 98)	
	Odds ratio	95% confidence interval	Odds ratio	95% confidence interval	Odds ratio	95% confidence interval	Odds ratio	95% confidence interval
Individual-level characteristics								
Gender of infant								
Male	1		1		1		1	
Female	1.19	0.96, 1.47	1.13	0.69, 1.85	0.89	0.76, 1.03	0.67*	0.44, 0.99
Interpregnancy interval								
>2 years	1		1		1		1	
≤2 years	1.39*	1.03, 1.86	2.10**	1.59, 5.28	1.30**	1.07, 1.65	0.8	0.40, 1.62
No previous pregnancy	1.24	0.98, 1.57	1.03	0.59, 1.79	0.99	0.83, 1.19	1.2	0.76, 1.90
Parity								
1 or 2 previous pregnancies	1		1		1		1	
0 previous pregnancies	1.32*	1.01, 1.72	1.03	0.57, 1.86	1.08	0.89, 1.32	1.13	0.69, 1.86
≥3 previous pregnancies	1.31*	1.03, 1.66	1.4	0.80, 2.45	1.29**	1.08, 1.53	0.86	0.53, 1.37
Quality of prenatal care								
Adequate	1		1		1		1	
Intermediate	1.42**	1.11, 1.82	0.91	0.48, 1.73	1.25**	1.05, 1.49	1.55	0.99, 2.44
Inadequate	2.12***	1.60, 2.82	2.66**	1.45, 4.87	1.79***	1.46, 2.19	1.65	0.93, 2.95
Unknown	2.44***	1.48, 4.00	3.42**	1.29, 9.02	1.83**	1.25, 2.67	2.37	0.92, 6.08
Cigarette use during pregnancy								
Did not report smoking	1		1		1		1	
Reported smoking	1.79***	1.45, 2.20	2.27***	1.46, 3.09	1.60***	1.38, 1.86	1.22*	1.04, 1.43
Alcohol use during pregnancy								
Did not report drinking	1		1		1		1	
Reported drinking	2.66***	1.98, 3.67	4.01***	2.30, 6.99	2.00***	1.58, 2.53	1.12	0.93, 1.34
Race								
Caucasian	1		1		1		1	
Not reported or other	1.8	0.97, 3.40	1.19	0.15, 9.54	1.5	0.90, 2.51	1.43	0.50, 4.11
Alaska Native	1.66***	1.26, 2.19	2.54**	1.21, 5.34	2.02***	1.64, 2.48	0.96	0.61, 1.50
Maternal age								
20–39 years	1		1		1		1	
<20 years or ≥40 years	1.68***	1.32, 2.15	1.49	0.83, 2.67	1.24*	1.03, 1.50	1.47	0.92, 2.35
Maternal education								
>12 years	1		1		1		1	
12 years	1.77***	1.28, 2.38	2.50*	1.12, 5.60	1.43***	1.16, 1.76	1.36	0.78, 2.36
<12 years	2.20***	1.58, 3.07	3.15**	1.39, 7.13	1.93***	1.54, 2.41	1.83	0.99, 3.41
Year of birth								
1997	1		1		1		1	
1998	0.94	0.67, 1.32	0.69	0.32, 1.50	0.96	0.76, 1.22	1.14	0.58, 2.23
1999	0.9	0.64, 1.27	0.51	0.22, 1.19	0.88	0.69, 1.12	1.26	0.65, 2.44
2000	1.03	0.74, 1.43	0.65	0.30, 1.44	1.02	0.81, 1.30	1.84	0.99, 3.41
2001	1.09	0.78, 1.51	1.19	0.60, 2.34	1.12	0.89, 1.41	1.07	0.53, 2.14
Village-level characteristics								
Available health care in village								
Qualified acute care facility	1		1		1		1	
Qualified emergency care center	1	0.70, 1.41	1.07	0.45, 2.52	1.14	0.90, 1.46	0.76	0.40, 1.44
Restricted health care options	1.25	1.00, 1.57	1.67	0.97, 2.88	1.47***	1.25, 1.73	0.86	0.56, 1.31
Piped water to households in village								
All households plumbed	1		1		1		1	
Some households plumbed	1.35*	1.06, 1.72	2.13**	1.21, 3.75	1.27**	1.07, 1.51	0.92	0.58, 1.50
No households plumbed	1.32*	1.00, 1.74	1.47	0.73, 2.93	1.41***	1.17, 1.71	1.118	0.71, 2.00

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

† The number of records for each analysis varied from 9,766 to 10,056.

