FETAL AND NEONATAL DEATHS AND CONGENITAL ANOMALIES ASSOCIATED WITH OPEN DUMPSITES IN ALASKA NATIVE VILLAGES

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ABSTRACT

Objective. To determine if women living in Alaska Native villages with open dumpsites ranked as higher hazard have higher rates of adverse pregnancy outcomes than women living in villages with sites that have lower hazard rankings. Adverse pregnancy outcomes examined included fetal and neonatal death and congenital anomalies.
Study Design. A population-based retrospective cohort study.
Methods. Birth records from 1997-2001 were used to identify the 10 360 eligible infants born to mothers who resided in 197 Alaska Native villages with dumpsite rankings. Exposure variables were derived from hazard rankings of dumpsites. Covariates were obtained from both birth certificate information and village-specific characteristics.
Results. Neither crude, nor adjusted estimates detected a statistically significant difference in rates between exposure levels, although adjusted estimates were positive in all congenital anomaly categories, except gastrointestinal defects. Infants born to mothers residing in villages with high hazard dumpsite contents were more likely (RR=4.27; 95% CI: 1.76, 10.36) to have anomalies classified as other defects. Other hazard factors were not significant predictors for any of the adverse outcomes examined.
Conclusions. This is the first study to evaluate fetal and neonatal deaths and congenital anomalies associated with open dumpsites in Alaska Native villages. Problems with the study include a population-based exposure measurement, small sample size, and biases related to birth record information. Future studies should include more comprehensive registries of congenital anomalies.
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Keywords: Alaska Native, dumpsites, hazardous waste, neonatal death, stillbirth, congenital anomalies

INTRODUCTION

Alaska has diverse cultures, severe temperatures, vast landscapes, and sparse local populations, which can affect public health. The U.S. Census 2000 reported that Alaska had 626 932 residents, 119 241 of whom were Alaska Native (AN). In this work, AN includes any people indigenous to the Western Hemisphere: Alaska Native, Native mixed, Aleut, Eskimo, Canadian Eskimo and Indian, and American Indian. Many of these ANs are dispersed throughout federally recognized tribal villages. Solid waste management (SWM) is severely deficient in many of these remote villages, comparable to what is found in developing countries (1,2). Over 95 percent of AN villages use open dumpsites for solid waste disposal. An open dumpsite is a solid waste site that is not maintained, is unlined, contains uncovered wastes, and with generally no marked perimeter and open access (1).

The Alaska Native Tribal Health Consortium (ANTHC) ranks dumpsites based on hazard point factors that include: dumpsite waste contents, average rainfall, distance to drinking water aquifer 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 (2). Of the 177 villages that have been scored by ANTHC, 70 percent have been scored as high hazard, 25 percent as moderate hazard, and 5 percent as low hazard. Without access to alternatives, all waste that is generated in villages is discarded at the dumpsite, including unknown quantities of hazardous waste from households and industry. The Alaska Department of Environmental Conservation (ADEC) reports that the dumpsites include household waste, as well as some commercial, construction and demolition waste (3). Open dumping can present an environmental and health threat through water and soil contamination, disease transmission, fire danger, and injury to site salvagers (4). In an attempt to reduce waste volume and visual blight, dump fires are set, or non-separated wastes are burned in metal containers (i.e. “burn boxes”), in approximately 75 percent of villages (5).

In 1997, over 45 percent of Alaska villages did not have running water in their homes, and inhabitants must haul their wastewater in “honeybuckets”, because the tundra makes the construction of latrines impractical (6). Human wastes are often discarded at, or near, open dumps, thereby increasing risks of exposure to pathogens when disposing of trash (6-8). Villagers hauling their solid wastes, site salvagers, children, and household pets frequent dumpsites. Many ANs have subsistence diets and there are concerns about contaminants getting into food and water supplies (9, 10).

Increased risks of adverse pregnancy outcomes have been reported near some individual landfill sites and in multi-site studies (11-15). However, these studies have never been performed in rural Alaska. Fetal and neonatal deaths and congenital anomalies (along with other reproductive outcomes) are considered to be sensitive indicators of potential health threats from environmental hazards (14,16-22). These outcomes were selected because they are associated with reproductive health (22) and are readily available through records.

Alaska has a lower neonatal mortality rate compared to the rest of the United States, but the AN rate is higher than the rest of Alaska (23). The AN fetal mortality rate is lower than the rate of other Alaskans, but the congenital anomaly rate is higher for ANs (23). No study has examined differences in mortality rates and congenital anomalies for Natives in relation to potential hazards from open dumpsites.

