Incidence of Childhood Leukemia and Oil Exploitation in the Amazon Basin of Ecuador

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To determine whether there was any difference in childhood leukemia incidence rates between populations living in the proximity to oil fields and those living in areas free from oil exploitation in the Amazon basin of Ecuador, 91 cancer cases among children (0–14 years) from the provinces of Sucumbios, Orellana, Napo, and Pastaza during the period 1985–2000 were studied. The relative risks for all leukemias indicated significantly elevated levels in the youngest age group (0–4 years), both genders combined (RR 3.48, 95% CI 1.25–9.67), and in all age groups (0–14 years) combined for females (RR 2.60, 95% CI 1.11–6.08) and both genders combined (RR 2.56, 95% CI 1.35–4.86). There was no significant difference between the two groups in all other cancer sites combined. Study results are compatible with a relationship between childhood leukemia incidence and living in the proximity of oil fields in the Ecuadorian Amazon. *Key words*: crude oil; leukemia; Amazon; Ecuador.

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The Amazon basin of Ecuador, known as the "Oriente," consists of more than 100,000 km[2] of tropical rainforest lying at the headwaters of the Amazon river network. The region contains one of the most diverse collections of plant and animal life in the world.[1]

In 1967, a Texaco–Gulf consortium discovered a rich field of oil beneath the rainforest, leading to an oil boom that has permanently reshaped the region. Since then, foreign companies together with Ecuador's national oil company have extracted more than two billion barrels of crude oil from the Ecuadorian Amazon. During this process, millions of gallons of untreated toxic wastes, gas, and oil have been released into the environment.[2] Indigenous federations, peasants' movements, and environmental groups in Ecuador have organized in opposition to unregulated oil development, charging that contamination has caused widespread damage both to people and to the environment.[3–5] Oil development activities include several contaminating processes. In the Amazon basin of Ecuador, each exploratory well that is drilled produces an average of 4,000 cubic meters of drilling wastes (drilling muds, petroleum, natural gas, and formation water) from deep below the earth's surface. These wastes are frequently deposited into open, unlined pits called separation ponds, from which they either are directly discharged into the environment or leach out as the pits degrade or overflow from rainwater.[2,3]

If commercial quantities of oil are detected, the production stage starts. During production, oil is extracted in a mixture with formation water and gas and separated in a central facility. At each facility, over 4.3 million gallons of liquid wastes are generated every day and discharged without treatment into pits. Roughly 53 million cubic feet of "waste" gas from the separation process are burned daily without temperature or emissions controls. Additional potential contamination of the air is generated at pits and oil spills by hydrocarbons coming from standing oil slicks.[6]

Routine maintenance activities at over 300 producing wells discharge an estimated 5 million gallons of untreated toxic wastes into the environment every year. Leaks from wells and spills from tanks have been common.[7] According to a study conducted by the government in 1989, spills from flow lines alone were dumping an estimated 20,000 gallons of oil every two weeks.[8]

Spills from the main and secondary pipelines are also common. In 1992, the Ecuadorian government recorded approximately 30 major spills, with an estimated loss of 16.8 million gallons of crude oil.[3] Currently, it has been estimated two big spills occur per week from the main oil fields in the region.[9] For instance, in 1989 at least 294,000 gallons and in 1992,

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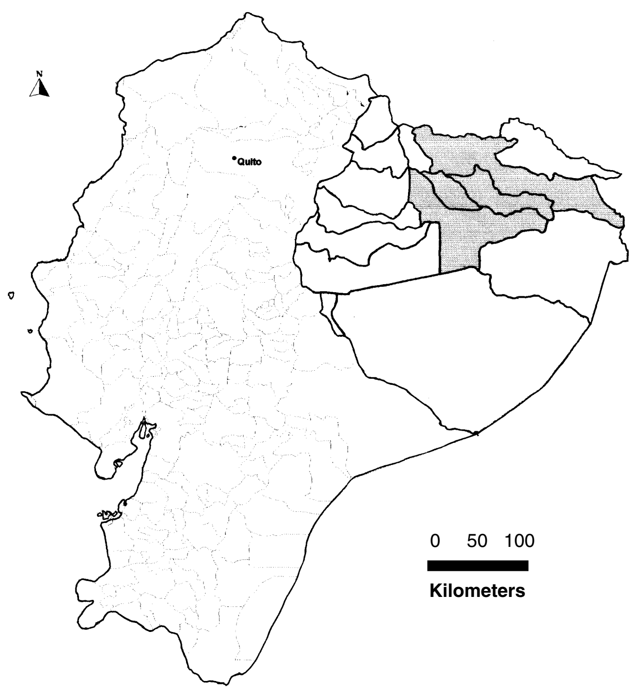

Figure 1—Map showing counties included in the study; exposed counties in grey.

about 275,000 gallons of crude oil caused the Napo river (1 km wide) to run black during one week.[10]

Overall, more than 30 billion gallons of toxic wastes and crude oil had been discharged into the land and waterways of the "Oriente" by 1993.[3] This compares to the 10.8 million gallons spilled in the Exxon Valdez disaster in Alaska in 1989, one of the most damaging sea oil spills that has ever occurred.

