Original Articles

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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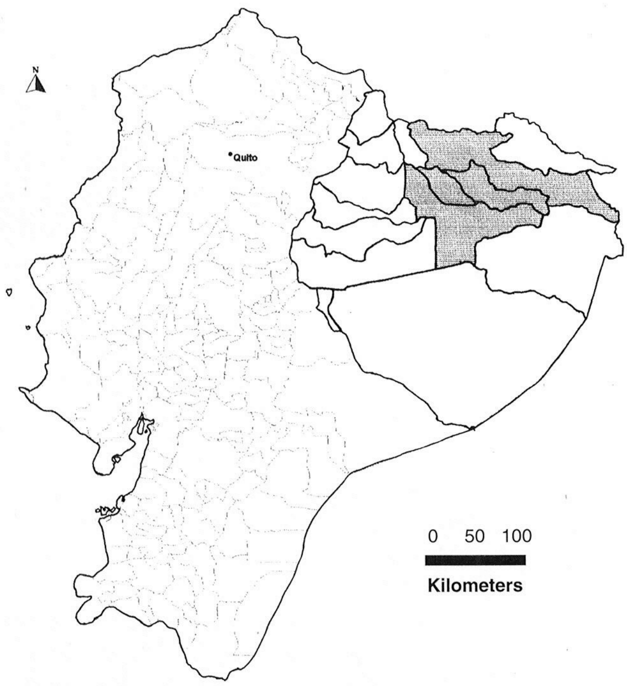

Figure 1—Map showing counties included in the study; exposed counties in grey.

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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Exposures and cancer incidence near oil fields in the Amazon basin of Ecuador

M San Sebastián, B Armstrong, J A Córdoba, C Stephens

Abstract

***Objectives*—To examine environmental exposure and incidence and mortality of cancer in the village of San Carlos surrounded by oil fields in the Amazon basin of Ecuador.**

***Methods*—Water samples of the local streams were analyzed for total petroleum hydrocarbons (TPHs). A preliminary list of potential cancer cases from 1989 to 1998 was prepared. Cases were compared with expected numbers of cancer morbidity and mortality registrations from a Quito reference population.**

***Results*—Water analysis showed severe exposure to TPHs by the residents. Ten patients with cancer were diagnosed while resident in the village of San Carlos. An overall excess for all types of cancer was found in the male population (8 observed *v* 3.5 expected) with a risk 2.26 times higher than expected (95% confidence interval (95% CI) 0.97 to 4.46). There was an overall excess of deaths for all types of cancer (6 *v* 1.6 expected) among the male population 3.6 times higher than the reference population (95% CI 1.31 to 7.81).**

***Conclusions*—The observed excess of cancer might be associated with the pollution of the environment by toxic contaminants coming from the oil production.**

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Keywords: cancer; oil; Amazon; Ecuador

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The tropical forests of Ecuador are among the most biologically diverse natural ecosystems on earth, and are home to peasants and several indigenous groups. The Amazon also has hundreds of oil fields, the most important source of income in Ecuador. Since 1972, foreign oil companies, led by Texaco and Ecuador's national oil company, Petroecuador, have extracted more than two billion barrels of crude oil from the Ecuadorian Amazon. Currently, 13 companies are operating in the country: 1 private national, Petroecuador, and 11 foreign companies. Oil has been the lynchpin of the economy. The 1970s oil price boom lifted Ecuador from being one of the poorest countries in Latin America—per capita income rose from $290 in 1972 to $1490 in 1982, decreasing to $1390 in 1995. Today, oil continues to account for nearly 50% of the nation's income from exports and government budget. However, in this development process, billions of gallons of untreated waste, gas, and crude oil have been released into the environment.[1] There are potential problems of this process of development on the environment and the health of local people. We examined this issue.

Oil, environment, and health: the literature

Oil extraction involves several contaminating processes. Drilling wastes can typically contain considerable amounts of several drilling muds (used as lubricants and sealants), and a water mixture can be formed deep below the earth's surface that contains hydrocarbons, heavy metals, and high concentrations of salt. Burning oil and gas pollutes the air with oxides of nitrogen, sulphur, and carbon, as well as heavy metals, hydrocarbons, and soot (carbon particulate).[2] Crude oil is a complex mixture of many chemical compounds, mostly hydrocarbons. The petroleum hydrocarbons of most toxicological interest are volatile organic compounds (benzene, xylene, and toluene) and polynuclear aromatic hydrocarbons (PAHs).[3]

Studies on mice have reported skin tumours after application of crude oil to the skin.[4–6] However, a review concluded that there is limited evidence showing carcinogenicity of crude oil in experimental animals, and also that there was inadequate evidence of carcinogenicity of crude oil in humans.[3]

Benzene is a well known cause of leukaemia,[7 8] and perhaps other haematological neoplasms and disorders.[9 10] No adequate data on the incidence of cancer after human exposure to the other volatile organic chemicals from oil exist.[11] A population based case-control study carried out in Montreal showed limited evidence that increased risk was found for the following associations: oesophagus-toluene, colon-xylene, rectum-toluene, rectum-xylene, and rectum-styrene.[12] An ecological study performed to examine the relation between the incidence of leukaemias and the occurrence of contamination of drinking water supplies by volatile organic chemicals (VOCs) suggested that VOCs might increase the incidence of leukaemia among exposed women.[13] Different epidemiological studies have reported direct evidence of the carcinogenic effects of PAHs in occupationally exposed subjects. Strong evidence of carcinogenic effects of PAHs on the skin, bladder, and scrotum has been found.[14–18] Workers in several industries with appreciable exposure to PAHs have also been shown to be at risk of lung cancer.[15 17–19]

Few studies of risk of cancer among inhabitants of areas close to petrochemical industries have been reported. In the United States, an ecological study found an association in both sexes between residential exposure to petroleum and chemical emissions in air and cancer of the buccal cavity and pharynx. In men, age adjusted incidences of cancers of the stomach, lung, prostate, and kidney and urinary organs were also associated with exposures to petroleum and chemical plant emissions in air.[20] A study in the same country found high rates of cancer of the lung, nasal cavity and sinuses, and skin among the resident male population.[21] Other studies in the United States have suggested high rates of lung cancer and an increased risk of brain cancer among people living near petrochemical plants.[22 23] Studies from the United States have also reported negative results.[24]

Childhood leukaemia and other childhood cancers have been geographically associated with industrial atmospheric effluent—for example with volatile compounds derived from petroleum in Great Britain.[25 26] By contrast, a study from Wales did not find an association between incidence of leukaemias and lymphomas in children and young people in the area around the BP Chemical site at Baglan Bay, South Wales.[27] A recent report around all industrial complexes that include major oil refineries in Great Britain found no evidence of association between residence near oil refineries and leukaemias or non-Hodgkin's lymphoma.[28]

Studies conducted in Taiwan have reported an excess rate for liver and lung cancer[29 30] and an excess of deaths from bone, brain, and bladder cancer in young adults associated with residence near petrochemical industries.[31]

Few studies have been conducted in petroleum exploration and production workers. In one of two case-control studies, an excess risk for testicular cancer was found among petroleum and natural gas extraction workers.[32] No such excess was found in the other study.[33] In a case-control study of cancer at many sites, an association was found between exposure to crude oil and rectal and lung cancer, however, the association was based on small numbers.[34] A study carried out on production and pipeline workers in the United States did not find significant differences for any major cause of death.[35] Sathiakumar *et al*[36] conducted an epidemiological study in oil and gas field workers in the United States that showed a positive association between work and acute myelogenous leukaemia. A study from China has also reported high incidences of leukaemia in oil field workers.[37]

Although several studies have focused on health effects of major oil spillages,[11 38 39] epidemiological studies of communities exposed to oil pollutants near oil fields are lacking. This is particularly true of developing countries where oil extraction is an aggressive strategy, but where impacts on the environment and population are little understood.

Oil, environment, and health in Ecuador: this study

In response to a community concern about the health effects of oil pollution, San Carlos village, which is surrounded by oil fields, was visited by one of us in October 1998. As part of a broader study of the situation, the study team found that some inhabitants mentioned the presence of several cases of cancer. These cases were attributed by local people to their continued exposure to oil pollution.

This paper reports the results of a preliminary analysis of environmental contamination of water sources, and cancer incidence and mortality in the village of San Carlos. To our knowledge, no studies about the association between oil pollutants, exposure, and cancer in residents near oil fields have previously been conducted.

Population and methods

AREA OF STUDY

San Carlos is a small village inhabited by peasants in the province of Orellana, in north eastern Ecuador. The population numbers about 1000, most of them came to the area in the 1970s to farm along the routes opened by the oil companies. They subsist mainly by raising cattle and involvment in other types of agriculture.

The physical infrastructure of San Carlos is poor. There is electricity but no piped drinking water or sewer services. The roads are deliberately paved with crude oil products. There is a primary health centre in the village run by a doctor and a nurse. The nearest reference centre for histopathological examinations is in Quito, 300 km away (12 hours by bus).

In the entrance to the village there is a large pumping station. More than 30 oil wells surround the village. Most of the oil wells are just a few meters from the houses (fig 1). The station and the wells dispose of waste, without treatment, in the small rivers that cross the village.[40] These rivers are the only sources of water, and are used by the population for drinking, cooking, bathing, and washing clothes. In the pumping station, there are four powerful gas burners burning gas day and night. The oil wells in San Carlos have been in operation for more than 20 years.[41] There are no chemical or other industries in the area or its surroundings.

ASSESSMENT OF EXPOSURE

Water samples from the places used by the community for drinking, bathing, and washing clothes were collected. The water was analysed for total petroleum hydrocarbons (TPHs) and was carried out by the water and soil laboratory of the P Miguel Gamboa Technical School, Coca. The TPHs were extracted with 1,1,2-trichlortrifluorethane and measured by infrared spectrophotometry. Special bottles for samples of water were provided by the laboratory. Laboratory technicians were kept blind to the origin of the water samples.

The main stream that crosses San Carlos is the Huamayacu river. Also, in the outskirts of San Carlos the population use the Basura, Parker, and other small rivers. During the month of March 1999 samples of the Huamayacu, Basura, Parker, and Iniap rivers were taken (one sample per river, taken close to the road). The samples were taken without visible presence of crude oil in the rivers.

Table 1 Concentration of total petroleum hydrocarbon (TPH) in the streams of San Carlos, 1999*

Stream	*TPH (ppm)*
Parker	0.53
Huamayacu	1.444
Basura	2.883
Iniap	0.097

*The permitted limit for hydrocarbons in drinking water according to the European Community laws is 0.01 ppm.

Because of economic and technical limitations it was not possible to measure land and air pollution.

DATA COLLECTION

A preliminary list of potential cancer cases from 1989 to 1998 was prepared by the health workers at the village of San Carlos. The list included the name, age, time of residence, and place of diagnosis. To confirm the diagnosis, data from the hospitals where people had been treated were solicited. Cases were included only when pathological evidence was present. No cancer registry is available in the Amazon region.

The cancers were grouped as in the 9th international classification of diseases (ICD-9).

Population data of San Carlos, stratified by age and sex, were taken from census county statistics for 1998. These used the 1991 national census extrapolated to 1998.[42] Information on dates on which any individual cohort members migrated to or from the village was not available.

STATISTICAL METHODS

Statistical analysis was based on the comparison of observed and expected numbers of cancer cases; the expected numbers of deaths and cancer registrations were calculated from the incidences of the Quito reference population from 1989 to 1998, stratified by 5 year age group and sex. Quito, the capital city, is the only place in the country with an adequate cancer registry or publishing deaths by specific cause.[43 44]

Observed and expected values, observed/expected ratios, and their 95% confidence intervals (95% CIs) based on the Poisson distribution exact method are reported.

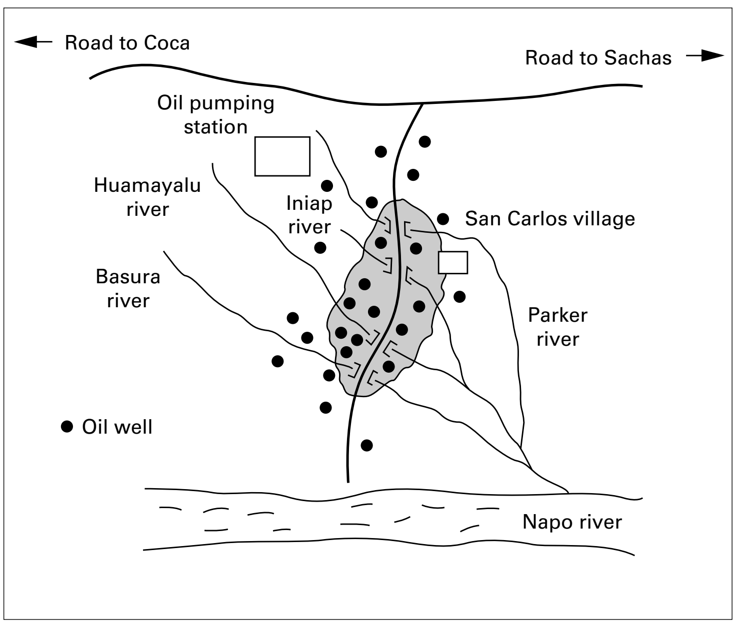

Figure 1 Map of San Carlos village and position of oil wells and rivers.

Table 2 Cases of cancer found in the village of San Carlos, Orellana, 1989–98

*ICD-9**	*Sex*	*Type of cancer*	*Date of diagnoses*	*Age at diagnoses*	*Date of death*	*Duration of residence in San Carlos (y)*
156	M	Ampulla of Vater†	March 89	68	July 89	22
151	M	Stomach	June 91	64	92	20
151	M	Stomach	August 92	55	September 92	15
151	M	Stomach	June 97	65	October 98	16
161	M	Larynx	September 97	46	—	
155	M	Liver	August 98	86	September 98	26
172	M	Melanoma	Novenber 96	52	August 97	15
204	M	Leukaemia‡	July 93	5	—	7
202	F	Lymphoma§	96	28	April 99	16
180	F	Cervix	May 98	52	—	30

*ICD-9=ninth revision of the international classification of diseases.
†Ampulla of Vater=others and non-specific from the biliary tract.
‡Acute lymphoblastic leukaemia.
§Non-Hodgkin's lymphom.

Results

EXPOSURE ASSESSMENT

The results of the analysis of the samples taken from the rivers are presented in table 1. In the Iniap stream, the hydrocarbon concentration was 0.09 parts per million (ppm), 0.5 in the Parker river, 1.44 in the Huamayacu, and 2.88 ppm in the Basura river. This compares with a permitted limit for hydrocarbons in drinking water according to the European Community laws of 0.01 ppm.[45]

CANCER INCIDENCE

The population of San Carlos was estimated to be 1000 (555 men and 455 women) in 1998. Eighteen cases of cancer were identified in the preliminary list. Out of them, 10 of the patients diagnosed were resident in the village of San Carlos during the period 1989–98, and were confirmed by pathological evidence. Three were diagnosed as benign tumours and for five cases there was no access to medical records.