Fetal and neonatal mortality rates and the incidence of congenital anomalies were selected to evaluate potential environmental hazards posed by these dumpsites. This was a population-based study that utilized a retrospective cohort design for the years 1997-2001. The purpose of the study was to determine if women living in villages with open dumpsites that have higher hazard rankings would have a higher incidence of these adverse pregnancy outcomes than women living in villages with sites that have lower hazard rankings. We also examined whether the three factors that make up the majority of a dumpsite score (dumpsite contents, distance to drinking water aquifer, and site drainage) were individually associated with the adverse pregnancy outcomes.

MATERIAL AND METHODS

Birth records were obtained from the Alaska Bureau of Vital Statistics for all births to women living in federally recognized Native villages for the period 1997-2001. It is estimated that over 97 percent of births and 99 percent of deaths are entered electronically (24). Eligible pregnancies were those coded as lasting at least 20 weeks, resulting in singleton births, whose mothers' residences were listed as Native villages. Additionally, the women had to reside in villages for which there existed an evaluation of the hazard potential of the community dumpsite(s). There were 10 360 births in 197 villages determined to be eligible. Birth outcomes of interest included: fetal death (defined in Alaska as occurring in a pregnancy where the last menstrual date subtracted from the date of delivery is at least 20 weeks (23), neonatal death (death to liveborn infants less than 28 days of age), and congenital anomalies. Neonatal deaths that were successfully linked with birth files were included (greater than 98 percent of deaths were linked with birth records by the Alaska Bureau of Vital Statistics). Only when a birth and a death both occurred within the state of Alaska, and were entered electronically, was it possible to link records. Neonatal deaths were coded to the ICD-9 (international classification of diseases, ninth revision) for deaths in 1997 and 1998, and to the ICD-10 thereafter. Neonatal deaths resulting from unintentional injuries were excluded. Cause of death for fetal deaths is not specified on Alaskan fetal death certificates, so fetal deaths that resulted from maternal trauma and injuries could not be excluded. Observable congenital anomalies are coded into 22 categories (including no defects and other defects) in Alaskan birth records. For analytic purposes, these anomalies were placed into five broader categories according to anatomic similarity. Central nervous system anomalies included: anencephalus, spina bifida or meningocele, hydrocephalus, microcephalus, and other central nervous system defects. Circulatory and respiratory anomalies included all heart malformations and other circulatory or respiratory defects. Gastrointestinal anomalies included: rectal atresia/stenosis, tracheo-esophageal fistula/esophageal atresia, omphalocele/gastroschisis, and other gastrointestinal defects. Urogenital anomalies include malformed genitalia, renal agenesis, and other urogenital anomalies. Musculoskeletal and integumental anomalies include cleft lip and palate, polydactyly/syndactyly/adactyly, club-foot, diaphragmatic hernia, and other musculoskeletal or integumental defects. Anomalies classified as chromosomal were not examined, unless other defects were indicated on the birth record.

Exposure information was the hazard ranking of the dumpsite of the village indicated on the birth certificate as the mother's residence. Exposure information was ecological, because it was not known that women experienced all, or any part, of their pregnancies in the village of their residence. Dump scores were categorized by ANTHC 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. Because of small numbers, intermediate and low hazard ranked villages were collapsed into a lower hazard category. An additional 21 sites were ranked on the same hazard point factors as above, using data from the Central Council of Tlingit and Haida Indian Tribes of Alaska (CCTHITA) solid waste management database.

Site contents, the distance of the site to a drinking water aquifer, and site drainage are the factors that weighed most heavily in calculated hazard rankings (2). The ranking system scored dumpsites that contained greater than two percent hazardous waste highest on content factors, sites that contained special waste moderate scores, while sites that contained only municipal waste did not affect the overall hazard ranking. Sites that were less than 50 feet from a drinking water aquifer score maximum points in that category, sites within 51 to 600 feet of an aquifer were given moderate scores, while sites that were greater than 600 feet from aquifers did not affect scores. Site drainage that increased the likelihood of ground or surface water contamination was considered a high factor, sites that had moderate drainage, limited ponding, or neutral effects, were considered moderate factors. When dumpsite drainage contributed to the protection of ground or surface water, no points were added to the overall hazard ranking for the site drainage category (2). These factors were used as additional exposure information for the pregnancies occurring in the 180 villages that had detailed hazard point factor rankings.

Covariate information was obtained from birth records and included gender, parity, adequacy of prenatal care, smoking status, alcohol intake, race, mother's age, and mother's education, year of birth, gestation, and birth weight.