TABLE 3. Crude and adjusted odds ratios and 95% confidence intervals describing the relations between low, intermediate, and high hazard exposure categories and incidence of low and very low birth weight, preterm birth, and intrauterine growth retardation, Alaska, 1997–2001

Outcome	Outcome not present		Outcome present		Odds ratio (crude)	95% confidence interval	Odds ratio (adjusted)†	95% confidence interval
	No.	%	No.	%				
Low birth weight ($n = 10,056$)								
Low hazard dumpsite	4,236	42.1	126	2.9	1		1	
Intermediate hazard dumpsite	1,199	11.9	46	3.7	1.29	0.90, 1.84	1.73*	1.06, 2.84
High hazard dumpsite	4,268	42.4	181	4.1	1.43**	1.12, 1.81	2.06**	1.28, 3.32
Low birth weight adjusted for gestation ($n = 10,037$)								
Low hazard dumpsite	4,227	42.1	125	2.9	1		1	
Intermediate hazard dumpsite	1,198	11.9	46	3.7	1.52*	1.01, 2.32	2.69***	1.50, 4.84
High hazard dumpsite	4,263	42.5	178	4	1.13	0.86, 1.48	2.20**	1.26, 3.85
Very low birth weight ($n = 9,766$)								
Low hazard dumpsite	4,236	43.4	22	0.5	1		1	
Intermediate hazard dumpsite	1,199	12.3	8	0.7	1.28	0.57, 2.89	0.91	0.27, 3.10
High hazard dumpsite	4,268	43.7	33	0.8	1.49	0.87, 2.56	1.17	0.37, 3.67
Preterm birth ($n = 10,054$)								
Low hazard dumpsite	4,087	40.7	272	6.2	1		1	
Intermediate hazard dumpsite	1,176	11.7	70	5.6	0.89	0.68, 1.17	0.77	0.52, 1.12
High hazard dumpsite	4,057	40.4	392	8.8	1.45***	1.24, 1.70	1.24	0.89, 1.74
Intrauterine growth retardation ($n = 9,319$)								
Low hazard dumpsite	4,052	43.9	34	0.8	1		1	
Intermediate hazard dumpsite	1,158	12.6	19	1.6	1.78*	1.01, 3.14	4.38***	2.20, 8.77
High hazard dumpsite	4,011	43.5	45	1.1	1.15	0.73, 1.80	3.98***	1.93, 8.21

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

† Adjusted for gender, interpregnancy interval, parity, adequacy of prenatal care, smoking status, alcohol intake, race, mother's age and education, health care options, piped water, and missing values.

95 percent CI: 0.78, 1.51) compared with the referent category.

Intrauterine growth retardation

Of the qualified full-term births, 9,221 records had complete birth weight information. Ninety-eight (1.1 percent) of these infants were born with IUGR (table 2). Only male gender and smoking were significantly associated with IUGR, although quality of prenatal care, alcohol use, maternal age, maternal education of less than 12 years, and birth year in 2000 also indicated IUGR.

Crude odds ratios revealed that mothers residing in villages with intermediate hazard rankings were at an 80 percent increased risk for IUGR (OR = 1.78, 95 percent CI: 1.01, 3.14) compared with mothers residing in villages with low hazard rankings. Mothers residing in villages with high hazard rankings had no appreciable difference in risk for IUGR (OR = 1.15, 95 percent CI: 0.73, 1.80) compared with mothers who had low hazard-ranking villages listed on birth records (table 3). Adjusted estimates detected a fourfold increase in risk for mothers residing in villages with intermediate hazard rankings (OR = 3.99, 95 percent CI: 1.95, 8.15) and a slightly lower estimate in the villages with high hazard rankings (OR = 3.68, 95 percent CI: 1.72, 7.87) compared with the referent category.

Average birth weight and gestational length

The average birth weight was 3,569.9 g for infants born to mothers from low hazard villages, 3,565.5 g for those from intermediate hazard villages, and 3,542.1 g for those from high hazard areas (table 4). Infants in the high hazard villages weighed, on average, 27.8 g less than did infants in the low hazard villages (95 percent CI: −51.4, −4.1 g). The average gestational length (days) is displayed in table 4 for each hazard category. The gestational length was 273.4 days for pregnancies in mothers from low hazard villages, 272.5 days for those from intermediate hazard villages, and 270.9 days for those from high hazard villages. Mothers from the intermediate hazard villages had pregnancies that, on average, lasted 0.9 days less than did mothers from low hazard villages (95 percent CI: −1.7, −0.01 days). Mothers from the high hazard villages also had pregnancies lasting 2.5 days less than did mothers from the low hazard villages (95 percent CI: −3.0, −1.9 days) and 1.6 days less than did