The characteristics of the patients and the types of cancer are presented in table 2. Most of the cancers diagnosed were in males (8/10), three were stomach cancer. Six were diagnosed in the past 3 years. The age of diagnoses varied from 5 to 86 years. Of the 10 patients, six (all males) had already died; most of these deaths took place a short time after the diagnoses. The residence time of the patients in San Carlos was from 7 to 30 years, with a mean of 17 years.

Only one patient had worked in the oil industry, as a guardian of an oil field. From medical histories one patient was identified as a smoker.

A comparison with expected numbers, adjusted for age, is presented in table 3. An overall excess for all types of cancer was found in the male population (8 observed *v* 3.5 expected) with a risk 2.26 times higher than expected (95% CI 0.97 to 4.46). No overall excess for all types of cancer was found in females (2 observed *v* 4 expected; O/E ratio 0.5; 95% CI 0.06 to 1.80).

Table 3 Cancer incidence in the village of San Carlos, 1989–98

		Males				*Females*			
Cancer	*ICD-9*	*O*	*E*	*SIR*	*95% CI*	*O*	*E*	*SIR*	*95% CI*
All cancers*	140–208	8	3.53	2.26	0.97 to 4.46	2	4	0.5	0.06 to 1.80
Stomach	151	3	0.64	4.68	0.95 to 13.68	0	0.36	0	—
Liver	155	1	0.06	16.66	0.41 to 92.83	0	0.05	0	—
Ampulla of Vater†	156	1	0.05	20.0	0.50 to 111.40	0	0.05	0	—
Larynx	161	1	0.03	33.33	0.83 to 185.66	0	0.004	0	—
Melanoma	172	1	0.06	16.66	0.41 to 92.83	0	0.06	0	—
Leukaemia‡	204	1	0.37	2.70	0.06 to 15.05	0	0.26	0	—
Lymphoma§	202	0	0.26	0	—	1	0.14	7.14	0.17 to 39.78
Cervix	180	0	—	0	—	1	0.43	2.32	0.05 to 12.95
Others		0	2.06	0	—	0	2.65	0	—

*All cancers excluding non-melanoma skin cancer.
†Ampulla of Vater=others and non-specific from the biliary tract.
‡Acute lymphoblastic leukaemia.
§Non-Hodgkin's lymphoma.
O=observed number of cancers; E=expected number of cancers; SIR=standardised incidence ratio (O/E).

CANCER MORTALITY

Table 4 shows the results of the mortality analysis for the 10 years. There was an overall excess of deaths for all types of cancer (6 observed *v* 1.6 expected) among the male population 3.6 times higher than the reference population (95% CI 1.31 to 7.81). The excess was apparent for all sites represented, cancer of the stomach and melanoma being nominally significant ($p<0.05$). No deaths due to cancer were found in women (0 observed *v* 1.39 expected; 95% CI 0 to 2.64).

Discussion

This report presents an analysis of environmental contamination and incidence and mortality of cancer (1989–98) in a village in an oil producing area of the Amazon basin of Ecuador.

The analysis of water used for drinking, washing, and bathing showed a severe exposure to TPHs by the residents of San Carlos, with samples ranging from 10 to 288 times higher than the limit permitted by the European Community regulations. These data confirm that the residents of this village are exposed to concentrations of pollutants that originated from oil activity, which considerably exceed the recognised European safety limits. Although the initial time of exposure is not known, numerous reports have stated that unregulated oil exploration has occurred in the area since the 1970s.[2 41 46–48] In 1994, a study carried out by the Center for Economic and Social Rights[48] also found highly increased concentrations of oil pollutants in the streams and rivers of the area, evidence which also supported long term exposure of the residents to these toxins. Concentrations of PAHs were 10–10 000 times greater than the recommendations of the United States Environmental Protection Agency.

Table 4 Mortality from cancer in males in the village of San Carlos, 1989–98

		Males			
Cancer	*ICD-9*	*O*	*E*	*SMR*	*95% CI*
All cancers*	140–208	6	1.67	3.59	1.31 to 7.81
Stomach	151	3	0.36	8.33	1.69 to 24.33
Liver	155	1	0.046	21.73	0.54 to 121.08
Melanoma	172	1	0.014	71.42	1.78 to 397.85
Ampulla of Vater†	156	1	0.037	27.02	0.67 to 150.54
Others		0	1.23	0	—

*All cancers excluding non-melanoma skin cancer.
†Ampulla of Vater=others and non-specific from the biliary tract.
O=observed number of cancer deaths; E=expected number of cancer deaths; SMR=standardised mortality ratio of cancer (O/E).

Also the study suggests an excess of cancers among the male population in the village of San Carlos. All specific cancer sites showed an excess. Results of overall cancer mortality were also 3.6 higher than expected among males.

Despite the excess of cancer found in San Carlos and the high exposure to oil pollutants, the attribution of causality to this association must be considered with caution. When interpreting the results, several issues should be taken into the account.

When disease in an area is studied formally solely because a cluster of disease has been perceived informally, statistical results should be interpreted very cautiously. This process has been described as the "Texas sharp-shooter's" procedure.[49] However, this study was led by local concern about overall health effects of oil pollution on their communities. This concern preceded identification of a cancer cluster. Therefore, the presented data are not wholly subject to the application of Texas sharp-shooter caution, strengthening the likelihood of a real effect. However, the high risk of cancer found in the population was based on small numbers, which is reflected in the wide 95% CIs, making it difficult to reject the possibility of chance.

Several limitations in the data and methods need also to be considered. Population data relied on county census estimated from the 1991 national census. Errors in population estimates, including differential migration patterns, might bias estimates of risk. However, to avoid this bias, the population of San Carlos was overestimated and migration is considered to be low (mayor of the village, personal communication).

The completeness of the cancer registration in Quito is high, 95%,[44] but there may have been cancer cases in San Carlos that were not diagnosed, making our risk estimation conservative.

The general excess in all cancers argues against a specific toxic agent which might be expected to affect the incidence of only one or perhaps a few cancer sites.[50] However, epidemiological studies have reported different types of cancer being associated with occupational or residential exposure to oil pollutants.[17–23 25 26 29–31 36 37 51 52] These cancers could be grouped in six systems: digestive (buccal cavity, pharynx, stomach, liver), respiratory (nasal cavity and lung), urinary (prostate, bladder, kidney), dermal (skin), blood (leukaemia) and others (brain, bone). In our study, all diagnosed cancers—except the cervix—can be included in these groups.

The main known risk factors for the cancer most often found, stomach, are cigarette smoking, alcohol drinking, and diet. However, none of the three patients were smokers. San Carlos has a rural population, with diet based mainly on the consumption of rice, cassava, banana, meat, and occasionally fish. No data on alcohol ingestion were available.

One possibility to explain any excess risk near an industrial source is that it reflects occupational rather than environmental factors. However, just one of the patients worked in an oil facility. There is no other industrial process in the area, apart from oil, which is suspected of entailing exposures that might cause cancer. The long duration of residence of the patients in the study area is consistent with a possible environmental carcinogen, due to the long latency time of most of the carcinogens.[3]

The excess of morbidity was especially strong in males and only males had died of cancer. The reasons for the higher cancer incidence and mortality in males in our study are unclear. Six of the patients (and one more deceased in April 1999) had already died; most of these deaths took place a short time after the diagnoses. These data suggest either extremely aggressive cancers or they may reflect the poor access of the population of San Carlos to ameliorative health services.

There is also an uncertainty over the comparability of the Quito population and the local population. Access to health services, and socioeconomic and other possible unmeasured factors might confound the risk estimates. For some cancers—such as cancer of the larynx and skin melanoma—there is the added problem of possible residual socioeconomic confounding which could not be measured due to the lack of data.

In summary, there is evidence of severe contamination of water sources and apparent excess of cancer morbidity and mortality in the village of San Carlos. The excess of cancer could be linked, as local people suspect, to the pollution of the environment by toxic contaminants coming from oil production. Further research is necessary to obtain information on the extent of exposure of these populations to environmental contamination through water, soil, and air. Evidence is also needed on risk factors that could be producing the potentially high rates of cancer found in this population and on other populations similarly exposed. We recommend an environmental monitoring system to assess, control, and assist in 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. We are also concerned that, despite the economic gains brought to Ecuador as a whole by the oil industry, the people who live alongside the process may experience problems as a result of the practice, and few of the benefits.

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CANCER

Geographical differences in cancer incidence in the Amazon basin of Ecuador in relation to residence near oil fields

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Background Since 1972, oil companies have extracted more than 2 billion barrels of crude oil from the Ecuadorian Amazon, releasing billions of gallons of untreated wastes and oil directly into the environment. This study aimed to determine if there was any difference in overall and specific cancer incidence rates between populations living in proximity to oil fields and those who live in areas free from oil exploitation.

Methods Cancer cases from the provinces of Sucumbios, Orellana, Napo and Pastaza during the period 1985–1998 were included in the study. The exposed population was defined as those living in a county (n = 4) where oil exploitation had been ongoing for a minimum of 20 years up to the date of the study. Non-exposed counties were identified as those (n = 11) without oil development activities. Relative risks (RR) along with 95% CI were calculated for men and women as ratios of the age-adjusted incidence rates in the exposed versus non-exposed group.

Results The RR of all cancer sites combined was significantly elevated in both men and women in exposed counties. Significantly elevated RR were observed for cancers of the stomach, rectum, skin melanoma, soft tissue and kidney in men and for cancers of the cervix and lymph nodes in women. An increase in haematopoietic cancers was also observed in the population under 10 years in the exposed counties in both males and females.

Conclusion Study results are compatible with a relationship between cancer incidence and living in proximity to oil fields. An environmental monitoring and cancer surveillance system in the area is recommended.

Keywords Crude oil, cancer, Amazon, Ecuador

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The Amazon basin of Ecuador, known as the 'Oriente', consists of more than 40 million hectares 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 2 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]

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Indigenous federations, peasants movements and environmental groups in Ecuador have organized in opposition to unregulated oil development, charging that contamination has caused widespread damage to both people and to the environment.[3–5]

Oil development activities include several contaminating processes. In the Amazon basin of Ecuador, exploration for crude oil has involved thousands of miles of trail-clearing and hundreds of seismic detonations that have caused erosion of land and dispersion of wildlife. Each exploratory well that is drilled produces an average of 4000 m^3 of drilling wastes (drilling muds, petroleum, natural gas and formation water) from deep below the earth's surface. These wastes are deposited into open, unlined pits called separation ponds, from which they are either 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. Beneath the earth's surface oil is mixed with gas and liquid substances. It is not possible to separate the oil from these other components during extraction, this is instead done at a later stage 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 is burned daily. The gas is burned without temperature or emissions control, and contaminants from the gas flares pollute the air. Additional potential contamination of the air is generated at pits and oil spills by hydrocarbons coming from standing oil slicks.[2]

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.[6] 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 2 weeks.[7]

Overall, more than 30 billion gallons of toxic wastes and crude oil had been discharged into the land and waterways of the 'Oriente' up until 1993.[3] This compares to the 10.8 million gallons spilled in the Exxon Valdez disaster in 1989. For instance, in 1989 at least 294 000 gallons and in 1992, about 275 000 gallons of crude oil caused the Napo river (1 km wide) to run black for 1 week.[8]

In 1994, the Ecuadorian environmental and human rights organization *Centro de Derechos Económicos y Sociales* (Centre for Economic and Social Rights), released a report documenting dangerous levels of toxic contamination.[9] Concentrations of polynuclear aromatic hydrocarbons (PAH) were found in drinking, bathing and fishing waters. These were 10 to 10 000 times greater than the US Environmental Protection Agency guidelines. In 1999, the *Instituto de Epidemiología y Salud Comunitaria 'Manuel Amunárriz'* (IESCMA), a local non-governmental organization concerned with health, undertook water analysis for total petroleum hydrocarbons (TPH) in communities in the proximity of oil fields and communities far away from them. Water analyses showed high exposure to oil-derived chemicals among the residents of the exposed communities.[10] In some streams hydrocarbon concentrations reached 144 and 288 times the limit permitted by European Community regulations.[11] 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.[12]

Although several studies have focused on residents exposed to major oil spillages,[13–15] epidemiological studies of communities exposed to oil pollutants near oil fields are scarce.[10] Few studies have been conducted in petroleum exploration and producing workers. In one of two case-control studies, an excess risk for testicular cancer was observed among petroleum and natural gas extraction workers.[16] No such excess was found in the other study.[17] In a case-control study of cancer at many sites, an association was observed between exposure to crude oil and rectal and lung cancer, however the association was based on small numbers.[18] A study carried out in producing and pipeline workers in the US did not find significant differences for any major cause of death.[19] Sathiakumar *et al.*[20] conducted an epidemiological study in oil and gas field workers in the US which showed a positive association between work and acute myelogenous leukaemia. A study from China has also reported increased incidences of leukaemia in oil-field workers.[21] A recent update of a study of crude oil production workers showed a lower mortality risk for these employees compared with the general US population (perhaps a reflection of the 'healthy worker effect'). An increased mortality from acute myelogenous leukaemia was found in those people who were first employed before 1940 and who were employed in the production of crude oil for more than 30 years.[22]

In a recent study in the Amazon basin of Ecuador, an excess of cancers was observed among males in a village located in an oil producing area.[23] The objective of this study was to determine if there was any difference in overall and specific cancer incidence rates between populations living in the proximity of oil fields and those who live 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 280 000 indigenous people and peasants.[24] The indigenous people live in small communities scattered along the rivers, making their living by hunting, fishing and subsistence agriculture. The peasants arrived in 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.[25] Physical infrastructure in the region is poor. Few villages and small towns (10–15 000 citizens) have electricity

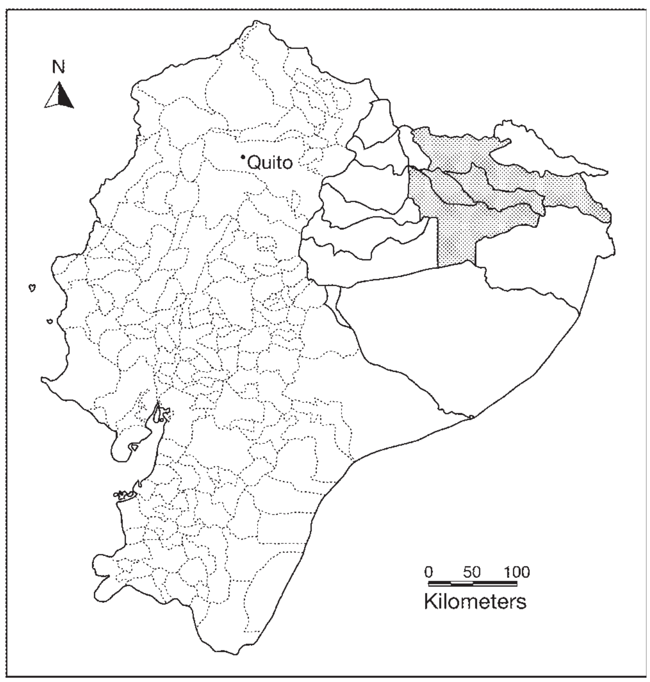

Figure 1 Map showing counties included in the study; exposed counties in grey

and piped drinking water and 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 centres. The hospitals have no histopathological services and no access to radio- or chemotherapy treatment. Two mission hospitals with efficiently functioning infrastructure are located in the counties Mera and Archidona—these are not oil producing areas. 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 the case of health problems. Only recently have some oil companies included health expenditure in their contracts with residents. Two counties, Sachas and Shushufindi, are producing and processing palm oil. There are no other major industries in the region apart from oil.