More information on the mothers' residence villages was obtained from the state of Alaska Community Database (25). This included average family household size and income, percent of population Native, percent of population in poverty, the population of the village in the year 2000, and the land area of the village in square miles. 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. Distributions of the number and percent of births for each covariate in lower and higher potential hazard villages were calculated to determine if these covariates were approximately equally distributed across each exposure category (Table I). The same distributions were calculated for the subset of pregnancies that occurred in villages with specific exposure information on dump-site contents, distance from a drinking water aquifer, and site drainage (Table II). Per agreement with the Alaska Bureau of Vital Statistics, cells in tables with less than five observations are not displayed.

Data analysis

Chi-square tests were used to determine if the distribution of covariates was homogeneous across exposure groups. Fisher's exact tests were used when expected cell counts were less than five. These tests were performed with all data, and then again with the subset of data with detailed hazard potential information.

Crude incidence rate ratios (RR) and 95 percent confidence intervals (95% CI) were calculated for the effect of hazard ranking on each separate birth outcome and on all deaths combined and all congenital anomalies combined. Fetal deaths were excluded from the analyses for neonatal deaths, and neonatal deaths were excluded from analyses of fetal deaths. We tested homogeneity of the rate ratio across strata of year of incidence and confirmed the assumption of homogeneity by examining a plot of standardized residuals (26).

Poisson regression (26) was used to model the natural log of the incidence rates of deaths and congenital anomalies as linear combinations of the risk factors and covariates. Adjusted incidence rate ratios and 95 percent confidence intervals were calculated to quantify the relationships between the hazard potential of villages and occurrences of all deaths, fetal and neonatal deaths, all congenital anomalies, five anatomic categories of defects, other defects, and multiple defects. Multiple anomalies were counted under each outcome and counted only once for the outcome of all congenital anomalies combined.

Information on gender (female versus male), parity (one or two previous pregnancies, three or more previous pregnancies, and unknown), adequacy of prenatal care, smoking status (did not smoke, smoked during pregnancy, and unknown), alcohol intake (did not drink, drank during pregnancy, and unknown), race (Caucasian, unknown and other, and Native), mother's age (under 20, 20 through 39, and 40 or more years), mother's education (less than 11 years, 12 years, and more than 12 years), gestation and birth weight (in one variable), year of birth, village healthcare options (restricted, qualified emergency care center, and qualified acute care facility), and village water hookup (no households plumbed, some household plumbed, and no households plumbed) were used in models. The Kessner Index (27) is a classification scheme of adequacy of prenatal care that accounts for the gestational month in which prenatal care began and the number of prenatal visits with respect to the length of gestation. The Kessner Index was used to define the adequacy of prenatal care into categories of adequate, intermediate, inadequate, and unknown. The gestation/birth weight variable was classified into four categories: term birth, not low birth weight; preterm birth, not low birth weight; preterm birth, low birth weight; and insufficient information/ missing value. Preterm birth was defined as gestation lasting less than 37 weeks, and low birth weight was defined as less than 2500 grams.

All analyses were performed again, examining the subset of data that had complete information for hazard point factors. The three factors weighted the most in calculating dump scores were used individually as predictors for each outcome of interest. Villages that received the maximum score on site contents were categorized as "high" and contrasted against those that received the median score (categorized as moderate). Only two villages representing 56 pregnancies received a "low" score on contents, so these pregnancies were excluded from analyses. In the next series of models, distance to a drinking water aquifer was categorized as within 50 feet, 50 to 600 feet, and greater than 600 feet. In the last series of models, dumpsites receiving maximum scores for site drainage were categorized as "high", those receiving median scores were "moderate", and those receiving no points were "low".

RESULTS

Chi-square tests revealed that the distributions of gender and year of birth were roughly equal between exposure levels (Table I). There were wide disparities ($p < 0.001$) in the distribution of parity, quality of prenatal care, cigarette and alcohol use, race, maternal age, maternal education level, birth weight and gestation, type of healthcare, and water hookup to households (Table I). Mothers in villages with low hazard ranked dumpsites tended to have had fewer previous pregnancies, better prenatal care, smoked and drank less frequently, were more frequently Caucasian, completed more years of education, had fewer low birth weight and/or preterm births, more often had access to acute care medical facilities, and were more likely to have households in their villages completely plumbed, compared to mothers from villages with higher hazard ranked dumpsites. Other village level covariates are not displayed, as they were not used in any analyses, because, after adjusting for other factors listed on the birth certificate, these factors did not add any additional information to the model.