TABLE 4. Crude and adjusted average birth weights and gestational lengths, as well as mean differences, across low, intermediate, and high hazard exposure categories, and 95% confidence intervals, Alaska, 1997–2001

Model	No.	Mean	Contrast	Mean difference	95% confidence interval
			Births to all women		
Weight (g)					
Low hazard	4,362	3,569.90	Intermediate-low	−4.3	−40.0, 31.3
Intermediate hazard	1,245	3,565.50	High-intermediate	−23.4	−59.0, 12.1
High hazard	4,449	3,542.10	High-low	−27.8*	−51.4, −4.1
Gestation (days)					
Low hazard	4,359	273.4	Intermediate-low	−0.9*	−1.7, 0.0
Intermediate hazard	1,246	272.5	High-intermediate	−1.6***	−2.4, −0.8
High hazard	4,449	270.9	High-low	−2.5***	−3.0, −1.9
Weight (adjusted†) (g)					
Low hazard	4,350	3,584.90	Intermediate-low	−19.4	−64.4, 25.6
Intermediate hazard	1,245	3,565.50	High-intermediate	−36.0*	−71.2, −0.8
High hazard	4,442	3,529.50	High-low	−55.4**	−95.3, −15.6
Gestation (adjusted†) (days)					
Low hazard	4,350	272.7	Intermediate-low	0.1	−0.9, 1.2
Intermediate hazard	1,245	272.8	High-intermediate	−1.2**	−2.0, −0.3
High hazard	4,442	271.6	High-low	−1.0*	−2.0, −0.1
			Births to Alaska Native women only		
Weight (g)					
Low hazard	2,092	3,587.60	Intermediate-low	−26.5	−94.7, 41.7
Intermediate hazard	929	3,597.50	High-intermediate	−55.6**	−97.9, −13.3
High hazard	3,907	3,545.60	High-low	−82.1**	−142.4, −21.8
Gestation (days)					
Low hazard	2,036	271.8	Intermediate-low	−0.1	−1.7, 0.0
Intermediate hazard	913	271.5	High-intermediate	−1.8**	−2.2, −0.9
High hazard	3,845	269.8	High-low	−1.9*	−3.8, −0.1
Weight (adjusted‡) (g)					
Low hazard	2,031	3,616.80	Intermediate-low	−29	−97.6, 39.7
Intermediate hazard	910	3,587.80	High-intermediate	−48.4*	−90.8, −5.9
High hazard	3,829	3,539.40	High-low	−77.3**	−138.1, −16.6
Gestation (adjusted‡) (days)					
Low hazard	2,031	271.8	Intermediate-low	−0.2	−2.3, 1.8
Intermediate hazard	910	271.5	High-intermediate	−1.7**	−3.0, −0.4
High hazard	3,829	269.8	High-low	−1.9*	−3.7, −0.1

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

† Adjusted for gender, interpregnancy interval, parity, adequacy of prenatal care, smoking status, alcohol intake, race, mother's age and education, health care options, piped water, and missing values.

‡ Adjusted for gender, interpregnancy interval, parity, adequacy of prenatal care, smoking status, alcohol intake, percentage of village population that is Alaska Native, mother's age and education, health care options, piped water, and missing values.

mothers in the intermediate hazard villages (95 percent CI: −2.4, −0.8 days).

The multivariate analysis revealed adjusted mean birth weights of 3,584.9 g, 3,565.5 g, and 3,529.5 g for births to mothers from low, intermediate, and high hazard villages, respectively (table 4). Infants born to mothers from high hazard villages weighed, on average, 36.0 g less than did infants whose mothers were from intermediate hazard villages (95 percent CI: −71.2, −0.8 g) and 55.4 g less than did those from low hazard villages (95 percent CI: −95.3, −15.6 g). The adjusted mean gestational length was 272.7 days in low hazard villages, 272.8 days in intermediate hazard villages, and 271.6 days in high hazard villages. Mothers in the high hazard villages had pregnancies that, on average, lasted 1.2 days less than did mothers in intermediate hazard villages (95 percent CI: −2.0, −0.3 days). Mothers in the high hazard villages also had pregnancies lasting, on average, 1.0 day less than did mothers in the low hazard villages (95 percent CI: −2.0, −0.1).