In 1994, the Ecuadorian environmental and human rights organisation *Centro de Derechos Económicos y Sociales* [Center for Economic and Social Rights] released a report documenting dangerous levels of toxic contamination.[11] Concentrations of polynuclear aromatic hydrocarbons found in drinking, bathing, and fishing waters were 10 to 10,000 times greater than allowable under the United States Environmental Protection Agency guidelines. In 1999, the *Instituto de Epidemiología y Salud Comunitaria "Manuel Amunárriz"* (IESCMA), a local health nongovernmental organization, undertook water analysis for total petroleum hydrocarbons (TPH) in communities in the proximity of oil fields and communities far distant from them. Water analyses showed high levels of exposure to oil-derived chemicals among the residents of the exposed communities.[12] In some streams hydrocarbon concentrations reached 144 and 288 times the limit permitted by the European Community regulation.[13] The same year, a report from the Ministry of Environment supported these results, when concentrations of TPH over 300 times the limit permitted were found in the streams of one of the communities of the previous study.[14]

Although several studies have focused on residents exposed to major oil spillages,[15–17] epidemiologic studies of communities exposed to oil pollutants near oil fields are few.[18,19]

In a study in the Amazon basin of Ecuador, an excess of cancers was observed among males in a village located in an oil-producing area.[20] A later study from the Amazon basin of Ecuador found significantly higher incidences of all cancer sites combined in both men and women in counties where oil exploitation had been on going for at least 20 years. Significantly elevated levels were observed for cancers of stomach, rectum, skin (melanoma), soft tissue, and kidney in men and for cancers of the cervix and lymph nodes in women. An increase in hematopoietic cancers was also observed in children.[21] The object of the present study was to examine in detail of the incidence of leukemia in the age group 0–14 years to determine whether there was any difference in incidence rates between populations living in proximity to oil fields and those living in areas free from oil exploitation in the Amazon basin of Ecuador.

POPULATION AND METHODS

Area of Study

The study was carried out in the provinces of Sucumbios, Orellana, Napo, and Pastaza, situated in the eastern part of Ecuador (Figure 1). Each province is divided into counties (cantones). The study area has a total population of approximately 356,406 indigenous people and peasants.[22] The indigenous people live in small communities scattered along the rivers, making their living by hunting, fishing, and subsistence agriculture. The peasants arrived to the area in the 1970s, following the paths opened by oil companies. They make their living mainly by agriculture and cattle-raising. In oil-producing areas approximately 2% of the working population is employed by the oil industry.[23] Physical infrastructure in the region is poor. Few villages and small towns (10,000–15,000 citizens) have electricity and piped drinking water, the majority of the inhabitants live without these facilities. Many of the roads in oil-producing counties are paved by crude oil to reduce the amount of dust otherwise produced in this tropical climate. In each province there is a provincial hospital and the counties have health centers. The hospitals have no histopathology services and no access to radiotherapy or chemotherapy. Two mission hospitals with well functioning infrastructures are located in the no–oil-producing counties of Mera and Archidona. Oil-producing areas have no better medical facilities than those areas where no such industry is present. Qualified personnel in the oil industry are contracted from the capital or abroad and flown out in case of health problems. Only recently have some oil companies included health expenditures in their contracts

TABLE 1. Risks of Leukemia and All Other Cancers for Exposed versus Non-exposed to Oil Pollution by Age Group and Sex, Amazon Region, 1985–2000

	All Leukemias		All Other Cancers	
	Cases in Exposed Group	RR (95 % CI)	Cases in Exposed Group	RR (95 % CI)
0–4 years old				
Female	6	7.58 (0.91–62.99)	6	1.52 (0.46– 4.97)
Male	8	2.45 (0.74– 8.13)	8	1.96 (0.64– 5.98)
Both	14	3.48 (1.25– 9.67)	14	1.74 (0.77– 3.92)
5–9 years old				
Female	4	1.72 (0.38– 7.68)	3	0.77 (0.18– 3.24)
Male	3	3.78 (0.39–36.37)	3	3.78 (0.39–36.37)
Both	7	2.23 (0.65– 7.62)	6	1.28 (0.41– 3.95)
10–14 years old				
Female	6	2.05 (0.58– 7.26)	4	1.82 (0.41– 6.96)
Male	1	1.31 (0.08–20.94)	3	1.31 (0.26– 6.49)
Both	7	1.87 (0.59– 5.89)	7	1.56 (0.34– 4.64)
0–14 years old				
Female	16	2.60 (1.11– 6.08)	13	1.30 (0.60– 2.81)
Male	12	2.52 (0.95– 6.72)	14	1.96 (0.85– 4.53)
Both	28	2.56 (1.35– 4.86)	27	1.57 (0.90– 2.76)

with residents. Two counties, Sachas and Shushufindi, are producing and processing palm oil. The oil industry is the only major industry in the region.