When examining the subset of villages with detailed hazard information, chi-square tests revealed the distributions of gender, quality of prenatal care, reported cigarette use during pregnancy, and year of birth, were roughly equal between exposure levels (Table II). Parity ($p = 0.03$), alcohol use ($p = 0.04$), maternal education ($p = 0.05$), and birth weight and gestation ($p = 0.03$) were less evenly distributed. There were wide disparities ($p < 0.001$) in the distribution of race, maternal age, type of healthcare, and water hookup to households (Table II). Mothers from villages with high hazard ranked dumpsites were more often Native, more likely to have qualified emergency care facilities rather than acute care hospital facilities in their villages, and more likely to have households either all plumbed, or not plumbed in their villages, than the mothers from villages with low hazard ranked dumpsites.

As the incidences of all outcomes were homogeneous throughout the study period, incidence rates for the entire study period are presented (Table III). The overall mortality rate (fetal and neonatal deaths combined) for the 10 360 infants born between 1997 and 2001 and included in the analyses, was 7.7

Table I. The distribution and chi-square results of individual maternal and village level characteristics across villages with lower and higher hazard potential dumpsites, Alaska, 1997-2001.

Covariates	Lower hazard dumpsite (n = 5774)		Higher hazard dumpsite (n = 4586)		
	Number	Percent	Number	Percent	p-value
Maternal characteristics					
Gender of infant					0.41
Male	3031	52.5	2370	51.7	
Female	2743	47.5	2216	48.3	
Parity					<0.001
1 or 2 previous pregnancies	2327	40.3	1588	34.6	
0 previous pregnancies	1432	24.8	1053	23.0	
3 or more previous pregnancies	1998	34.6	1925	42.0	
Missing	17	0.3	20	0.4	
Quality of prenatal care					<0.001
Adequate	3278	56.8	1731	37.7	
Intermediate	1665	28.8	1798	39.2	
Inadequate	633	11.0	934	20.4	
Missing	198	3.4	123	2.7	
Cigarette use during pregnancy					<0.001
Did not report smoking	4189	72.5	3117	68.0	
Reported smoking	1560	27.0	1444	31.5	
Missing	25	0.4	25	0.5	
Alcohol use during pregnancy					0.001
Did not report drinking	5418	93.8	4224	92.1	
Reported drinking	316	5.5	332	7.2	
Missing	40	0.7	30	0.7	
Race					0.001
Caucasian	2329	40.3	383	8.4	
Not reported or other	240	4.2	55	1.2	
Alaska Native	3205	55.5	4148	90.4	
Maternal Age					<0.001
<20 years	777	13.5	785	17.1	
20-39 years	4837	83.8	3691	80.5	
40+ years	160	2.8	110	2.4	
Maternal education					<0.001
More than 12 years	1808	31.3	626	13.7	
12 years	2697	46.7	2846	62.1	
Less than 12 years	1115	19.3	974	21.2	
Missing	154	2.7	140	3.1	
Birth weight and gestation					<0.001
Not low birth weight/term birth	5319	92.2	4101	89.5	
Not low birth weight/preterm birth	236	4.1	265	5.8	
Low birth weight/term birth	54	0.9	51	1.1	
Low birth weight/preterm birth	140	2.4	146	3.2	
Missing	20	0.3	19	0.4	
Year of birth					0.61
1997	1154	20.0	967	21.1	
1998	1161	20.1	923	20.1	
1999	1160	20.1	930	20.3	
2000	1148	19.9	887	19.3	
2001	1151	19.9	879	19.2	
Village level characteristics					
Available healthcare in village					<0.001
Qualified acute care facility	4303	74.5	136	3.0	
Qualified emergency care center	405	7.0	992	21.6	
Restricted healthcare options	1066	18.5	3458	75.4	
Piped water to households in village					<0.001
All households plumbed	3861	66.9	1127	24.6	
Some households plumbed	1509	26.1	1743	38.0	
No households plumbed	404	7.0	1716	37.4	

Table II. The distribution and chi-square results of individual maternal and village level characteristics across the subset of villages with detailed hazard score information with lower and higher hazard potential dumpsites, Alaska, 1997-2001.

