Lead exposure in indigenous children of the Peruvian Amazon:
Seeking the hidden source, venturing into participatory research

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To Cristina and Julio
My two angels
Abstract

Introduction. In 2006, a Peruvian environmental agency reported the presence of elevated blood lead levels (BLLs) in indigenous communities of the Corrientes river basin. This is a territory in the Peruvian Amazon where oil activity has been associated with serious environmental effects, with impact on an ongoing social conflict.

This PhD project aimed to determine the lead sources, risk factors and pathways in children of these communities and to suggest control and prevention strategies. Given the arguments attributing the lead source to the oil activity pollution, the second objective was to clarify any potential connection between the two. This project was conducted by a collaborative research partnership with the regional health authorities and the community-based organization. The third objective was to characterize the challenges, facilitating factors and the lessons learned from the research process.

Methods. Two epidemiological studies were conducted. Study I (2009) was carried out in three communities and study II (2010) in six communities with different levels of exposure to oil activity. The participants were children 0–17 years old. Data collection included: determination of BLLs, hemoglobin levels and anthropometric indicators, a risk factor questionnaire, an environmental assessment and a risk map. Data analysis included univariate, bivariate and multivariate logistic regression. Data for the third objective came from field notes, documents, interviews and a process of collective reflection.

Results. Study I (n= 221) found no significant difference in the geometric mean (GM) BLLs between the communities exposed and not exposed to oil activity. Older age and being a boy were found as risk factors for BLLs ≥ 10 µg/dL. In study II (n= 346), age stratified logistic regression models indicated that children 0–3 years whose mothers had BLLs ≥ 10 µg/dL, children 0–6 years who played with pieces of lead and children 7–17 years who fished 3 times or more per week or chewed pieces of lead to manufacture fishing sinkers had a significant increased risk of having BLLs ≥ 10 µg/dL. Children who lived in communities near oil battery facilities also had a significant increased risk of having BLLs ≥ 10 µg/dL. In both studies, environmental samples showed lead concentrations below reference levels.

The challenges and facilitating factors identified focused on five interrelated themes: i) mutual trust, ii) multiple agendas, iii) equal participation, iv) competing research paradigms and v) complex and unexpected findings.
**Conclusions.** Metal lead appeared to be the main source of exposure. Playing with pieces of lead and chewing pieces of lead to construct fishing sinkers appeared to be pathways of exposure for children aged 0–6 years and 7–17 years, respectively. Mothers’ BLLs ≥ 10 µg/dL was a risk factor for BLLs ≥ 10 µg/dL in children aged 0–3 years. Living in a community with high exposure to oil activity was a risk factor for BLLs ≥ 10 µg/dL. The identified connection with oil activity was the proximity of communities to oil battery facilities and thus greater access to lead from cables and other industrial waste.

Despite the numerous challenges, participatory research appears to be the most appropriate approach for this type of context. The study findings led us to recommend: i) a comprehensive community-based lead control and prevention plan, ii) the introduction of substitute non-harmful material(s) for fishing sinkers and iii) secure containment of the oil company’s waste deposits.

**Keywords:** lead exposure, children, indigenous, Corrientes river, participatory research, Peruvian Amazon.
Resumen

Introducción. En el 2006, una agencia ambiental del Perú informó de la presencia de niveles elevados de plomo sanguíneo en las comunidades indígenas de la cuenca del río Corrientes. Este es un territorio en la Amazonía peruana, donde la actividad petrolera ha sido asociada con graves efectos ambientales, originando un continuo conflicto social.

Este proyecto de tesis doctoral tuvo como objetivo determinar las fuentes, factores de riesgo y vías de exposición de plomo en niños de estas comunidades para proponer estrategias de control y prevención. Teniendo en cuenta previos argumentos que relacionaban la exposición de plomo con la contaminación por la actividad petrolera, el segundo objetivo fue esclarecer cualquier conexión entre ambos. Este proyecto se condujo con la participación de miembros de la Dirección Regional de Salud de Loreto (DIRESA Loreto) y de la organización indígena FECONACO. El tercer objetivo fue caracterizar los desafíos, las oportunidades y los aprendizajes del proceso participativo.

Métodos. Se condujeron dos estudios epidemiológicos. El estudio I (2009) se desarrolló en tres comunidades y el estudio II (2010) en seis comunidades con diferentes niveles de exposición a la actividad petrolera. Los participantes fueron niños de 0–17 años. La recolección de datos incluyó: determinación de plomo sanguíneo, de niveles de hemoglobina y de indicadores antropométricos, un cuestionario de factores de riesgo, una evaluación ambiental y un mapa de riesgo. El análisis de datos incluyó análisis univariado, bivariado y multivariado de regresión logística. Para el tercer objetivo, los datos provinieron de notas de campo, documentos oficiales, entrevistas informales y un proceso de reflexión colectiva.

Resultados. En el estudio I (n = 221) no se encontró diferencia estadísticamente significativa entre las medias geométricas de los niveles de plomo sanguíneo de las comunidades expuestas y no expuestas a la actividad petrolera. Los niños de género masculino y los del grupo etario de mayor edad tuvieron un riesgo significativamente mayor a presentar niveles de plomo sanguíneo ≥ 10 µg/dL. En el estudio II (n = 346), los modelos estratificados por edad indicaron que los niños de 0–3 años cuyas madres tenían niveles de plomo ≥ 10 µg/dL, los niños de 0–6 años que jugaban con piezas de plomo y los niños de 7–17 años que pesocaban 3 veces o más por semana o masticaban piezas de plomo para fabricar pesas de pescar tenían un riesgo significativamente mayor de presentar niveles de plomo sanguíneo ≥ 10 µg/dL. Los niños que vivían en comunidades cercanas a las baterías de petróleo también tuvieron un riesgo significativamente mayor a presentar plomo sanguíneo ≥ 10 µg/dL. Las muestras ambientales en ambos
estudios mostraron concentraciones de plomo por debajo de los niveles de referencia. En cuanto al proceso de investigación, los desafíos y oportunidades más importantes se centraron en cinco temas interrelacionados: i) la confianza mutua, ii) múltiples agendas, iii) participación equitativa, iv) competencia de paradigmas en la investigación y v) diseminación de resultados complejos e inesperados.

**Conclusiones.** La fuente de exposición principal sería el plomo metálico. Jugar con piezas de piezas de plomo y masticar piezas de plomo para la construcción de pesas de pescar serían vías de exposición para los niños de 0–6 años y 7–17 años, respectivamente. Niveles de plomo sanguíneo $\geq 10$ µg/dL en las madres sería un factor de riesgo para presentar niveles de plomo sanguíneo $\geq 10$ µg/dL en niños de 0–3 años. Vivir en una comunidad con alta exposición a la actividad petrolera sería también un factor de riesgo para presentar niveles de plomo sanguíneo $\geq 10$ µg/dL. La conexión con la actividad petrolera parece estar en la proximidad de las comunidades a las baterías del petróleo y por ende, el mayor acceso al plomo proveniente de cables y otros residuos industriales.

A pesar de los varios desafíos, la investigación participativa parece ser el enfoque más apropiado para este tipo de contextos. Los hallazgos nos llevaron a recomendar: i) un programa comunitario de control y prevención de plomo, ii) la introducción de pesas de pescar de materiales seguros, alternativos al plomo y iii) el control de la disposición de residuos de la actividad petrolera.

**Palabras clave:** exposición al plomo, niños, indígenas, río Corrientes, investigación participativa, Amazonía peruana.
Original Papers

This thesis is based on the following four papers, referred to as Papers I-IV:


IV. Anticona C, Coe AB, Bergdahl I, San Sebastián M. Easier said than done: applying the Ecohealth principles to a study of heavy metals exposure among indigenous communities of the Peruvian Amazon (submitted).
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List of Abbreviations

Organizations and other entities

ATSDR: Agency for Toxic Substances and Disease Registry
CDC: Centers for Disease Control and Prevention
CENSOPAS: National Center of Occupational Health and Protection to the Environment/Centro Nacional de Salud Ocupacional y Protección del Ambiente para la Salud
DESA: Executive Directorate of Environmental Health/Dirección Ejecutiva de Salud Ambiental
DIGESA: General Directorate of Environmental Health/Dirección General de Salud Ambiental
DIRESA Loreto: Regional Directorate of Health in Loreto/Dirección Regional de Salud de Loreto
EPA: Environmental Protection Agency
ERI: Earth Rights International
FECONACO: Federation of Native Communities of the Corrientes River/ Federación de Comunidades Nativas del Río Corrientes
HUD: Department of Housing and Urban Development
IIAP: Research Institute of the Peruvian Amazon/Instituto de Investigación de la Amazonía Peruana
INEI: National Institute of Statistics and Informatics/Instituto Nacional de Estadística e Informática
MINEM: Peru’s Ministry of Energy and Mines/Ministerio de Energía y Minas del Perú
MINSA: Peru’s Ministry of Health/ Ministerio de Salud del Perú
NGOs: Non-Governmental Organizations
OSINERG: Energy Supervisory Agency/Organismo Supervisor de Energía
PEPISCO: Special Project for the Corrientes River Comprehensive Health Plan/Proyecto Especial Plan Integral de Salud del Corrientes
UNEP: United Nations Environment Program
U.S.: Unites States
USA: Unites States of America
WHO: World Health Organization
Technical terms

**BLL:** Blood lead level
**CI:** Confidence interval
**GEE:** Generalized estimating equation
**GFAAS:** Graphite furnace atomic absorption
**Hb:** Hemoglobin
**OR:** Odds ratio
**ppm:** particles per million
**QA/QC:** Quality assurance/Quality control
**µg/dL:** Micrograms per deciliter
**TPH:** Total petroleum hydrocarbons
**Glossary of terms**

**Biomagnification**: The accumulation and concentration of a contaminant at higher levels of the food chain.

**Blood lead testing**: Examination of blood lead level from any sample drawn on a child (capillary, venous or unknown sample type) that produces a quantifiable result.

**Discharge**: A spill that reaches a navigable water or adjoining shoreline.

**Elevated blood lead level**: Blood lead level ≥ 10 μg/dL that was the CDC’s BLL of concern at the time of the study. Note that CDC has recently changed their recommendation to 5 μg/dL (reference value based on the current 97.5th percentile BLLs in the U.S. children aged 1–5 years) (CDC, 2012).

**Environmental contamination**: The impairment of water, sediments, plants, or animals by chemicals or bacteria to such a degree that it is likely to pose a hazard to public health through poisoning, bioconcentration (bioaccumulation), or the spread of disease/ill-health condition. Contamination can be naturally occurring or manmade.

**Epidemiology**: The study of the distribution and determinants of health conditions or events among populations and the application of that study to control health problems.

**Exposed group/population**: A group whose members are likely to come in contact with a suspected cause of, or possess a characteristic that is a suspected determinant of, a particular health problem.

**Exposure**: Having come into contact with a cause of, or possessing a characteristic that is a determinant of, a particular health problem.

**High-risk group**: A group of persons whose risk for a particular disease, injury, or other health condition is greater than that of the rest of their community or population.

**Lead hazard**: Accessible paint, dust, soil, water, or other source or pathway that contains lead or lead compounds that can contribute to or cause elevated BLLs (CDC, 2004)
Medium/media: Path through which a chemical is released into the environment (e.g., direct water or fugitive air).

Odds ratio: A measure of association used in comparative studies, particularly case-control studies, that quantifies the association between an exposure and a health outcome.

Oil: Petroleum

Oil battery facility: Facility at which the fluids obtained from one or more wells are disposed of. Oil, gas and produced water are separated in tanks, impurities removed and the purified liquids are piped for further processing or distribution. Often, oil spills, contaminated runoff (that reach streams, rivers and other navigable waters) and discharge of produced waters occur at these sites.

Pathway of exposure: The mechanism by which chemical reaches the exposed individual. This is related to the type of release.

Pica: Ingestion of non-food items such as soil, stones and paint chips. It is observed most frequently in children up to 2 years old, but it is also the most common eating disorder in individuals with developmental disabilities.

Point source pollution: Pollution that comes from a specific, identifiable source, such as a pipe or channel.

Pollutant: A chemical or biological substance in a form that can be incorporated into, onto, or be ingested by aquatic organisms, consumers of aquatic organisms, or users of the aquatic environment.

Polycyclic aromatic hydrocarbons (PAHs): A group of organic chemicals that includes several petroleum products and their derivatives.

Produced water: Water trapped in geologic formations, which is extracted along with the oil, constituting the oil industry’s most important by-product on the basis of volume. Produced water is typically hyper saline and contains high concentrations of heavy metals and water soluble fractions of oil (Arthur et al., 2005).

Reference value: The concentration or measure of a parameter in a certain medium that, based on present knowledge, does not result in any significant risk to the health of the organisms (i.e. plants, animals, humans) which enter in contact with it.
**Re-injection of produced waters:** Injection of produced water into the geological formation where it was extracted or another suitable formation. It is considered an environmentally-sound solution to water disposal problems but entails the risk of poor injectivity due to a complex interaction between rock mechanics and the plugging potential of the injected fluid (Arthur et al., 2005).

**Risk:** The probability that an event will occur.

**Risk factor:** An aspect of personal behavior or lifestyle, an environmental exposure, or a hereditary characteristic that is associated with an increase in the occurrence of a particular health condition.

**Risk map:** Graphic representation of each community including the location of every housing unit and other important sites as well as the BLLs of resident children classified in elevated (≥ 10 μg/dL) and not elevated (<10 μg/dL). The risk map served to identify where children with elevated BLLs live, possible clusters of houses with multiples cases of elevated BLLs and potential relationships between houses location and BLLs of resident children.

**Salinity:** The presence of soluble salts in or on soils or in water.

**Screening blood lead test:** A blood lead test that helps to identify children with elevated blood lead levels.

**Seasonality:** Change in physiologic status or in the occurrence of a disease, chronic condition, or type of injury that conforms to a regular seasonal pattern.

**Sediment:** Loose particles of sand, clay, silt and other substances that settle at the bottom of a body of water.

**Toxic substance:** A substance that can cause short-term or long-term damage to biological tissue following contact or absorption.
Chapter I

Introduction

In the face of alarming increase in new environmental health hazards, response from diverse sectors of society becomes inevitable and necessary. Traditionally, environmental health hazards have been identified and controlled by two sources, scientific research and government regulation (Pan American Health Organization, 2000). However, initiatives from a third force represented by community members and civil organizations started to gain recognition in the early eighties (Brown, 1997). These initiatives influenced the appearance of more holistic approaches and the establishment of multi-sector collaborative partnerships to conduct research. In the last two decades, these approaches have been supported by theoretical and empirical studies in high-, middle- and low-income countries (Wing et al., 2008).

This thesis examined the case of lead exposure in children from indigenous communities of the Peruvian Amazon and the participatory epidemiological study conducted to elucidate the “origin” of the exposure.

The main objective of this research project was to determine the reasons for the children’s elevated blood lead levels (BLLs) in order to suggest prevention and control strategies. In addition, I aimed to examine the various challenges and facilitating factors encountered in the participatory process in order to strengthen my understanding of the findings and to assist other researchers working in similar contexts.

The case of lead exposure in the Peruvian Amazon was first raised in 2006, when the Peru’s Ministry of Health (MINSA) reported the presence of elevated blood lead and cadmium levels among indigenous communities of the Corrientes river basin. This basin is an isolated area of the Amazon rainforest where the most productive oil extraction activity of the country is concentrated (General Directorate of Environmental Health [DIGESA], 2006) (See Figure 1).

The evidence of lead and cadmium exposure in the population appeared in the context of a historical struggle by the indigenous communities for recognition of environmental damage posed by oil activity. Therefore, speculations pointed to the contaminated environment as the likely source of the heavy metals exposure. The lack of response from the government aggravated serious public alarm and led to radical actions where communities mobilized against the oil company
demanding immediate solutions (Lu, 2009; Orta, 2007). Through this mobilization, the communities achieved a set of commitments from the oil company and the regional government. One of these commitments was an epidemiological study that could legitimately clarify the source(s) of the heavy metals exposure.

In that context, the community-based organization FECONACO (Federation of native communities of the Corrientes river) requested the collaboration of the Unit of Epidemiology and Global Health at Umeå University, Sweden, to conduct the study. This request was made in an effort to address issues of impartiality, credibility, accountability and empathy with the affected population. The University was specifically chosen based upon similar research work they had undertaken in indigenous communities affected by oil activity in Ecuador. In January 2008, the collaborative project was formalized by an official agreement signed by representatives of FECONACO, the Regional Directorate of Health in Loreto (DIRESA Loreto) and Umeå University.

My engagement in this project started few months later (March 2008), during my studies in the Master of Public Health program at Umeå University. For my masters thesis, I had the opportunity to investigate the relationship between heavy metal levels and nutritional indicators among the population of two communities from the Corrientes river basin, using data that FECONACO had provided to Umeå University.

Later, I travelled to Loreto to collect some complementary data for my masters thesis and to assess the feasibility of getting involved in the new project, in the capacity of the University’s research representative and taking the study on as the core of a PhD project.

My early concerns about the feasibility of this research project were put to rest after meeting with FECONACO leaders and representatives from FECONACO’s allied non-governmental organizations (NGOs), who highlighted the positive impacts that the potential research evidence could have on the affected communities. Furthermore, they emphasized their priority to find not only expert scientists but enthusiastic and sensitive persons who could commit to their pursuit of justice for the communities. Finally, FECONACO leaders welcomed me as the researchers’ representative and I embarked on the project feeling extremely glad for the opportunity I had to generate knowledge that could be directly transferred into practical solutions.

Lastly, it is important to note that there were important differences between this PhD project and the original project on lead and cadmium exposure that we conducted in the Corrientes communities. First, this PhD project was only focused
on lead due to i) the lack of comprehensive, consistent and reliable data on cadmium in previous studies and ii) the population’s “low” levels of cadmium exposure found in our last study (2010), suggesting that more attention should be given to lead.

Second, this PhD project was only focused on children while the original project involved the total population of the communities. There were two reasons for this, i) the higher risk of children (compared to adults) to have elevated BLLs, documented in previous studies (National Center of Occupational Health and Protection to the Environment [CENSOPAS], 2007; DIGESA, 2006); and ii) the well-known increased vulnerability of this group to the adverse effects of lead exposure (Agency for Toxic Substances and Disease Registry [ATSDR], 2007).

The assessment of cadmium exposure and all related information is described in the official report submitted to DIRESA and FECONACO (Anticona and San Sebastián, 2011).

**Structure of the thesis**

This thesis consists of three parts and nine chapters. After the introduction in chapter 1, part one “Setting the scene” describes the background of the study in chapter 2, delineates the objectives in chapter 3 and summarizes the context in chapter 4.

Part two “Seeking the hidden source” (chapters 5–6) focuses on the epidemiological component of the project. Chapter 5 presents the research process, methodology and results of the two epidemiological studies conducted. Chapter 6 is then devoted to the discussion of both studies’ results.