Average birth weight and gestational length among Alaska Native women only

There were 7,147 Alaska Native women in this study. The average birth weights of infants born to Alaska Native mothers were 3,587.6 g, 3,597.5 g, and 3,545.6 g for mothers from low, intermediate, and high hazard villages, respectively (table 4). Infants in the high hazard villages weighed, on average, 82.1 g (95 percent CI: −142.4, −21.8 g) less than did infants in the low hazard villages and 55.6 g (95 percent CI: −142.4, −21.8 g) less than did infants born to mothers from intermediate hazard villages. The gestational length was 271.8 days for pregnancies in mothers from low hazard villages, 271.5 days for those from intermediate hazard villages, and 269.8 days for those from high hazard villages. Mothers from high hazard villages had pregnancies lasting, on average, 1.9 days less than did mothers from low hazard villages (95 percent CI: −3.8, −0.1 days) and 1.8 days less than did mothers from intermediate hazard villages (95 percent CI: −2.2, −0.9 days).

The multivariate analysis revealed the adjusted mean birth weights as 3,616.6 g, 3,587.8 g, and 3,539.4 g for births to mothers from low, intermediate, and high hazard villages, respectively (table 4). Infants born to mothers from high hazard villages weighed, on average, 48.4 g less than did infants whose mothers were from intermediate hazard villages (95 percent CI: −90.8, −5.9 g) and 77.3 g less than did those from low hazard villages (95 percent CI: −138.1, −16.6 g). The adjusted mean gestational lengths were 271.8 days in low hazard villages, 271.5 days in intermediate hazard villages, and 269.8 days in high hazard villages. Mothers in the high hazard villages had pregnancies that, on average, lasted 1.9 days less than did mothers in intermediate hazard villages (95 percent CI: −3.7, −0.1). Mothers in the high hazard villages also had pregnancies lasting, on average, 1.7 days less than did mothers in the low hazard villages (95 percent CI: −3.0, −0.4).

DISCUSSION

This work detected a meaningful increase in risk of low birth weight births to mothers who resided in villages with intermediate and high hazard dumpsites compared with villages with low hazard sites. There was also an increase in risk estimates with a higher level of exposure. Although this apparent dose response disappeared when adjustment was made for gestation, the estimates of risk increased. The risk estimates were higher in the exposed group than in another similarly sized study (4).

There was also a meaningful birth weight reduction detected when comparison was made of average birth weights in infants born to mothers from high, intermediate, and low hazard villages. There was evidence of dose-response grouping of birth weights with respect to exposure level. These reductions are similar to those found in a comparable study in California (35). When restricting the analyses of births to Alaska Native women, we found that the reductions in mean birth weight were greater, although the infants weighed slightly more. However, even the difference in weight between low and high hazard villages would be clinically significant only for the smallest infants, and it was approximately one third of the 200-g reduction in weight predicted by smoking during pregnancy (36).

No dumpsite hazard effects were detected for very low birth weight babies. Table 3 shows that the covariates associated with low birth weight were the same as those associated with very low birth weight, but the effect estimates were higher in the very low birth weight group. Very low birth weight infants comprised less than 1 percent of the study population, so any differences across exposure levels may have been difficult to detect. Additionally, no information was available on other potentially confounding variables, such as drug use and maternal health status. Some risk factors, such as structural abnormalities of reproductive organs, may affect the incidence of very low birth weight infants more than that of moderately low birth weight infants (37).

This study also detected no excess risk of preterm births. In fact, births to mothers in intermediate hazard villages bordered on being protected from preterm birth. Interestingly, the 7 percent preterm birth rate was lower than that reported in Alaska. Other studies detecting decreases in low birth weight across environmental exposure levels have not found differences with respect to very low birth weight or preterm births (4, 35). The multivariate analysis of the covariance predicted an approximate 1-day difference in mean gestational length when comparison was made of births to mothers residing in high hazard villages with those to mothers residing in low hazard villages and 2 days when examining only births to Alaska Native women. This would be clinically significant only in the most premature of infants and apparently was not enough of a reduction to have an effect on the incidence of preterm births.

Information about gestation was obtained from the calculated gestation entered on the birth record. This variable is based on the mothers' estimate of the date of last menses and could be subject to reporting errors. Gestation was estimated in weeks but converted to days for analyses, so a reduction of 1 day should be interpreted cautiously. Risk factors for preterm birth, such as urogenital infections and placental abnormalities, were not adjusted for in the analyses and could differ across strata as the study population was not homogenous.