Covariates	Lower hazard dumpsite (n = 966)		Higher hazard dumpsite (n = 4462)		
	Number	Percent	Number	Percent	p-value
Maternal characteristics					
Gender of infant					0.85
Male	503	52.1	2308	51.7	
Female	463	47.9	2154	48.3	
Parity					0.03
1 or 2 previous pregnancies	366	37.9	1536	34.4	
0 previous pregnancies	198	20.5	1021	22.9	
3 or more previous pregnancies	402	41.6	1885	42.2	
Missing	*		20	0.4	
Quality of prenatal care					0.16
Adequate	358	37.1	1690	37.9	
Intermediate	402	41.6	1748	39.2	
Inadequate	172	17.8	901	20.2	
Missing	34	3.5	123	2.8	
Cigarette use during pregnancy					0.18
Did not report smoking	631	65.3	3052	68.4	
Reported smoking	329	34.1	1386	31.1	
Missing	6	0.6	24	0.5	
Alcohol use during pregnancy					0.04
Did not report drinking	901	93.3	4104	92.0	
Reported drinking	54	5.6	329	7.4	
Missing	11	1.1	29	0.6	
Race					0.001
Caucasian	117	12.1	373	8.4	
Not reported or other	8	0.8	52	1.2	
Alaska Native	841	87.1	4037	90.5	
Maternal Age					0.65
<20 years	153	15.8	760	17.0	
20-39 years	788	81.6	3593	80.5	
40+ years	25	2.6	109	2.4	
Maternal education					0.05
More than 12 years	119	12.3	610	13.7	
12 years	570	59.0	2763	61.9	
Less than 12 years	240	24.8	952	21.3	
Missing	37	3.8	137	3.1	
Birth weight and gestation					0.03
Not low birth weight/term birth	897	92.9	3990	89.4	
Not low birth weight/preterm birth	37	3.8	257	5.8	
Low birth weight/term birth	9	0.9	50	1.1	
Low birth weight/preterm birth	21	2.2	142	3.2	
Missing	*		23	0.5	
Year of birth					0.49
1997	194	20.1	937	21.0	
1998	209	21.6	902	20.2	
1999	177	18.3	907	20.3	
2000	186	19.3	850	19.0	
2001	200	20.7	866	19.4	
Village level characteristics					
Available healthcare in village					<0.001
Qualified acute care facility	118	12.2	136	3.0	
Qualified emergency care center	89	9.2	973	21.8	
Restricted healthcare options	759	78.6	3353	75.1	
Piped water to households in village					<0.001
All households plumbed	126	13.0	1127	25.3	
Some households plumbed	548	56.7	1743	39.1	
No households plumbed	292	30.2	1592	35.7	

* Cell value less than 5

Table III. Incidence rates of neonatal and fetal deaths and congenital anomalies, in 197 Alaska Native villages, 1997-2001

Outcome	Outcome present	Number of pregnancies	Incidence (per 1000 births)
Deaths			
All	80	10360	7.7
Fetal	47	10327	4.6
Neonatal	33	10313	3.2
Congenital Anomalies			
All	261	10360	25.2
Central nervous system	15	10360	1.4
Circulatory/respiratory	23	10360	2.2
Urogenital	23	10360	2.2
Musculoskeletal/integumental	82	10360	7.9
Other	123	10360	11.9
Multiple	19	10360	1.8

Table IV. Crude and adjusted rate ratios and 95% confidence intervals describing the relationships between lower and higher hazard exposure categories and incidence of fetal and neonatal death and congenital anomalies, Alaska, 1997-2001.

Outcome	Outcome present	Number	Rate per 1000	Rate ratio crude (95% CI)	Rate ratio adjusted † (95% CI)
Deaths					
All deaths (n = 10360)					
Lower hazard dumpsite	44	5774	7.6	1.00	1.00
Higher hazard dumpsite	36	4586	7.9	1.03 (0.66, 1.60)	0.65 (0.34, 1.27)
Fetal (n = 10327)					
Lower hazard dumpsite	28	5758	4.9	1.00	1.00
Higher hazard dumpsite	19	4569	4.2	0.85 (0.48, 1.53)	0.75 (0.28, 1.99)
Neonatal (n = 10313)					
Lower hazard dumpsite	16	5746	2.8	1.00	1.00
Higher hazard dumpsite	17	4567	3.7	1.34 (0.68, 2.65)	0.55 (0.22, 1.38)
Congenital Anomalies					
All (n = 10360)					
Lower hazard dumpsite	142	5774	24.6	1.00	1.00
Higher hazard dumpsite	119	4586	26.0	1.06 (0.83, 1.35)	1.37 (0.92, 2.04)
Central nervous system					
Lower hazard dumpsite	6	5774	1.0	1.00	1.00
Higher hazard dumpsite	9	4586	2.0	1.89 (0.67, 5.31)	2.36 (0.37, 14.71)
Circulatory/respiratory					
Lower hazard dumpsite	12	5774	2.1	1.00	1.00
Higher hazard dumpsite	11	4586	2.4	1.17 (0.51, 2.64)	1.42 (0.39, 5.42)
Gastrointestinal					
Lower hazard dumpsite	[a]	5774		1.00	1.00
Higher hazard dumpsite	6	4586	1.3	1.88 (0.53, 6.65)	0.58 (0.14, 2.40)
Urogenital					
Lower hazard dumpsite	10	5774	1.7	1.00	1.00
Higher hazard dumpsite	13	4586	2.8	1.64 (0.72, 3.73)	2.71 (0.67, 10.95)
Musculoskeletal/integumental					
Lower hazard dumpsite	41	5774	7.1	1.00	1.00
Higher hazard dumpsite	41	4586	8.9	1.26 (0.81, 1.94)	1.61 (0.79, 3.29)
Other					
Lower hazard dumpsite	71	5774	12.3	1.00	1.00
Higher hazard dumpsite	52	4586	11.3	0.92 (0.65, 1.32)	1.38 (0.77, 2.39)
Multiple					
Lower hazard dumpsite	9	5774	1.6	1.00	1.00
Higher hazard dumpsite	10	4586	2.2	1.40 (0.57, 3.44)	1.33 (0.34, 5.20)