Part three “Venturing into participatory research” (chapters 7–9) is focused on the participatory component of this project. Chapter 7 describes the approaches of Ecohealth and Popular Epidemiology, which guided our reflection and interpretation of the research process. Then, chapter 8 summarizes the challenges and facilitating factors encountered along the process, as well as the lessons learned. Finally, chapter 9 presents the conclusions and implications for practice and for further research.

The appendix section includes a guide of main actors and entities in the research process.
Part one: Setting the scene

Chapter II

Background

2.1. Oil industry in the Corrientes river basin
During the last five years, Peru has been the fastest growing market in South America and this growth has increased even more the burgeoning need for energy resources. The ongoing discoveries of oil and gas reserves together with favorable policies for foreign capital have set the platform for an emerging Peruvian oil industry and promoted a massive exploration, extraction and marketing of the energy resources (Bezerra et al., 2011).

The oil industry in Peru started in the early 70’s with the discovery of oil reserves in the Loreto region and the demarcation and concession of two major lots for oil activity. Lot 1AB was located in the upper basin of the Pastaza, Corrientes and Tigre rivers and lot 8 was located in the middle and lower basins of the Corrientes river (Earth Rights International [ERI], Racimos de Ungurahui and Amazon Watch, 2007).

Up to the present time, 84% of the Peruvian Amazon territory has been zoned for oil activity and the Corrientes river lots remain some of the most productive areas in the territory (Finer and Orta, 2010).

Located in the Loreto region, the Corrientes river basin is home for 36 indigenous communities and has been considered as one of the Global 2000 ecoregions for the conservation of biodiversity in the planet (ERI et al., 2007) (Figure 1).

To date, the Corrientes river basin has been an active oil extraction region for more than forty years. Extraction was first managed by the American company, Oxy and since 2000 has been managed by the Argentinean company Pluspetrol Norte S.A. (ERI et al., 2007).

Unfortunately, early operations led to serious environmental impacts (Orta, 2007) as a result of i) massive discharges of oil by-products into local streams, ii) improper storage of waste and iii) periodic unremediated oil spills (ERI et al., 2007). One of the first environmental assessments undertaken in the eighties (Research
Institute of the Peruvian Amazon [IIAP], 1987) found high concentrations of heavy metals, total petroleum hydrocarbons (TPH) and crude oil layers in surface river water. In the subsequent years, other evaluations of surface river water and sediments have reported the presence of oils, fats, TPH and different heavy metals as well as high levels of salinity and chloride concentration (ERI et al., 2007; Executive Directorate of Environmental Health [DESA], 2005; Energy Supervisory Agency [OSINERG], 2004; Peru’s Ministry of Energy and Mines [MINEM], 1998).

Apparently, the environmental situation started to improve when the company Pluspetrol introduced the re-injection system of produced waters in 2007 (injection of the most important by-product of oil extraction activity into suitable geological formations), in order to prevent their release into the river and streams. However, a number of environmental assessments in the recent years have proved that the high level of contamination continues. For example, an environmental monitoring survey conducted in the Corrientes from 2006 to 2009 identified 158 new oil spills, 10 damaged sites and several previous oil spills that had not been yet remediated (FECONACO, 2010).

Despite the evidence of environmental contamination, there is limited information about the health and social impacts of oil activity in the local population. Some clinical registries have shown a high prevalence of dermatological conditions in the Corrientes communities compared to other nearby river communities not exposed to the oil activity (13% prevalence in the Corrientes, 8.6% prevalence in the Pastaza) (MINSA, 2006). In addition, the nutritional deficiencies reported in previous assessments have been attributed to the invasion and destruction of the tropical forest and reduced productivity of the fishing, hunting and agriculture activities by the local population (MINSA, 2006). Some epidemiological studies in similar settings have found adverse effects including spontaneous abortion and cancer in communities exposed to oil activity (San Sebastián and Hurtig, 2004; San Sebastián et al., 2002; 2001). However, these conditions have not been rigorously evaluated in the population residing in the Corrientes river basin.
Figure 1. Location of the Corrientes river basin in Loreto region, Peru. Source: Regional Government of Loreto/ Gobierno Regional de Loreto.
2.2. Indigenous communities’ mobilization towards a better environment and health

In the two last decades, numerous popular struggles based on environmental concerns have lead to a growing environmental consciousness and activism in Latin America. In this context, a focal point of mobilization has been the defense of indigenous peoples’ rights for a safe environment and resources (Carruthers, 2008).

In Peru, there has been considerable high level of organization and political involvement in this regard, especially among indigenous communities affected by oil extraction activity (La Torre, 1999). One emblematic case was the mobilization of the Corrientes indigenous communities for their rights to citizenship and the recognition and remediation of the impacts of oil activity on their health (Lu, 2009).

This mobilization gained considerable momentum with the formation of FECONACO in the early nineties; with subsequent local and international environmental NGOs alliances such as Racimos de Ungurahui, Amazon Watch, World Wide Fund and Earth Rights International. These organizations provided FECONACO with financial resources, technical advice and international contacts that contributed to the communities’ empowerment and led to increased political representation (Lu, 2009).

FECONACO’s first achievements arrived in 2005 when the indigenous leaders and environmental health officials from CENSOPAS and DIGESA agreed upon a plan for a toxicological study to determine the presence of lead and cadmium in the population. Although the ultimate aim of this study was to assess potential health impacts from oil activity, the national institutions’ limitations did not allow testing specific biomarkers of oil exposure in humans (e.g. 1-hydroxypyrene). Instead lead and cadmium were selected based on previous data revealing elevated levels of heavy metals in river surface waters, sediments and some animal species (IIAP, 1987; 1985).

The publication of this study results (eleven months from the time of the samples collection) indicated that more than 50% of the children (total=74) exceeded the reference limit for BLLs 10 μg/dL (the United States Centers of Disease Control and Prevention [CDC]’s level of concern at the time of the study) and 99% of the total population (total=199) exceeded blood cadmium limits for non-smokers (0.1μg/dL), as cited by DIGESA (2006). Data from a concurrent analysis of water and sediments did not permit making any conclusion about the source of exposure (CENSOPAS, 2007).
In light of this information, activists and scholars turned their attention to previous evidence showing elevated levels of heavy metals in the environment (IIAP, 1987; 1985) and, suggested that the main source of exposure might be related to oil activity, specifically through produced waters that had been released to the river since the early operations (ERI et al., 2007; MINSA, 2006). Produced water is defined as water trapped in underground formations, which is extracted along with the oil. Produced water is typically hyper saline and contains high concentrations of heavy metals and water soluble fractions of oil (Arthur et al., 2005).

The idea of a causal association between the heavy metals exposure and oil activity became widespread in the communities and concerns were voiced to the national and international levels (Amazon Watch, 2006; Salazar, 2006). These concerns were accompanied by demands to both the government and the oil company Pluspetrol for regulatory and remediating actions. However, no immediate response was taken when these demands were presented and regulators at the regional and national level (from the sectors of environment, health and energy) conditioned their action to the availability of scientific evidence that could support the suggested “oil-related hypothesis”.

The concern among the communities together with the authorities’ reluctance to provide solutions were the main drivers for the blockade of Pluspetrol’s facilities in October 2006, effectively interrupting activities for two weeks. As a result, the communities achieved the Dorissa agreement, a document drafted by FECONACO, which included a set of commitments such as i) the 100% re-injection of produced waters, ii) the provision of health care, iii) safe water and food supply for the communities and iv) the dedication of 5% of all oil royalties received by the Loreto region for financing projects of economic development and education in the Corrientes (Orta, 2007).

The provision of health care was realized through implementation of an integrated health care project called Special project for the Corrientes river comprehensive health plan (PEPISCO) to be conducted by DIRESA Loreto and financed by Pluspetrol over a 10-year period.

Having in mind the need for scientific research to clarify the association between oil activity and heavy metal exposure, FECONACO also included the conduct of a scientific study as one key component of the health care plan. Furthermore, they got autonomy to decide the selection of the research group that would lead the study.
Chapter III

Objectives

The main objective of this research project was to understand the reasons for the elevated BLLs reported in children from indigenous communities of the Corrientes river basin, Peruvian Amazon, in order to suggest control and prevention strategies.

On this basis, the first specific objective was to determine the sources, risk factors and pathways of the lead exposure in this population (Paper I, II and III). As oil activity was a key factor in the historical perception of lead exposure that required special attention, the second specific objective was to understand the potential connection between lead exposure in this population and oil activity (Paper I and III).

In order to strengthen the understanding of the findings and share lessons learned from this project, the third specific objective was to reflect on the participatory research process and discuss the various challenges and facilitating factors encountered, guided by the “Ecohealth” and “Popular epidemiology” frameworks (Paper IV).
OBJECTIVES
Chapter IV

Context

4.1. The Corrientes river basin and the indigenous communities

The Corrientes river has its headwaters in the Ecuadorian highlands and flows south-east, crossing the Peruvian border where it drains in the Tiger river. The Tiger together with the Pastaza rivers confluence into the Marañón river, which is one of the main tributaries of the Amazon river. In the Peruvian territory, the Corrientes is navigable for its 425 km, at Loreto region. It flows through the Trompeteros district and its basin, with an area of 15 thousand square kilometers of lowland tropical forests, holds 36 villages of indigenous communities and various oil facilities (Perrault-Archambault and Coomes, 2008). The basin is located at 200 km west of the city of Iquitos (capital of Loreto), at 1–3 days’ travel by riverboat or 45 minutes by plane.

In 2008, the total population of the Corrientes river basin (Trompeteros district) was estimated as 8000, mainly formed by indigenous communities from the Achuar ethnic group (79%), few from the Urarina and Quichua groups and a minority of mestizos (21%) (PEPISCO, 2010; MINSA, 2006). The population is considered young (52% aged under 15 years) and in average, each indigenous community concentrates 154 people (Pluspetrol Norte, 2006). Their households are located in clusters nearby the common areas such as the school, health post or the communal meeting center (Image 1). Informal data suggest that 90–95% of the people speak Spanish in communities in the lower Corrientes, while the majority of inhabitants in the upper Corrientes speak their native language.

Despite the profitability from the oil industry, the Trompeteros district’s human development index (0.49) appears in the last quintile of the country, below the national (0.59) and the regional average (0.53) (National Institute of Statistics and Informatics [INEI], 2005a; 2005b). The great majority (85.8%) consumes ground water from wells operated by solar panels (Image 2), in addition to river water (Cáritas del Perú, 2006).

The population’s subsistence based activities include agriculture, hunting, fishing and gathering of edible forest products (MINSA, 2006). However, in the last decades, the frequent employment of men in the oil company has decreased the workforce within the communities to maintain their traditional productive system (MINEM, 2008).

Image 2. View of the water system in the community Peruanito, Corrientes river basin, Peruvian Amazon, 2009.
Regarding the transportation system, the main means is the river while the air transport is managed and used by the oil company. Generally, travelling from one to another community takes 8 to 72 hours by rustic motorboats. Though time consuming and expensive, migration is a typical characteristic of this population and it is related to various purposes, such as seeking better sources of food supply, marital engagements and conflicts among different ethnic groups (Walsh, 2009). The main mode of communication is the radiophone system (MINSA, 2006).

Concerning educational and cultural aspects, a study in 2006, counted 29 communities with primary schools, eighteen of which were staffed by one teacher and 2 communities with secondary schools (Pluspetrol Norte, 2006). In 2007, 74% of children aged 5–14 attended school. Education is in Spanish in the lower Corrientes and bilingual in some schools in the upper Corrientes (PEPISCO, 2007). In addition, there is a notorious disadvantage in the women’s educational level caused in part by the socio-cultural structure of these communities (MINSA, 2006; Cáritas del Perú, 2006).

Though their recognized system of beliefs and cosmology, the growing phenomenon of transculturation (process of cultural transformation marked by the influx of new culture elements and reduced influence of the cultural traditions through generations) in recent decades has been considered another impact from local oil activity (MINEM, 2008).

Finally, the provision of health care depends on the Trompeteros Health Network based in the Trompeteros health care center, in Villa Trompeteros (Trompeteros district capital). Health care services are delivered in 4 medical establishments at the largest communities, in basic health care units at other smaller communities and through medical outreach campaigns. Apart, each community has its own health promoter, trained to diagnose and give medication for prevalent diseases like malaria (MINSA, 2006). Despite these resources, the system seems to be insufficient to meet the needs of the communities, in terms of health personnel, infrastructure, medical equipment and equipment for transportation (ERI et al., 2007).

According to the epidemiological profile, respiratory infections, acute diarrhea, malaria, nutritional deficiencies and dermatological pathologies would be the most frequent morbidities among this population. Another important health issue is related to the possible effects of oil activity for which the reported lead and cadmium exposure seem to be the only indicator (MINSA, 2006).
4.2. Evidence of lead exposure in children from the Corrientes river basin

Three evaluations of lead exposure were carried out in the Corrientes population before our project started. All three reported elevated BLLs in more than 40% of the participant children. However, their results are not fully comparable due to divergences in the participants’ characteristics including the community of residence and the age range (See Table 1). Apart from the BLLs determination, the three evaluations included additional procedures including the administration of a questionnaire on risk factors and an environmental assessment.

The environmental assessment carried out by DIGESA in 2005 determined lead concentrations in a number of surface river water, consumable water and sediment samples. All surface river samples (n=16) and consumable water samples (n=8) showed lead concentrations below the value 0.025 mg/L, interpreted as acceptable according to the Peruvian general water law for river water. Likewise, the sediments samples (n=5) showed lead concentrations below the value 31 mg/Kg, which is the cutoff point taken on by the New York State Department of Environmental Conservation to assess quality of sediments, as it has been determined as lowest effect level for benthic organisms (New York State Department of Environmental Conservation, 1999; Persaud et al., 1992).

The environmental assessment and risk factors questionnaire conducted by ERI et al. (2007) concluded that no sources of lead could explain such elevated BLLs, other than the contamination arising from upstream oil operations.

Table 1. Summary of previous assessments of blood lead levels (BLLs) in children of indigenous communities, Corrientes river basin, Peruvian Amazon, 2005-2006.

<table>
<thead>
<tr>
<th>Institutional author, year</th>
<th>Analytical method</th>
<th>Communities</th>
<th>Participants</th>
<th>Mean BLLs µg/dL</th>
<th>BLLs ≥ 10 µg/dL (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIGESA-CENSOPAS, 2005</td>
<td>Atomic absorption</td>
<td>7 (Nueva Jerusalén, José Olaya, San José, Pucacuro, Sta. Elena, Palmeras, Trompeteros)</td>
<td>Random sampling 10% of the total population n=74 (2-17 years)</td>
<td>NR</td>
<td>66.2%</td>
</tr>
<tr>
<td>CENSOPAS-DIRESA Loreto, 2006</td>
<td>Atomic absorption</td>
<td>2 (San Cristobal and Jose Olaya)</td>
<td>Total population on a voluntary basis: n=59 (2-17 years)</td>
<td>NR</td>
<td>69.5%</td>
</tr>
<tr>
<td>ERI et al. 2006</td>
<td>Leadcare system</td>
<td>5 (Pampa Hermosa, Sauki, Antioquia, José Olaya, Jerusalén)</td>
<td>No selection method reported n=59 (0-17 years)</td>
<td>10.1</td>
<td>43%</td>
</tr>
</tbody>
</table>

NR: No reported
Part two: Seeking the hidden source

Chapter V

The research process

This research project started in August 2008 and ended in September 2011. Along this time frame, two epidemiological studies were conducted, study I and study II. Chapter V describes the research process divided in five phases, alongside the objectives, hypothesis, methodology and results of study I and II.

5.1. Phase one: Establishing a collaborative research partnership

Under the Dorissa agreement described in chapter II, FECONACO obtained funding for a scientific study that would elucidate the origin of the heavy metals exposure. Later, a cooperative inter institutional agreement was signed between Umeå University, FECONACO and DIRESA Loreto to concretize the research partnership.

Umeå University was given the leadership of the study and exclusive responsibilities, including data analysis and elaboration of the final report. Meanwhile, FECONACO assumed the role of representing the communities and their specific responsibilities included facilitating the communication with the communities and administrating the funding. DIRESA Loreto did not assume any specific duty.

The study adopted two levels of governance. The first was an “operational research committee” formed by delegates of the three institutions (parties) to lead the formulation and operationalization of the study plan. The second was represented by the head of each institution and the members of the PEPISCO’s board, who were less involved in the actual study but exercised a more powerful influence compared to the committee.

As delegate of Umeå University and representative of the research team based in Umeå, my prior task aimed to build a trust-based relationship with partners based in Iquitos (Loreto’s capital).
With the support from the NGO Racimos de Ungurahui representatives, I was stationed at FECONACO’s office where I received all the facilities to develop my work. My first field visit to Iquitos was two months long and devoted to increase my knowledge on the historical background of the study, the parties and stakeholders involved. Through several meetings with the committee members, I tried to define a common understanding of the research problem, the objectives, hypotheses and design of the study and to establish preliminary contact with the communities.

After a complicated period of logistics organization, the field work took place between January and February 2009. Representatives from both FECONACO and DIRESA Loreto accompanied me to the communities.

5.2. Objectives and hypotheses study I

The main objective of this study was to determine the source(s), risk factors and pathways of lead exposure in children from three indigenous communities.

According to the literature, classical lead sources and pathways among children include i) leaded paint by ingesting paint chips or dust, ii) dust or soil contaminated by emissions from lead smelters or leaded gasoline which could be inhaled or ingested and iii) drinking water from the corrosion of leaded plumbing materials. Other less common sources and pathways of exposure include: i) lead from acid battery plates, lead-glazed ceramics or lead radiators by occupational take home exposures (battery reclamation, ceramics, construction and radiator repair), ii) contaminated food, food containers or cooking utensils, iii) lead gasoline sniffing, iv) ingestion of lead pellet gun or fishing sinkers, and v) folk remedies, etc (CDC, 2002).

In addition, common risk factors for elevated BLLs in children include younger age in relation to hand to mouth activities and the eating soil and pica habits (ingestion of non-food items). Also malnutrition, iron deficiency, low socioeconomic status and low parental education status have been factors associated with high BLLs. Lead exposure in the mother or caregiver would be another associated factor, especially in small children (CDC, 2005; ATSDR, 2004; Vahter et al., 1997).

In this case, results from three different studies (CENSOPAS, 2007; ERI et al., 2007 and DIGESA, 2006) indicated elevated BLLs in children from the Corrientes river basin, an area where no apparent classical source of occupational or environmental lead existed and where the only major industry has been the oil extraction activity. Oil activity has led to serious environmental impacts as a result of
frequent oil spills and the release of produced water containing heavy metals and other contaminants into the river. Hence, a number of publications suggested that produced water containing lead might contaminate the river water, sediments and food chain, three media to which children might be directly or indirectly exposed (ERI et al., 2007; Orta et al., 2007; MINSA, 2006).

