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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