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

[a] Cell value less than 5

Table V. Crude and adjusted rate ratios and 95% confidence intervals describing the relationships between site contents, distance from site to drinking water aquifers, and site drainage with incidence of fetal and neonatal death and congenital anomalies, Alaska, 1997-2001.

Models	Outcome present	Number	Rate per 1000	Rate ratio crude (95% CI)	Rate ratio adjusted † (95% CI)
All deaths (n = 5428)					
Site contents (moderate)	38	5214	7.3	1.00	
Site contents (high)	[a]		12.7	1.74 (0.42, 7.20)	2.04 (0.48, 8.57)
Distance to aquifer >600 ft	26	3892	6.7	1.00	
Distance to aquifer 50-600 ft	9	1011	8.9	1.33 (0.62, 2.84)	1.28 (0.59, 2.79)
Distance to aquifer <50 ft	5	525	9.5	1.43 (0.55, 3.71)	1.09 (0.41, 2.93)
Site drainage (low)	[a]		7.1	1.00	
Site drainage (moderate)	26	3541	7.3	1.03 (0.21, 4.40)	0.95 (0.21, 4.40)
Site drainage (high)	12	1606	7.5	1.05 (0.21, 5.35)	1.07 (0.21, 5.35)
Fetal					
Site contents (moderate)	20	5196	3.9	1.00	
Site contents (high)	[a]		6.4	1.65 (0.22, 12.33)	3.08 (0.38, 25.27)
Distance to aquifer >600 ft	15	3881	3.9	1.00	
Distance to aquifer 50-600 ft	5	1007	5.0	1.28 (0.47, 3.53)	1.46 (0.51, 4.19)
Distance to aquifer <50 ft	[a]		1.9	0.50 (0.07, 3.76)	0.54 (0.07, 4.20)
Site drainage (low)	[a]		7.1	1.00	
Site drainage (moderate)	13	3528	3.7	0.52 (0.12, 2.29)	0.57 (0.10, 3.39)
Site drainage (high)	6	1600	3.8	0.53 (0.11, 2.61)	0.65 (0.09, 4.56)
Neonatal					
Site contents (moderate)	18	5194	3.5	1.00	
Site contents (high)	[a]		6.4	1.84 (0.25, 13.77)	3.67 (0.45, 29.86)
Distance to aquifer >600 ft	11	3877	2.8	1.00	
Distance to aquifer 50-600 ft	[a]		4.0	1.40 (0.45, 4.40)	1.80 (0.55, 5.92)
Distance to aquifer <50 ft	[a]		7.6	2.69 (0.86, 8.45)	2.77 (0.86, 8.98)
Site drainage (moderate)	13	3528	3.7	1.00	
Site drainage (high)	6	1600	3.8	1.02 (0.39, 2.68)	1.12 (0.42, 3.03)
Congenital Anomalies (n = 5367)					
Musculoskeletal/integumental					
Site contents (moderate)	45	5214	8.6	1.00	
Site contents (high)	[a]		6.3	0.73 (0.10, 5.32)	0.75 (0.10, 5.47)
Distance to aquifer >600 ft	32	3892	8.2	1.00	
Distance to aquifer 50-600 ft	8	1011	7.9	0.96 (0.44, 2.09)	1.01 (0.46, 2.21)
Distance to aquifer <50 ft	6	525	11.4	1.39 (0.58, 3.32)	1.37 (0.56, 3.35)
Site drainage (low)	5	281	17.8	1.00	
Site drainage (moderate)	27	3541	7.6	0.43 (0.17, 1.11)	0.39 (0.14, 1.08)
Site drainage (high)	14	1606	8.7	0.49 (0.18, 1.36)	0.45 (0.15, 1.33)
Other					
Site contents (moderate)	50	5214	9.6	1.00	
Site contents (high)	6	158	38.0	3.96* (1.70, 9.24)	4.27* (1.76, 10.36)
Distance to aquifer >600 ft	40	3892	10.3	1.00	
Distance to aquifer 50-600 ft	12	1011	11.9	1.15 (0.61, 2.20)	1.15 (0.60, 2.20)
Distance to aquifer <50 ft	[a]		7.6	0.74 (0.27, 2.07)	0.72 (0.26, 2.02)
Site drainage (low)	[a]		10.7	1.00	
Site drainage (moderate)	28	3541	7.9	0.74 (0.23, 2.44)	0.72 (0.22, 2.38)
Site drainage (high)	25	1606	15.6	1.46 (0.44, 4.83)	1.43 (0.43, 4.77)