A secondary objective of this study was to verify whether the portable instrument Leadcare Analyzer II (ESA Biosciences, Inc., USA) could determine elevated BLLs as well as the reference technique with graphite furnace atomic absorption (GFAAS) in the study population., with the aim to suggest a practical and affordable resource for carrying out further screening or monitoring activities in all the communities. The main differences between the Leadcare and the reference technique include the analytical method and the type of blood sample they employ. While the Leadcare system measures BLLs from capillary blood samples via anodic stripping voltametry, the reference technique employs venous blood samples and the method GFAAS.

Previous studies have supported the use of the Leadcare technique for clinical evaluation and monitoring of BLLs, provided sampling is carried out by trained staff and using lead free materials (Sobin et al., 2011; CDC, 2005).

Guided by these facts, we formulated the following hypotheses for study I:

1. Communities located in the Corrientes river basin, downstream and near oil battery facilities (sites where most oil spills, contaminated runoff and discharge of produced waters occurred) have a higher exposure to the oil contamination and therefore higher BLLs than those communities located in another river basin and far from oil battery facilities.

2. Risk factors to elevated BLLs in this child population are younger age, lower socioeconomic status and parental educational level, malnutrition and anemia status.

3. Family occupation in oil extraction activities, the storage and use of certain home goods such as batteries, gasoline, glazed pottery and fishing nets and the presence of painted walls in the child’s dwelling are risk factors for elevated BLLs.

4. Hand to mouth, pica or eating soil habits and mothers’ elevated BLLs are additional risk factors for elevated BLLs among the youngest children.

5. Lead concentrations in samples of natural media (water, soil) in the communities are elevated compared to reference levels.
6. The portable instrument Leadcare can determine elevated BLLs in a capillary blood samples as well as the method GFAAS in venous blood samples from the study population.

**5.3. Methodology study I**

**5.3.1. Setting and participants**

This study was set in the communities San Cristobal, Peruanito and Santa Isabel de Copal (Figure 2), selected based on their different degrees of exposure to oil activity. Exposure to oil activity was defined based on the location of the communities and their distance to the nearest oil battery facility, in relation to the occurrence of oil spills and employment of the population in oil extraction activities (see data analysis section). Detailed information of each community is shown in Table 2.

The participants were all children aged 0–17 years from the three communities whose families had lived there for the past 5 years and whose parents consented to their participation.

![Figure 2. Location of the study communities, study I, Corrientes river basin,](image)
Table 2. Setting and participants of study I, Corrientes river basin, Peruvian Amazon, 2009.

<table>
<thead>
<tr>
<th>Community</th>
<th>Location</th>
<th>Population</th>
<th>Exposure to oil activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Cristobal</td>
<td>Downriver, 4 km downstream from oil batteries “One” and “Two”</td>
<td>13 children</td>
<td>- Residents report continuous oil spills in the surroundings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13 families</td>
<td>- Men are regularly employed in oil extraction activities</td>
</tr>
<tr>
<td>Peruanito</td>
<td>In the middle of the Corrientes, 5 km downstream from oil battery “Four”</td>
<td>91 children</td>
<td>- Last registered oil spill in 2007. Minor spills from the oil pipeline crossing the community area occur frequently.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25 families</td>
<td>- Men are regularly employed in oil extraction activities</td>
</tr>
<tr>
<td>Santa Isabel de Copal</td>
<td>In the Copalyacu river basin (tributary of the Corrientes), 42 km (fluvial distance) from the junction Corrientes-Copalyacu rivers</td>
<td>129 children</td>
<td>- No history of oil activity in the surroundings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>32 families</td>
<td>- No employment in oil extraction activities</td>
</tr>
</tbody>
</table>

Sources: (1) Census of Trompeteros district 2006 (PEPISCO, 2007), (2) Report of the independent environmental monitoring program in the Corrientes river basin (FECONACO, 2011).

5.3.2. Data collection

The field work, undertaken in January and February 2009, included five main procedures: i) a blood lead testing in all the children and in the mothers of the group aged 0-3 years, ii) a Hb and anthropometrics measurement, iii) a questionnaire on risk factors, iv) an environmental sampling and v) the elaboration of a risk map.

The blood lead testing has been explained in detail in paper I (Anticona et al., 2011) and paper II (Anticona et al., 2012a) included at the end of this thesis. The analysis for lead concentration was performed using the portable instrument Leadcare Analyzer II in the field (Image 3).

In order to verify whether the Leadcare instrument could determine elevated BLLs as well as the GFAAS method, the participants who showed Leadcare BLLs ≥ 10 μg/dL were asked for a venous blood sample for further analysis using GFAAS. Later on, double pair results were compared. To increase quality assurance, we also conducted an interlaboratory comparison by analyzing 10% of the venous blood samples (previously analyzed by GFAAS) in the laboratory of Lund University Hospital, Sweden, using the method of inductively coupled plasma mass spectrometry (ICP-MS).
The hemoglobin and anthropometrics measurement and the risk factor questionnaire are explained in detail in paper II (Anticona et al., 2012a).

In general, the questionnaire encompassed demographic information, dwelling characteristics, indicators of socioeconomic status, parents’ education, occupation and history of employment at the oil company, cooking practices, use of ethnic remedies or cosmetics, the children’s eating, sucking or chewing habits of non-food items and their consumption of game meat (wild animal meat), fish and other traditional foodstuffs.

The environmental samples collection was conducted in the communities and in selected dwellings in each community. These dwellings (four to six from each community) were selected on the basis of the children BLLs results. Half where at least two children had BLLs ≥ 10 μg/dL and half where no children had BLLs ≥ 10 μg/dL. Further details on this section and a full description of the chemical analysis can be found in paper I (Anticona et al., 2011). The sampling protocol has been synthesized in Table 3.

The map of each community was drawn to represent i) the spatial location of every housing unit and other sites including the river or stream, the school(s), sport and recreational facilities and ii) the BLLs of resident children classified in elevated (≥ 10 μg/dL) and not elevated (<10 μg/dL). This representation was used to identify where children with elevated BLLs lived, possible clusters of houses with multiples cases of elevated BLLs and potential relationships between houses location and BLLs of resident children.
Table 3. Environmental collection protocol of study I, Corrientes river basin, Peruvian Amazon, 2009.

<table>
<thead>
<tr>
<th>Type</th>
<th>Source</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Water</td>
<td>River bathing sites</td>
<td>Samples were collected in polyethylene containers (1L) and preserved in the field with nitric acid added until a pH &lt; 2 was reached</td>
</tr>
<tr>
<td>Drinking water</td>
<td>Water containers of selected dwellings</td>
<td></td>
</tr>
<tr>
<td>Soil (community)</td>
<td>Sporting facilities, community house, port area and/or some of the school classrooms</td>
<td>Samples 5–10 cm depth from a 1 m² area were collected with aluminum spoons and placed in Ziploc plastic bags</td>
</tr>
<tr>
<td>Soil (dwelling)</td>
<td>Surface floor of the kitchen and/or the patio of selected dwellings</td>
<td></td>
</tr>
</tbody>
</table>

5.3.3. Ethical considerations

The study protocol was approved by the Review Board of the Universidad Peruana Cayetano Heredia. Informed consent was explained to parents in Spanish and their native language. Medical care was provided whenever was needed.

The study findings were conveyed to the communities in coordination with FECONACO and DIRESA Loreto. Parents received their children’s results on individual tracking cards and a thorough individual explanation (to interpret the results) by a medical doctor from the Trompeteros Health Centre. In addition, those who showed elevated BLLs were referred for medical evaluation to the Trompeteros Health Centre.

5.3.4. Data analysis

a) Categorization of variables

Age data was used to create the variable “age group” with 3 categories, 0–3, 4–6 and 7–17 years. These cut-off points were determined to account for the various age-dependent risks factors to elevated BLLs in children. For instance, the first group (0–3 years) was defined based on i) the average age range for breastfeeding in this population (MINSA, 2006). Then, the first and second age groups were merged (0–6 years) to study other risk factors common to both groups such as the hand to mouth, pica or eating soil habits. The last group (7–17 years) was defined based on the age at which children from these communities start engaging in outdoor activities.

The variable “anemia status” was created based on the Hb results (anemia=Hb<11.0 g/dL) (CDC, 1989).
Height and weight data were used to calculate height-for-age, weight-for-age and height-for-weight Z-scores using NutStat from Epi Info 3.5.1™ (CDC, Atlanta, Georgia, USA). Subsequently, thresholds of Z-scores < –2 were used to create the variables stunting, undernutrition and wasting.

The variable “communities’ exposure to oil activity” was generated based on the community’s location and distance from the community to the nearest oil battery facility.

<table>
<thead>
<tr>
<th>Not exposed</th>
<th>In a tributary of the Corrientes river, &gt;20 km from junction with the Corrientes river</th>
<th>Sta. Isabel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposed</td>
<td>In the Corrientes river, 4-5 km down-stream from the nearest oil battery facility</td>
<td>Peruanito</td>
</tr>
<tr>
<td></td>
<td></td>
<td>San Cristobal</td>
</tr>
</tbody>
</table>

b) Statistical methods
We conducted univariate analysis for all variables. For continuous variables this included measures of central tendency and spread, graphs of frequency distributions and tests of normality. For dichotomous and categorical variables it included reporting of frequencies and proportions.

A number of variables (e.g. the presence of painted walls, parents’ education, use of self-prepared remedies, utilization of glazed pottery, time of breastfeeding, number of disease events in the past month and traditional foods consumption) were excluded from the analysis because of their small variability.

BLLs and Hb levels were transformed to a log10 scale because of their skewed distribution and geometric means (GM) were used. BLLs below the limit of detection were replaced with the detection limit divided by √2 as performed by Eisenberg (2009).

We conducted bivariate analysis to examine associations between BLLs and single potential risk factors. For continuous variables, we used linear regression and for categorical variables, we used student’s t-test (for variables with two categories) and ANOVA, followed by Scheffe’s post hoc test (for variables with more than two categories).

Further, we conducted multivariate logistic regression analysis to examine simultaneous impact of several factors on the probability to have BLLs ≥ 10 μg/dL. The models were created following a stepwise selection procedure and using the generalized estimating equation (GEE) to account for correlation of BLLs among children from the same house. Independent models, adjusted by age, gender and community, were created for the total population and for each age group because many factors were age-specific activities.
Although CDC has recently changed their BLL of concern 10 μg/dL with 5 μg/dL (reference value based on the current 97.5th percentile BLLs in the U.S. children 1–5 years old) (CDC, 2012), we decided to conduct most of the analyses based on 10 μg/dL because of two reasons: i) this value is widely used by clinicians, researchers and decision makers and ii) the results could be more directly comparable to previous studies. However, the value 5 μg/dL was also considered for some analysis.

Lead concentrations in environmental samples were compared to reference values: 50 mg/kg for soil (Council of the European Communities, 1986) and 0.01 mg/L for water (WHO, 2008). Lead concentration GM of soil and sediment samples were calculated by community. As all concentrations were below reference values, no further analysis was performed. All analyses were conducted using Stata 10 (StataCorp LP, 193 USA).

Simple regression analyses and a pair-wise t-test were conducted to compare the Leadcare and GFAAS BLL results.

### 5.4. Epidemiological results

#### 5.4.1. Demographic characteristics

The final study sample consisted of 221 children aged 0–17 years. Five percent of the children registered in the census did not participate because they were away from their communities during the fieldwork (families usually stay on their farms for weeks). Detailed demographic information appears in Table 4.

<table>
<thead>
<tr>
<th></th>
<th>San Cristobal</th>
<th>Peruanito</th>
<th>Sta. Isabel de Copal</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>13(5.8)</td>
<td>88(39.8)</td>
<td>120(54.3)</td>
<td>221(100.0)</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Girls</td>
<td>9 (69.3)</td>
<td>47(53.4)</td>
<td>68(56.7)</td>
<td>124(56.1)</td>
</tr>
<tr>
<td>Boys</td>
<td>4(30.7)</td>
<td>41(46.6)</td>
<td>52(43.3)</td>
<td>97(43.9)</td>
</tr>
<tr>
<td><strong>Age group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–3</td>
<td>6(46.2)</td>
<td>19(21.6)</td>
<td>33(27.5)</td>
<td>58(26.2)</td>
</tr>
<tr>
<td>4–6</td>
<td>3(23.1)</td>
<td>21(23.8)</td>
<td>26(21.7)</td>
<td>50(22.6)</td>
</tr>
<tr>
<td>7–17</td>
<td>4(30.7)</td>
<td>48(54.5)</td>
<td>61(50.8)</td>
<td>113(51.1)</td>
</tr>
</tbody>
</table>

#### 5.4.2. Characteristics of lead exposure

Overall, the GM LeadCare BLLs was 7.7 μg/dL (95% confidence interval [CI] = 7.2–8.2) and the range was between 2.3 and 26.8 μg/dL. Twenty six percent of
the children were found with BLLs ≥ 10 µg/dL and 85.1 % were found with BLLs ≥ 5 µg/dL. The overall distribution of BLLs is illustrated in Figure 3 and the data stratified by communities is shown in Table 5.

![Figure 3](image)

**Figure 3.** Distribution of blood lead levels (BLLs) in children of three communities, Corrientes river basin, Peruvian Amazon, 2009.

**Table 5.** Blood lead levels (BLLs) in children of three communities, Corrientes river basin, Peruvian Amazon 2009.

<table>
<thead>
<tr>
<th></th>
<th>San Cristobal</th>
<th>Peruanito</th>
<th>Sta. Isabel de Copal</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM BLLs µg/dL</td>
<td>5.2 (4.4–6.0)</td>
<td>8.3 (7.5–9.0)</td>
<td>7.7 (7.1–8.2)</td>
<td>7.7 (7.2–8.2)</td>
</tr>
<tr>
<td>BLLs ≥ 10 µg/dL n(%)</td>
<td>0 (0)</td>
<td>26 (29.5)</td>
<td>31 (25.7)</td>
<td>57 (26.0)</td>
</tr>
<tr>
<td>BLLs ≥ 5 µg/dL n(%)</td>
<td>78 (53.8)</td>
<td>78 (88.6)</td>
<td>103 (85.8)</td>
<td>188 (85.1)</td>
</tr>
</tbody>
</table>

GM: geometric mean, CI: confidence interval

### 5.4.3. Risk factors

Bivariate analyses showed no significant difference of BLLs GM between communities exposed (n=101, GM=7.8 µg/dL [95% CI=7.1–8.4]) and not exposed (n=120, GM=7.6 µg/dL [95% CI=7.1–8.2]) to oil activity. BLLs ≥ 10 µg/dL were found in both communities exposed (25.7%) and not exposed (25.8%) to oil activity.

The bivariate analyses also showed that boys, older age groups and those whose families owned a radio or a motorboat had significantly higher BLLs. Children 0–6 years who had the pica habit had significantly higher BLLs than those who
did not. Children aged 0–3 years whose mother’s BLLs were ≥ 10 µg/dL had significantly higher BLLs than their counterparts (Table 6).

The logistic regression model (with GEE) in the overall population showed that boys had significantly higher risk of having BLLs ≥ 10 µg/dL compared to girls. In addition, children aged 4–6 and 7–17 years had significantly higher risk of having BLLs ≥ 10 µg/dL compared to those in the group aged 0–3 years. In the age stratified models, no predictors for BLLs ≥ 10 µg/dL were found in the age group 0–6 years. In the group aged 7–17 years, boys had significantly higher risk of having BLLs ≥ 10 µg/dL compared to girls (Table 7).

Through the community risk maps, it was not possible to establish a relationship between the location of the dwellings in each community and the distribution of elevated BLLs. However, it allowed identifying clusters of households where the majority if not all the children presented elevated BLLs.

5.4.4. The environmental assessment

All the superficial river water samples (n=4) and the drinking water samples (n=17) had lead levels < 0.01 mg/L (reference value by WHO) (WHO, 2008). Also, the soil samples (n = 38) showed lead levels < 0.8 mg/kg (reference value = 50 mg/kg) (Council of the European Communities, 1986).

5.4.5. BLLs identified by the Leadcare instrument

We compared BLLs in 60 capillary blood samples analyzed by the Leadcare system with the GFAAS results from venous blood samples of the same individuals. Detailed results can be revised in paper II (Anticona et al., 2012a).
Table 6. Blood lead levels (BLLs) according to potential risk factors in children of three communities, Corrientes river basin, Peruvian Amazon, 2009.