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.[26] This register was used for the purpose of our study. In all, 985 cases of cancer were reported to the National Cancer Registry from the provinces of Sucumbios, Orellana, Napo and Pastaza during 1985–1998. The National Cancer Registry contains personal identification, gender, age at diagnosis, cancer site, histology (Ninth International Classification of Diseases), year of diagnosis, residence at diagnosis and education.

Population data

Population data from the counties of the four provinces by gender and 5-year age strata for the year 1992 were used. These were projections of the National Institute of Statistics and Census based on the 1990 National Census.[27]

Exposure status

The study was ecologic and the exposure status defined at a county level. The exposed population was defined as those living in a county where oil exploitation had been ongoing for a minimum of 20 years to the date of the study. The 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) (118 264 people; 55.0% males) were defined as exposed and 11 as non-exposed (Cascales, Pto El Carmen, La Bonita, Lumbaqui, Aguarico, Tena, Archidona, El Chaco, Baeza, Puyo, Mera) (155 710 people; 52.4% males).

Statistical analysis

Incidence rates for overall and specific sites were calculated and age-adjusted to the world standard population.[28] Relative risks (RR) along with 95% CI were calculated for men and women as ratios of the age-adjusted incidence rates in the exposed versus non-exposed group.

Results

In all, 473 cancer cases (39.1% in males) were identified in exposed counties and 512 (40.2% in males) in non-exposed counties. An increased incidence for all sites combined by age was observed in both men and women (Figure 2). The RR of all cancer sites combined was significantly elevated in both men (RR = 1.40; 95% CI: 1.15–1.71) and women (RR = 1.63; 95% CI: 1.39–1.91) in exposed counties (Table 1). Significantly elevated RR were observed for cancers of the stomach (RR = 2.51; 95% CI: 1.60–2.94), rectum (RR = 10.40; 95% CI: 1.16–12.98), skin melanoma (RR = 10.15; 95% CI: 2.91–46.97), soft tissue (RR = 15.59; 95% CI: 1.74–139.30) and kidney (RR = 9.2; 95% CI: 1.03–82.20) in men and for cancers of the cervix (RR = 4.01; 95% CI: 2.97–5.41) and lymph nodes (RR = 4.74; 95% CI: 1.89–11.88) in women. Four cases of larynx cancer were found in males in exposed counties but none in the non-exposed countries (Table 1).

An increase in haematopoietic cancers was also observed in the population under 10 years in the exposed counties both in males (cases in exposed group: 10; RR = 2.63; 95% CI: 0.90–7.69) and females (cases in exposed group: 8; RR = 3.60; 95% CI: 0.95–13.57).

Discussion

This study compared cancer incidence in counties with oil development and those without such activities in the Amazon basin of Ecuador (1985–1998). The results showed considerable geographical differences in the incidence of several cancers. Epidemiological studies have reported the same types of cancer being associated with occupational or residential exposure to oil pollutants.[20,21,29–33]

Crude oil is a complex mixture of many chemical compounds, mostly hydrocarbons. The petroleum hydrocarbons of most toxicological interest are volatile organic compounds (benzene, xylene and toluene) and PAH.[34] Studies on mice have reported skin tumours after application to the skin of crude oil.[35–37] However, a review concluded that there is limited evidence for

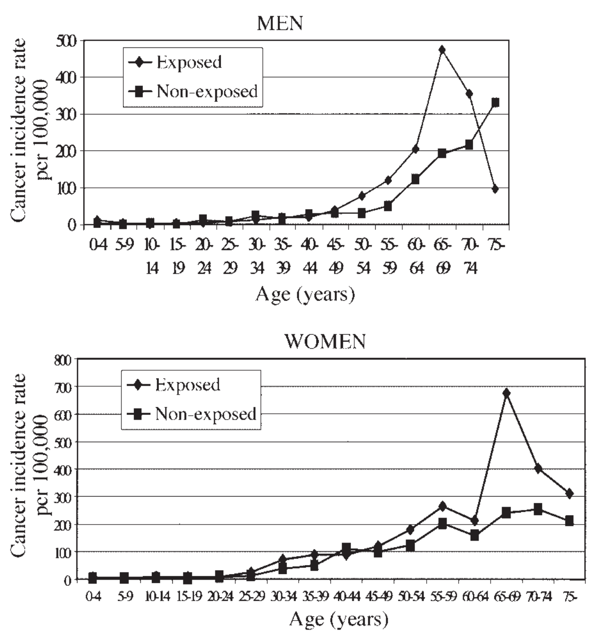

Figure 2 All sites cancer incidence by age group in men and women, Amazon basin of Ecuador, 1985–1998

Table 1 Risk of all cancers and specific cancers for category of exposed versus non-exposed to oil pollution, Amazon region, 1985–1998

	Men			**Women**		
Site (ICD-10)	Cases in exposed group	RR[a]	95% CI	Cases in exposed group	RR[a]	95% CI
All (C01–C80)	185	1.40	1.15–1.71	288	1.63	1.39–1.91
Mouth (C01–C10)	4	1.22	0.27–5.45	1	1.02	0.11–9.80
Oesophagus (C15)	2	0.82	0.15–4.48	1	0.85	0.35–2.04
Stomach (C16)	49	2.51	1.60–3.94	13	0.90	0.46–1.77
Colon (C18)	7	1.50	0.51–4.46	1	0.064	0.007–0.53
Rectum (C20)	4	10.40	1.16–12.98	2	–	–
Liver (C22)	4	1.53	0.34–6.83	3	1.52	0.31–7.52
Gallbladder (C23)	1	0.41	0.04–4.51	4	1.00	0.37–2.70
Pancreas (C25)	2	2.58	0.36–18.32	–	–	–
Larynx (C32)	4	–	–	–	–	–
Bronchus and lung (C34)	7	1.54	0.54–4.39	2	1.65	0.23–11.72
Haematopoietic, retic. endothel syst. (C42)	23	0.90	0.56–1.44	22	1.29	0.70–2.36
Skin melanoma (172)	9	10.15	2.19–46.97	–	–	–
Skin (C44)	16	1.12	0.58–2.15	14	1.24	0.62–2.48
Connective, subcut., other soft tiss. (C49)	4	15.59	1.74–139.30	2	0.56	0.12–2.58
Breast (C50)				19	1.17	0.65–2.09
Cervix (invasive) (C53)				96	4.01	2.97–5.41
Corpus uteri (C54)				4	2.65	0.59–11.85
Ovary (C56)				5	0.74	0.25–2.17
Placenta (C58)				4	1.80	0.40–8.05
Penis (C60)	2	0.39	0.071–2.13			
Prostate (C61)	6	0.46	0.18–1.17			
Testis (C62)	4	0.45	0.15–1.38			
Kidney (C64)	4	9.2	1.03–82.20	1	0.37	0.02–5.91
Bladder (C67)	–			1	0.54	0.03–8.62
Eye (C69)	4	0.87	0.22–3.48	–	–	–
Brain (C71)	1	0.14	0.015–1.34	1	3.80	0.24–60.65
Thyroid (C73)	2	0.71	0.12–4.24	6	0.48	0.17–1.38
Lymph nodes (C77)	17	1.15	0.62–2.12	13	4.74	1.89–11.88

[a] Relative risk.

carcinogenicity of crude oil in experimental animals. The same review concluded that there was inadequate evidence for carcinogenicity of crude oil in humans.[34]

Benzene is a well known cause of leukaemia,[38,39] and perhaps other haematological neoplasms and disorders.[40,41] No adequate data on the incidence of cancer after human exposure to the other volatile organic chemicals exist.[42] A population-based case-control study carried out in Montreal showed limited evidence of increased risk for the following associations: oesophagus-toluene, colon-xylene, rectum-toluene, rectum-xylene and rectum-styrene.[43] An ecological study performed to examine the relation between the incidence of leukaemia and the occurrence of volatile organic chemical (VOC) contamination of drinking water supplies suggested that drinking water contaminated with VOC might increase the incidence of leukaemia among exposed females.[44] Different epidemiological studies have reported direct evidence of the carcinogenic effects of PAH in occupationally exposed subjects. Strong evidence of the carcinogenic effects of PAH on the skin, bladder and scrotum has been found.[29,30,44–46] Workers in several industries with significant PAH exposure have also been shown to be at risk of lung cancer.[29–31,45]

There have been few studies of residents near oil fields or petrochemical industries. In the US, an ecological study found an association in both sexes between residential exposure to petroleum and chemical air emissions and cancer of the buccal cavity and pharynx. In males, increased age-adjusted incidence rates for cancers of the stomach, lung, prostate and kidney and urinary organs were also associated with petroleum and chemical plant air emission exposures.[47] A study in the same country found high rates of cancer of the lung, nasal cavity and sinuses, and skin among the resident male population.[48] Other studies in the US have suggested high rates of lung cancer and an elevated risk of brain cancer among people living near petrochemical plants.[49,50] Studies from the US have also reported negative results.[51] Studies conducted in Taiwan have reported an excess rate for liver and lung cancer[52,53] and an excess of cancer (bone, brain, and bladder) deaths in young adults associated with residence near petrochemical industries.[54]

The increase in haematopoietic cancers found among children under 10 years old is troubling. Childhood leukaemia and other childhood cancers have been geographically associated with industrial atmospheric effluent, for example with petroleum derived volatiles in the UK.[32,33] By contrast, a study from

Wales did not find an association between incidence of leukaemia and lymphomas in children and young people in the area around the BP Chemical site at Baglan Bay, South Wales.[55] A recent report around all industrial complexes that include major oil refineries in the UK found no evidence of association between residence near oil refineries and leukaemia or non-Hodgkin's lymphoma.[56]

The findings of this study are consistent with earlier reports from the area evidencing severe contamination of water sources and an apparent excess of cancer morbidity and mortality in males in a village located in an oil producing area.[23] The type of cancers found in that village, ampulla of Vater, stomach, larynx, liver and melanoma in males, lymphoma and cervix in women and leukaemia in children, are similar to those found in this study.

Because they reflect group rather than 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.[57] Using narrow exposure data and small units of analysis (parishes) could have minimized the effect of this bias but this could not be carried out due to the lack of data. Overall, it is difficult to measure the impact of the ecologic bias in the study.

Because of geographical and socioeconomic difficulties in accessing adequate health care, it is likely that many cases of cancer were never referred to Quito from the study area. Health services are poor in both exposed and unexposed 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 lifestyle patterns between exposed and unexposed populations that might confound risk estimates. However, no information was available on the distribution of these potentially important confounders.

Several limitations in the data and methods also need to be considered. Population data relied on county census estimated from the 1990 National Census. Errors in population estimates, including differential migration patterns, might bias estimates of risk. It is possible that exposed counties have had a more rapidly increasing population compared to non-exposed, providing a relatively greater underestimate of population denominators for these counties. However, population projections from the National Institute of Statistics and Census give no evidence that this is the case.[27] 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.

Furthermore, the study design did not allow for measurement of relevant exposure over time. Although there is documented contamination of water sources used by the population in exposed areas, the relevant exposure period for cancers may extend one or two decades further back. However, in the four counties defined as exposed there is a commonly known history of heavy oil development activities since the early 1970s.[2,4,6]

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

The results suggest a relationship between cancer incidence and living in proximity to oil fields, although this ecologic study cannot lead to 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, there has been considerable attention devoted to the biological mechanism by which some of the components of crude oil (benzene, PAH) could increase cancer risk.[58–62] Third, consistency with other investigations is apparent after reviewing the body of literature that associates oil pollutants and cancer. Fourth, 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 if the observed associations do reflect an underlying causal relationship. A next step could be epidemiological studies at the individual level. Meanwhile, an environmental monitoring system to assess, control and assist in 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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KEY MESSAGES

- Since the early 1970s millions of gallons of untreated toxic wastes, gas and oil have been released into the environment in the Amazon basin of Ecuador during oil exploration activities.
- Our study shows significantly higher incidence of cancer for all sites combined in both men and women living in proximity to oil fields.
- Significantly higher incidences were observed for cancers of the stomach, rectum, skin melanoma, soft tissue and kidney in men and for cancers of the cervix and lymph nodes in women.
- There have been few studies of those resident near oil fields, further research is necessary.
- An environmental monitoring and cancer surveillance system in the region are urgently recommended.

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Outcomes of Pregnancy among Women Living in the Proximity of Oil Fields in the Amazon Basin of Ecuador

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Oil companies have released billions of gallons of untreated wastes and oil directly into the environment of the Ecuadorian Amazon. This cross-sectional study investigated the environmental conditions and reproductive health of women living in rural communities surrounded by oil fields in the Amazon basin and in unexposed communities. Water from local streams was analyzed for total petroleum hydrocarbons (TPH). The women, aged 17 to 45 years, had resided for at least three years in the study communities. Socioeconomic and reproductive histories of the last three pregnancies were obtained from interviews. Information from the questionnaire was available for 365 exposed and 283 non-exposed women. The study was conducted from November 1998 to April 1999. Streams of exposed communities had TPH concentrations above the allowable limit. After adjustment for potential confounders, the pregnancies of women in exposed communities were more likely to end in spontaneous abortion (OR: 2.47; 95% CI: 1.61–3.79; $p < 0.01$). No association was found between stillbirth and exposure. An environmental system to control and eliminate the sources of pollution in the area is needed. *Key words:* reproductive; spontaneous abortion; oil; Amazon; Ecuador.