† Adjusted for gender, interpregnancy interval, parity, adequacy of prenatal care, smoking status, alcohol intake, race, mother's age and education, healthcare options, piped water, and missing values.
[a] Cell value less than 5
* $p < 0.001$
CI = Confidence interval
ft = feet (1 foot = 0,3048 metres)

per 1000 births, while the rate for fetal deaths was 4.6 and neonatal deaths was 3.2 per 1000 births. The incidence rate for all congenital anomalies combined was 25.2 per 1000 births. The category "other" defects had the highest rate, with 11.9 per 1,000 births, where musculoskeletal/integumental defects had the highest incidence of a specific anomaly (7.9 per 1000). Incidence rates for other defects ranged from 1.4 to 2.2 per 1000 births.

Crude estimates revealed that mothers residing in villages with higher hazard rankings were at no detectable increased risk for all deaths combined, fetal deaths, or neonatal deaths, compared to mothers residing in villages with lower hazard rankings (Table IV). Adjusted estimates failed to detect significant differences at the 5 percent level of confidence between exposure groups. However, effect estimates were in a positive direction for combined congenital anomalies, central nervous system anomalies, circulatory and respiratory anomalies, urogenital anomalies musculoskeletal and integumental anomalies, other defects, and multiple defects (Table IV). The outcome group including all anomalies (RR = 1.37, 95% CI: 0.92, 2.02) had the narrowest confidence intervals, embracing fewer values below 1.00 than other outcomes.

There were 5428 births in villages with detailed exposure rankings. Crude estimates did not detect any significant difference in death rates for infants born to mothers in villages with high hazard site contents versus infants born to mothers residing in villages with moderate hazard site contents (Table V). Adjusted estimates also failed to detect significant differences for the two exposure categories for all deaths (RR = 2.04; 95% CI: 0.73, 1.80) fetal deaths (RR = 3.08; 95% CI: 0.38, 25.27), and neonatal deaths (RR = 3.67; 95% CI: 0.45, 29.86). Neither crude, nor adjusted estimates detected a significant difference in incidences for all deaths, fetal deaths, or neonatal deaths, when using the distance of the dumpsite from the drinking water aquifer as a predictor. In fact, estimates for the moderately exposed group were higher than estimates for the more heavily exposed group for all deaths and fetal deaths (Table V). Crude models detected no significant differences in incidence of death across low, moderate, and high site drainage exposure groups when predicting deaths. Adjusted estimates were close to unity for all deaths and fetal deaths, and in a protective direction for neonatal deaths.

When examining congenital anomalies, there were only 5367 births in villages with detailed exposure information available for analyses. Only models examining risks for musculoskeletal and integumental defects and other defects converged. Crude estimates predicting musculoskeletal and integumental defects did not demonstrate any differences when examining site contents, dumpsite distance to drinking water aquifer, or site drainage (Table V). Likewise, adjusted estimates did not differ across exposure groups for dumpsite contents, distance to a drinking water aquifer, or site drainage. In fact, when comparing moderate hazard site drainage to low hazard site drainage, it was found to be somewhat protective against defects (RR = 0.39; 95% CI: 0.14, 1.08). For the analysis containing only other defects, the crude rate ratio revealed infants born to mothers residing in villages with high hazard site contents had an increased rate for other defects (RR = 3.96; 95% CI: 1.70, 5.32), compared to infants born to mothers residing in villages with moderate hazard site contents. Adjusted estimates also detected an increased rate (RR = 4.27; 95% CI: 1.76, 10.36) for high hazard site contents, compared to the referent category. Neither crude, nor adjusted rate ratios for other defects detected a significant difference with respect to dumpsite distance to a drinking water aquifer and site drainage.