<table>
<thead>
<tr>
<th>Variables</th>
<th>n</th>
<th>Geometric mean µg/dL (95% CI)</th>
<th>BLLs ≥ 10 µg/dL (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Individual</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
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</tr>
<tr>
<td>0–3</td>
<td>58</td>
<td>6.8(6.1-7.6)</td>
<td>7(12.0)</td>
</tr>
<tr>
<td>4–6</td>
<td>50</td>
<td>7.4(6.7-8.2)</td>
<td>13(26.0)</td>
</tr>
<tr>
<td>7–17</td>
<td>113</td>
<td>8.4(7.3-9.5)*</td>
<td>37(33.0)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>124</td>
<td>7.0(6.5-7.6)</td>
<td>24(19.4)</td>
</tr>
<tr>
<td>M</td>
<td>97</td>
<td>8.7(7.9-9.5)**</td>
<td>33(34.0)</td>
</tr>
<tr>
<td>Anemia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>46</td>
<td>6.7(5.8-7.6)</td>
<td>7(15.2)</td>
</tr>
<tr>
<td>No</td>
<td>175</td>
<td>8.0(7.5-8.5)*</td>
<td>50(28.6)</td>
</tr>
<tr>
<td>Pica habit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>55</td>
<td>7.5(6.7-8.4)*</td>
<td>12(21.8)</td>
</tr>
<tr>
<td>No</td>
<td>47</td>
<td>6.7(5.9-7.4)</td>
<td>6(12.8)</td>
</tr>
<tr>
<td>Eating soil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>9</td>
<td>8.2(5.9-11.2)</td>
<td>3(33.3)</td>
</tr>
<tr>
<td>No</td>
<td>93</td>
<td>7.0(6.5-7.6)</td>
<td>15(16.1)</td>
</tr>
<tr>
<td>Stunting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>25</td>
<td>7.3(5.8-9.0)</td>
<td>8(32.0)</td>
</tr>
<tr>
<td>No</td>
<td>169</td>
<td>7.8(7.4-8.4)</td>
<td>45(26.6)</td>
</tr>
<tr>
<td>Underweight</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>32</td>
<td>7.3(6.1-8.7)</td>
<td>7(21.9)</td>
</tr>
<tr>
<td>No</td>
<td>163</td>
<td>7.9(7.4-8.4)</td>
<td>46(28.2)</td>
</tr>
<tr>
<td><strong>Dwelling</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location of the kitchen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside</td>
<td>110</td>
<td>8.0(7.4-8.7)</td>
<td>34(30.9)</td>
</tr>
<tr>
<td>Inside</td>
<td>111</td>
<td>7.4(6.8-8.0)</td>
<td>23(20.7)</td>
</tr>
<tr>
<td>Water to cook/drink</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well</td>
<td>135</td>
<td>7.8(7.3-8.3)</td>
<td>34(25.2)</td>
</tr>
<tr>
<td>River</td>
<td>86</td>
<td>7.6(6.8-8.3)</td>
<td>23(26.7)</td>
</tr>
<tr>
<td>Own a radio</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>70</td>
<td>8.3(7.5-9.3)*</td>
<td>21(30.0)</td>
</tr>
<tr>
<td>No</td>
<td>151</td>
<td>7.5(6.9-7.9)</td>
<td>36(23.8)</td>
</tr>
<tr>
<td>Own a motorboat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>86</td>
<td>8.3(7.5-9.0)*</td>
<td>27(31.4)</td>
</tr>
<tr>
<td>No</td>
<td>135</td>
<td>7.4(6.9-7.9)</td>
<td>30(22.2)</td>
</tr>
</tbody>
</table>
### The Research Process

#### Variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>n</th>
<th>Geometric mean μg/dL (95% CI)</th>
<th>BLLs ≥ 10 μg/dL. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own and use a fishnet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>152</td>
<td>7.6(7.1-8.1)</td>
<td>43(28.3)</td>
</tr>
<tr>
<td>No</td>
<td>69</td>
<td>7.9(7.2-8.7)</td>
<td>14(20.3)</td>
</tr>
<tr>
<td>Storage of a car battery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>44</td>
<td>6.7(5.9-7.5)</td>
<td>7(15.9)</td>
</tr>
<tr>
<td>No</td>
<td>177</td>
<td>7.9(7.5-8.5)*</td>
<td>50(28.3)</td>
</tr>
<tr>
<td>Storage of gasoline</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>102</td>
<td>8.1(7.4-8.8)</td>
<td>31(30.4)</td>
</tr>
<tr>
<td>No</td>
<td>119</td>
<td>7.4(6.8-7.9)</td>
<td>26(21.9)</td>
</tr>
<tr>
<td>Family</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mother’s BLLii</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;10 μg/dL</td>
<td>37</td>
<td>6.2(5.4-7.2)</td>
<td>3(8.1)</td>
</tr>
<tr>
<td>&gt; 10 μg/dL</td>
<td>16</td>
<td>9.0(7.7-10.5)**</td>
<td>4(25.0)</td>
</tr>
<tr>
<td>Father’s work at the oil company</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>46</td>
<td>7.1(6.2-8.1)</td>
<td>8(17.4)</td>
</tr>
<tr>
<td>No</td>
<td>175</td>
<td>7.9(7.3-8.4)</td>
<td>49(28.0)</td>
</tr>
<tr>
<td>Oil spill clean up</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>33</td>
<td>7.4(6.4-8.5)</td>
<td>4(12.1)</td>
</tr>
<tr>
<td>No</td>
<td>188</td>
<td>7.8(7.2-8.2)</td>
<td>53(28.2)</td>
</tr>
<tr>
<td>Community of residence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposed to to oil activity</td>
<td>101</td>
<td>7.8(7.1-8.4)</td>
<td>26(25.7)</td>
</tr>
<tr>
<td>Not exposed to oil activity</td>
<td>120</td>
<td>7.6(7.1-8.2)</td>
<td>31(25.8)</td>
</tr>
</tbody>
</table>

Note: ANOVA analysis was conducted using log BLLs
CI: confidence interval, i applicable only to the group 0–6 years old
ii applicable only to the group 0–3 years old, * p-value< 0.05 , ** p-value< 0.01

**Table 7.** Age group-specific multivariate logistic models of OR and 95% CI for blood lead levels (BLLs) ≥10 μg/dL in children of three communities, Corrientes river basin, Peruvian Amazon, 2009.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Overall n= 221</th>
<th>0–6 years n=102</th>
<th>7–17 years n=113</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys a compared to girls</td>
<td>2.4(1.3-4.6)</td>
<td>0.6(0.2-1.8)</td>
<td>5.3(2.2-12.5)</td>
</tr>
<tr>
<td>Age group 4–6 years b compared to age group 0–3 years</td>
<td>2.8(1.1-8.6)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Age group 7–17 years b</td>
<td>3.0(1.2-14.2)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Reside in a community with exposure to oil activity c</td>
<td>1.0(0.5-1.8)</td>
<td>1.0(0.3-2.9)</td>
<td>1.0(0.4-2.3)</td>
</tr>
<tr>
<td>Pica habit vs. no taste habit c</td>
<td>NA</td>
<td>2.1(0.7-2.3)</td>
<td>NA</td>
</tr>
</tbody>
</table>

OR: odds ratio, CI confidence interval, NA: not applicable
a compared to girls, b compared to age group 0–3 years, c compared to reside in a community with no exposure to oil activity.
In summary, elevated BLLs (≥10 µg/dL) were found in both the communities exposed and not exposed to oil activity, with no significant difference in the GM BLLs between them. Therefore, hypothesis 1 was rejected. Boys and children from older age groups had significantly higher risk of having BLLs ≥ 10 µg/dL than girls and younger age groups respectively. Therefore, hypothesis 2 was rejected. Hypotheses 3 and 4 were also rejected. The analysis of water and soil samples showed lead concentrations reference levels (therefore, hypothesis 5 was rejected). The comparison of the BLLs determined by the Leadcare system and the reference method GFAAS indicated that the portable instrument well estimated the true blood lead value in the study population (hypothesis 6 validated). These results did not allow us to identify the sources of lead exposure but suggested that oil-related contamination was not a direct relevant source.

All this information was synthesized in a final report written in Spanish and submitted to DIRESA Loreto and FECONACO in June 2009.

5.5. Phase two: Rethinking the sources and risk factors for exposure

The inability to identify the lead source(s) and risk factors in the first study brought us to rethink our hypothesis. Bearing in mind the increased risk observed in older boys (7–17 years), we thought that a more profound assessment of this specific group’s activities and practices would provide a better understanding of the exposure. Hence, additional methods such as participant observations and group discussions were suggested.

Harnessing the interest and active participation that DIRESA Loreto and FECONACO delegates still had in identifying the source, we proposed to undertake a short visit to one community, to get a better insight of the risk group’s activities and practices that could be related to lead exposure. We selected the community Peruanito because of the residents’ hospitality and greater willingness to cooperate with the study, compared to the other communities. A committee formed by FECONACO and DIRESA Loreto delegates, an external advisor and I visited Peruanito in July 2009. I conducted group discussions with volunteer parents about potential ways they/their children could be exposed to lead in a daily basis. In addition, we visited the dwellings of those children who in our previous study, had shown the highest and the lowest BLLs (which were also those where the environmental samples had been collected from) and held informal conversations with the all the families’ members.
From all the collected information, all members of the committee agreed on the following facts:

i) Peruanito residents used metal lead to construct fishing sinkers. This activity was especially common in boys who were not strong enough to use the fishing nets. Some parents constructed the fishing sinkers for their children but the majority of children did know how to and made the fishing sinkers by themselves.

ii) Scraps of metal lead were obtained from different sources “we collect lead from wherever we can find it” (community member) but the most common way was through recycling copper cables (wrapped by a layer of lead) that they collected from the oil company’s waste deposits, located in the battery facilities. Other sources to obtain lead included car batteries and lead ammunition. Lead could also be bought from itinerant vendors or in particular stores in Villa Trompeteros (the main village in the Corrientes).

iii) Apparently, handling lead was a common practice in the Corrientes and possibly in other nearby river basins. However, none of the residents considered this practice could be connected to the children’s elevated BLLs.

iv) Other potentially harmful practices identified were breathing fumes emitted after shooting lead ammunitions when hunting (due to the belief that this could enhance their shooting abilities), breathing fumes emitted from motorboats when driving (given the uncertainty about the content of lead in gasoline) and using gasoline and/or crude oil as corporal repellents against mosquitoes (Images 4–6).
The research process

**Image 5.** Storage of potential contaminants at home, Corrientes river basin, Peruvian Amazon, 2009.

**Image 6.** Storage of potential contaminants at home, Corrientes river basin, Peruvian Amazon 2009.
5.6. Phase three: Communicating results

Both the data analysis and the elaboration of the study report were carried out in Umeå, while maintaining a fluid communication with the committee members based in Iquitos. FECONACO staff organized virtual meetings on a weekly or monthly basis that allowed us to provide updates on the progress of the study as well as discuss controversial topics, ask questions, get feedback and answers. Unfortunately, the good relationship and support were affected when we shared the preliminary study results with DIRESA Loreto and FECONACO. On the one hand, FECONACO and the NGOs leaders were surprised by the findings and reluctant to accept their veracity. They especially criticized the results of the environmental assessment and suggested that the official report be considered inconclusive about the linkage with the oil contamination without disregarding this factor among the causes of lead exposure.

On the other hand, DIRESA Loreto criticized the fact that we could not analyze all the environmental samples that we planned (fish and other food stuff). Unfortunately, there was no laboratory in Peru using advanced technology to detect minimal lead concentrations that was needed in order to compare with reference values. Considering all those concerns, my research team agreed that the final report would state our inability to identify the source(s) of lead exposure without discarding the hypothesized connection between lead exposure and oil activity.

The final report was presented orally to DIRESA Loreto, FECONACO and other stakeholders in Iquitos. There, we proposed conducting a new study that would include an in-depth examination of older boys’ practices as potential risk factors for elevated BLLs and a broader environmental analysis to assess lead levels in other potential natural sources (sediments, fish and plants).

Although contradictory opinions flowed within FECONACO, the leaders supported our proposal as did DIRESA Loreto authorities. A favorable factor was that all the committee members were willing to find out the source, even if not related to oil activity.

Lastly, all the committee coordinated the dissemination of the results to the three study communities. We crafted the message and prepared flipcharts with graphs and figures to enhance the understanding of the results. We also designed and reproduced a tracking card to provide individual results to all the study participants (Image 7).

In the communities, I tried to explain that sources other than oil pollution might be behind the lead exposure and that further research was required to clarify this issue. FECONACO delegates, who assisted me with the translation, emphasized
that they needed to know the lead source, and for this, more research was necessary. However, some delegates transmitted a different message (that I could not prevent) suggesting that the new study would likely confirm the causal relationship between the oil contamination and the lead exposure. According to them, such a message was necessary to provoke the communities’ reaction and decision to participate in the second study. Finally, the three communities expressed their consent towards the second study.

Image 7. Tracking card for nutritional indicators and blood lead levels (BLLs), PEPISCO project, DIRESA Loreto, Peru’s Ministry of Health, 2010.
5.7. Phase four: Conducting study II

For the new study, I undertook the responsibility elaborating the research plan and coordinating the logistics for fieldwork from Sweden (as I had to return to Umeå to continue with my academic activities). I intended on returning to Iquitos in December 2009 in order to carry out the data collection at the beginning of 2010. However, this plan was never achieved. I returned to Iquitos only to discover that DIRESA Loreto had decided to terminate the research partnership, arguing that Umeå University had not fulfilled its commitments in the agreement to elaborate a treatment protocol for the affected population. To counteract this argument and defend my research team’s position, I held several meetings with DIRESA Loreto and FECONACO authorities.

We were unable to suggest a treatment protocol because the level of lead exposure in the population mainly required prevention measures to avoid contact with the lead source(s) but unfortunately, the source(s) had not been identified yet. An aggravating factor was the lobbying efforts on the part of Pluspetrol to prevent the conduct of the second study. Based on a set of criticisms of our first study, they requested DIRESA Loreto to include Pluspetrol representatives in the research team, in order to guarantee clear and objective results (Pluspetrol Norte, 2009a; 2009b). Pluspetrol executives went so far as to solicit support from Umeå University’s vice-chancellor for their inclusion in our research team, given that we had previously opposed to this intention. Finally, they tried to pressure FECONACO for the same purpose, by retaining for several months the annual funding that FECONACO received to cover other institutional activities.

In order to circumvent these barriers, I called the attention to several regional governmental officials and indigenous leaders who could mediate DIRESA’s decision in favor of the research project. It took four months of continuous pressure on DIRESA Loreto and FECONACO authorities but at the end, we got the consent for the second study and the ratification of the same research team.

5.8. Objectives and hypothesis study II

Like study I, the main objective of this study was to determine the sources, risk factors and pathways of lead exposure. As it was still unclear, this study also aimed to elucidate the potential connection between lead exposure and oil activity.

Though few studies have been conducted in indigenous populations or in communities in the Amazon, the evidence suggests that important lead sources might be the manufacture of fishing sinkers (Brown et al., 2005), the consumption of game meat containing lead pellets (Hanning et al., 2003) and other traditional
foods (farinha) contaminated with lead during its preparation process (Barbosa Jr et al., 2009).

Additionally, information from our research visit to Peruanito showed that children manipulated lead to construct fishing sinkers. Lead could be obtained from the oil company’s waste deposits, from car batteries and lead ammunition. Furthermore, older children used to breathe fumes emitted when shooting with lead ammunition or driving motorboats that used gasoline (which lead content was unknown). Based on these facts and evidence from previous studies, we formulated the following hypotheses:

1. Elevated BLLs in younger children are associated with pica or eating soil habits and with mothers’ elevated BLLs.

2. Elevated BLLs in older children are associated with the practices of playing with pieces of metal lead or cartridge of lead ammunition.

3. Elevated BLLs in older children are associated with the practices of chewing or melting pieces of metal lead to construct fishing sinkers.

4. Elevated BLLs in older children are associated with breathing fumes when shooting lead ammunitions or when driving motorboats that uses potentially leaded gasoline.

5. Elevated BLLs are associated with the ingestion of game meat or food products contaminated with lead.

6. Elevated BLLs are associated with familial occupation in oil extraction activities, the storage and use of certain home goods such as batteries and pieces of lead ammunition or ammunition cartridges.

7. Elevated BLLs are associated with living in communities near oil battery facilities, with greater access of the population to industrial waste deposits where lead materials are recycled.

8. Lead concentrations in environmental samples and food products are elevated compared to reference levels.
5.9. Methodology study II

5.9.1. Setting and participants

This study was set in six communities, Jose Olaya, Antioquia, Peruanito, Santa Isabel de Copal, San Cristobal and Palmeras (Figure 4). As described in study I, the communities were selected based on their exposure to oil activity, defined by the communities’ location and distance to the nearest oil battery facility (in relation to the occurrence of oil spills in the surroundings and the employment of the population in oil extraction activities).

It is notable that the population of these six communities also represented the three ethnic groups who inhabit in the Corrientes river basin, Achuar, Quichua and Urarina. Detailed information by community is shown in Table 8. Participants were all children aged 0–17 years, with the same criteria as described in study I.

![Figure 4](image-url) Location of the study communities, study II, Corrientes river basin, Peruvian Amazon, 2010.
Table 8. Setting and participants of study II, Corrientes river basin, Peruvian Amazon, 2010.

<table>
<thead>
<tr>
<th>Community</th>
<th>Geographical location</th>
<th>Population</th>
<th>Exposure to oil activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jose Olaya</td>
<td>On the upper basin, 2.5 km far from oil batteries “Huayuri” and “Jibarito”</td>
<td>74 children</td>
<td>High exposure - Five major oil spills near Jose Olaya in 2008</td>
</tr>
<tr>
<td>(ethnic group</td>
<td></td>
<td>37 families</td>
<td></td>
</tr>
<tr>
<td>Achuar)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antioquia</td>
<td>On the upper basin, 2.5 km down-stream from oil battery “Jibarito”</td>
<td>65 children</td>
<td>High exposure - Six oil spills in the surroundings in the period 2008-2009</td>
</tr>
<tr>
<td>(ethnic group</td>
<td></td>
<td>19 families</td>
<td></td>
</tr>
<tr>
<td>Achuar)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peruanito</td>
<td>On the mid Corrientes, 5 km down-stream from oil battery “Four”</td>
<td>98 children</td>
<td>Medium exposure - Last registered oil spill in 2007. Minor spills from the oil pipeline crossing the community area, occur frequently</td>
</tr>
<tr>
<td>(ethnic group</td>
<td></td>
<td>27 families</td>
<td></td>
</tr>
<tr>
<td>Achuar)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Santa Isabel de Copal</td>
<td>On the Copalyacu river basin (tributary of the Corrientes), 42 km (fluvial distance) from the junction Corrientes-Copalyacu rivers</td>
<td>146 children</td>
<td>No history of oil activity</td>
</tr>
<tr>
<td>(ethnic group</td>
<td></td>
<td>35 families</td>
<td></td>
</tr>
<tr>
<td>Quichua)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>San Cristobal</td>
<td>4 km down-stream from oil batteries “One” and “Two”</td>
<td>17 children</td>
<td>Medium exposure - Seven oil spills occurred near San Cristobal and Palmeras in the period 2009–2010</td>
</tr>
<tr>
<td>(ethnic group</td>
<td></td>
<td>14 families</td>
<td></td>
</tr>
<tr>
<td>Achuar)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palmeras</td>
<td>5 km down-stream from oil batteries “One” and “Two”</td>
<td>33 children</td>
<td></td>
</tr>
<tr>
<td>(ethnic group</td>
<td></td>
<td>10 families</td>
<td></td>
</tr>
<tr>
<td>Urarina)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.9.2. Data collection

The field work took place in November–December 2010 and included the same procedures as in study I, except for the anthropometrics measurement and the risk map (which were no longer considered necessary).

The blood lead determination from all the children and the mothers of the group aged 0–3 years were obtained and analyzed following the same protocol of study I. Detailed information on the Leadcare calibration and quality control can be found in paper III attached to this thesis (Anticona et al., 2012b).

Hb levels determination used the same protocol as in study I.

The risk factors questionnaire was constructed based on the questionnaire used in study I, to which we added questions on key variables including:

i) the places and frequency (during the last week) to which the household’s members fished, hunted or engaged in other activities or practices involving contact with lead including constructing fishing sinkers, melting and chewing pieces of lead and breathing fumes when shooting with lead ammunition and
ii) the frequency of consumption of fish, fish intestines (guts), game meat and farinha consumption during the last week.

Depending on the child’s age, other questions referred to the frequency of practices or activities potentially involving contact with lead. For example:

i) playing with ammunition cartridge cases, pieces of lead, regular batteries or paints,

ii) disassembling batteries, fishing or hunting,

iii) melting or chewing pieces of lead to construct fishing sinkers,

iv) breathing fumes when shooting with lead ammunition and

v) driving motorboats (with consequent breathing of gasoline fumes).

The environmental samples collection and analysis considered other samples not included in the first study such as sediments, agricultural soil, fish and cassava (a woody shrub native to South America) roots from the communities’ surroundings. In addition, samples of dust, stove ash, firewood, traditional beverages (made of cassava) and prepared fish from a subsample of participant children’s houses. Four to six houses from each community were selected in the same way as in study I.