Cancer Data

No cancer registry is available in the Amazon region. Suspected cancer cases are referred from these provinces to Quito, the capital. All cases diagnosed in Quito are registered in the National Cancer Registry.[24] This register was used for the purpose of our study. During 1985–2000, 1,207 cases of cancer were reported to the National Cancer Registry from the provinces of Sucumbios, Orellana, Napo, and Pastaza among all ages. The National Cancer Registry contains personal identification, gender, age at diagnosis, cancer site, histology (the 10th International Classification of Diseases), year of diagnosis, residence at diagnosis (county), and education. In the register, eight cases lacked data on age and three cases among the age group 0–14 years lacked data on place of residence; those were excluded from the study.

Population Data

Population data from the counties of the four provinces by gender and five-year age strata for the year 1993 were used. These were the projections of the National Institute of Statistics and Census based on the 1990 National Census.[25]

Exposure Status

The study was ecologic, and exposure status was defined on a county level. Exposed children were defined as those living in a county where oil exploitation had been ongoing for at least 20 years at the time of the study. Non-exposed were identified as those counties without oil development activities (excluding seismic studies during the late 1990s with no exploitation activities). Four counties (Lago Agrio, Shushufindi, Orellana, and Sachas; 56,202 children; 51.5% males) were defined as exposed and 11 (Cascales, Pto. El Carmen, La Bonita, Lumbaqui, Aguarico, Tena, Archidona, El Chaco, Baeza, Puyo, Mera; 71,970 children; 50.7% males) as non-exposed.

Statistical Analysis

Incidence rates for overall and specific cancer sites were calculated. Relative risks (RRs) along with the 95% confidence intervals (CIs) were calculated for males and females.

RESULTS

Between 1985 and 2000 a total of 91 cases of cancers, including 42 leukemia cases, were observed in the study area among children 0–14 years old. Twenty-eight cases of leukemia and 27 cases of other cancers occurred in exposed counties.

Data on all leukemia and all other cancer sites combined by gender and age group are presented in Table 1. The RR for all leukemia indicated significantly elevated levels in the youngest age group (0–4 years), both genders combined (RR 3.48, 95% CI 1.25-9.67), and in all age groups (0-14 years) combined for females (RR 2.60, 95% CI 1.11–6.08) and both genders combined (RR 2.56, 95% CI 1.35–4.86) in the exposed counties. There was no significant difference in relation to exposure status in all other cancer sites combined.

TABLE 2. Risks of Acute Leukemia cell type for category of exposed versus non-exposed by sex, Amazon region, 1985-2000

	Cases in Exposed Group	Incidence Rate	RR (95 % CI)
Lymphoblastic leukemia			
Female	14	3.21	2.60 (1.05- 6.45)
Male	6	1.30	2.52 (0.63-10.09)
Both	20	2.22	2.56 (1.20- 5.47)
Myeloblastic leukemia			
Female	2	0.46	2.60 (0.24-28.69)
Male	6	1.30	2.52 (0.63-10.09)
Both	8	0.89	2.56 (0.77 -8.50)
All leukemia cell types			
Female	16	3.67	2.60 (1.11- 6.08)
Male	12	2.60	2.52 (0.95- 6.72)
Both	28	3.11	2.56 (1.35- 4.86)

Data on the distribution of leukemia cell types by group and gender are presented in Table 2. Acute lymphoblastic leukemia (ALL) accounted for 20 (71.0%) of the leukemia cases in the exposed group and 10 (71.0%) of those in the unexposed group. ALL was found to be significantly elevated in the exposed counties for females (RR 2.60, 95% CI 1.05–6.46) and for both genders combined (RR 2.56, 95% CI 1.35–4.86).

DISCUSSION

This study compared incidences of childhood leukemia in counties with oil-development activities and those without in the Amazon basin of Ecuador (1985–2000). The results showed considerable differences in the incidences of childhood leukemia according to our exposure definition.