DISCUSSION

This work failed to detect a significant increase in the rates of fetal, or neonatal deaths, or all deaths combined, in infants whose birth certificates indicated that their mothers resided in villages with higher hazard dumpsites, compared to villages with lower hazard sites. Although 95 percent confidence intervals included unity, adjusted estimates suggested a protective effect associated with residence in high hazard villages.

Aside from gastrointestinal defects, adjusted estimates for all categories of congenital anomalies were in a positive direction. However, all 95 percent confidence intervals included values below one. Estimates were slightly higher than, or within range of, results reported in studies with positive results for birth defects (11-15). This study had a much smaller sample size than these other studies with positive results, and the 95 percent confidence intervals for the largest category, which contained all defects combined, included the fewest values below one. This indicates that a study using a larger sample size may be able to detect meaningful associations between dumpsite hazard potential and the incidence of congenital anomalies as significant.

In an attempt to define exposure more finely, hazard factors that had the most influence on overall dumpsite scores were used as individual predictors. Defining these models resulted in a nearly 50 percent reduction in sample size. Only models predicting all deaths, fetal deaths, neonatal deaths, musculoskeletal and integumental defects, and other defects, had enough cases in each level of exposure for the statistical models to converge. There was a four-fold increase in the rate of other congenital defects in infants born to mothers residing in villages with dumpsites with high hazard dumpsite contents, compared to mothers residing in villages with moderate hazard dumpsite contents. Although confidence intervals included one, high hazard dumpsite contents also indicated an elevated rate for fetal and neonatal deaths (individually and combined). No patterns could be detected in any models using distance of dumpsites to drinking water aquifers and site drainage. This could be because of no actual effect, a small sample size, or because some AN villages prefer to use rain catchment systems, snowmelt, or untreated river water to obtain drinking water, and other villages test and treat water regularly.

The largest obstacle encountered with this study is the definition of exposure. It is not known what proportion of their pregnancies women spent in their village of residence indicated on the birth record. Although the dumpsites were ranked in generally the same time period as the study period, the quality of the dumpsites could conceivably have been labile during each pregnancy.

The available level of village healthcare was adjusted for in the analyses, but information on covariates, such as underlying health conditions and occupational exposures, were not. Covariates were distributed differently between exposure levels. Other potentially confounding factors not measured may have been distributed differently. These covariates could have differed between exposure groups. Another concern is that studies performed in other states have found that birth record information often does not correlate with the patients' medical records (28,29). Although this analysis has not been performed with Alaskan records, results need to be interpreted cautiously.

Information on congenital anomalies was gathered from birth records. This method reduced complications associated with linking records in different databases. Additionally, birth defects occurring in stillborn infants may be less likely to be reported to the Alaska Birth Defects Registry (ABDR) (30), so using birth certificate information might find more cases with respect to defects in fetal deaths. However, only birth defects apparent within the first few days following birth are entered on the birth certificate. The overall congenital anomaly rate in our study was 25.2 per 1,000 births (excluding chromosomal abnormalities). However, the rate of children with at least one major congenital anomaly for 1996-2000 was 52.6 per 1000 births as reported by the ABDR. The ABDR rate includes chromosomal defects, but, as these defects were relatively uncommon, it is still approximately twice the rate of the birth record rate in this study. Defects are categorized into fairly broad categories on birth records, rather than coded to the ICD-10, which can make comparability between studies difficult. Since the inception of the ABDR in 1996, reporting rates and early case ascertainment have improved, so further studies may increase power by using the registry rather than birth records when defining cases.

Conclusions

Future studies examining potential health effects associated with open dumpsites in AN villages should include exposure measurements that are more precise. Studies with crude exposure definitions sometimes provide information indicating potential risks, but misclassification bias is inherent. Several contaminants identified in, and proximal to, individual dumpsites (arsenic, lead, methyl mercury, and several petroleum hydrocarbons) are associated with negative birth outcomes (14,31,32). In examining health effects associated with environmental exposures from hazardous waste sites, it is always preferable, though rarely possible, to identify direct pathways of exposure. Reproductive outcomes can be sensitive indicators of environmental insults, as the reproductive system often fails before other systems (14,19,33). Other outcomes of interest could include chromosomal abnormalities or DNA adducts. Sparse populations and long incubation periods make the study of cancers difficult, although this is an outcome of great interest to ANs.

Although a substantial number of studies have been conducted, risks to health from dumpsites are difficult to quantify. Exposure information is often poorly defined, and effects of exposure to low levels of environmental contaminants are not easy to quantify, either singly or jointly. The most important aspect of this study is that it is the first to attempt to characterize the relationship of infant deaths and congenital anomalies to residents of AN villages with respect to open dumpsites.

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