The sampling collection procedure for each sample type is summarized in Table 9 and illustrated in the Images 8–11.

The chemical analysis was performed at the ALS Scandinavia Laboratory, Sweden (accredited by SWEDAC, Reg No:s 1087). Further details on the analytical methods can be found in paper III attached to this thesis (Anticona et al., 2012b).
**THE RESEARCH PROCESS**


<table>
<thead>
<tr>
<th>Type</th>
<th>Source</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediments</td>
<td>Corrientes river (adjacent to each community), streams and watersheds (where residents mostly fished)</td>
<td>Sediment (20 cm depth) and soil samples (5 cm depth) were collected using a stainless steel core sampler, stored in labeled plastic Ziploc TM bags and cooled to 4°C until analysis</td>
</tr>
<tr>
<td>Soil</td>
<td>Selected families’ farms and from the mineral licks (natural deposits) where residents mostly hunted</td>
<td>Fish and cassava specimens were rinsed with de-ionized water. A portion of muscle from each fish specimen was removed. Samples were stored in labeled Ziploc bags and maintained frozen until analysis</td>
</tr>
<tr>
<td>Fish (mostly consumed)</td>
<td>Fresh fish caught in the same places as the sediments by local techniques (gillnets, traps, poisons) and prepared fish from selected houses when available</td>
<td>Dust and ash were collected with a stainless steel spoon, stored in labeled Ziploc bags and maintained at ambient temperature</td>
</tr>
<tr>
<td>Cassava roots</td>
<td>Farms of selected families</td>
<td></td>
</tr>
<tr>
<td>Dust</td>
<td>Low-transit areas (1 m² ) where dust gathers and where children play.</td>
<td></td>
</tr>
<tr>
<td>Stove ash</td>
<td>Stove surroundings (1 m² )</td>
<td></td>
</tr>
</tbody>
</table>
The research process

Images 8, 9, 10 and 11. Sampling of dust, soil, masato and other food stuff in study II, Corrientes river basin, Peruvian Amazon, 2010.

5.9.3. Ethical considerations

As was described for study I, the same aspects were considered in this study. The second study protocol was also submitted and approved by the Review Board of the Universidad Peruana Cayetano Heredia.

5.9.4. Data analysis

a) Categorization of variables
   - Data on Hb levels was used to generate the variable “anemia status” (< 11.0 g/dL).
   - The variable “communities’ exposure to oil activity” was generated based on the distance between the community and the nearest oil battery facility:

<table>
<thead>
<tr>
<th>Exposure Level</th>
<th>Distance Description</th>
<th>Community</th>
</tr>
</thead>
<tbody>
<tr>
<td>No exposure</td>
<td>In a tributary of the Corrientes river, &gt;20 km from junction with the Corrientes river</td>
<td>Sta. Isabel</td>
</tr>
<tr>
<td>Medium exposure</td>
<td>In the Corrientes river, 3–6 km from the nearest oil battery facility</td>
<td>Peruanito, San Cristobal, Palmeras</td>
</tr>
<tr>
<td>High exposure</td>
<td>In the Corrientes river, &lt; 3 km from the nearest oil battery facility</td>
<td>Antioquia, Jose Olaya</td>
</tr>
</tbody>
</table>
- The variable age group with three categories (0-3, 0-6 and 7-17 years) was created to account for the age-dependent risk factors. For example, practices related to fishing and hunting which involved the manipulation of lead, in the group aged 7-17 years.

b) Statistical methods

Univariate analysis was conducted for all variables. As in study I, some variables were excluded from the analysis because of their small variability.

Bivariate analysis and multivariate logistic regression analysis were conducted with the same criteria as in study I.

Lead concentrations in environmental samples were first compared to reference values,
- for sediments, 31.0 mg/kg (Persaud, 1992).
- for soil, 50 mg/kg (Council of the European Communities, 1986)
- for dust, 1076 µg/m² (U.S. Department of Housing and Urban Development, 2004)
- for fish, 0.3 mg/kg (Commission Regulation EC, 2006).
- for cassava roots, 0.1 mg/kg (Commission Regulation EC, 2006).

As lead concentrations in all fish samples were under the reference value, no further analysis was performed. GM lead concentrations of soil and sediment samples were calculated by community. As all concentrations were below reference values, no further analysis was performed. Geometric means of dust, stove ash, firewood, beverage and cassava samples were calculated by the households lead exposure status (“Lead exposed”/”lead not exposed”) and compared among them using ANOVA. All analyses were performed using Stata 10 (StataCorp LP, 193 USA).

5.10. Epidemiological results

The results of this study have been comprehensively described in paper III attached to this thesis (Anticona et al., 2012b). In total, 346 children participated in the BLLs assessment, showing a GM BLLs of 7.5 µg/dL (range between 2.3 and 34.6). The overall distribution of BLLs is illustrated in Figure 5 and the data among communities is shown in Table 10.
The research process

The bivariate analyses identified some factors associated with higher BLLs, which were then included in multivariate logistic regression models (using GEE). Those models identified common and particular factors which significantly increased the risk of having BLLs ≥ 10 µg/dL, across the different age groups. For instance, children who lived in communities with high exposure to oil activity had an increased risk of having BLLs ≥ 10 µg/dL. Children aged 0–3 years whose mothers’ BLLs were ≥ 10 µg/dL had an increased risk of having ≥ 10 µg/dL. Children aged 0–6 years who played with pieces of lead had an increased risk of having of BLLs ≥ 10 µg/dL. Finally, children aged 7–17 years who fished 3 times or more per week or chewed pieces of lead to manufacture fishing sinkers had a significantly increased risk of having ≥ 10 µg/dL.

**Figure 5.** Distribution of blood lead levels (BLLs) in children of six communities. Corrientes river basin, Peruvian Amazon, 2010.

**Table 10.** Distribution of blood lead levels (BLLs) in children of six communities, Corrientes river basin, Peruvian Amazon, 2010.

<table>
<thead>
<tr>
<th>Community</th>
<th>Jose Olaya</th>
<th>Antioquia</th>
<th>Peruanito</th>
<th>Sta Isabel de Copal</th>
<th>San Cristobal</th>
<th>Palmeras</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM BLLs (95% CI)</td>
<td>9.4 (7.7-11.4)</td>
<td>9.6 (8.7-10.6)</td>
<td>6.7 (6.1-7.3)</td>
<td>7.1 (6.6-7.7)</td>
<td>4.9 (4.1-5.8)</td>
<td>6.5 (5.0-8.3)</td>
<td>7.5 (7.0-7.9)</td>
</tr>
<tr>
<td>BLLs ≥10 µg/dL n(%)</td>
<td>16 (41.0)</td>
<td>23 (43.4)</td>
<td>15 (18.3)</td>
<td>33 (25.4)</td>
<td>1 (6.7)</td>
<td>6 (22.2)</td>
<td>94 (27.0)</td>
</tr>
<tr>
<td>BLLs ≥5 µg/dL n(%)</td>
<td>34 (87.2)</td>
<td>53 (100.0)</td>
<td>61 (74.4)</td>
<td>100 (76.9)</td>
<td>7 (46.7)</td>
<td>16 (59.3)</td>
<td>271 (78.0)</td>
</tr>
</tbody>
</table>

GM: geometric mean, CI: confidence interval
The research process showed lead concentrations below the reference values. It is important to remark that for stove ash, firewood and beverage samples, there were no reference values available to compare with. However, the results were used to identify potential differences between households of participants with (lead exposed households) and without BLLs $\geq 10$ µg/dL (lead not exposed households). An interesting finding was the extremely high content (4000 mg/kg) of lead in an ash sample from a household in Jose Olaya, where all the children (n=5) had BLLs $\geq 10$ µg/dL. Overall, no significant difference was found between lead levels of the samples from “households exposed” and “households not exposed” to lead.

In summary, children aged 0–3 years whose mothers had BLLs $\geq 10$ µg/dL had a significantly increased risk of having BLLs $\geq 10$ µg/dL compared to those whose mothers had BLLs < 10 µg/dL. Therefore, hypothesis 1 was partly confirmed.

Children aged 0–6 years who played with pieces of lead had a significantly increased risk of having BLLs $\geq 10$ µg/dL compared to those who did not (hypothesis 2 was confirmed).

Children aged 7–17 years who fished 3 times or more per week or chewed pieces of lead to construct fishing sinkers had a significantly increased risk of having BLLs $\geq 10$ compared to those who did not (hypothesis 3 was confirmed).

Children who lived in a community with high exposure to oil activity had a significantly increased risk of having BLLs $\geq 10$ µg/dL compared to those who lived in communities with low exposure to oil activity. The connection with oil activity appeared to be the proximity of communities to oil battery facilities (where waste deposits are located) and thus the greater access of people to lead from cables and other industrial waste. Thus, hypothesis 7 was confirmed.

The environmental assessment showed lead concentrations below the reference values. Therefore, hypothesis 8 was rejected.

The other hypotheses were also rejected.

5.11. Phase five: The end of the study
As in study I, a final report was elaborated in Umeå and submitted electronically to DIRESA Loreto and FECONACO authorities. A few weeks later, I travelled again to Loreto to disseminate the study results personally and propose the
implementation of the recommended strategies (intervention) to FECONACO, DIRESA Loreto and the communities.

Unfortunately, I found a very adverse scenario. FECONACO had a completely new group of leaders and administrative staff who knew little if anything about the study. To make it worst, DIRESA Loreto authorities had also changed and the group of delegates in the study operational committee had been dissolved. My first attempt to present the study findings (at one of the PEPISCO public meetings) was interrupted by Pluspetrol representatives who alleged that a previous review of the report was necessary before its official dissemination. DIRESA Loreto conducted the review during the following 6 weeks, and finally after that, I was authorized to make a public presentation of the study results in Iquitos and the communities.

In general, the reactions were hostile. FECONACO leaders rejected the results, arguing that manipulating and chewing pieces of metal lead were harmless practices that they had adopted many years ago to prepare fishing sinkers. Moreover, they claimed that these practices were also common among other communities of the Amazon region, who did not have any problem of lead exposure as the communities in the Corrientes. But the reality is that no other community in the Peruvian Amazon has been tested for lead. Meanwhile, DIRESA showed a very neutral, almost indifferent position. The authorities seemed to be interested in potential interventions but not in collaboration with Umeå University.

Later on, I travelled to the communities accompanied by three FECONACO delegates but none DIRESA Loreto’s representative. The communities’ reactions were mostly negative. Despite my explicit and constant clarifications that only lead exposure had been investigated in this study, many residents argued that the results negated the whole contamination of the Corrientes river, and that the study only benefitted the oil company. Others claimed that the communities had lost a great deal of time and funding in this study, which in end only produced preposterous explanations for the children’s elevated BLLs. Only in Peruanito, residents were interested in understanding my points and even in adopting the recommended strategies. But those strategies required key decisions and actions from DIRESA Loreto, who was not present in that moment, so no concrete commitment could be made.

After visiting the communities, I left Loreto in September 2011. As far as I know, no decision or action regarding the problem of lead exposure in children of the Corrientes river basin has been taken to date.
CHAPTER VI

Discussion

6.1. Overall BLL distribution

The results of our two studies confirmed previous data indicating a problem of chronic lead exposure in children of the Corrientes river communities. Our most recent study indicated that nearly a third of the study population had BLLs ≥ 10 µg/dL and nearly 80% had BLLs ≥ 5 µg/dL (the new CDC’s reference level) (CDC, 2012).

The majority of children affected had BLLs below 20 µg/dL (97.8% in study I and 96.2% in study II) and none above 40 µg/dL. This level of the exposure has no immediately visible or noticeable symptoms. The only means of detection is a clinical test and the management is focused on primary prevention activities and the identification of the lead hazards (sources or pathways) so that the exposure can be eliminated or controlled (CDC, 2004; 2002).

One of the contributions of this investigation has been the identification of the sources, risk factors and pathways of exposure.

6.2. The main source, risk factors and pathways of exposure

A first main finding of this study has been that the source, risk factors and pathways of lead exposure in the child population of the Corrientes seem to be related to contact with pieces of metal lead. Apparently, the primary pathway in young children (0–6 years) was related to playing with lead materials while the pathway in older children (7–17 years) was related to preparing fishing sinkers. The presence of metal lead as a common element in these communities could be attributed to the artisanal manufacture of fishing sinkers. Lead fishing sinkers and their artisanal manufacture are not part of the group of common sources or pathways of lead exposure (CDC, 2002) and the sparse published research is mostly focused on remote, indigenous populations. For example, three case studies have been described in different islands of the Federated States of Micronesia. In Pohnpei, a study in children aged 24–47 months found a strong association between elevated BLLs and the practice of putting lead sinkers or paint chips in their mouths (Vimoto and Finau, 1997). In Yap, another study in children aged 1–12 years found that residence in: i) neighborhoods where lead...
was recycled or melted or ii) homes where fishing sinkers were manufactured was also associated with elevated BLLs (CDC, 2000). The third study based in Chuuk indicated that the manufacture of lead fishing sinkers and battery melting were the main reasons for lead exposure in caregivers and their children aged 2–6 years (Brown et al., 2000). Likewise, other lead exposure studies in fishing communities in Colombia (Olivero-Verbel, 2007) and Indonesia (Foo and Tan, 1998) have described similar situations, with some local variations in the manipulation of metal lead.

In the Corrientes, fishing is a traditional activity which commonly starts at the age of 7 years. Although this is considered a “boy’s activity” (91% [n=69] of the boys aged 7–17 years fished), our data suggested that it would be also undertaken by girls (50% [n=46] of the girls aged 7-17 years fished). We observed that children aged 7–17 years who fished 3 times or more per week had a significantly increased risk of having elevated BLLs compared to those who did not fish. Also, children who chewed pieces of lead to make fishing sinkers had a higher risk for elevated BLLs compared to those who did not. Probably, children who fished had to make fishing sinkers more frequently because the pieces of lead were easily lost in the deep water. However, not all children who fished made fishing sinkers (based on our data, 65% of boys [n=49] and 28% of girls [n=26] aged 7–17 years made fishing sinkers). Sometimes parents, especially the father could prepare the sinkers for all his children.

The procedure to make fishing sinkers varied, but generally involved one or more of these steps: i) modeling the pieces of lead with the hands and a knife, ii) modeling the pieces of lead with the teeth and iii) heating the pieces of lead in the kitchen stove to increase their malleability and facilitate the modeling. The latter situation could partly explain why we found notably high concentrations of lead in some samples of stove ash.

Regardless of the variations, inhalation or ingestion of traces of lead might occur if no protection is used (Environmental Protection Agency [EPA], 2012; European Commission, 1999), as appears to be the case of these communities.

According to the residents, younger children aged 4–6 years would not be directly involved in this practice. However, they may come in contact with lead sinkers when accompanying their siblings to fish (information reported by parents during the questionnaire’s administration and informal interviews). Furthermore, as this practice could be performed inside the house, air emissions from heating lead, contaminated dust and small pieces of lead on the floor may become sources of exposure for all members of the household, especially for the youngest children who are usually at home (EPA, 2012; European Commission, 1999). In
fact, our participants aged 0–6 years, who played with pieces of lead had significantly higher risk of having BLLs >\(10 \mu g/dL\) compared to those who did not.

A second finding (in study II) pointed to mothers’ BLLs >\(10 \mu g/dL\) as a risk factor for elevated BLLs in children aged 0–3 years. One mechanism to explain this association might be lead transference through breastfeeding (Dudarev et al., 2011; Watson et al., 1997; Abadin et al., 1997; Hallen et al., 1995). In fact, the age range 0–3 years defined in this study corresponded to the average age span for breastfeeding in the Corrientes population (MINSA, 2006). Another mechanism for newborn babies would be gestational transmission of lead (Hanning et al., 2003; Snyder et al., 2000). Further analysis of lead concentrations in breast milk, umbilical cords or placenta tissues would be required to clarify these potential mechanisms.

Alternatively, this finding might reflect the existence of a common environmental source or pathway for mothers and children. For instance, indoor coal burning was identified as a common source of lead exposure for young children and their caregivers in rural China (Wang et al., 2004). Likewise, the fabrication of lead fishing sinkers inside the house was associated with lead exposure in infants and their caregivers in Chuuk, Micronesia (Brown et al., 2005). Probably a similar situation could explain our findings in the Corrientes communities.

### 6.3. The connection with oil activity

Another finding from study II was the significantly increased risk of elevated BLLs among children living in communities with high exposure to oil activity, compared to those who lived in communities with no exposure to oil activity. To explain this association, it is relevant to recall our initial hypothesis that the source of lead might be produced waters from oil extraction activity that contaminated the river waters, sediments, soil and food chain of the indigenous population. Based on that rationale, our first study included three communities with different degrees of exposure to oil activity. Two communities were located in the Corrientes river basin, down-stream from oil battery facilities and one community was located in a tributary of the Corrientes river with no history of oil activity and popularly known as the cleanest community in the area. Unexpectedly, we found that the GM BLLs and the percentages of BLLs >\(10 \mu g/dL\) between the communities exposed and not exposed to oil activity were similar.

Another interesting finding was the heterogeneous distribution of elevated BLLs across the total population, being more prevalent in older boys. These findings prompted us to change our thinking. Thus, study II focused on exploring other lead sources related to older boys’ activities or practices involving the manipula-
tion of lead. As the potential exposure through all natural media (e.g. sediments, fish) remained unknown, we also undertook a broader environmental sampling to assess lead concentrations and identify any possible lead source(s) or exposure pathway(s). The results showed low lead concentrations, suggesting that the natural media investigated were not significant lead sources or exposure pathways. However, we found other important mechanisms linking lead exposure and oil activity.

First, we noted that the proximity between the communities and the oil battery installations facilitated the access of both adults and children to industrial waste deposits containing high-voltage electrical cables (made of cooper wires and wrapped in lead) and other lead elements that people collected for recycling purposes. Part of this lead was sold and part was taken home for the manufacture of fishing sinkers. Also, during the dwelling inspections, we found that some families from communities with high exposure to oil activity kept long pieces of lead (extracted from cables) at home, in places accessible to children.

Second, in the communities with high exposure to oil activity, most men (heads of households) reported working for the oil company. A recent environmental assessment in these communities described that when men were absent; women had to undertake the duties of subsistence fishing (Walsh, 2009). In this study we also observed that children, particularly boys undertook the duty of subsistence fishing in the absence of men. Given women and children’s limited capacity to employ heavy fishing nets, traps or harpoons, they often used lines and lead sinkers (Walsh, 2009; MINSA, 2006), which likely increased their exposure to the metal.

Oil facilities were not the only source of metal lead to make fishing sinkers. We observed that communities with medium or no exposure to oil activity obtained lead from used batteries or ammunition and in some cases, they bought it from itinerant vendors in their communities or in Villa Trompeteros.