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The Amazonian tropical forests of Ecuador are among the most biologically diverse natural ecosystems on earth and home of many indigenous and peasant peoples. The Amazon is also home to hundreds of oil fields, the most important source of income for the country. Since 1972, foreign companies together with Ecuador's national oil company have extracted more than two billion barrels of crude oil from the Ecuadorian Amazon. The 1970s oil price boom lifted Ecuador from being one of the poorest countries in Latin America—per capita income rose from $290 in 1972 to $1,490 in 1982, decreasing to $1,390 in 1995. Today, oil continues to account for nearly 50% of the nation's export earnings and government budget. However, during this process, millions of gallons of untreated toxic wastes, gas, and oil have been released into the environment.[1,2]

Both peasants and indigenous people have reported that many local streams and rivers, once rich in fish, now support little or no aquatic life; cattle are reported to be dying from drinking from contaminated streams and rivers.[1] These are typically the same waters people use for drinking, cooking, and bathing. Peasants have reported that bathing in these waters causes skin rashes, especially after heavy rains, which accelerate the flow of wastes from nearby pits into the streams.[3]

In 1993, a local community health workers' association conducted a descriptive study in their communities, including communities exposed to oil contamination and controls. The study suggested that exposed communities had elevated morbidity and mortality rates and increases in rates of spontaneous abortions.[4]

In 1994, the New York City–based Center for Economic and Social Rights released a report documenting high levels of toxic contamination and related health problems in Ecuador's Amazon. Concentrations of polynuclear aromatic hydrocarbons were found in drinking, bathing and fishing waters that were 10 to 10,000 times greater than those considered acceptable according to the U.S. Environmental Protection Agency guidelines.[5]

Several studies of animals have provided evidence for an association between adverse reproductive outcomes and exposures to oil pollutants. Crude oil administered orally to pregnant rats decreased fetal weight and length, and multiple exposures also caused a significant reduction in maternal body weight.[6,7] Other studies have demonstrated pronounced effects of crude oil on the reproductive capacities of birds (deformed bills, incomplete ossification and feather formation, dead embryos) after oral administration or application on the shells of eggs surface.[8–10]

Few epidemiologic studies have examined the association between exposures to oil pollutants and outcomes of pregnancy, particularly among women living close to petrochemical industries. In one study conducted in

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Sweden, the miscarriage rate was slightly elevated in the exposed area, although the study concluded that ambient community exposures were not associated with an increased risk of unfavorable pregnancy outcome.[11] However, studies from Bulgaria have shown significantly higher prevalences of toxemia, spontaneous abortion, and prematurity among populations living in areas polluted by petrochemical industries.[12,13] To our knowledge, no study of reproductive outcomes in populations living in close proximity of oil fields exists.

The study presented in this paper aimed to investigate the environmental conditions of the area and determine whether residence near an oil field was associated with an increased risk of adverse reproductive outcomes in peasants' communities of the Amazon basin of Ecuador. This research is part of a larger study assessing the health impacts of oil pollution in rural communities of Ecuador.[14]

METHODS

Study Area and Population

The study was carried out in communities of peasants situated in the Orellana and Sachas districts of the Orellana province, and in the Shushufindi district of the Sucumbíos province, both in the northeastern part of Ecuador. This area was chosen because of local concern and the long term and high density of oil-drilling activities.

Peasants are organized in small communities, where each peasant owns 50 hectares of land. The total population of the area is approximately 50,000.[15] Many people live in close proximity to oil-production facilities. Most communities in the area lack electricity and piped water supplies and have difficulty accessing health services.[16]

Selection of Communities

Two groups of communities were selected for the study: communities based in areas with potential exposures to toxic contaminants from oil fields and unexposed communities selected as controls. The people living in the control communities had sociodemographic and geographic characteristics similar to those of the people in the exposed communities.[16]

An exposed community was defined as a community within 5 km of an oil field, following a downstream direction. A non-exposed community was defined as a community at least 30 km upstream from any oil field. All studied communities were considerable distances away from other chemical industries.

The target population was women aged 17 to 45 years resident for periods of at least three years in the study communities. This population was selected because: 1) they were at reproductive age; younger and older women were excluded because spontaneous abortions tend to be less common at those ages[17]; 2) they were easier to contact because of the local work activities; and 3) the criterion of living at least three years in the same community was chosen as a proxy measure for long-term exposure.

The sampling method used was a two-stage sampling procedure. Initially, a list of communities was prepared, stratified into exposed and non-exposed. Nine exposed and 14 unexposed communities were selected randomly and all women aged 17 to 45 years old who had lived for at least three years in the selected communities were included.

Community leaders were used to identify women who met the eligibility criteria for age and length of residence and asked these women to participate in the study.

The sample size calculation was based on the number of reproductive outcomes required to detect a double difference in spontaneous abortions between the exposed and unexposed groups at the 5% level with 80% power. It was calculated using the baseline prevalence of spontaneous abortion of 10% as reported for females living in the Orient.[4]

The sample size was doubled to adjust for the cluster nature of the sampling. The calculations were based on the Epi-Info 6 program. This gave a requirement of 438 pregnancy outcomes per group. To allow for 70% participation, the sample size was increased to 625 for each group to obtain a more realistic estimate. To reach that number, the history of the three most recent pregnancies was collected.

Environmental Data

To assess whether the communities surrounding oil fields were exposed to pollution, samples of water from the places used by the communities to obtain water for drinking, bathing, and washing clothes were collected. The water analysis included determination of total petroleum hydrocarbons (TPH) and was carried out by the Water and Soil Laboratory of the P. Miguel Gamboa Technical School, Coca. The method to measure TPH comprised extraction with 1,1,2-trichlor-trifluorethane and determination by infrared spectrophotometry (limit of detection 0.001). Special bottles for water samples taken were provided by the laboratory. Laboratory technicians were kept blind to the water origins.

Because of economic and technical limitations, it was not possible to measure the levels of land and air pollution.

During the months of February to April 1999, samples of different rivers used by the exposed and non-exposed communities were collected. The samples were taken in the winter season without visible crude oil presence in the rivers. Twenty streams from the nine exposed communities and two streams from two non-exposed communities were investigated. Existing data from water analysis reports from the areas were also reviewed.

Data Collection

The field work was conducted between November 1998 and April 1999. A structured questionnaire was developed for administration to the female head of the household.

The questionnaire comprised two parts. The first part elicited sociodemographic details (age, ethnic group, length of residence, marital status) and socioeconomic characteristics (educational level, female occupation, husband's occupation, and living conditions). The second part elicited information about the reproductive histories of the women during residence in the community. Information was obtained about the number of pregnancies to the time of interview, the outcomes (live births, spontaneous abortions, and stillbirths) of the three most recent pregnancies, the date and gestational age at the end of each pregnancy, and whether liveborn children were still alive. The three most recent pregnancies were selected to maximize recall of pregnancy and exposure information. Smoking and alcohol use habits and medications taken during pregnancy were also investigated. This part of the questionnaire was adapted from Doyle et al.[18]

The questionnaire, in Spanish, took approximately 30 minutes to administer. The questionnaire was piloted in one community of the area. The study was presented as a health status survey. The women selected for the study were asked to participate in a personal interview. A date for the interview was arranged, and the women agreed to be interviewed at a central location in the community. Respondents were interviewed in a private room of the school or the community center. Informed consent was obtained from all study participants.

Confidentiality of all information collected was maintained, and sick persons received free medical attention and treatment. At the completion of the investigation, the communities were informed of the preliminary results of the study.

Definition of Reproductive Outcomes

Pregnancy outcomes were recorded according to the following definitions: 1) pregnancy was defined as the delayed-"period" perception by the subject more than three months from the last menstrual period; 2) spontaneous abortion was defined as fetal loss at 28 weeks' gestation or earlier; 3) stillbirth was defined as a fetal loss after 28 weeks of gestation, but without any evidence of life at birth, and 4) a full-term baby was one born alive after the 36th week of gestation.

Only pregnancies that ended before December 31, 1998, and occurred during the residence of the women in the communities were included.

Neonatal deaths were differentiated from stillbirths by reports of respiratory efforts or crying by the infant after birth.

Only self-reported miscarriages were considered in the study due to the lack of hospital records or medical attendance.

Elective abortions, multiple pregnancies, and pregnancies of women having used an intrauterine device at the time of conception were excluded from analyses because of the high rate of spontaneous abortions among women who become pregnant while using the latter method of contraception.[17,19]

Data Analysis

The statistical analysis treated each pregnancy as one unit. Multiple pregnancies of the same woman were treated as independent observations, even though this is not strictly true. Statistical analyses were also carried out separately for each of the three most recent different pregnancies to take into account the variability in the risk of spontaneous abortion between women.

Prevalence rates for the three most recent pregnancy outcomes occurring in the study communities were compared between women living in contaminated and noncontaminated areas. Odds ratios (ORs) for the pregnancy outcomes in the exposed group were calculated with 95% confidence intervals (CIs) and *p*-values.

Potential confounders included those that had been identified in international studies as confounders.[18,20–22] Thus, age at interview, age at pregnancy, pregnancy order, year of pregnancy, socioeconomic status (level of education, mother's and father's occupations, living conditions) were used as potential confounders. Multiple logistic regression was used to estimate ORs adjusted for several potential confounders simultaneously. In the analytic process, standard errors were adjusted for the clustered nature of the sampling using the Huber–White method.[23]

History of previous spontaneous abortion was examined but was not included in the statistical model, as these losses might have been caused in part by the exposure to oil pollutants and might be correlated with the index outcome under study and thus have resulted in biased risk estimates.[24,25]

RESULTS

Environmental Assessment

The results of the water analysis in the exposed communities are presented in Table 1. No TPH contamination was found in rivers close to non-exposed communities, in two samples taken. In the "exposed" area, 18 streams close to eight communities were contaminated with TPH, ranging from a concentration of 0.02 parts per million (ppm) in the Manduro 1 stream to 2.883 ppm in the Basura river. No contamination was found in two streams in the other exposed community.

TABLE 1. Concentrations of Total Petroleum Hydrocarbon (TPH)* in the Streams of Communities Surrounding Oil Fields, Ecuador 1999

Identification (Stream)	TPH (ppm)
Community 1	
Toachi	0
Escuela 28-M	0
Community 2	
Pozo 66	0.04
Río Negro	1.438
Community 3	
Victoria 1	0.051
Victoria 2	1.426
Community 4	
Itaya 1	0.043
Itaya 2	0.028
Community 5	
Escuela 18-N	0.036
Jiménez	0.028
Community 6	
Huamayacu	1.444
Basura	2.883
Iniap	0.097
Huamaverde	0.529
Community 7	
Lumu pueblo	0.066
Lumu 3	0.055
Community 8	
Dayuma	0.145
Community 9	
Manduro 1	0.02
Pisc Manduro	0.434
Manduro 2	0.108

*The permitted limit for hydrocarbons in drinking water according to the European Community laws is 0.01 parts per million (ppm).

Review of existing data collected independently by Zehner et al.[26] in 1998 from 46 streams showed contamination in those located in areas of oil activities, while in areas without such activities no water contamination by TPH was found.

Characteristics of the Population

Nine communities in the exposed area (out of 87 communities) and 14 in the control area (out of 125) were included in the study. Of 610 exposed and 439 non-exposed women identified as within the age range, 428 (70.2%) and 347 (79.0%), respectively, were interviewed. Of these, 60 women (14.0%) from the exposed area were subsequently excluded because of living less than three years in the communities; 56 (16.1%) from the non-exposed area were excluded for the same reason. Finally, three women in the exposed group and eight in the non-exposed group were excluded because their forms were incomplete or unreadable. Information from the questionnaire was therefore available for 365 (59.8%) and 283 (64.4%) of the potential participants, respectively.

Those exposed showed little difference in lengths of residence, ags, ethnicity, marital status, or educational levels from the controls (Table 2). However, the exposed women worked less in agriculture (72.6%) than did the non-exposed women (86.3%). The women's husbands in the exposed communities tended to work for oil companies more (7.8%) than did the husbands in the control group (1.3%).

Living conditions were assessed through three indicators: type of house, possession of refrigerator, and availability of latrine. Living conditions, as measured by these variables, were better in the exposed communities than in the control communities. None of the women was classified as a cigarette smoker or alcohol consumer.

The exposed and non-exposed communities showed differences in sources of water for drinking, bathing, and washing. Women from the exposed communities were less likely to use water from the rivers (Table 2).

Reproductive Health

Over all, 555 women (85.6%) reported having at least one pregnancy, with little difference between groups. Of the women reporting at least one pregnancy, 508 (78.3%) had had at least one liveborn child and 111 (17.1%) a fetal loss (spontaneous abortion or stillbirth).

Table 3 shows details of the individual pregnancies (including the three most recent reported) according to exposures of the mothers. The total number of pregnancies reported was 1,377. Of these pregnancies, 7.5% ended as spontaneous abortions and 1.8% ended as stillbirths.

Pregnancies of women living in exposed communities were more likely to end in spontaneous abortion than were those of women living in comparison communities (OR: 2.34; 95% CI: 1.48–3.71; $p < 0.01$). No association was found between stillbirth and exposure (OR: 0.85; 95% CI: 0.35–2.05; $p = 0.83$).

Logistic regression analysis was used to examine the combined effects of the potential confounding factors and exposure on spontaneous abortion. After adjustment, the estimated OR was slightly higher than the crude value and the association between spontaneous abortion and living in the proximity of oil fields remained highly significant (OR: 2.47; 95% CI: 1.61–3.79; $p < 0.01$).

These results were also observed when the analysis was stratified by pregnancy number (numbering from the last) (Table 4). Higher risks of spontaneous abortion were found in the three different groups; the risks in the first two pregnancies were statistically significant.

No evidence of interaction between exposures and the investigated potential confounders was found with respect to their effects on spontaneous abortion.

TABLE 2. Sociodemographic Characteristics of the Study Population

	Exposed Group (%) (*n*= 365)		Comparison Group (%) (*n*= 283)	
Age (years)				
17-20	44	(12.0%)	43	(15.1%)
21-30	146	(40.0%)	105	(37.1%)
31-40	119	(32.6%)	89	(31.4%)
41-45	56	(15.3%)	46	(16.2%)
Mean age (SD)	30.6 years	(7.9)	30.7 years	(8.3)
Time of residence (years)				
4-10	116	(31.7%)	108	(38.1%)
11-20	186	(50.9%)	142	(50.1%)
> 20	63	(17.2%)	33	(11.6%)
Mean residence (SD)	14.4 years	(6.2)	13.5 years	(6.1)
Ethnic group				
Mestizo	357	(97.8%)	276	(97.5%)
Black	6	(1.6%)	2	(0.7%)
Indigenous	2	(0.5%)	5	(1.8%)
Marital status				
Single	38	(10.4%)	30	(10.6%)
Married	305	(83.6%)	237	(83.7%)
Widowed	22	(6.0%)	16	(5.7%)
Education				
None	17	(4.7%)	8	(2.8%)
Primary non-finished	73	(20.0%)	67	(23.7%)
Primary	215	(58.9%)	173	(60.1%)
Secondary non-finished	41	(11.2%)	28	(9.9%)
Secondary	19	(5.2%)	7	(2.5%)
Persons at home, mean (SD)	6.3	(4.5)	6.2	(2.4)
Main occupation				
Agriculture	264	(72.3%)	244	(86.2%)
Other	101	(27.6%)	39	(13.8%)
Husband's occupation				
Agriculture	241	(75.1%)	216	(88.5%)
Oil company	29	(9.0%)	3	(1.2%)
Palm company	8	(2.5%)	0	(0%)
Other	43	(13.4%)	25	(10.3%)
Living conditions				
Cement house	49	(13.4%)	20	(7.0%)
Refrigerator	126	(34.5%)	39	(13.7%)
Latrine	177	(48.4%)	111	(39.2%)
Water use				
Drink from river	27	(7.3%)	70	(24.0%)
Bath in river	103	(28.0%)	162	(55.6%)
Wash in river	132	(35.9%)	191	(65.6%)

DISCUSSION

Analysis of the river water showed heavy exposure to oil chemicals among the residents of the exposed communities. In some streams, hydrocarbon concentrations reached 144 and 288 times the limit permitted by the European Community regulation.[26] These data suggest that residents of communities close to oil fields are exposed to pollutant levels originating from oil-related activities that significantly exceed the internationally recognized safety limits. Though the initial time of such exposures is not known, numerous reports have indicated they may date from the beginning of the oil exploration in the area in the 1970s.[1,5,27]

The lesser use of river water in the exposed communities suggests that women who live in these communities are aware of its contamination and try to use other sources of water; however, this is not always possible.