Women from intermediate and high hazard villages were more likely to have babies afflicted with IUGR than were women from low hazard villages. Effect estimates were slightly higher in babies from intermediate hazard villages than in those from high hazard villages. This is similar to the decreases in length of gestation in the intermediate and high hazard villages compared with low hazard villages and the effects observed when adjustment was made for gestation in the low birth weight models. These results contrast with the dose response observed when we examined low birth weight and birth weight reduction. Possible explanations include the different risk factors for low birth weight and preterm birth.

Perhaps these inconsistencies could be reconciled with a more specific definition of exposure. The assumption behind this study was that women living in villages with intermediate or high hazard dumpsites were all exposed to these sites via proximity and waste disposal throughout their pregnancies, although this is impossible to ascertain with the current study design. Dumpsites were ranked in generally the same time period as the study period, but the quality of the dumpsites could have been labile. It is not known what proportion of their pregnancies women spent in their villages. Women living in isolated villages in Alaska typically spend the last 3–6 weeks in prematernal homes in regional centers that have access to hospitals. Approximately 70 percent of the mothers who lived in high hazard villages would have left those villages for prematernal homes during the last portion of their pregnancies. These prematernal homes are located in villages that generally have lower hazard scores. Birth weight reductions are often associated with factors that occur later in pregnancy (7, 38), although other research demonstrates that first trimester exposures can also affect birth weight (39).

Covariates were distributed differently throughout exposure levels. Hazard categories could have been surrogates for other factors affecting birth weight. For example, important risk factors such as underlying health conditions and occupational exposures were not adjusted for in the analyses. Another concern is that studies performed in other states have found that birth record information often does not correlate with information on patients' medical records (40, 41).

Future studies examining the potential health effects associated with open dumpsites in Alaska Native villages should include measurements that are more precise in nature. Misclassification errors are inherent in studies with crude exposure measurements. Several contaminants identified in and proximal to individual dumpsites (arsenic, lead, methyl mercury, and several petroleum hydrocarbons) are associated with negative birth outcomes (7, 42, 43). During examination of the health effects associated with environmental exposures from hazardous waste sites, it is always preferable, although rarely possible, to identify direct pathways of exposure. Other birth outcome studies with well-defined exposure routes have found more convincing associations (3, 5). Reproductive outcomes can be sensitive indicators of environmental insults, as the reproductive system often fails before other systems (7, 11, 44). The most important aspect of this study is that it is the first to attempt to characterize the relation of these adverse pregnancy outcomes among residents of Alaska Native villages to open dumpsites.

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(Appendix table 1 follows)

APPENDIX TABLE 1. Guidelines from the Indian Health Service for classifying the possible threat to health and the environment posed by the solid waste site*

Hazard point factors	High factors	Moderate factors	Low factors
Contents	Site waste content ≥ 2% hazardous waste by volume (30 points)	Site waste content contains special wastes (<2% hazardous waste by volume) (15 points)	Site waste content contains municipal waste only
Rainfall	High rainfall (>25 inches† per year) (4 points)	Medium rainfall (25–10 inches per year) (2 points)	Low rainfall (<10 inches year)
Distance to drinking water aquifer	≤50 feet† (30 points)	51–100 feet (10 points)	>600 feet
		101–200 feet (8 points)	
		201–600 feet (4 points)	
Site drainage	Site drainage increases the likelihood of ground or surface water contamination (8 points)	Effects of moderate drainage, limited ponding, and drainage are largely neutral (2 points)	Site drainage contributes to protection of ground or surface water
Potential to create leachate at site	High probability (4 points)	Moderate probability (2 points)	Low probability
Distance to domestic water source	<1,000 feet (4 points)	1,000–5,000 feet (2 points)	>5,000 feet
Site accessibility	Unrestricted access with residences nearby (<1 mile†) (4 points)	Unrestricted access but remote from population (2 points)	Restricted, controlled access
Frequency of burning	Frequent burning (weekly) (4 points)	Infrequent burning (monthly) (2 points)	Burning never occurs
Site materials' exposure to public and vectors	Surface materials, no cover, scavenging by public (4 points)	Materials in open trenches, limited scavenging (2 points)	Materials covered, no scavenging
Degree of public concern over site aesthetics	Frequent expressions of public concern over site (4 points)	Little public concern, government awareness only (2 points)	No concern expressed by any entity
Hazard score	Points total 30 or more (high)	Points total 14–29 (intermediate)	Points total 13 or less (low)

* Based on the *Report on the Status of Open Dumps on Indian Lands: 1998 Report* (20).

† Metric equivalents: 1 inch = 2.54 cm; 1 foot = 30.48 cm; 1 mile = 1.61 km.