It is important to note that the connection between oil activity and lead exposure proposed in this study could coexist with the initial hypothesis based on produce water-related contamination. However, the results from our environmental assessment do not support the initial hypothesis.
6.4. The environmental assessment

After detecting elevated BBLs in a child population, key steps to reducing the present and preventing further lead exposure are the identification and removal of the lead hazards in the environment (CDC, 2004). The positive correlation between environmental exposure to lead and total body load is well recognized (Irwin et al., 1997). In that vein, we conducted two environmental sample collections (study I and II) and examined lead concentrations in potential sources or pathways of exposure. The lead concentrations found in samples of water, sediments, soil, fresh fish, indoor dust and cassava plants were low; sometimes not detectable and mostly below the reference values. These results differed from those reported in previous evaluations. For example, the first environmental assessment in the Corrientes conducted in the period 1983–1987 by the Research Institute of the Peruvian Amazon IIAP reported high concentrations of lead and copper in superficial waters and fish tissues (cited by Orta et al., 2007). Another evaluation in 1993 reported the presence of heavy metals in surface waters from various streams, highlighting that the large volume of water of the Corrientes river could dilute any concentrated heavy metal released (MINEM, 1998). Likewise other monitoring reports have indicated lead levels over acceptable limits according to the General Water Law in Peru (0.03 mg/L) and WHO (0.01 mg/L) (WHO, 2008; DESA, 2005; Pluspetrol Norte, 2006).

In our opinion, the difference between our findings and those from previous environmental evaluations could be explained by the reduction of produced waters release into the river, with impact in the environmental profile of heavy metals. The release of massive amounts of produced waters into the Corrientes river and various tributary streams was practiced for many years since the initial operations. However, this situation begun to change in 2007, when the re-injection of produced waters was introduced (Powers, 2008).

In fact, our results were consistent with those from the water quality monitoring program conducted by PEPISCO (DIRESA Loreto) since 2007. The latest assessments reports to which we have had access (2009) showed high levels of various contaminants but no elevated levels of lead. In sediments and superficial river water, they encountered TPH, oil and fats above the acceptable limits. Elevated concentrations of manganese, chlorides and iron and some concentrations (although not reported as elevated) of mercury, zinc, cooper, iron, chromium and arsenic were also found. In drinking water, excessive turbidity and elevated iron levels were reported (DIRESA Loreto, 2009; 2008). Likewise, an independent assessment sponsored by FECONACO reported high levels of TPH but not elevated levels of lead in samples of subsurface soil and running water collected from remediation sites (Quarles, 2007).
One natural medium that we did not include in our evaluation was air, although many residents in the communities suspected that the burning of oil and gas in the production plants could also be a lead source. To our view, a more uniform distribution of BLLs geographically (i.e. across children living in the same community) and demographically (i.e. across age groups and genders) would be expected if air emissions contained elevated lead concentrations. Furthermore, previous analysis of air quality near the oil production plants encountered elevated levels of hydrogen sulphide but not lead (MINEM, 1998). Burning of gasoline historically has been a source of lead exposure but only after the addition of organic lead. Even though we do not know the exact lead content of the crude oil that is burnt in the oil facilities in the Corrientes, gas and crude oil do not normally contain as high a lead concentration as leaded gasoline.

After reviewing the environmental data available, it is clear that the Corrientes river has been severely polluted by local oil activity, posing multiple health hazards for the resident population. Despite efforts from different agencies, the pollution continues. For instance, one hundred oil spills in the Corrientes and tributary streams occurred in the period December 2006- September 2011 (FECONACO, 2011). Therefore, it should be stressed that our findings are not evidence of a clean environment and do not negate the deleterious environmental impact of oil activity. Instead, our results have helped better characterize the major source of lead exposure for the population.

6.5. Other factors investigated

In the logistic regression models where the variables related to contact with metal lead (e.g. chewing pieces of lead when making fishing sinkers) were not included, being a boy and older age appeared as risk factors for elevated BLLs. This association disappeared in the age stratified models of study II, where the variables related to contact with metal lead were included. Age and gender may have been confounding factors in the first statistical models. To illustrate this, the making of fishing sinkers was more prevalent among boys (91%, n=69) than girls (50%, n=46) and elevated BLLs were also more prevalent in boys (38%, n=62) compared to girls (17%, n=32).

The potential relationship with nutritional indicators like anemia and anthropometric measurements was also examined. Anemia was taken as an indicator of iron deficiency, which has been frequently associated with elevated BLLs (Vahter et al., 1997; Goyer, 1997). However, no association was encountered in either the overall nor the age stratified models. It might be that hemoglobin levels and the presence or absence of anemia were not the best indicators for iron deficiency, compared to other recommended tests such as serum ferritin, transferrin satura-
tion and free erythrocyte protoporphyrin (FEP) (Kazal, 1996). Moreover, iron deficiency may exist without frank anemia (Eisemberg, 2009). Another possible explanation might be that the lead exposure was not sufficient to cause lead-induced anemia, which is expected to occur when BLLs are higher than 20 µg/dL. (Schwartz et al., 1990; Agency for Toxic Substances Disease Registry [ATSDR], 2007; WHO, 1995). In study II, only 3.8% (n=13) of the participants showed those BLLs in that range.

We also evaluated a possible association between BLLs and anthropometric indicators based on previous evidence supporting an inverse association between them. Apparently, iron nutritional deficits that retard growth or reduce weight might also increase lead absorption (Kordas et al., 2009).

Our results indicated that neither low height-for-age z score nor low height-for-weight nor low weight-for-age was associated with BLL increases. Nevertheless, these results were not completely surprising, given the great inconsistency of previous studies on the same topic (Frisancho and Ryan, 1991; Ballew et al., 1999; Selevan et al., 2003).

Another potential source of exposure investigated was food. Previous studies have related food exposure to i) the consumption of game meat containing lead pellets from ammunition (Hanning et al., 2003; Tsuji et al., 2002) and ii) the use of cooking utensils containing lead e.g. wheels for flour that are coated with lead (WHO, 2010) and lead-glazed ceramics (Villalobos et al., 2009; Rojas-Lopez et al., 1994). Similarly, a study in riverside communities in the Brazilian Amazon has related elevated BLLs to the consumption of farinha (roasted cassava) contaminated by the metal plate where it was prepared (Barbosa Jr et al., 2009).

In this case, our results showed no significant association between the consumption of game meat and elevated BLLs. Furthermore, the elaboration and use of ceramic items in the Corrientes was found to be rare (out of the total, only two families elaborated and seven families used cooking ceramic items). The consumption of farinha (30% of the children consumed farinha at least once in the previous week) was not associated with elevated BLLs either.

Food exposure could also be explained by the food chain in aquatic organisms living in contaminated habitats (El-Ghasham et al., 2008). In the present case, i) the low lead concentrations found in the captured fish as well as ii) the lack of association between consumption of fish or fish intestines/guts (the tissue in fish shown to accumulate the highest concentrations of lead) and BLLs did not support this possibility.
Furthermore, fish has been described as a good vehicle and biomagnifier for mercury (Hg) but not for lead (Alfonso et al., 2007; Herreros et al., 2008). Interestingly, the samples of cooked fish had higher lead levels than the captured fish, suggesting that exposure could be related to the contamination of fish or other food stuffs during the manipulation or preparation process in a contaminated environment, but not through biological contamination.

Apart from fish, plants can also be biologically contaminated with lead. The amount of lead in food plants depends on soil concentrations and is often found to be the highest around mines and smelters (WHO, 2010). In this case, cassava plants (the most consumed plant in this area) and a traditional beverage (mashato) made from cassava were analyzed. However, the results did not identify those as lead sources.

6.6. Comparing available data on lead exposure in the study population

When comparing the BLL’s distribution between study I and II, in the communities San Cristobal, Peruanito and Santa Isabel de Copal, we noticed a small decline in both, the GM BLLs and the percentage of children with BLLs ≥ 10 µg/dL and ≥ 5 µg/dL, particularly in the community Peruanito. Although we did not intend to examine changes in BLLs over time, we think these changes might be related to a number of factors. First, a different composition of the sample with more newborn babies in study II, who had low BLLs. Taking the example of Peruanito, the sample size of the youngest group (0-3 years) increased from 21.6% (n=19) in study I, to 32.6% (n=27) in study II. As such, small changes in the population resulted in large changes in the prevalence, which might have affected the calculation. In addition, BLLs in the group aged<1 year (n=7) were low (5.1 µg/dL, 95% CI=3.2–8.3). Second, nutritional and behavioral changes as a result of the awareness of potential lead sources among the communities after study I, especially in Peruanito, where we undertook additional field work (research visit) including focus group discussions and interviews.

A similar decline can be observed when comparing the distribution of BLLs in our studies with those from previous studies in the region. However, a number of variations in the participants’ characteristics such as different communities, age ranges and methods to measure BLLs do not favor a reliable comparison.

Regarding declines in BLLs, various authors have suggested that the time needed for a child’s BLL to decline below10 µg/dL varies by BLL, with a linear association between time and initial BLLs (Roberts et al., 2001; Dignam et al., 2008). The half-life of lead in blood is approximately 35 days, but lead is ultimately
stored in bone and can be released into blood by bone remodeling. Bone holds about 90% of the total lead body burden and has a biological half life ranging from seven years to several decades (Cheng et al., 2001). Additionally, these estimations might be altered by a number of other conditions like the frequency and duration of exposure and the impact of case management activities as cited by Eisemberg (2009).

6.7. Limitations

The cross-sectional design of the two studies limited our ability to account for temporality or seasonal variations that might have influenced certain factors related to the exposure. For instance, seasonal changes in the river flow and school vacations during summer time likely affected the frequency of fishing and the making of fishing sinkers. However, it is not likely that this limitation influenced our final results. First, because temporality variations would affect all the communities equally, regardless of their exposure to oil activity. Second, because lead levels in blood are relatively stable. As mentioned before, circulating lead levels can remain elevated for relatively long periods after the exposure ceases due to the mobilization of internal stores accumulated over in long-term or chronic exposure situations such as this one appears to be (Roberts et al., 2001).

As a side note, it might be possible that temporality influenced the participation rates, posing potential selection bias. Study I (participation rate = 95%) was conducted during summer vacation time when most children were at home and thus, had the same probability to undergo the blood lead testing. In contrast, study II (participation rate = 80%) was conducted during school time when some children, especially those attending secondary school, were not present in their communities and did not participate in the study. Despite this fact, the age group distribution in both studies was similar, making it an unlikely potential source of selection bias. Another factor to explain the lower participation rate in study II could have been the loss of interest/motivation among the population, as the first results suggested that oil-related environmental pollution would not be the main lead source. All in all, we consider that the participation rate in both studies (95% in study I and 80% in study II) was good enough to reflect the reality concerning lead exposure in these communities.

We did not measure BLLs following the gold standard method, which is based on venous blood sampling and laboratory analyses with inductively coupled plasma mass spectrometry or atomic absorption spectrophotometry. Instead, we collected capillary blood samples and analyzed them using the Leadcare instrument. The latter technique was chosen as it was a less invasive procedure that increased acceptability among young children and allowed us to process the
samples in the field to provide immediate results to participants of the results on site; which also strengthened our credibility. However, this method has been criticized for its potential limitations. One limitation is the greater tendency of the capillary blood sampling to show false positives compared to the venous blood sampling (related to skin contamination during the blood draw), leading to a reduced specificity in identifying children with higher BLLs (Eisenberg, 2009). Another limitation includes the greater percentage of error and sensitivity to environmental conditions seen in the Leadcare method when compared to other laboratory methods. Nevertheless, previous publications have supported the use of this technique for clinical evaluation and monitoring of BLLs, provided sampling is carried out by trained staff and using lead free devices (Sobin et al., 2011; CDC, 2005). In this manner, we tried to counteract the limitations by ensuring a correct sampling procedure as well as by giving special training to the local medical technicians. We also undertook a methods’ comparison to verify whether the Leadcare instrument could determine BLLs for screening purposes and obtained satisfactory results (Antcona et al., 2012a).

The use of a questionnaire to collect information on risk factors, may have introduced recall bias which we tried to mitigate by employing several strategies. Firstly, the questionnaires were pre tested with a small sample of respondents and this allowed us to make amendments. Secondly, interviewers visited every dwelling at a time when all members of the household (or the majority) were present, so that all could contribute to give comprehensive and reliable answers. Depending on the nature of the question, different members of the household, who could provide more exact information, were allowed to contribute. Thirdly, a local interpreter was available in case the majority of the household’s members did not speak Spanish to ensure the questions were completely understood.

The variable “exposure to oil activity” was categorized on the basis of community-level characteristics (the geographic location in relation to known oil spills) and then assigned to all the participants from each community, assuming the same level of exposure for all. According to the literature, this assumption may introduce potential ecological bias due to the existence of within-area confounding factor(s) or when a confounding factor modifies the exposure-response relationship across areas (Morgenstern, 1998). However, in this case, we did not identify considerable variability in potential confounding factor across individuals living in the same community. On the contrary, all households were similar in terms of number of children, dwelling characteristics, diet, parents’ occupation and common child activities and practices. Furthermore, the risk map could not identify any pattern in the geographical distribution of elevated BLLs within each community. Therefore, we do not believe that ecological bias could have misled our interpretation of the results.
Due to time and financial constraints, we studied only six out of thirty six communities of the Corrientes river. Thus our sample does not necessarily represent the entire child population residing in the Corrientes river basin. None the less, the risk factors and pathways of exposure identified in this study seem to be similar across all the communities in the Corrientes, regardless of the ethnic group. Therefore, it is unlikely that any factor related to lead exposure would affect children in non-studied communities more/less than children in the communities where we conducted the study, enabling us to generalize our findings to all the communities of the Corrientes river.
DISCUSSION
Part three: Venturing into participatory research

This part of the thesis focuses on the participatory research process. First, general concepts of participatory research and the approaches Ecohealth and Popular Epidemiology are delineated and the framework developed in this thesis is described. Then, the challenges, facilitating factors and lessons learned from the participatory process are discussed. Finally, the conclusions and implications for practice and for further research are summarized.

Chapter VII

The participatory approaches

7.1. Participatory health research

The term “participatory research” describes the involvement of lay individuals or groups (community members, local groups and organizations) in scientific research (Israel et al., 1998). This notion emerged in the late 20th century, when the process of social change in developed countries facilitated the democratization of scientific research (Ismail, 2009).

In recent decades, there has been a renewed interest in increasing community involvement in the health care system and in the health research process. Its relevance has been argued in funding initiatives, policy statements and major declarations by various health federal and international organizations. For example, the CDC’s Urban Center for Applied Research in Public Health Initiative, the Principle 10 of the Rio Declaration and the Aarhus Convention (Public Participation in Decision-Making and Access to Justice in Environmental Matters) (Pohjola, 2011; Israel et al., 1998).

The initiatives to incorporate public participation in research have evolved in various similar approaches such as community based participatory research and participatory action research, which share core principles, values and positive outcomes (Minkler and Wallerstein, 2003; Wallerstein, 1999). For instance, Israel et al. (2005, 1998) considered that i) recognizing the constraints of a “value-free” science, ii) building trust and iii) sharing knowledge and power among all partners involved were some important principles. Greenwood (2006)
added that the participation must be cyclical in action and reflection throughout the whole process.

Among the outcomes, the most notorious seem to include: i) the generation of knowledge that is accessible, understandable and relevant to all the partners’ interests and needs, ii) the creation of a reciprocal co-learning relationship to strengthen research and program development capacities among all the partners and iii) the empowerment of communities/organizations to struggle against social inequalities (Macaulay et al., 2011; Leung et al., 2004; Israel, 1998).

Despite the potential positive outcomes, participatory research projects may also pose considerable challenges and barriers, for instance, the existence of competing paradigms, the manipulation of power, differing agendas and interfering political/economic interests (Bell and Brambilla, 2001). The nature of the challenges and barriers may vary depending on who participates and what is the level of participation. Such level can range from a minimal contribution, in which lay participants are approached through standard consultation, towards a higher degree, in which community organizations might define the research question and steer the research in particular directions.

All in all, various public health-related disciplines have started to apply participatory research tools, ranging from anthropology and systems ecology, to epidemiology and environmental health science (Parkes, 2011).

7.2. Participatory research in the field of environmental epidemiology

Searching for causes, pathways and other factors that influence the occurrence of environmental exposures-related disorders requires the application of epidemiological methods. Thus, it is relevant to know the extent to which epidemiologists can integrate public participation into their practice.

In this regard, the traditional positivist bio-medical perspective argues that epidemiology must employ only rigorous methods to generate “accurate and useful information”, thus, the scientific method and direct observation should be the only sources of knowledge (Krieger, 1999; Savitz, 1999). On the contrary, the newly emerging paradigm argues that scientists and research are part of ongoing social and political processes; thus, community participation and the integration of lay and scientific expertise become invaluable conditions to producing useful knowledge (Charron, 2012; Leugn et al., 2004).

The new paradigm appears to offer specific advantages for epidemiological research, such as: i) the decreased likelihood that researchers will impose their own
The participatory approaches

values and biases on defining the problem, the approaches and methods, ii) the increased quantity and quality of data, because the communities motivation to obtain useful data leads to greater participation rates, decreased loss to follow-up and strengthened external validity and iii) the emergence of new research questions derived from learning a broader picture of the problem and the perspectives of those affected (O’Fallon and Dearry, 2002; Allison and Rootman, 1996).

Furthermore, this new paradigm has inspired the development of a number of research frameworks drawn by concepts and methods from epidemiology, environmental and public health. All those frameworks address situations of environmental hazards in disadvantaged populations. Yet, each of them proposes a nuanced understanding of the connection between health and environment and underscores distinct principles in relation to the context from which it emerged. Some of these frameworks are “Environmental justice”, “Popular epidemiology” and “Ecohealth” (Parkes, 2011; Jacobs, 2010; Leugn et al., 2004; Witten et al., 2000).

The next sections will describe briefly the Ecohealth and Popular epidemiology approaches.

7.3. Ecohealth, the ecosystems approach for human health

Ecohealth has evolved from the school of community participation approaches into a specialized framework to address the impact of pollution on ecosystems and human health (Parkes et al., 2003). Ecohealth is part of a broader call for “ecosystem approaches” to health, based in a number of principles. First, “system thinking” requires the consideration of different dimensions (e.g. ecological, social-cultural and economic), scales of time and contexts (e.g. individual, communitarian, regional) in order to locate health in one system and understand the drivers of a particular problem (Charron, 2012). Second, “transdisciplinarity” looks for the integration of different views, types of knowledge and research methodologies by the involvement of academicians from different fields and stakeholders working in research partnerships. Finally, “participation” emphasizes that these partnerships involve the affected population throughout the research process and the formulation and the implementation of actions (Charron, 2012).