The study revealed a risk for spontaneous abortion 2.34 times higher among women living in communities exposed to oil pollutants. After adjusting for the different confounders, the significant difference remained (OR: 2.47; 95% CI: 1.61–3.79). No association was observed for stillbirth.

TABLE 3. Outcomes of Pregnancies by Exposure Status

	Exposed		Unexposed		Total	
	No.	(%)	No.	(%)	No.	(%)
Total reported pregnancies	791	(100)	586	(100)	1,377	(100)
Live births	700	(88.4)	548	(93.5)	1,248	(90.6)
Spontaneous abortions (< 28 weeks)	78	(9.8)	26	(4.4)	104	(7.5)
Stillbirths (≥ 28 weeks)	13	(1.6)	12	(2.0)	25	(1.8)

These findings are consistent with earlier reports from the area suggesting an increased risk of spontaneous abortions in women living in communities surrounded by oil fields.[4]

Corresponding studies of residents near oil fields are rare, and have concentrated on industrialized countries. More problematic, existing studies tend to be based on lower levels of exposures than those in Ecuador. In Sweden, a study concluded that the exposure levels near a petrochemical industry were not associated with an increased risk of unfavorable pregnancy outcomes.[11] However, in Bulgaria an investigation of the association between exposures to emissions from petrochemical industries and outcomes of pregnancy showed a higher prevalence of spontaneous abortions among residents near the industries.[12] An increased risk of spontaneous abortion for women workers with frequent exposure to petrochemicals compared with those working in non-chemical-related plants was also found in China.[28] In addition, studies of animals support the evidence for a high risk of adverse reproductive outcomes when exposed to oil pollutants.[6,10]

No association was found between stillbirth and living in the proximity of oil fields. Due to its low frequency, stillbirth has been considered a weak indicator of developmental toxicity in relation to environmental chemicals.[29]

Limitations of the study design and the methods of data collection, due to logistic and economic shortcomings, create some potential for biases in this study.

The similarity of the sociodemographic variables among the study groups indicates that non-exposed communities were an adequate reference population. Response rates were quite high were and similar in the exposed and control areas (70.2% vs 79.0%), limiting the potential for non-response bias. Reasons for non-participation were unknown.

The study was community-based, and cases were selected from communities randomly chosen. Only current residents of the target or comparison areas were eligible, and migration might have been considerable. However, there seems no reason for migration to be related to both pregnancy outcome and living in an exposed area, so it should not cause bias in the association between exposure and outcome.

One important threat to the validity of the findings in this type of study comes from reporting (recall) bias, since recall is likely to be incomplete, and people who believe they are exposed might be more likely to recall spontaneous abortions.[30] We tried to limit this problem by presenting the study to the communities as a general health study within a primary health care program. In addition, the women in the exposed communities were not aware of spontaneous abortion as an outcome related to oil pollution.[31] However, the overall proportions of pregnancies reported as ending in spontaneous abortions in the unexposed communities were lower than those in other similar surveys in developing countries. Percentages of self-reported pregnancies terminating in miscarriage have ranged from 6.3 in Peru to 9.1 in Colombia and Venezuela.[32] It has also been reported that when the event is ascertained retrospectively by means of a questionnaire, the rates of spontaneous abortion are between 5% and 10%.[33] In this study, the rate in the unexposed population was 4.4%, suggesting a true low risk or underreporting.

Recall might also be expected to increase with proximity of the pregnancy to the date the questionnaire was administered. The presence of the association with exposure after stratifying by pregnancy order, numbering from the last, suggests that it is not due to this bias.

The study design did not allow us to address certain other questions. First, the validity of the reported spon-

TABLE 4. Risk of Spontaneous Abortion in the Last Three Pregnancies by Exposure Status*

	Exposed		Unexposed		Crude		Adjusted	
	No.	(%)	No.	(%)	OR	(95% CI)	OR†	(95% CI)
Last pregnancy (first)	24	(7.9)	12	(4.9)	1.64	(0.80–3.36)	1.62	(0.70–3.75)
Previous one (second)	24	(8.9)	7	(3.5)	2.65	(1.11–6.32)	2.76	(1.03–7.39)
Previous one (third)	30	(14.4)	7	(5.0)	3.15	(1.33–7.48)	3.66	(0.97–13.73)
All three	78	(9.8)	26	(4.4)	2.34	(1.48–3.71)	2.47	(1.61–3.79)

*Standard errors adjusted for clustering.
†Adjusted for age at interview, age at pregnancy, pregnancy order, year of pregnancy, educational level, woman's and her husband's occupations, and living conditions.

taneous abortion was not possible to address due to the lack of medical records.

Several studies from industrialised countries have reported that such a problem does not necessarily cause a serious distortion.[34] In a study among laboratory workers in Sweden, the accuracy of reporting of miscarriages was high.[35] Ninety-four percent of self-reported spontaneous abortions could be confirmed by reviewing medical records in a study conducted among workers at two semiconductor manufacturing plants in the United States.[22] Self-report of fetal loss was also reliable in a study conducted on dry cleaning workers in England.[18] Second, we could not assess whether early (subclinical) fetal loss might be affected by oil pollutants. There is a high probability for women not to recognize the event as such but to perceive it as a delayed menstrual period if it occurs very early in pregnancy.[36]

Accurate exposure assessment is always a major concern in epidemiologic studies, especially when the relevant exposure occurred in the past. No data on how people have been affected by past exposure to the chemicals in the area exist. In addition, there is little or no information about chronic toxicity from the diverse chemical substances spilled from the oil fields. Even the exact nature of the chemical substances spilled by oil companies in the Amazon basin of Ecuador is unknown.[1] In our study, the same exposure status was assigned to every individual within the same study area, even though the individuals certainly did not all have the same level of exposure to oil pollutants.

None of the potential confounders examined—age at interview, age at pregnancy, pregnancy order, year of pregnancy, socioeconomic status—could explain the association between spontaneous abortion and living in the proximity of oil fields. However, some residual confounding may remain due to misclassification of some factor in the analysis.

Repeated spontaneous abortions in the same women are treated as independent events in our analyses, which can lead to spuriously narrow confidence intervals. However, the allowance for clustering by community allows implicitly for this source of additional variation, so confidence intervals should not be misleading. The persistence of the association of spontaneous abortions with exposure after stratifying by pregnancy number (from the last), statistically significant in two of three strata, gives further reassurance on this point.

This study has demonstrated the presence of contamination by oil pollutants in communities close to oil fields, at levels high enough to cause alarm. It also provides some evidence of an increased risk of spontaneous abortions in women living in the proximity of the oil fields, after adjustment for other better-known risks common in developing-country settings. Further research is necessary to confirm these results in other communities experiencing similar exposures. There is also a need for studies to contribute to clearer understanding of the overall implications of this form of development for local health, particularly for women. The oil industry argues that it has a role to play in development, but it should not be at the expense of unnecessary contamination, exposures, or health impacts. We concur with the community's wish to address urgently environmental control and remediation of contamination in the exposed areas.

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Brief communication

Gynecologic and breast malignancies in the Amazon basin of Ecuador, 1985–1998

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Cervical and breast cancer are considered some of the most detectable, and therefore, preventable forms of cancer. Although cervical cancer has declined in many industrialized countries over the last 10 years, it remains the most deadly cancer among women in the developing world [1].

In Ecuador, based on Quito data, the incidence rate of invasive cancer is 30 per 100 000 women which places the country among the highest incidence regions in the world [2]. No information about the cancer situation in the Amazon region of Ecuador exists. This paper reports the site-specific cancer frequencies and incidence rates of gynecologic and breast malignancies in the Amazon basin of Ecuador, provinces of Sucumbios, Orellana, Napo and Pastaza, where approximately 280 000 indigenous people and peasants live.

In each province there is a provincial hospital without histopathological services and access to radiotherapy or chemotherapy treatment. There are no cervical or breast cancer screening programs in the 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 [3]. This register was used for the purpose of our study. Population data from the four provinces by gender and 5-year age strata for the year 1992 were used. These were the projections of the National Institute of Statistics and Census based on the 1990 National Census [4].

Out of 985 cancer cases reported to the National Cancer register from the study area 1985–1998, 594 cases of cancer (60.3%) were diagnosed in women. Three hundred thirty-eight (56.9%) of these constituted gynecologic and breast cancers. Crude, world standardized and truncated rates for each specific gynecologic cancer are presented in Table 1.

Fig. 1 shows the distribution of cervix cancer, in situ and invasive, by age groups. Invasive cancer reached the highest rate after the 30 years.

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Table 1
Annual incidence rate per 100 000 gynecologic and breast cancers, Amazon basin of Ecuador, 1985–1998

Site (ICD-9)	No. all ages		Crude rate	A.S.R.W.[a]	TR.R.[b] 35–64
	n	(%)			
Breast (C50)	47	(13.90)	2.64	5.08	10.52
Vulva (C51)	2	(0.59)	0.11	0.35	0.37
Vagina (C52)	2	(0.59)	0.11	0.20	0.47
Cervix uteri (in situ) (233)	84	(24.85)	4.72	8.26	5.21
Cervix uteri (C53)	172	(50.88)	9.66	21.58	44.91
Corpus uteri (C54)	7	(2.07)	0.39	0.82	1.35
Uterus nos (C55)	2	(0.59)	0.11	0.12	0.21
Ovary (C56)	15	(4.43)	0.84	1.74	3.58
Placenta (C57)	7	(2.07)	0.39	0.46	1.01
Total	338	(100.0)	18.98	38.61	67.63

[a]Adjusted Standardized Rates Worldwide.
[b]Truncated rates.

The proportion of cervix cancer in situ vs. invasive was higher in women with secondary educational level than in those with no or just primary level education (data not shown).

Because the geographical and socio-economic difficulties to access adequate health care, cancer rates may be underestimated. However, the data show that gynecologic and breast malignancies are a considerable problem in the region with late diagnosis of invasive cervical cancer.

It is time for national and local health services to face the challenge of a locally adapted screening program in the Amazon basin of Ecuador.

Acknowledgements

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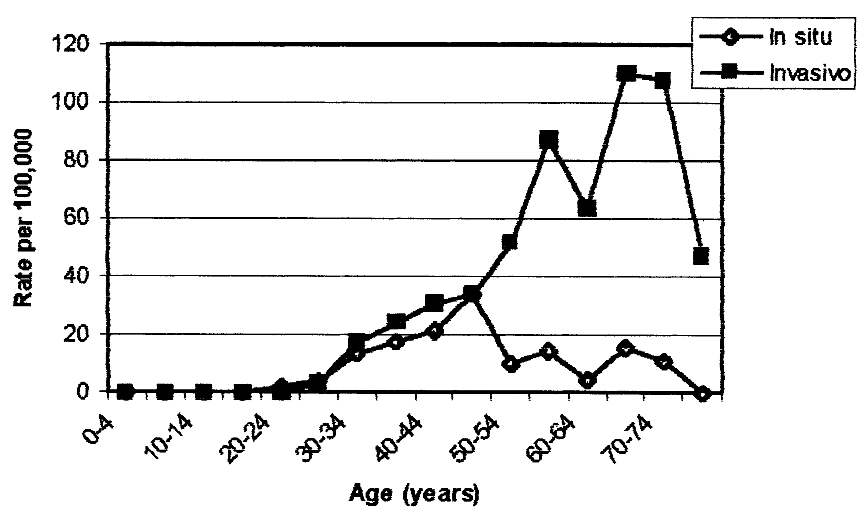

Fig. 1. Incidence rates of cervix uteri cancer by age; Amazon basin of Ecuador, 1985–1998.

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Oil exploitation in the Amazon basin of Ecuador: a public health emergency

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Key words: petroleum, extraction and processing industry, environmental pollution, water pollution, Ecuador.

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Oil is a major source of income for Ecuador and since the 1970s has been the "engine" of the nation's economy. Before the 1970s oil price boom, Ecuador was one of the poorest countries in Latin America. Since then, oil production has been the primary cause of Ecuador's economic growth, which has averaged 7% annually. Per capita income rose from US$ 290 in 1972 to US$ 1 200 in 2000. Today, oil continues to account for 40% of the nation's export earnings and of the budget of the national Government (1, 2). Most of this oil comes from the northeastern part of the country, the Amazon basin.

The Amazon basin of Ecuador, known as *el Oriente* (the provinces of Sucumbios, Orellana, Napo, Pastaza, Morona Santiago, and Zamora-Chinchipe), consists of more than 100 000 km^2 of tropical rain forest 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 (3). The Oriente region is also the home of some 500 000 people, or about 4.5% of the country's population. These half-million persons include eight groups of indigenous people as well as peasants who, encouraged by land policies of the national Government, moved to the area from Ecuador's coastal and highland regions in the 1970s and the 1980s (4).

In 1967 a Texaco-Gulf consortium discovered a rich field of oil beneath the rain forest, leading to an oil boom that has permanently reshaped the region. The Amazon of Ecuador now houses a vast network of roads, pipelines, and oil facilities. While the national Government has retained dominion over all mineral rights, several private foreign companies have built and operated most of the oil infrastructure.

Current oil production activities in the Oriente region span nearly one million hectares, with over 300 producing wells and 29 production camps. The country has 4.6 billion barrels of proven oil reserves, with crude production of around 390 000 barrels per day. Of this production, Petroecuador, the Government-owned company, accounts for about 55% of Ecuador's total output, with private companies accounting for the remaining 45%. Petroecuador is attempting both to attract foreign investment to the country's largest oil fields and to boost its own production from around 215 000 barrels per day today to 600 000 barrels per day by 2005 (5).

Since 1967 many different companies have been involved in the oil exploitation process. There are currently 16 companies operating in the country: Petroecuador, 3 private Ecuadorian companies, and 12 foreign companies (6). Figure 1 shows the oil companies now operating in the country and the blocks where they are located.

Since the beginning of oil exploitation, foreign oil companies and Petroecuador have extracted more than two billion barrels of crude oil from the Ecuadorian Amazon. However, in this development process, billions of gallons (1 gallon = 3.7853 liters) of untreated wastes, gas, and crude oil have been released into the environment (7).

This paper examines the environmental and health impacts brought about by the oil development process in the Amazon region of Ecuador.