Childhood leukemia is the most common cancer among children. In Ecuador, 60% of deaths due to cancer in children less than 14 years of age are attributable to leukemia. The standardized incidence of leukemia for the Quito population has not changed in the 15 years of the NCR (5–6/100.000), being similar for both sexes.[24] While low incidences could be expected in our rural population compared with Quito, the possibility of underreporting must be considered. The reasons for a higher incidence among girls are unclear. A possible explanation might be more exposure to contaminated water during daily activities.

Crude oil is a complex mixture of many chemical compounds, mostly hydrocarbons. The petroleum hydrocarbons of most toxicologic interest are volatile organic compounds (benzene, xylene, and toluene) and polynuclear aromatic hydrocarbons (PAH).[26] Benzene is a well-known cause of leukemia,[27,28] and perhaps other hematologic neoplasms and disorders.[29,30] No adequate data on the incidences of cancers after human exposures to the other volatile organic chemicals exist.[15] An ecologic study that examined the relationship between the incidence of leukemia and volatile organic chemical (VOC) contamination of drinking water supplies in the United States suggested that drinking water contaminated with VOCs might increase the incidence of leukemia among exposed females.[31]

Corresponding studies of the incidence of leukemia in people residing near oil fields are lacking. More problematic, related existing studies tend to be based on lower levels of exposure than those in Ecuador. A study from Wales did not find an association between the incidence of leukemias and lymphomas in children and young people and their residence in the area around the BP Chemical site at Baglan Bay, South Wales.[32] A report encompassing all industrial complexes that include major oil refineries in Great Britain found no evidence of an association between residence near oil refineries and leukemia or non-Hodgkin's lymphoma.[33] However, the relationships between leukemia and toxic exposures were examined in a case–control study of a cluster of 14 childhood cases in a restricted area in The Netherlands. Results showed excessive exposures both to insecticides and to petroleum products among the cases.[34] There are also several studies showing that petroleum and fuel exhaust exposures are leukemia hazards in industrial workers, and that not all of the toxicity is explained by benzene. Childhood leukemia and other childhood cancers have been geographically associated with industrial atmospheric effluent, for example, with petroleum-derived volatiles in Great Britain.[35,36] Few studies have been conducted in petroleum-exploration and petroleum-production workers. High incidences of leukemia in oil-fields workers have been found in studies carried out in the United States and China.[37,38]

Because they reflect group rather that individual characteristics and exposures, ecologic studies must be interpreted cautiously. The use of aggregated data instead of the joint distributions of exposure, outcome, and covariates at the individual level may lead to severe bias in ecologic analyses.[39] Using narrow exposure data and small units of analysis (parishes) could have minimized the effect of this bias, but was not feasible in the present study due to the lack of data. Overall, it is difficult to measure the impact of the ecologic bias in the study.

Because pf geographic and socioeconomic impediments to accessing adequate health care, it is likely that many cases of cancer never got referred to Quito from the study area. Health services are poor in both exposed and non-exposed counties, but factors such as diagnostic skills and transport facilities might influence referral patterns. It is also possible that on a county level there are differences in racial composition and life-style patterns between populations that might confound risk estimates. However, no information about the distribution of such potentially important confounders was available.

Several limitations in the data and methods need also to be considered. Population data relied on county census figures estimated from the 1990 National Census. Errors in population estimates, including differential migration patterns, might bias estimates of risk. It is possible that the exposed counties had had more rapidly increasing populations compared with the non-exposed ones, providing a relatively greater underestimate of population denominators for these counties. Data from the National Institute of Statistics and Census give no evidence that this is the case.[22,25] Cancer rates were based on county of residence at time of diagnosis without information as to length of time at current residence. Because the latency period for cancer can be long, an assessment of migration into and out of counties as well as residence time in the county would have been useful, but no data were available.

One possibility to explain any excess risk near an industrial source is that it reflects parents' occupational exposures rather than environmental factors. Parents' occupational data were not available. Two exposed counties have also oil palm industry, where pesticide use is common. The impact of this exposure on the results presented could not be measured.

The results suggest a relationship between leukemia incidence in children and living in the proximity of oil fields, although this ecologic study cannot lead to a causal inference. However, the possibility of a causal relationship is supported by several criteria. First, the strength of the association between the outcome and the exposure; second, the finding that only leukemia was at increased risk in the exposed area increases the plausibility of the results. Third, by using surrogate data that are representative of several decades of oil pollution exposure, a plausible time sequence from exposure to development of disease can be inferred.

Further research is necessary to determine whether the observed associations do reflect an underlying causal relationship. A next step could be epidemiologic studies at the individual level. Meanwhile, an environmental monitoring system to assess, control, and assist in the elimination of sources of pollution in the area and a surveillance system to gain knowledge of the evolution of cancer incidence and distribution in the area are urgently recommended.

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