As with any participatory approach, Ecohealth poses advantages and barriers. However, most of the reported case studies have shown that the use of key strategies has allowed research partnerships to achieve successful outcomes. Some of those strategies include: i) changing the research question to account for stakeholders’ concerns, ii) providing participation incentives, iii) conducting workshops to generate dialogue and even iv) implementing education programs
to engage the population. Yet a few cases have also demonstrated that despite the partnerships’ endeavors, the influence of structural factors such as socio-political conditions and competing interests prevented the translation of knowledge into positive actions (Charron, 2012; Lebel, 2003).

The Ecohealth framework proposes a model of four phases, two for the research process: i) participatory design (organization of the partnership, agreement on the research question, principles and methods) and ii) knowledge development (data collection, generation and dissemination of findings), plus two other phases for the implementation of public health actions: iii) intervention strategy and iv) systematization. Although framed as following a sequence, the process is not unidirectional and the phases might overlap with each other (Charron, 2012).

7.4. Popular epidemiology

The term Popular epidemiology appeared in the late eighties to describe a set of emerging cases in which lay people led research initiatives and mobilized political attention to document environmental contaminants in their neighborhoods and seek for solutions (Brown, 1997). From that starting point, the construction of a theoretical framework has provided guidance for an in-depth examination of similar processes, characterizing phases, identifying key elements/principles and supporting the applicability (despite numerous challenges) of the related approach.

Ten common but non-static stages have been distinguished in the popular epidemiology process. It starts when communities detect the presence of health effects and pollutants (phase 1) and are able to hypothesize connections between them in an organized and coherent way (phase 2). Later on, the acquisition of more information and its diffusion among the community members allow the generation of a common perspective and a cohesive group (phase 3) to call for the attention of authorities and scientists (phase 4) and pursue an investigation (phase 5). In response to that pressure, government agencies conduct official studies, but they usually tend not to find connections between contaminants and health effects (phase 6). Hence, independent experts are brought in to conduct a new investigation (phase 7). If a connection is established, the community groups press for corroboration of their findings by official experts and agencies (phase 8). Simultaneously, community groups can start processes of litigation and confrontation against those potentially responsible for the contamination (phase 9) (Brown, 1997). The process goes ahead because the activist groups remain continuously involved in actions to vigil their case, such as new surveillances, media reports or the actual implementation of strategic interventions (phase 10).
From the previous description, three important characteristics can be highlighted: i) the considerable leadership and ownership of the research process by the affected community, ii) the influencing role of the social movement(s) and political action grounded not in a political ideology but in the personal experience of being affected and iii) the value of the scientific knowledge, which is secondary to the popular perception of risk, ethics and morality (San Sebastián and Hurtig, 2005; Wing et al., 1996).

7.5. Examining the research process through the lens of Ecohealth and Popular epidemiology

This section describes the commonalities and divergences between the Ecohealth and Popular epidemiology approaches. Then, it explains how the two approaches were combined in a new framework and the reasoning behind it.

Both Ecohealth and Popular epidemiology are considered holistic approaches aiming at advancing public health and reducing health inequalities by undergoing a participatory process. Likewise, both put special emphasis in the role of communities and social organizations (ownership/control and regulation) over the role of the state or academic institutions. However, each of them has particular roots and fields of action, different purposes and values. Ecohealth has grown up and been useful for addressing issues of community development, especially in rural and indigenous populations. In this approach, the generation of new scientific knowledge is a pillar that will inform the formulation of policies and the implementation and evaluation of interventions. According to Cargo and Mercer (2008), the drivers and purposes of this approach would have a utilitarian focus, aiming to translate knowledge into action.

In contrast, Popular Epidemiology has evolved in line with the toxic wastes movement and the environmental justice field. Popular epidemiology seeks to document environmental health hazards through a lay type of science process (an evolutionary process of learning and growing) that might or might not include or not the establishment of partnerships with scientists and the generation of scientific knowledge. This approach would be more focused on the values of social and environmental justice and the community’s self-determination (Cargo and Mercer, 2008).

In this study, we recognize features from the Ecohealth and Popular epidemiology approaches in three aspects. First, the objectives and methods encompass concepts of environmental pollution, health and community development. Second, the research process was grounded in a lay type of science that continued with the formalization of a collaborative partnership with scientists to conduct research. Third, the project was aimed at producing useful research (utilitarian
focus) but at the same time was driven by values of environmental justice and the community’s self-determination.

Those features are combined in a new framework model, illustrated in Figure 6. The Popular epidemiology process (trapezium at the bottom) is echoed in the way the historical struggle of the indigenous organization, supported by the communities and NGOs, made possible the recognition of the oil activity’s impacts on the environment; although most impacts on the population are still unknown (see the central trapezium). Within the central trapezium of unknown impacts, the evidence of heavy metals exposure (core of this research project) appears to be the “tip of the iceberg”, although the connection with oil activity was not clear at the beginning of the study.

The upward spirals behind the trapezium represent the cyclical course of this popular epidemiology process, which continues after the research phase and is markedly influenced by the research outcomes.

In addition, the Ecohealth approach is reflected in the dynamic collaborative interaction among the policy makers (DIRESA Loreto), the communities’ organization (FECONACO) and the researchers (University) as members of the partnership (circle in dark grey) and their interactions with the government, oil company, NGOs and communities as the other stakeholders (circle in light grey).

The parties will share a common objective but also hold various competing features that will have a two-way influence on the process and generation of knowledge (double-edged arrows). This two-way influence will also be seen in the role of the other stakeholders including the oil company, regional government and NGOs.

Beyond that, contextual factors (socio-economic, socio-cultural influences, public policy and legislation, physical environmental factors, societal structures) will influence this interaction and add more complexity to the research process.

Finally, the confluence of: i) the interactive/participatory process, ii) certain features of the knowledge produced (e.g. whether effective or not in addressing the research question, or whether strengthening or not the interests/agendas of the parties involved), iii) the feasibility/suitability of the recommended strategies and iv) the role of macro level/ contextual factors, will all influence the application of the generated knowledge in further decision making or actions. In this vein, Ecohealth promotes the production of knowledge that can be immediately applicable to changing a given problematic situation. In theory, this is likely to happen when research questions are locally relevant and there is great initiative and leadership from communities; however, those conditions will not necessarily guarantee positive outcomes.
Figure 6. Diagram of the research process connecting the Ecohealth and Popular epidemiology approaches.
Chapter VIII

Reflecting on the research process

The case of lead exposure in the Corrientes population emerged in the context of a social conflict around the impacts of oil activity. Unfortunately, this is only one example of the numerous socio-environmental conflicts that are currently affecting Peru. In the last year, there have been 229 socio-environmental conflicts in the country and from those, more than 70% are related to extractive industry projects (Servindi, 2012).

In order to investigate the reasons for lead exposure, we embarked on a participatory research project where we encountered challenges and facilitating factors.

8.1. Challenges and facilitating factors

The most important challenges and facilitating factors have been grouped in a set of interrelated themes that underlie the different phases of the research process (described in chapter 7). Those themes are: i) mutual trust, ii) multiple agendas, iii) equal participation, iv) competing research paradigms and v) complex and unexpected findings.

8.1.1. Mutual trust

Trust is defined as “a reliance on the integrity and veracity of another person”. Building and maintaining trust are recognized as core elements for successful partnerships, fostering open communication, coherence of goals, an honest exchange of ideas and resolution of conflicts (Israel et al., 2006). Thus, many have investigated the process, challenges, facilitating factors and key strategies for building and maintaining trust (McKnight et al., 1998).

In this case, the major challenges and facilitating factors for building and maintaining trust were related to i) the interaction among people with different backgrounds, ii) the historical context of the research, iii) the communities’ previous experience engaging in research and iv) the instability among leadership positions (Greene-Moton et al., 2006).

Concerning the first point, Christopher (2008) posit that the harmonic interaction among partners with contrasting backgrounds and characteristics in terms of gender, ethnicity, education and values constitute a key challenge to trust
building, implying a long standing exercise of cultural competence and humility. In addition Covey (2009) underscores that trust is built from two dimensions: character and competence. Character refers to integrity, motives and intent whereas competence includes the capabilities, skills, results and track record.

To illustrate these arguments, I will describe how my background, character and competence as researcher had an impact on the trust building process. The fact of being a young, female PhD student put me in an initially disadvantaged position compared to the senior male DIRESA Loreto officers, authoritative male FECONACO leaders and the powerful oil company representatives, all interacting in a patriarchal society. Early on, I found that my commitment and efforts to maintain a friendly and open minded attitude (character) were not enough to gain the other partners and stakeholders’ respect and credibility because they were overshadowed by other “debilitating characteristics” of being a young woman. Nevertheless, my academic degree and the support from Umeå University were favorable circumstances that demonstrated my capabilities and skills (competence) and helped me, with time, to inspire respect, expertise and objectivity while at the same time being friendly and open to learn from others.

Concerning the second point, one of the challenges was based on the history of conflict between the members of the partnership. Although their relationship at the time of the study was diplomatic, FECONACO and DIRESA Loreto had had a series of confrontations surrounding the apparent lack of accountability, capacity and willingness of DIRESA Loreto to attend the communities’ needs. In 2006, a period of positive mutual understanding between the leaders of both institutions led them to agree upon the conduct of the epidemiological study and the research partnership. Sadly, there was an unexpected change of authorities, which brought a return to the history of confrontation and mistrust. As researchers, our objective was to develop the same level of trust in our relationship with both institutions. However, the greater interest of FECONACO in the study was determinant in building a closer relationship with them. I was stationed at FECONACO’s office and given the necessary resources to develop my work. Moreover, I received their help to approach and gain support from the communities to conduct the study. Unfortunately, this close relationship with FECONACO posed negative implications too. We were strongly criticized by the oil company representatives for taking sides. Based on that argument, they went into a pressing campaign to include their own participation in study II to ensure neutrality, delaying the research process and affecting our credibility. In this context, establishing a good relationship with DIRESA representatives was key, given its role as the official decision maker, but it was also negative because it endangered the support from FECONACO and the communities, who had an explicit skepticism towards any governmental agency.
Some other challenges were related to the previous experience of the communities participating in other studies. First, there was a general suspicion of engaging in a project that would not provide any tangible solution, as it had apparently happened with the three previous studies on lead exposure in the Corrientes.

Second, there was a particular fear towards the use that we could give to their blood samples and the potential danger that providing blood so many times could pose on their health. In that context, the use of the Leadcare method on capillary blood samples and the ability to provide immediate results were extremely helpful.

Finally, some people were suspicious about my agenda as a researcher. They felt that as PhD student, I would use them solely to learn and then leave. To some extent, this was a likely scenario due to our limitations in terms of time and power to provide visible solutions to the communities. Overcoming this situation was not easy; on one hand, I tried to convey that my interest was not only devoted to the study itself but to the alleviation of their health problems. On the other hand, I had to be realistic regarding the extent of that contribution and proceed to not create false expectations, which was sometimes inevitable.

The last challenge was related to the instability among leadership positions (Edwards, et al., 2008), especially in the case of FECONACO. Over the first three years, frequent changes in FECONACO leaders were possible to overcome, given the facilitating factor of the permanent staff that always helped me gain the trust of the incoming leaders.

Unfortunately, in the last phase of the study, all FECONACO leaders and staff were changed and, hence, I became a complete stranger for the new leaders. This situation was aggravated by the reaction to the final study results, making useless my efforts to build a good relationship with them.

### 8.1.2. Multiple agendas

Working amid research partnerships is complex especially when the partners pursue diverse agendas, mandates and reward structures that might be in conflict with each other and with the study objectives; even where there is a commitment of mutual cooperation and a shared purpose (Jacobs, 2010; Cargo, 2008, Shoultz et al., 2006; Lantz, 2001).

In this case, the major challenges for the research process arrived from the partners and stakeholders’ unclear roles and changing agendas.

For instance, DIRESA Loreto was supposed to play an independent neutral role, providing support to the study through their delegates in the operational com-
mittee. But throughout the research process their agenda appeared to be influenced by other interests. For example, our intention of conducting a second study was strongly criticized by Pluspetrol, who initiated a campaign to either abort the continuation of the project or to include their representatives within the research partnership (Pluspetrol Norte, 2009a; 2009b). Coincidentally at this time, DIRESA Loreto withdrew their support for the project and without any clear explanation, tried to terminate our partnership. Moreover, when the plan for the second study succeeded, DIRESA Loreto upheld Pluspetrol’s request to participate in the research partnership, despite the clear conflict of interests. Favorably for us, DIRESA Loreto was primarily dependent on the regional government and its head’s decisions had to adhere to the regional president’s political agenda. Thus, appealing to the regional government’s attention in the pre-elections campaign period likely was an opportunity to turn over DIRESA Loreto’s opposition to the second study (Stern, 1991).

FECONACO’s agenda was unclear and intricate. It seems that the interplay of various actors including its own leaders, the communities and the allied NGOs, made it difficult to define a clear role, aim and discourse regarding the problem of lead exposure and this study.

FECONACO’s role in the study was to represent the communities, ensuring that all the residents’ concerns and needs be addressed and facilitating a fluid two-way communication with the researchers. But in practice, FECONACO had scarce resources (personnel and funding) for maintaining a fluid communication with the communities in order to acknowledge all their problems. Other barriers were political rivalries inside and among communities and personal interests of FECONACO leaders, different from the institutional goals.

Apprecably FECONACO’s aim regarding the problem of lead exposure was to achieve strategies of solution. But early on, we learnt that their real expectation was to find scientific proof that oil activity was the source of exposure. In that context, it is understandable why FECONACO expressed insecurity towards the prolongation of the study after the first results that rejected the association with oil activity. Fortunately, the determination of some leaders likely became a facilitating factor. For them, the continuation of the study was key to demonstrating skills in managing conflicts and fulfilling their commitment to the communities. Also, continuing with the project implied small but significant material benefits for FECONACO which was suffering a financial crisis at that time.

Finally, FECONACO leaders argued that the communities had been able to maintain a healthy and environmentally respectful “ancestral” lifestyle; consequently, the only source of contamination could be the by-products from oil activity (ERI et al., 2007). But in reality, they knew that the younger generations had consid-
erably lost their traditional lifestyle and often engaged in harmful practices involving the manipulation of industrial waste and other potential contaminants including lead. Although some leaders recognized these lifestyle changes, none were willing to accept the potential connection with lead exposure proposed by our study. In this vein, there are many examples of indigenous communities that have mixed traditional and Western practices and others that act without any trace of ancestral culture (Hern, 1991). For Ulloa (2007), there are some cases where the perceived identity of indigenous groups, as living in a harmonious relationship with the environment, is mostly embedded in stereotypes, since the introduction of commercial circuits and adoption of foreign lifestyles in the last decades have eradicated that harmonious relationship.

As previously mentioned, the role of the NGOs was intimately attached to FECONACO. They bolstered the campaign to gain funding and legitimacy for the PEPISCO project (including this study) and convoked us (the researchers) to conduct the investigation. Once in Loreto, they helped me to build up a close relationship with FECONACO leaders and gain their trust. Apparently, they shared our objective to find the source of the heavy metals exposure. Yet, after the first study results, they expressed that their priority was to find the mechanisms through which oil activity was endangering the population’s health and if our current research question could not address this priority, they suggested that we change it.

The communities’ agenda also had contrasting sides. They showed concern for the fact of being exposed to heavy metals and wanted solutions. But they also believed that such circumstances were “beneficial” because it would allow them to obtain economic compensation from the company. Many residents whose children did not have elevated BLLs showed discontent and refused to believe they were not “contaminated”. Some of them expressed their fear that the previous victorious struggle against Pluspetrol would be defeated if their heavy metals exposure decreased.

Finally, our agenda as university researchers was also tangled. First, the university’s previous publications documenting the health impacts of oil activity in Ecuador (San Sebastián et al., 2002; 2001) led to a misleading perception that we had a similar objective in this study. I must recognize that my initial expectation was to find a straightforward association between the heavy metals exposure and the oil activity but, all in all, my aim was to find the source of exposure. Second, the researchers’ agenda was mainly driven by my personal agenda, which had different dimensions. On one side, my academic goals, (since I had framed my PhD thesis on the results of this project) and commitment with the communities to find the source of lead exposure were my motives to pursue the study even with the worst contextual conditions. On another side, my desire to avoid
conflicutive and stressful situations constantly discouraged me from continuing with this project. Dealing with such ambivalence constituted another challenging task, but the permanent support from my research team and the broad social capital I had were determinant facilitating factors.

8.1.3. Equal participation

The Ecohealth approach promotes the establishment of collaborative partnerships in which all parties contribute as equal members and share control/power over all phases of the research process (Lebel, 2003; Israel, 1998). Previous experiences suggest that this democratic ideal may be problematic (Wallerstein and Duran, 2006; Fadem et al., 2003).

In our case, the multi-stakeholders governance implied that we yielded control over key research issues. For example, in the selection of the study communities, FECONACO’s leaders insisted that their own communities be included. Also, in the funding distribution, FECONACO’s leaders opposed costly components of the study, even though these could have improved the study quality in our view. In order to deal with these challenges, “non-academic” skills including consensus building, negotiation, communication, financial and strategic planning were extremely necessary.

Other constraints were related to issues of representation, since the parties were not single individuals but collective bodies with internal conflicts of interests and power dynamics. For instance, the operational committee delegates had limited power and a low degree of authority. This implied that the delegates’ decisions had to be approved by their superiors, who knew little about the study. Thus, decisions were delayed. As a strategy, I tried to confer directly with the main authorities but at the expense of undermining the role of the committee delegates.

Another example was related to the participation of FECONACO as the communities’ representatives. This representation was efficient in terms of time, resources and effort, but also embedded negative conditions that affected the participatory including historical tensions between the communities and FECONACO leaders low capacity to decide and mistrust in the study’s financial management by FECONACO. Despite these potential risks, practical reasons likely explain why most Ecohealth projects continue to work primarily with local NGOs or government agencies and limit the involvement of the study population (Lebel, 2003).
8.1.4. Competing research paradigms

Research paradigm can be defined as the assumptive base which guides scientists to produce knowledge (Rubin and Rubin, 2005). In health research, different fields are oriented by one or another paradigm, depending on how they interpret the nature of knowledge and reality (Broom and Willis, 2007). For instance, epidemiology has been traditionally driven by a positivist paradigm, pursuing universal truths. In contrast, a post modern paradigm in epidemiology has evolved from recognizing the importance of participatory research and pursuing local understandings rather than universal truths (Schwab and Syme, 1997).

The distinction in these paradigms often challenges researchers to choose between artificial, dichotomies; for instance, between exerting authority or promoting equal participation, recognizing the experiential knowledge or putting the scientific evidence first, becoming an activist and advocate or remaining as a neutral agent. Yet, reality is full of non strict grey areas and most of the times researchers choose the best means and draw on a number of different paradigmatic positions in order to answer a research question in a particular context. (David, 2001).