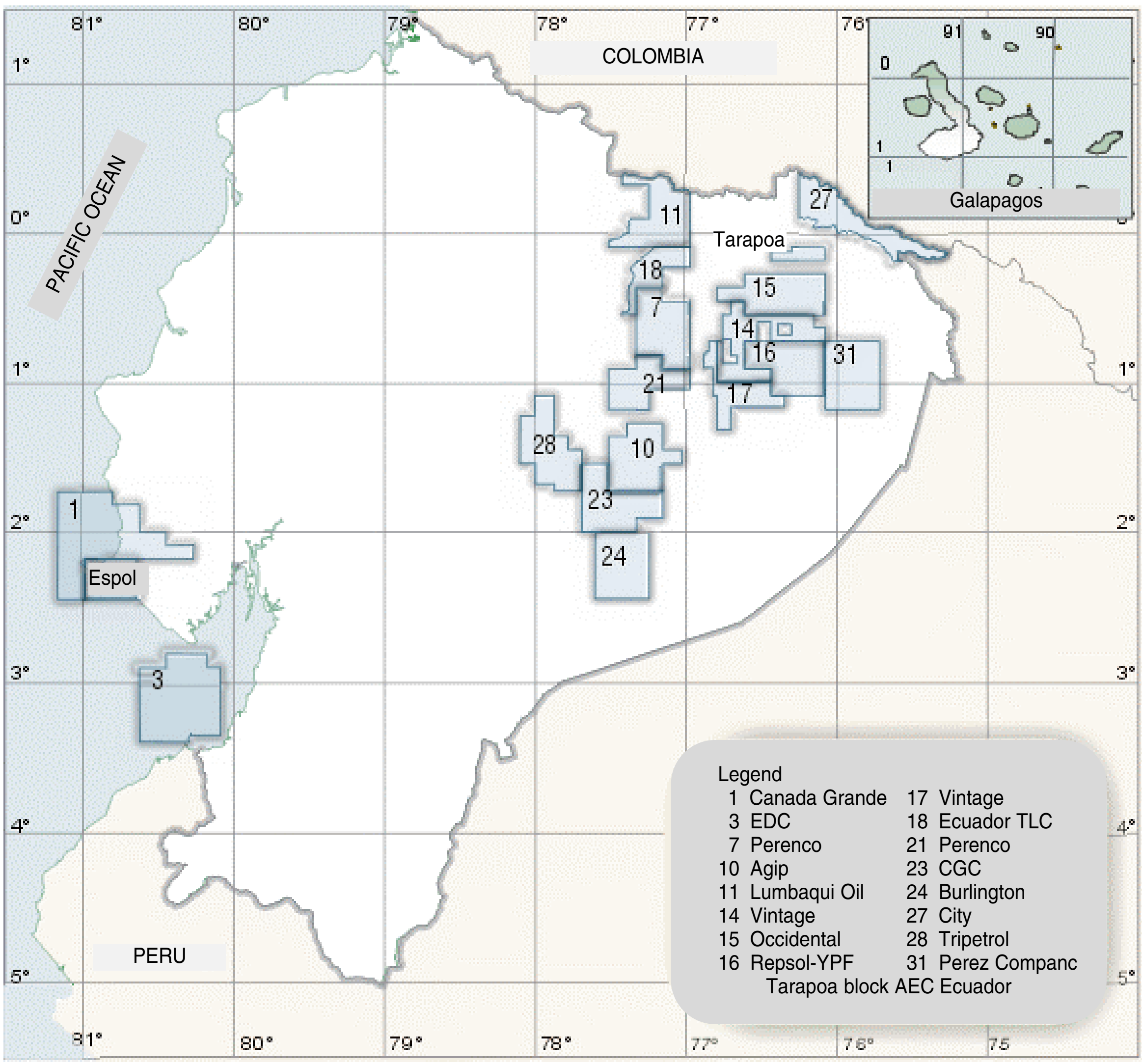
THE ENVIRONMENTAL EXPOSURE

Source and extent of pollution

Oil development activities include several contaminating processes. The extent of these polluting processes depends mainly on the environmental practices and technology used by oil companies. In Ecuador these practices have repeatedly been questioned (8–10).

Deep below the earth's surface, oil is usually mixed with natural gas and "formation water," which contains hydrocarbons, heavy metals, and a high concentration of salts. In the Amazon basin of

FIGURE 1. Oil blocks operated by oil companies, Ecuador, 2003



Source: Petroecuador (http://petroecuador.com.ec/donde.htm). Used with permission.

Ecuador, each exploratory well that is drilled produces an average of 4 000 cubic meters of drilling wastes, including formation water and drilling muds (which are used as lubricants and sealants). These wastes were frequently deposited into open, unlined pits called separation ponds, from which they were either directly discharged into the environment or they leached out as the pits degraded or overflowed from rainwater (7, 8). Although some companies have modified this practice in the last 10 years by building protected ponds, these practices still occur. There are currently nearly 200 open ponds in the Amazon region (11).

If commercial quantities of oil are found, the production stage starts. During production, oil is extracted in a mixture with formation water and gas and then separated in a central facility. At each facility, over 4.3 million gallons (16.3 million liters) of liquid wastes are generated every day and discharged without treatment into pits. Roughly 53 million cubic feet (1.5 million cubic meters) of "waste" gas from the separation process is burned daily without temperature or emissions controls. Air contamination can also be generated at pits and oil spills by hydrocarbons coming from standing oil slicks (1, 7).

Routine maintenance activities at over 300 producing wells discharge an estimated five million gallons (18.9 million liters) of untreated toxic wastes into the environment every year. Leaks from wells and spills from tanks have been common (12). According to a study conducted by the Government of Ecuador in 1989, spills from the flowlines that connect the wells to the stations were dumping an estimated 20 000 gallons (75 800 liters) of oil every two weeks (13).

Spills from the main and secondary pipelines, which connect the separation stations to the refinery in the coastal region, are also common. In 1992 the Ecuadorian Government recorded approximately 30 major spills, with an estimated loss of 16.8 million gallons (63.6 million liters) of crude oil (7). In 1989 a spill of at least 294 000 gallons (1.1 million liters) of crude oil caused the Napo River, which has a width of one km, to run black for a week; the same thing happened in 1992, when there was a spill of about 275 000 gallons (1.0 million liters) of crude oil (12). It was estimated in 2002 that two big spills per week were occurring from the main oil fields in the Oriente region (14).

Overall, during the period of 1972 through 1993, more than 30 billion gallons (114 billion liters) of toxic wastes and crude oil were discharged into the land and waterways of the Oriente (7). This compares to the 10.8 million gallons (40.9 million liters) spilled in the *Exxon Valdez* tanker disaster in 1989 in Alaska, one of the largest sea oil spills that has ever occurred.

Environmental analysis

Numerous reports have indicated that the contamination has occurred since the beginning of the oil exploration in the Ecuadorian Amazon (8–10, 15) even though longitudinal data on the levels of population exposure over time do not exist.

A study in 1987 by the Ecuadorian Government found elevated levels of oil and grease in all of the 36 samples taken from rivers and streams near productions sites. That study also found that a shortage of dissolved oxygen in the majority of water samples had seriously harmed the aquatic ecosystem (16). In 1989 another Ecuadorian Government study of 187 wells found that crude oil was regularly dumped into the forests and into bodies of water (13).

In 1994 a study carried out by the Ecuadorian environmental and human rights organization *Centro de Derechos Económicos y Sociales* (the Center for Economic and Social Rights) also found highly elevated levels of oil pollutants in the streams and rivers of the Oriente area. Concentrations of polynuclear aromatic hydrocarbons were 10 to 10 000 times greater than the levels recommended by the Environmental Protection Agency of the United States of America (9).

In 1998 an independent local laboratory that is frequently used by the oil companies surveyed 46 streams in the Oriente region (17). The laboratory found contamination by total petroleum hydrocarbons (TPH) in areas of oil activities, while no water contamination was found in areas without such activities.

In 1999 the *Instituto de Epidemiología y Salud Comunitaria "Manuel Amunárriz"* ("Manuel Amunárriz" Institute of Epidemiology and Community Health), a local nongovernmental organization concerned with health issues, undertook water analyses for TPH in communities near oil fields and also in communities far away from the fields. Those analyses showed high levels of TPH concentrations in rivers used by the communities that were close to the oil fields. In some streams, hydrocarbon concentrations exceeded by more than 100 times the limit permitted by European Community regulation (18).

Since 1999 the oil companies have been required by law to regularly monitor the level of pollution in the environment and to send reports to the national Government of Ecuador. This information is not open for public scrutiny. However, in 1999, when one of these reports was presented to a community that had made several complaints to the Ministry of Environment, it showed that streams in the community had concentrations of TPH that were over 500 times the limit permitted by European Community regulations (19). Nevertheless, the oil company and a representative of the Ecuadorian Government insisted that the levels that had been found were acceptable.

For the Amazon basin of Ecuador, there is a lack of data on soil pollution and its possible impact, and no study has been conducted on the impact that oil development has had on fish and fishing. However, studies from the Amazon basin of Peru found, after an oil spill in the Marañon River, high concentrations of TPH in the stomach and muscles of fish (20).

THE HEALTH EFFECTS

Several studies have focused on residents exposed to major coastal oil spills from tankers (21–23). However, there are few epidemiological studies concerning persons who live in communities that are near oil fields and who are exposed to acute and/or long-term contamination (24).

For many years residents of the oil-producing areas of the Ecuadorian Amazon have raised concerns over pollution related to oil development. Both peasants and indigenous people have reported that many local streams and rivers, once rich in fish, now support little or no aquatic life; further, cattle are reported to be dying from drinking from contaminated streams and rivers. These are typically the same waters that people use for drinking, cooking, and bathing. Residents have also reported that bathing in the river waters causes skin rashes, especially after heavy rains, which accelerate the flow of wastes from nearby pits into the streams (25).

In 1993 a community health workers association in the Ecuadorian Amazon conducted a descriptive study in its communities. The study suggested that, compared to communities free from oil exploitation, communities in oil-producing areas had elevated morbidity rates, with a higher occurrence of abortion, dermatitis, skin mycosis, and malnutrition, as well as higher mortality rates (26).

In 1994 the Center for Economic and Social Rights released a study reporting skin problems (dermatosis) in the population in the Ecuadorian Amazon, apparently related to crude oil contamination of local rivers (9).

In recent years the "Manuel Amunárriz" Institute of Epidemiology and Community Health has been involved in a research process to assess the potential health impact of oil pollution in communities near oil fields. In the first of these studies, women living in communities near oil fields reported higher rates of various physical symptoms than did women in control areas. These symptoms included skin mycosis, tiredness, itchy nose, sore throat, headache, red eyes, ear pain, diarrhea, and gastritis. After adjustment for possible confounding factors, the symptoms significantly associated with exposure were those expected from known toxicological effects of oil (27). Another study found that the risk of spontaneous abortions was 2.5 times as high in women living in the proximity of oil fields (28).

Research done in 1998 found an excess of cancers among males in a village located in an oil-producing area in the Oriente region (29). Another study, from 2000, examined the differences in cancer incidences over the period of 1985 to 1998 in the Amazon region of Ecuador. This study found a significantly higher overall incidence of cancer in both men and women in the *cantones* ("counties," or divisions of provinces) where oil exploitation had been going on for at least 20 years. Significantly elevated levels were observed for cancers of the 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 observed in children (30).

GOVERNMENT RESPONSES

Peasants and indigenous people from the Amazon have presented their complaints to various administrations of the national Government of Ecuador. The inhabitants of the Ecuadorian Amazon have asked for a better quality of life and for technical assistance; that electricity, water, health services, and other basic services be provided; and, above all, that the oil pollution be remediated. Through their own organizations and with support from national environmental groups, Oriente residents have demanded that the companies clean up the environmental pollution and compensate them for damages caused by oil-related contamination. The measures adopted so far by oil companies and the various administrations of the national Government have been described as "patches," such as covering some waste pits, building some schools, and constructing roads, all without facing the root causes of the problem (10, 31, 32).

Various administrations of the national Government of Ecuador have declared the essential importance of oil to Ecuador's development. However, despite the oil revenues, improvements in socioeconomic conditions in the country have fallen short of expectations. Ecuador now has the highest per capita debt of any country in South America, nearly US$ 1 100 per person (1). In the period from 1970 to 2002 the unemployment rate rose from 6.0% to 7.7%, and the percentage of people living in poverty climbed from 47.0% to 61.3% (2, 33). The ratio of the income received by the poorest 5% of the population and by the richest 5% changed from 1:109 in 1988 to 1:206 in 1999 (34). The Amazon region has the worst infrastructure and the lowest socioeconomic and health indicators in the country (35).

In response to the nearly $16 billion in external debt that Ecuador has, one of the main economic strategies of the national Government and the International Monetary Fund has been to expand the oil exploitation in the country. The national Government's proposals include opening two million hectares of pristine rain forest in the south of the Amazon to oil exploitation and constructing a new heavy crude oil pipeline in the north of the Amazon, to allow further oil exploitation in that area (36, 37).

WHAT NEEDS TO BE DONE

Modern oil and gas development, if compatible with sustainable development and the well-being of Amazonian peoples, must be based on comprehensive environmental planning that fully considers the cumulative impact of ongoing and planned oil exploitation throughout the region. Strict environmental controls and careful long-term monitoring of oil activities—with both of those firmly grounded in the rule of law and broad participation by local communities, local governments, and nongovernmental groups—are necessary in order to prevent further negative environmental and health impacts in the Oriente region (38). Five interrelated actions are urgently needed:

- The Ecuadorian Government should conduct an evaluation of the environmental situation in the Oriente region. It is also necessary to develop and oversee the implementation of a plan to repair the damage that has already occurred and to limit further destruction. While oil pollution persists, the health of the population of the Oriente area and other populations in similar situations will remain at risk. Some indigenous and environmental groups have called for the application of the precautionary principle. (The precautionary principle has been defined as "when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically" (39)). That principle has been developed by scientists in the face of scientific uncertainty, and it is a strong call for prevention of potential harm and for caution in actions taken. Those indigenous and environmental groups have also asked the national Government for a moratorium on oil and gas development in new areas of the Amazon. Such development alternatives as ecotourism and rain forest conservation have been proposed, and they should be seriously considered (40, 41).
- Oil companies operating in the Ecuadorian Amazon should change their practices to minimize environmental impacts and to build partnerships with local communities so that local residents benefit from development. Environmental protection standards and environmental management plans should be accessible to and appropriately discussed with communities and independent environmental groups. Without such basic information, these groups are left unaware of potential risks, they cannot participate meaningfully in formulating public policy, and they cannot hold companies accountable for their actions. In addition, an environmental monitoring system should be established, with the involvement of the affected communities. As a minimum, this system should include regular detailed chemical sampling of the environment and reporting on the emissions and effluent controls.
- Oil development policies have an impact on health, and the consequences of those policies need to be assessed and taken into account. The Ecuadorian Government should acknowledge the need for health impact assessments as an integral feature of policy development and evaluation. Community consultation and participation are essential in assessing impacts on the environment and health (42).
- Ecuador enacted a new constitution in 1998. That document acknowledges the right of communities to be consulted by oil companies before the companies begin the exploratory stage of oil development. To enforce these rights, it is essential for community organizations to work with regional, national, and international environmental groups. The Ecuadorian Government has already given a commitment to develop mechanisms to enforce the laws protecting the environment and the health of their citizens, but developing those mechanisms will be difficult. This should be addressed within the context of promoting human rights, combating corruption, and strengthening democratic institutions.
- Concern has been raised around the world that globalization of trade does not bode well for the environment and for people's health (43–45). Shifting trade policies in the direction of environmental sustainability and social justice is urgently needed if environmental protection, economic security, and health benefits are to be received by the majority of the world's population.

We believe that oil exploitation in the Amazon basin of Ecuador has resulted in a public health emergency because of its adverse impact on the environment and health. So far, the Ecuadorian Government has not designed an adequate strategy to prevent further negative environmental and health impacts. The oil industry argues that it has a role to play in the development of the country (46-48), but that development should not come with the added cost of pollution and poor health.

At first, it may appear that the oil industry and public health are not related. However, we have shown that they are closely interconnected. Unfortunately, Ecuador is not the only country in Latin America to suffer the negative consequences of oil exploitation; Bolivia, Colombia, and Peru are in a similar situation (49, 50). There are already public health problems, and these problems may grow if unregulated oil exploitation continues to expand in Latin America. Preventing additional health and environmental damage will require action on a local, national, and international level.

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Note on conflicts of interest. In 1993 a lawsuit was filed in the United States of America against Texaco, an oil company that had worked in Ecuador for more than 20 years. The plaintiffs—some 30 000 indigenous persons and peasants—claimed that the oil company had caused irreparable damage to the rain forest of the Amazon region of Ecuador. In 2000 the suit was dismissed in the United States and sent to Ecuador to be considered. In October 2003 one of the authors, Miguel San Sebastián, presented testimony in an Ecuadorian court on behalf of the plaintiffs; he did not receive any payment for his testimony.

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SINOPSIS

La explotación petrolera en la cuenca amazónica de Ecuador: una emergencia para la salud pública

Desde la década de 1970, el petróleo ha sido una de las principales fuentes de ingresos del Ecuador y ha servido como "motor impulsor" de la economía nacional. La mayor parte del petróleo ecuatoriano se extrae en la cuenca amazónica del nordeste del país. Desde que comenzó la explotación petrolera, compañías extranjeras y la empresa petrolera estatal Petroecuador han extraído más de dos mil millones de barriles de petróleo crudo de la Amazonía ecuatoriana. A lo largo de este proceso se han liberado al medio ambiente miles de millones de galones de desechos sin tratar, gas y petróleo crudo. Este artículo analiza el impacto ambiental y sanitario provocado por el desarrollo petrolero en la región amazónica del Ecuador. Por ejemplo, el análisis del agua de varias corrientes fluviales de la localidad ha demostrado la presencia de altas concentraciones de productos químicos derivados del petróleo en las zonas petrolíferas en explotación. Los estudios epidemiológicos han encontrado un mayor riesgo de sufrir síntomas asociados con el petróleo y abortos espontáneos en las mujeres que viven en las proximidades de los campos petroleros. También se ha encontrado una incidencia excesiva de cáncer. Se necesitan intervenciones locales, nacionales e internacionales para evitar que se empeoren los efectos negativos que ejerce sobre el medio ambiente y la salud el desarrollo petrolero. Estas intervenciones deben abarcar un sistema de monitoreo y remediación ambiental, consultas a la comunidad y participación comunitaria, mecanismos para hacer cumplir las leyes que protegen el medio ambiente y la salud de la población, y cambios en las políticas comerciales dirigidos a lograr la sostenibilidad en materia ambiental y la justicia social.

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Prevalencia de anemia en escolares de la zona amazónica de Ecuador

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RESUMEN

Objetivo. *Determinar la prevalencia de anemia en niños campesinos de edad escolar en la región amazónica de Ecuador.*

Métodos. *Se realizó un estudio transversal durante los meses de mayo a octubre de 2000 en dos cantones de la provincia de Orellana, al noreste de Ecuador. Se eligieron 17 escuelas aleatoriamente hasta completar el tamaño muestral deseado, que fue de 626 niños. Se recogieron los datos demográficos y antropométricos (peso y talla); se determinaron los valores de hemoglobina y de protoporfirina eritrocitaria, y se analizaron muestras de heces en busca de infestación por parásitos.*

Resultados. *La prevalencia general de anemia fue de 16,6% y de los escolares afectados, 75,5% tenían anemia por déficit de hierro. La prevalencia de desnutrición crónica moderada fue de 28,8% y la de desnutrición crónica grave, de 9,3%. Asimismo, se encontró una prevalencia de desnutrición aguda moderada de 8,4% y de desnutrición aguda grave de 3,4%. Las infecciones parasitarias fueron muy frecuentes (82,0%). Los parásitos más comunes fueron* Entamoeba coli *(30,3%) y* Ascaris lumbricoides *(25,0%). No se encontró ninguna relación entre la prevalencia de anemia y anemia por déficit de hierro por un lado, y los indicadores nutricionales o de infección parasitaria por el otro.*

Conclusión. *La anemia no es un problema grave de salud pública en la población estudiada. No obstante, la elevada prevalencia de niños con desnutrición crónica apunta a la necesidad de mejorar las características de la dieta. La falta de asociación entre la prevalencia de desnutrición y la anemia podría deberse a una baja biodisponibilidad o absorción de hierro, más que a una ingestión insuficiente. Se necesitan estudios que evalúen el tipo de dieta consumida habitualmente por esta población.*

Palabras clave Anemia, hierro, escolares, Amazonas, Ecuador.

La anemia es uno de los problemas de salud pública más frecuentes en países en desarrollo (1). Si bien las causas de anemia son multifactoriales, el déficit de hierro se considera el principal factor responsable de su alta prevalencia (1, 2). Numerosos estudios han mostrado que la anemia por déficit de hierro incrementa la morbilidad y la mortalidad en grupos vulnerables, retrasa el crecimiento de los niños y dificulta la función cognoscitiva y el desarrollo escolar (3, 4). En los adultos disminuye la capacidad de trabajo y dificulta la labor obstétrica (5, 6).

Aunque la anemia por déficit de hierro es más común y grave en los niños menores de 5 años y en las mujeres embarazadas (7, 8), este tipo de anemia es también muy frecuente en niños en edad escolar (9, 10). En los países en desarrollo, la prevalencia de anemia en escolares se ha estimado en 46%, encontrándose las tasas más altas en África (52%) y en el sudeste asiático (63%) (11). En América Latina, el número estimado de niños anémicos en la década de los ochenta del siglo pasado fue de 13,7 millones, lo que equivalía a una prevalencia de 26% (12). Un informe de la Organización Pana-

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mericana de la Salud (OPS) basado en estudios locales o estatales señaló a Perú como el país con la mayor prevalencia de anemia en toda América Latina y el Caribe (57%), seguido de Brasil, donde 35% de los niños de 1 a 4 años estaban anémicos (13).

En América Latina existen, sin embargo, pocos estudios que evalúen la prevalencia de anemia en la población escolar. En un estudio realizado en el altiplano boliviano, se encontró una prevalencia de anemia por déficit de hierro que variaba entre 22% y 70% en una población de 0,5 a 9 años de edad (14). En Brasil se encontró una prevalencia de anemia de 26,7% en niños entre los 7 y 15 años de edad (15). Sin embargo, en un grupo de niños indígenas yaqui de México de 6 a 10 años de edad, tan solo 1,3% de ellos presentaron anemia (16).

En Ecuador son escasos los estudios sobre la situación de la anemia en los niños. Según los resultados de un estudio de 1996 basado en una muestra representativa de escuelas en zonas de pobreza extrema, 37% de los escolares tenían anemia, siendo mayor la prevalencia en el primer grado escolar (45%) que en el sexto (22%) (17). En otro estudio sobre la relación entre el estado nutricional y la leishmaniasis cutánea que se realizó en niños entre los 0,5 y los 14 años de edad en un área subtropical del noroeste del país, 12% de la muestra estaba afectada por anemia por déficit de hierro (18). Vinuesa et al. (19) encontraron una prevalencia de anemia de 32,2% en niños entre los 6 y 132 meses en la región nororiental del Ecuador.

Cada vez hay un mayor reconocimiento de que los niños en edad escolar, especialmente en los países en desarrollo, sufren de problemas de salud que pueden limitar su capacidad para beneficiarse de la educación (20, 21). Por otro lado, el ambiente escolar ofrece un contexto adecuado para efectuar intervenciones de salud pública de diferentes tipos, tales como las que se basan en la educación en materia de salud, en la suplementación de la alimentación con hierro o en la prevención de las infecciones parasitarias (22–24).

El objetivo de este estudio fue determinar la prevalencia de anemia y de deficiencia de hierro en niños campesinos de edad escolar en la región amazónica del Ecuador.

MÉTODOS

Área de estudio

La provincia de Orellana, ubicada en el noreste de la región amazónica de Ecuador, consta de cuatro cantones: Francisco de Orellana, Sachas, Loreto y Aguarico. La provincia abarca un área de aproximadamente 20 000 km^2 y está situada a 300 m sobre el nivel del mar. El clima de la región es característico de la selva tropical húmeda (precipitación media de 294 mm; temperatura media de 27,9 °C). Una humedad de 80% se mantiene constante en el transcurso del año (25).

La población es de aproximadamente 70 000 personas, de las cuales unas 15 000 son indígenas y el resto campesinos que en los años 70 llegaron de las regiones costeras o de la Sierra. Aproximadamente un tercio de estos pobladores actualmente viven en ciudades pequeñas donde el comercio y las actividades relacionadas con la industria petrolera son las principales fuentes de ingresos. El resto de la población vive diseminada en diversas comunidades campesinas (con 100 a 400 habitantes) en un área rural tropical, donde una agricultura de subsistencia es la base de la economía. La mayor parte de las comunidades carecen de electricidad y de agua canalizada y tienen una gran dificultad de acceso a los servicios de salud (26). La provincia de Orellana se considera un área donde la transmisión de la malaria es baja y no muestra variaciones estacionales, siendo *Plasmodium vivax* el parásito prevalente (27).

Diseño del estudio y metodología

El estudio se realizó durante los meses de mayo a octubre de 2000 en las escuelas fiscales mixtas (educación primaria) de las comunidades campesinas localizadas en los cantones de Francisco de Orellana y Sachas, en la provincia de Orellana. El ausentismo escolar es raro y los niños acuden diariamente a las escuelas de sus propias comunidades.

Se elaboró una lista con los nombres y el número de alumnos de todas las escuelas de estos dos cantones que estuvieran registradas en la Dirección Provincial de Educación. El número total de alumnos fue de 6 081. Teniendo en cuenta una prevalencia de anemia en la población escolar de 37% (17), una precisión deseada de 6% y un nivel de confianza de 95%, se calculó una muestra de 239 niños. El tamaño de la muestra se duplicó para que se ajustara a la naturaleza del agrupamiento del muestreo. Dando por sentada una participación de 80%, el tamaño de la muestra se incrementó a 598. Diecisiete escuelas se eligieron aleatoriamente hasta completar el tamaño muestral. Todos los niños presentes en cada escuela formaron parte de la muestra.

Un equipo técnico integrado por un médico, una enfermera y un promotor de salud se encargó de recoger los datos y las muestras. Se realizó un estudio piloto en una comunidad elegida al azar. Antes del estudio se obtuvo el consentimiento fundamentado de los padres de familia, los profesores y las autoridades provinciales de salud y educación. Los niños que en el momento del estudio presentaban algún trastorno de salud de manejo primario obtuvieron atención y medicamentos gratuitos.

Datos demográficos. A cada niño o niña se le identificó por su nombre, sexo, edad, el nombre de la escuela y el de la comunidad. La fecha de nacimiento se obtuvo del registro de la escuela o del profesor. Todos los niños registrados estuvieron presentes y fueron examinados, salvo cinco que no participaron en el estudio a solicitud de sus padres.

Análisis de sangre. Se extrajeron 3 mL de sangre de una vena antecubital con una jeringuilla desechable. La sangre se colocó en un tubo de ensayo con anticoagulante (ácido etilendiaminotetra(a)cético, EDTA) y se transportó refrigerada al Instituto de Biotecnología de la Facultad de Ciencias Médicas de Quito para la determinación de hemoglobina (Hb) y de protoporfirina-cinc (PPC) eritrocitaria. La Hb se midió mediante el método de la cianometahemoglobina por espectrofotometría (Eppendorf PCP 6121). Los valores de hemoglobina se estimaron de acuerdo con la corrección de Hb por altitud y se usaron los puntos de corte para niños establecidos por la Organización Mundial de la Salud y el Grupo Consultivo Internacional sobre Anemia Nutricional (28). Para la altitud de la provincia de Orellana, el punto de corte de la Hb fue de 11,1 g/dL. Se definió como anemia grave una concentración de Hb < 7,0 g/dL (1). La PPC se determinó mediante fluorometría (hematofluorómetro AVIV 206) y se utilizó como indicador de la concentración de hierro. Concentraciones elevadas de PPC son indicio de déficit de hierro debido a un suministro inadecuado para la hemosíntesis. Se consideraron normales los valores de PPC ≤ 3 μg/g Hb (29). Debido a limitaciones económicas, no fue posible medir la ferritina sérica.

Datos antropométricos. Se utilizaron procedimientos normalizados para obtener el peso y la talla (30). El peso se midió a los 500 g más cercanos con una báscula portátil que se calibró diariamente, y para determinar la estatura se usó un tallímetro de madera adecuadamente calibrado. Los datos se compararon con los del Centro Nacional de Estadísticas de la Salud (31). Los índices de talla para la edad se calcularon en todos los niños que participaron en el estudio, y el índice de peso para la talla se calculó en las niñas hasta los 10 años y en los niños hasta los 11,5 (32). Los niños cuyo índice de talla para la edad estaba situado entre 2 y 3 desviaciones estándar (DE) por debajo de la mediana se clasificaron en la categoría de desnutrición crónica moderada; aquellos cuyos índices se situaban más de 3 DE por debajo de la mediana se clasificaron en la categoría de desnutrición crónica grave. Aquellos cuyos índices de peso para talla estaban entre 2 y 3 DE por debajo de la mediana se clasificaron en la categoría de desnutrición aguda moderada, y los que estuvieron más de 3 DE por debajo de la mediana, en la de desnutrición aguda grave.

Exámenes de heces. Se enseñó a los niños la forma de recoger las heces y se les entregó un pequeño recipiente de plástico con la instrucción de traer una muestra de heces. Se recogieron las muestras y el mismo día las examinó por observación directa un técnico de un laboratorio de Francisco de Orellana reconocido por el Ministerio de Salud Pública. Debido a restricciones logísticas, no fue posible investigar la intensidad de la infección por helmintos.

Examen clínico. A cada niño también se le realizó un examen clínico básico, prestando especial atención a la palidez conjuntival y palmar como signos de anemia (33). Los casos con sospecha de malaria se diagnosticaron clínicamente.

Análisis de los datos

Todos los datos se analizaron con el programa estadístico EPI-INFO 6.04 (Centers for Disease Control and Prevention, Atlanta, Georgia, Estados Unidos de América). Inicialmente se describieron y se resumieron los datos para documentar su distribución en la población estudiada. Las diferencias entre las variables categóricas se evaluaron mediante las pruebas de ji al cuadrado (χ^2) y de χ^2 para tendencias. Se consideró estadísticamente significativo un valor $P < 0{,}05$.

Para analizar la asociación entre las variables categóricas y la presencia de anemia se utilizó la razón de riesgos o el riesgo relativo (RR) con un intervalo de confianza de 95%.