In this case, one challenge was related to my role as researcher, which on one hand, was expected to be neutral, especially given the conflictive context behind the research question. But on the other hand, it had to acquire some advocate/activist connotations, given the participatory nature of the study (David, 2001) and the need to overcome several barriers along the research process. To illustrate this point, the barriers to conduct the second study forced me to undertake activist-like initiatives such as calling attention of key actors including the media or confronting Pluspetrol representatives when I had to defend the validity and applicability of the study findings.

In this respect, Savitz (1999) argues that epidemiologists may have competence to be effective scientists and public health advocates, but attempting to put both into practice simultaneously can create conflicts. On one side, the mainstream points that epidemiologists’ best contribution to public health should be striving for objectivity, validity and scientific rigor (Savitz, 1999). On another side, researchers adhered to more holistic streams like Ecohealth or Environmental justice, point that epidemiologists should become a tool of the community they investigate, advocating on behalf of the community, speaking out against environmental injustices and participating in incorporating findings into action (Leugn et al., 2004; Wing, 2003; Allison and Rootman, 1996; Coughlin, 1996).

8.1.5. Complex and unexpected findings

Despite the growing advancement of environmental sciences, research still faces major limitations in fully elucidating links between environmental chemicals and
health. These limitations make the task of informing the affected communities highly problematic. In addition, informing about environmental risks is controversial and conflictive, in that the multiple actors often disagree about the nature, magnitude, or severity of the risk in question (Morello-Frosh et al., 2009; Brown, 1997).

In this case, a set of major challenges were laid on the interpretation and reporting of results which were intricate for a number of reasons. First, the unclear evidence on which to establish acceptable exposure levels and the potential variability due to analytical errors led me to be extremely cautious when explaining the results. Unfortunately, this came at the expense of losing credibility and trust from the communities, who expected a deliberate simplistic classification between “sick” and “healthy”. After the second study, some residents would even compare their individual results (BLLs in 2009 and 2010) and expressed concern in any minimal increase that for us was not significant. This example illustrates as well, the community’s positivist perception of science as free of ambiguity or subjectivity.

Second, the fact that the potential health effects of lead exposure were subclinical (neurological impairments) and invisible for the communities, posed difficulties in talking about severity without provoking unnecessary alarm. Despite my endeavors to reach a balance, many community residents refused to accept that “only minor effects” and not other “major diseases” like cancer could be involved.

Third, the perception of lead exposure as the symbol of all the unquantified health impacts from oil activity led to a misleading interpretation of our results as negating the oil related pollution. Despite the clear differentiation between lead exposure and other oil-related contaminants in my discourse, the overall perception of the communities was guided by conflictive/instigator residents who stated that the study denied the contamination and accused me of favoring the oil company’s interest.

Another challenge that we faced was related to how to act on the results and give solutions to the affected population. For some authors, uncertainty about sources and pathways to environmental risks should prevent researchers from disseminating exposure results; otherwise, generating conflicts (Morello-Frosh et al., 2006). In contrast, others argue that researchers have the ethical obligation to provide results no matter the lack of potential solutions (Deck and Kosatsky, 1999). In this case, the first inconclusive results and the fact that only prevention and no pharmaceutical treatment was indicated for the exposure levels led to the popular perception that researchers had failed in addressing the most important need of the communities “a medicine that would remove the metals from their bodies” (community member). Formulating prevention strategies required the
identification of the lead sources, which we could not achieve in the first study; but even when the source of exposure was known after the second study, we could not succeed in leveraging any change through decisions or interventions. The decision making process had to be commanded by DIRESA Loreto’s officers, but at that time they had lost interest in the study to such a degree that none of the main authorities (those with the power to decide) participated in the results’ communication in the communities.

Our last main challenge was related to the unexpected nature of our results, which contradicted historical arguments defended by the communities, FECONACO and the NGOs. To our view, had the study results supported FECONACO’s and the NGOs’ objective to prove a straightforward association with oil activity, they would have likely supported us (the researchers) throughout the research process and taken the leadership to force actions. Instead, there was a general skepticism towards the study and unfriendly responses from FECONACO and the communities against me.

In this regard, McMichael (1989) has proposed key factors which determine a community’s receptiveness of results: i) the perception of the risk, ii) the benefits/harms that change may entail and iii) the extent to which solutions can be achieved by environmental management as opposed to changing the behavior of individuals. When exploring these factors in our study process, it is noticeable that the receptiveness to our results was probably constrained by: i) the solid pre-understanding that the risk source was associated with local oil activity, ii) the frustrated expectations of receiving a curative treatment or economical compensation for the damage and iii) the refusal to accept that a change of daily practices (manipulating or chewing pieces of meal lead) could substantially reduce the lead exposure more rapidly than any environmental remediation. As others have described, communities tend to underestimate risks that are voluntarily undertaken (Slovic, 1987), or that arise from an invisible source and manifest themselves only after a long time frame, if ever (Burger, 2000).

In order to overcome these challenges, the field of risk assessment and other similar approaches have developed protocols and communication strategies to formulate and deliver clear and comprehensive messages that anticipate probable questions and reactions. For instance, involving trustable individuals and institutions to communicate the information in the original language (Galvez et al., 2007). In this case, the participation of FECONACO’s representatives as local interpreters of my discourse was beneficial to gain credibility from the communities; however, it also posed difficulties because some leaders avoided providing clear messages regarding the sources of the heavy metals, other than the oil activity. Possibly, they presumed that contradicting the communities’ expectations, could endanger their sympathy and reputation. Apparently, this situation has
been common among native interpreters, who often introduce their own beliefs and personal agendas into the interaction with communities (Kaufert and O’Neil, 1990).

Another strategy would be the conduct of community education programs in order to help understanding the research findings and convincing people of their own responsibility and capacity to improve their ill-health situation (Lebel, 2003). However, this strategy requires leadership and long-term support from public health officials and other stakeholders that in this case were not present.

All in all, any strategy should take into account the underlying principle of the communication process as a two way exchange of information with the community’s participation seen as a democratic right. For some authors, strategies can contribute to preventing and managing conflicts when communicating risks (U.S. Public Health Service, 1995), especially when they are purposefully developed in partnership with study communities (Morello-Frosh et al., 2009). For others, conflicts are unavoidable and strategies such as drafting careful messages are unrealistic for the purpose (Stern, 1999). In this case, the research problem per se was politically problematic and my messages were sometimes intertwined with complex technical concepts not easily understood by the communities, who had a low or no formal education level and whose mother tongue was different than mine. Nevertheless, even if conflicts emerged after the communication of the results, a misleading perception or understanding of the message was not likely the major cause, but other contextual political factors that neither my research team nor I were able to control.

Based on the challenges and facilitating factors described, I have drafted some learning outcomes from this experience in hope that this will assist other researchers involved in similar research projects.

**8.2. Lessons learned**

First, residents from the six study communities and other communities in the Corrientes acknowledged that the handling of metal lead was a harmful practice especially for children and their contribution in minimizing this practice was key to reduce lead exposure. FECONACO’s leaders gained knowledge on various health topics and skills to participate in health research projects. DIRESA Loreto authorities acknowledged that the problem of lead exposure would likely be present in other fishing communities in the Peruvian Amazon and coordinated efforts from multiple sectors were necessary to tackle the problem. Finally, the researchers learned that “non-academic” skills for negotiating, dialoguing, promoting participation and consensus are extremely important as scientific skills when embarking in participatory projects. Participatory projects, especially those
involved in socio environmental conflicts are difficult to conduct because of the strong influence of contextual political factors. The researchers’ inputs and shaping forces in the process are limited. Other more relevant influencing factors include the context where the project develops, the history of the issue, the level of conflict involved, the nature of the evidence and the existing power dynamics.
Chapter IX

Conclusions

9.1. Epidemiological findings
Based on the results from study I and II, the following conclusions were formulated:
– Metal lead appeared to be the main source of exposure in the study population.
– Playing with pieces of lead and chewing pieces of lead to construct fishing sinkers appeared to be the pathways of lead exposure in children aged 0–6 years and children aged 7–17 years, respectively.
– Mothers’ BLLs > 10 µg/dL was a risk factor for BLLs > 10 µg/dL in children aged 0–3 years.
– Living in communities with high exposure to oil activity was a risk factor for BLLs > 10 µg/dL in all the age groups.
– The identified connection with oil activity was the proximity of communities to oil battery facilities and thus greater access of people to lead from cables and other industrial waste.

9.2. Implications for practice
Based on these conclusions, our recommendations for DIRESA and FECONACO authorities were focused on three main strategies:

The first strategy consisted in the conduct of a community-based lead poisoning prevention plan encompassing education, screening, routine monitoring and treatment in the form of measures to decrease the exposure. Educative programs to caregivers and children and other primary prevention strategies have proved to benefit more children than efforts only targeted at individuals with elevated BLLs (≥ 10 µg/dL). This is especially relevant given the fact that no safe BLL threshold has been established and the recommended level has repeatedly decreased as new significant evidence on health impairments has appeared (CDC, 2012). For instance, in our second study we identified a high proportion of children (78% [n=271]) with BLLs between 5 and 10 µg/dL, that is concentrations that were not high enough to trigger actions at the time of the study but they are no longer considered safe after the recent change in the CDC’s recommendations.

Concerning screening and routine monitoring activities, CDC recommends that screening BLLs ≥ 10 µg/dL should be confirmed with a venous sample and fol-
Followed up in a time frame depending on the initial BLLs, with higher screening BLLs requiring sooner confirmatory tests and follow-ups. In this case, we considered that the various limitations in terms of accessibility, human and financial resources and time would not allow completion of the CDC’s recommendation. Therefore, our suggestion was to employ the Leadcare system in order to both, conduct a baseline assessment for all the child population in the Corrientes communities and monitor BLLs biannually. It is noteworthy that this study made a special contribution in this respect. We acquired two Leadcare equipments to be placed in Trompeteros health care center and coordinated a special training for the health care personnel on the use of this technique. Also, we created and reproduced a tracking card for lead exposure that would help in to register and report the BLLs results to the communities in a long-term monitoring program. Though stated in the recommendations, we did not emphasize the aspect of clinical treatment for elevated BLLs. Chelation therapy has been indicated for children with BLLs ≥ 45 µg/dL, but in this case, the highest BLL identified from the two studies (34.6 µg/dL) was far below 45 µg/dL. Nevertheless, it is important to highlight that chelation therapy should be provided in a specialized health center capable of providing appropriate intensive care services (CDC, 2009). Thus, if any child from the Corrientes required this treatment, she/he would have to be transferred to health centers in the region’s or the country’s capital cities.

The second strategy was the introduction of fishing sinkers made from less toxic compounds to reduce to a minimum their artisanal manufacture among children. Currently, fishing sinkers on the market are created from diverse less toxic materials like tin, bismuth, iron, tungsten and brass, those which offer extra advantages for fishing (for instance the tungsten is denser, harder and heavier than lead) and for the environment (the use of fishing sinkers has been associated to waterfowl lead poisoning) (EPA, 2012; Jacks et al., 2001). Another less expensive alternative would be to use concrete sinkers with magnetite or chromite as filler, as cited by Jacks et al. (2001). To this respect, EPA has suggested some precautions for reducing lead exposure during the manufacture of fishing sinkers including: i) working in a well-ventilated area, ii) avoiding to put lead sinkers in the mouth and iii) washing the hands after handling lead sinkers (EPA, 2012). While these measures could be adopted by the adult population, we think that in children, the practice of preparing fishing sinkers from metal lead should be eradicated.

The third strategy was focused on the secure containment of the oil company’s waste deposits. According to the company’s waste management program, cooper cables and car batteries would be classified as “not dangerous reusable waste” and “dangerous not reusable waste”, respectively. After classification, both would be disposed in temporal deposits/storages, located inside oil central installations,
until being collected by a specialized waste management company (Walsh, 2009). Although the application of this procedure is supposed to be regularly monitored by environmental health authorities in Loreto, community residents who have worked for the oil company have a negative perception of how the solid waste disposal is conducted (Walsh, 2009). Moreover, testimonies from community residents in this study would indicate that there is a low if any control of the waste deposits located near the communities. Therefore, a more exhaustive and frequent monitoring by governmental authorities would be recommendable.

Furthermore, my strong advice to DIRESA and FECONACO authorities was regarding the need to coordinate efforts among themselves and other important actors in order to achieve an effective implementation of the recommended strategies. Those actors would include the regional and local governments, the health care providers and educators in each community, the oil company and NGOs working in the Corrientes as well as the community leaders.

Finally, we delineated some ideas for conducting further research as complementary actions, highlighting that prior efforts should focus in implementing the strategies recommended in this study. As Hember et al. (2000) argue, tackling the problem of chronic lead exposure does not need sophisticated research. On the contrary, existing knowledge must be utilized first and new investigations should be driven by public health aims. In this vein, further evaluations looking at other non-classical sources, risk factors and pathways of lead exposure in populations living in similar contexts would be recommendable.

In this research process, we acknowledged a number of non-classical sources of lead exposure which were not significant in the Corrientes child population but could be important in other communities. First, the release of produced waters containing lead and other contaminants has been apparently eradicated in the Corrientes river. However, there are many other rivers in the Peruvian Amazon (e.g. Tigre) where neither the reinjection system nor other mitigating measure for water pollution has been implemented yet. Hence, further evaluations of lead and other heavy metals exposure in the environment and the population of these areas would be recommendable. Second, game meat and contaminated farinha have been suggested as potential sources of lead exposure in similar populations (Barbosa Jr et al., 2009; Tsuji et al., 2002). Although, we did not find any significant association between these factors and elevated BLLs in the Corrientes, further evaluation in other communities of the Peruvian Amazon (where the consumption of these products is common) would be also recommendable.
9.3. The participatory research process

Our reflection and understanding of the research process was guided by the principles of the Ecohealth and Popular epidemiology approaches.

The research question emerged from the affected population in a complex context where multiple stakeholders, including the government, the oil company, the indigenous community based-organization and environmental NGOs all played important roles. These conditions determined the participatory nature of the research process, which along with other factors (e.g. context, knowledge) posed challenges that were difficult and sometimes impossible to overcome.

Despite the numerous challenges, we believe that participatory research may be the most appropriate approach in this type of complex context. Despite the lack of immediate action, we hope that useful interventions to prevent and control lead exposure in the Corrientes population will be implemented in not too distant future.
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Five years ago I felt the need to explore the world outside my home city Lima and to learn other views different from those I grew up with. For no special reason I decided to come to Sweden and today I feel extremely thankful for all the opportunities I found here, including this PhD journey.

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Apendix

Guide to the main actors and entities in the research process

This section describes the main characteristics and roles of the actors/entities involved in this research process. The actors include the institutional members of the research partnership as well as other stakeholders with a direct or indirect influence.

Communities of the Corrientes river basin: They comprise about 36 communities who live in villages along the Corrientes river basin. Each community has its own set of authorities (the main leader, the lieutenant governor and the women’s representative) who make the ultimate decisions concerning all the community’s issues, for instance participation in this project.

Federation of native communities of the Corrientes river (FECONACO): Indigenous organization created in 1991 to represent the Corrientes river communities, defend the indigenous peoples’ rights, promote their culture and values and pursue their sustainable development. FECONACO is directed by a board of indigenous leaders (president and delegates) elected by the communities’ authorities in annual meetings. Additionally, FECONACO counts on a staff of technical advisors and administrative personnel.

In January 2008, FECONACO leaders together with DIRESA authorities signed an agreement of collaboration with a representative from Umeå University, Sweden, to conduct an epidemiological study on heavy metals exposure in the Corrientes communities. Its main role in the study was to represent the communities and its main task was to administrate the funding that DIRESA Loreto would transfer to FECONACO’s bank account.

Regional Direction/bureau of Health in Loreto (DIRESA Loreto): governing body of the health sector in Loreto region. The regional health director, who is elected by Loreto’s regional governor, chairs its management.

According to the agreement of collaboration signed with Umeå University and FECONACO, DIRESA’s main role would be to provide institutional support for
the conduct of the study, for instance through the participation of their professional medical and non-medical staff in the field work and mediation to acquire assistance from other governmental and private institutions.

**Umeå University**: academic institution located in Umeå city, Sweden. Through a group of affiliated researchers (two associate professors and one PhD student), Umeå University had the role to lead the epidemiological study on heavy metals in the Corrientes communities.

**Epidemiological study on heavy metals in the Corrientes communities** was one of the core components/subprojects of the project for the Corrientes river comprehensive health plan (PEPISCO) and had two levels of governance, first the study operational committee and second, the PEPISCO board of directors.

**Study operational committee**: formed by delegates from DIRESA Loreto, FECONACO and Umeå University, that would jointly formulate and operate the plan for the epidemiological study on heavy metals exposure in the Corrientes communities. Though this committee held primary responsibility for the study, the main decisions (such as approval of the study plan and assignment of the budget) were in charge of the PEPISCO board of directors.

**PEPISCO’s board of directors**: formed by four indigenous representatives from the Corrientes communities (elected by the communities’ leaders) and four representatives of DIRESA Loreto (elected by DIRESA Loreto’s authorities). The board of directors held monthly public meetings to approve plans and budgets for the implementation and management of all PEPISCO components/subprojects.

**The special project for the Corrientes river comprehensive health plan (PEPISCO)**: designed by FECONACO leaders and DIRESA Loreto officers, it included a number of components/subprojects such as the conduct of the epidemiological study on heavy metals exposure. As part of the Dorissa agreement, its funding for a ten years period was assumed by Pluspetrol and its administration was delegated to DIRESA Loreto. The management of the project was entirely in charge of DIRESA Loreto staff, but the direction was handled by a special board of directors, including indigenous representatives. Additionally, FECONACO had special personnel to overlook and monitor the conduct of the project.

**Dorissa agreement (also known as act of Dorissa)**: inter-institutional agreement intended to restore the environmental damage in the Corrientes river basin and alleviate the negative impacts of oil activity in the indigenous
population. Signed in October 2006, it grouped a set of commitments to be accomplished by the oil company Pluspetrol and the Regional Government of Loreto, such as the execution of the PEPISCO project.

**Non-governmental organizations (NGOs):** these were environmental and human rights organizations allied to FECONACO who played a major role into empowering the Corrientes communities and achieving the legitimacy of the DORISA agreement, the PEPISCO project and the epidemiological study that we conducted.

**Pluspetrol:** Argentinean oil company operating in the Corrientes river basin since 2000. As funder of PEPISCO, Pluspetrol had the right to audit its financial management but not to participate in the implementation of the project. However, the imposed involvement of Pluspetrol representatives had a strong influence on the decisions taken by the PEPSICO board of directors, including those regarding the epidemiological study on heavy metals exposure in the Corrientes communities.

**Regional government of Loreto:** public democratic institution with autonomy (from the central government) to conduct Loreto’s regional governance. The role of the regional government on the epidemiological study was indirect through its influence on DIRESA Loreto.