RESULTADOS

Características de los participantes

Se examinaron 626 niños con edades comprendidas entre los 5 y 14 años (media = 8,98 años; DE = 2,25 años). De ellos, 328 (52,4%) eran de sexo masculino. El grupo étnico más numeroso fue el mestizo (96,2%).

Prevalencia de anemia y de deficiencia de hierro

De los 626 niños examinados, a 592 (94,6%) se les realizaron análisis de sangre. La prevalencia total de anemia fue de 16,6%, y en 75,5% de los casos se encontró anemia por déficit de hierro (cuadro 1). Ciento cincuenta y cinco niños (26,2%) tuvieron una PPC > 3 μg/g Hb, pero con un valor de Hb

CUADRO 1. Valores medios de hemoglobina y sus desviaciones estándar (DE) y prevalencia de anemia y de anemia por déficit de hierro, según sexo y edad en una población escolar campesina de la zona amazónica de Ecuador, 2000

Población	Hb (g/dL) Media	Hb (g/dL) (DE)	PPC[a] (μg/g Hb) Media	PPC[a] (μg/g Hb) (DE)	Anemia[b] (%)	Anemia por déficit de hierro[c] (%)
Sexo						
Varones (*n* = 314)	11,97	(1,085)	2,83	(1,155)	17,2	74,1
Mujeres (*n* = 278)	12,0	(1,019)	2,90	(0,968)	15,8	77,3
Edad (años)						
5–7 (*n* = 87)	11,70	(0,991)	2,97	(1,248)	24,1	76,2
7–8,9 (*n* = 165)	11,78	(1,061)	2,96	(1,119)	23,0	84,2
9–10,9 (*n* = 165)	12,06	(0,986)	2,82	(0,904)	10,3	70,6
11–12,9 (*n* = 140)	12,16	(1,053)	2,85	(1,058)	15,0	61,9
13–14 (*n* = 35)	12,65	(1,059)	2,42	(1,073)	2,9	100
Total (*n* = 592)	11,99	(1,11)	2,87	(1,071)	16,6	75,5

[a] PPC = protoporfinira-cinc.
[b] Hemoglobina < 11,1 g/dL.
[c] Anemia y concentración eritrocitaria de protoporfirina-cinc > 3 μg/gHb.

CUADRO 2. Prevalencia de desnutrición moderada y grave según el sexo en una población escolar campesina de la zona amazónica de Ecuador, 2000

	Hombres		Mujeres		Total	
	No.	(%)	No.	(%)	No.	(%)
Talla para la edad (*n* = 626)						
< –2 DE[a]	99	(30,2)	81	(27,2)	180	(28,8)
< –3 DE[b]	33	(10,1)	25	(8,4)	58	(9,3)
Peso para la talla (*n* = 442)						
< –2 DE	20	(7,4)	17	(10,0)	37	(8,4)
< –3 DE	8	(2,9)	7	(4,1)	15	(3,4)

Nota: DE = desviación estándar.
[a] Desnutrición moderada.
[b] Desnutrición grave.

CUADRO 3. Frecuencia de parasitismo intestinal y tipos de parásitos encontrados en las heces de una población escolar campesina de la zona amazónica de Ecuador, 2000

Resultados de examen de heces	Hombres		Mujeres		Total	
	No.	%	No.	%	No.	%
Negativos	46	15,1	58	21,2	104	18,0
Positivos	258	84,9	215	78,8	473	82,0
Helmintos						
Ascaris lumbricoides	76	25,0	68	24,9	144	25,0
Tricocéfalos	41	13,5	28	10,3	69	12,0
Anquilostomas	9	3,0	13	4,8	22	3,8
Oxiuros	4	1,3	1	0,37	5	0,9
Strongiloides	4	1,3	1	0,37	5	0,9
Protozoos						
Entamoeba coli	90	29,6	85	31,1	175	30,3
Entamoeba hystolitica	62	20,4	56	20,5	118	20,5
Giardia lamblia	42	13,8	22	8,1	64	11,1
Endolimax nana	21	6,9	22	8,1	43	7,5
Otros	26	8,6	15	5,5	41	7,1

normal. No se encontró ningún niño con anemia grave.

El porcentaje de niños con anemia fue mayor entre los varones que entre las mujeres, aunque la anemia por déficit de hierro fue ligeramente superior en estas. No hubo diferencias significativas por sexo en ninguno de los indicadores de anemia y de déficit de hierro. Las concentraciones de hemoglobina aumentaron con la edad, encontrándose los valores más bajos entre los 5 y los 9 años. Asimismo, los valores de PPC indicaron que las concentraciones de hierro más bajas se encontraron entre los 5 y los 9 años y aumentaron con la edad (cuadro 1). Esta tendencia de la prevalencia de anemia a reducirse conforme aumenta la edad fue estadísticamente significativa ($P < 0{,}05$).

En el examen clínico se encontró que 35,1% de los niños tenían palidez palmar y 17,5%, palidez conjuntival. Se encontró una relación directa significativa entre la anemia y la palidez conjuntival ($P < 0{,}05$). La sensibilidad del examen de las conjuntivas fue de 27,6% y la especificidad, de 83,4%. El valor predictivo positivo de la palidez conjuntival fue de 24,8%. Solamente a un niño se le hizo un diagnóstico clínico de malaria.

Estado nutricional. Del total de niños investigados, 273 (43,6%) mostraron indicios de algún tipo de malnutrición. Se encontró una prevalencia de desnutrición crónica (talla para la edad) moderada de 28,8% (180 casos) y de desnutrición crónica grave, de 9,3% (58 casos). La prevalencia de desnutrición aguda moderada, expresada en términos del peso para la talla, fue de 8,4% (37 casos) y la de desnutrición aguda grave, de 3,4% (15 casos). No se encontraron diferencias significativas por sexo (cuadro 2). Diecisiete niños (6,2%) tuvieron indicios de desnutrición crónica y aguda simultáneamente.

Prevalencia de parasitismo

En total se recogieron 589 (94,1%) muestras de heces y se obtuvieron los resultados de 577 (92,2%), habiendo sido descartadas las demás por ser inadecuadas. Se detectaron infecciones parasitarias en 473 niños (82,0%). Los parásitos más comunes fueron *Entamoeba coli* (30,3%), *Ascaris lumbricoides* (25,0%) y *Entamoeba hystolitica* (20,5%) (cuadro 3). El riesgo de tener parásitos fue mayor en los varones ($P = 0{,}05$) que en las niñas, pero solo se encontró una relación significativa entre el sexo y la presencia de *Giardia lamblia* ($P < 0{,}02$).

Variables relacionadas con la anemia

No se encontró ninguna relación entre la prevalencia de anemia o de anemia por déficit de hierro y ninguno de los indicadores nutricionales (cuadro 4). Aunque el riesgo de padecer anemia fue mayor en los niños con desnutrición aguda, no fue significativa la diferencia cuando estos niños se compararon con los que tenían desnutrición crónica. Tampoco se halló ninguna relación entre los indicadores de anemia (palidez palmar y conjuntival) y el estado nutricional cuando se restringieron los análisis a los grupos de niños de 10 años o menos y de más de 10 años. No se encontró ninguna relación entre las distintas infecciones por parásitos (salvo en el caso de los anquilostomas) y la concentración plasmática de hierro y de PPC en el grupo

CUADRO 4. Factores de riesgo asociados con la anemia y con la anemia por déficit de hierro en una población escolar de la zona amazónica de Ecuador, 2000

Factor de riesgo	Prevalencia del factor de riesgo	Riesgo relativo	IC 95%[a]
Anemia			
Ascaris	17,8	0,62	(0,37–1,02)
Trichiuris	13,3	1,12	(0,65–1,95)
Anquilostoma	4,4	1,11	(0,45–2,76)
Entamoeba hystolitica	20,0	0,98	(0,61–1,58)
Giardia lamblia	8,9	0,79	(0,40–1,56)
Desnutrición crónica	30,6	0,69	(0,46–1,03)
Desnutrición aguda	15,6	1,55	(0,91–2,63)
Anemia por déficit de hierro			
Ascaris	17,4	0,60	(0,33–1,09)
Trichiuris	13,0	1,10	(0,57–2,10)
Anquilostoma	5,8	1,47	(0,59–3,67)
Entamoeba hystolitica	23,2	1,19	(0,71–2,0)
Giardia lamblia	7,2	0,64	(0,27–1,52)
Desnutrición crónica	28,4	0,62	(0,38–1,0)
Desnutrición aguda	16,9	1,71	(0,94–3,13)

[a] Intervalo de confianza de 95%.

de niños menores de 10 años ($P < 0,05$) (datos no mostrados).

DISCUSIÓN

El presente estudio muestra que la prevalencia de anemia en los niños campesinos en edad escolar de la zona amazónica de Ecuador es de 16,6%. Esta baja prevalencia es similar a la observada en poblaciones rurales de otras zonas del país (18). Sin embargo, la alta proporción de niños con depósitos bajos de hierro y Hb normal (26,2%) indica que un importante número de participantes está en riesgo de padecer anemia.

La tendencia a que disminuya la prevalencia de anemia y a que aumenten las concentraciones de hierro a medida que aumenta la edad se ha encontrado también en otros estudios (34, 35). Una probable explicación es que los niños de menor edad podrían haber tenido recientemente, en la niñez, una mayor demanda de hierro como consecuencia del crecimiento, lo que hace que sus depósitos se reduzcan (10). Al igual que en otros estudios en este grupo de edad, no se encontraron diferencias importantes entre los distintos indicadores de la cantidad de hierro corporal en función del sexo (34, 36, 37).

Se encontró una relación significativa entre la presencia de anemia y la palidez conjuntival ($P < 0,05$), mientras que la sensibilidad y el valor predictivo positivo del examen de las conjuntivas fueron bajos. Esto significa que la palidez conjuntival no es un indicador fiable de la presencia de anemia leve, aunque sí lo es de la de anemia moderada y grave (38), como han señalado otros estudios. Otros estudios cuyos resultados han sido similares a los nuestros recomiendan valorar la palidez conjuntival para el tamizaje de casos probables, pero no para el diagnóstico (39).

El principal tipo de anemia en este estudio fue por déficit de hierro (75,5%). Tres motivos podrían explicar la alta prevalencia de anemia por déficit de hierro en nuestra población de estudio: una ingesta insuficiente de hierro en la dieta; una escasa biodisponibilidad o absorción del hierro ingerido, o una pérdida de sangre debido a la presencia de parásitos intestinales (40).

En numerosos estudios se ha observado el importante papel que desempeña la infección por parásitos en este tipo de anemia (41, 42). Según estudios realizados en Zanzíbar (África), 25% de los casos de anemia y 35% de los casos de anemia por déficit de hierro en niños escolares se atribuían a la infección por anquilostomas (10). Aunque en nuestro estudio todos los niños infectados por anquilostomas tenían anemia por déficit de hierro, la baja prevalencia de este tipo de parasitismo (4%) descarta la importancia de este factor como causa de anemia en nuestra población. La asociación negativa encontrada entre la anemia y *Ascaris lumbricoides* también se ha descrito en otros estudios (10, 43), y varios autores han observado que la infección por tricocéfalos no causa pérdida de sangre, a pesar de que se ha documentado una asociación entre la presencia de estos parásitos y la concentración hemática de hierro (44, 45).

Los protozoos fueron los parásitos más frecuentes en nuestra área, donde 20,5% de los niños estaban infectados por *E. hystolitica*. Sin embargo, no se encontró ninguna relación entre la presencia de este parásito y la anemia o el déficit de hierro. Si bien *E. hystolitica* podría causar diarrea con sangre, no es frecuente encontrar este cuadro ni en la región ni en el grupo de edad estudiados, y sería difícil atribuirle a este parásito la presencia de anemia en el área de estudio (46).

De los distintos factores asociados a la anemia, la ingestión insuficiente de hierro suele ser uno de los más mencionados en la literatura médica (46, 47). Aunque en nuestro estudio no se evaluó la ingestión de hierro en la dieta, la población campesina de la región amazónica mantiene una dieta constante basada en carbohidratos (arroz, yuca, plátano), pero la ingestión de proteínas y de frutas es también habitual. A pesar de la alta prevalencia de desnutrición crónica observada en los niños de esta edad (38,1%), los indicadores antropométricos no mostraron asociación con la anemia ni con la anemia por déficit de hierro. Este hecho apunta a que la causa inmediata del déficit de hierro podría no ser una ingestión insuficiente tanto como una baja biodisponibilidad o absorción. Diferentes estudios han mostrado que las dietas en los países en desarrollo carecen de variedad y contienen sustancias que pueden inhibir la absorción de hierro, como son los taninos, los fenoles y la fibra, componentes frecuentes de las dietas ricas en carbohidratos, como la de la región estudiada (46, 48).

El presente estudio muestra que la anemia no es un problema grave de salud pública en la zona amazónica de Ecuador. Sin embargo, es importante destacar la gran proporción de niños en riesgo de padecer anemia por agotamiento de sus depósitos de hierro. El elevado porcentaje de niños con desnutrición crónica apunta a un déficit de la ingestión de macro y micronutrientes (46, 49) y, por tanto, a la necesidad de mejorar las características de la dieta.

Para determinar si la anemia por déficit de hierro hallada en esta población se debe o no a un problema de biodisponibilidad o absorción se necesitan estudios más profundos que definan los factores de riesgo de la anemia por déficit de hierro y el tipo de dieta habitualmente consumida por la población estudiada. Por otro lado, el gobierno ecuatoriano ha iniciado recientemente en las escuelas de la región amazónica un programa de fortificación de alimentos con hierro. El programa debe vigilarse con miras a evaluar su impacto.

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ABSTRACT

Prevalence of anemia in schoolchildren in the Amazon area of Ecuador

Objective. To determine the prevalence of anemia in rural school-age children in the Amazon region of Ecuador.

Methods. We carried out a cross-sectional study during May to October 2000 in two cantons of the province of Orellana, in northeastern Ecuador, involving 626 children from 17 schools. Demographic and anthropometric data (weight and height) were collected, values for hemoglobin and for zinc erythrocyte protoporphyrin were determined, and feces samples were analyzed to check for infestation by parasites.

Results. The general prevalence of anemia was 16.6% among the schoolchildren; of the affected children, 75.5% of them had iron-deficiency anemia. The prevalence of moderate chronic undernutrition was 28.8% and that of serious chronic undernutrition was 9.3%. There was also a prevalence of moderate acute undernutrition of 8.4% and of severe acute undernutrition of 3.4%. Parasitic infections were very frequent (82.0%). The most common parasites were *Entamoeba coli* (30.3%) and *Ascaris lumbricoides* (25.0%). There were no relationships between the prevalence of either anemia or of iron-deficiency anemia and any of the indicators of nutrition or of parasitic infection.

Conclusions. Anemia is not a serious public health problem in the population studied. Nevertheless, the high prevalence of chronic undernutrition among the children points to the need to improve their diets. The lack of association between the prevalence of undernutrition and anemia could be due to low iron bioavailability or absorption rather than insufficient intake. Studies are needed to evaluate the customary diet of this population.